Is the Tariff the 'Mother of Trusts'? Reciprocal Trade Liberalization with Multimarket Collusion

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Abstract

In this paper we examine the impact of trade liberalization on collusive conduct between domestic and foreign firms interacting in multiple markets. We establish a non-monotonic relationship between trade barriers and the sustainability and profitability of collusion in a homogeneous product Cournot oligopoly with symmetric countries. We show that when trade barriers are sufficiently low, the efficient cartel outcome will involve cross-hauling of goods. As a result, an increase in trade barriers makes the cartel less profitable and harder to sustain. In particular, increases in trade barriers (from very low initial levels) may be welfare increasing because of their pro-competitive effect. We also show that when trade barriers are sufficiently high, the efficient cartel will involve no trade. In this region, increases in trade barriers will be pro-collusive because they protect markets from deviations by foreign firms. We also extend the analysis to consider the implications of product differentiation.

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I. Introduction

In 1899 the president of the American Sugar Refining Company, Harry Havemeyer, asserted that "The mother of all trusts is the customs tariff bill." Havermayer's argument was that tariff protection excludes competition from foreign firms, and hence makes it easier for domestic firms to collude behind protective tariff walls. Since then this remark has been frequently interjected in discussions concerning the possible benefits of reducing tariffs as an argument in support of the pro-competitive effects of trade liberalization. However, evidence from the 1990s suggests that cartels continue to be a significant policy problem, despite the substantial degree of global market integration due to multilateral trade liberalization and declining transportation costs. In particular, these cartels have frequently involved firms located in a number of different countries and allocating their market shares internationally.[1]

In light of the failure of declining trade barriers to eliminate international cartel activity, we think it is appropriate to re-examine the relationship between trade liberalization and collusive activity. Although this question has been addressed in the literature, the primary focus has been on the case of single market collusion. However, the evidence suggests that multimarket agreements are prominent features of international cartels.[2] In the spirit of Bernheim and Whinston (1990), we focus on the case in which firms use multimarket

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[1] A report by the WTO (1997, Chapter 4) concluded that "...while the extent of cartel activities is intrinsically difficult to assess ... there are some indications that a growing proportion of cartel agreements are international in scope." An additional source of evidence is the significant number of international cartels prosecuted by the US Department of Justice in the 1990's. Examples of international cartels involving U.S. and foreign firms that were successfully prosecuted include a food and food additive cartel (operating from 1991 to 1995), a vitamin cartel (1990-1999), and a graphite electrodes cartel (1992-1997). The U.S. Department of Justice (2000) reports that prosecution of participants in the food and feed additives cartel resulted in the imposition of a $100 million fine on the Archer-Daniel Midlands company, a U.S. firm, and a $50 million fine on a subsidiary of a German firm. In 1999, the government collected a record fine of $500 million from F. Hoffman-La Roche, a Swiss company involved in a conspiracy to fix the price of vitamins. The significance of these cartels is reflected in the fact that the fines from these prosecutions accounted for more than 90% of the fines imposed in criminal antitrust cases annually.

[2] The citric acid cartel, which consisted of 5 firms from 4 different countries, illustrates the sophistication of some recent cartel arrangements. Top executives of the companies initially met to set up the cartel; then, lower level executives worked out the details on product prices and market shares (to the tenth of a decimal point) that each company was allowed to earn in each market; companies then shared market information to verify that participating members had complied with the agreement. If firms exceeded their market shares, they were required to purchase the excess from another firm that had not met its assigned market share.
It is also worth noting that the use of multimarket collusive agreements in international cartels is not new. For

contact to sustain more profitable outcomes than would be possible by separate agreements covering individual markets. More specifically, we study the relationship between trade barriers (i.e., imports tariffs or transportation costs) and the profitability of collusion in the context of a symmetric, two-country model of homogeneous-goods oligopoly with firms interacting in their (segmented) domestic and export markets (as in Brander and Krugman (1983)). We treat the trade barriers that separate the two markets as parameters, and examine how (equal) changes in their (common) level affect the maximum global profits firms can sustain in a collusive multimarket agreement.

An important feature of our work is its emphasis on how efficient output allocations vary with the level of trade barriers. When trade barriers are high, the most profitable cartels are those that adopt a geographic allocation of outputs in which each country's firms serve only their own market. At that level, increases in trade costs typically enhance the profitability of collusion because they make deviations in foreign export markets less appealing. When trade barriers are low and deviation constraints are not binding, the most profitable allocations necessitate the "cross-hauling" of goods. This finding is driven by the fact that firms' deviation incentives are convex in their output assignments to domestic and foreign markets, which implies that the agreements with the lowest deviation incentives "smooth" output levels across markets by allocating firms similar market shares in each market. We show that this tension between the sustainability and profitability of agreements generates a non-monotonic relationship between trade costs and cartel profits when firms punish deviations through reversion to the Nash equilibrium of the single-period game. When goods are perfect substitutes and the incentive constraint is binding under free trade, an increase in trade costs causes cartel profits to decline because trade becomes more costly under the agreement. However, higher trade costs also increase the likelihood of firms being able to sustain an agreement with no trade, the most profitable agreement. Thus, when trade barriers are sufficiently high, further increases in them facilitate collusion.

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example, one of the earliest international collusion cases was a tobacco cartel in which U.S. and British firms agreed to stay out of each other's domestic market and divide shares in third country markets (U.S. vs. American Tobacco (1911)). See Bond (2002) for additional discussion of some of the legal and antitrust issues involved in international cartels.

These findings suggest that reciprocal trade liberalization in the presence of multimarket collusion can have important implications for welfare. We show that when trade barriers are initially low, trade liberalization may be welfare-reducing due to its pro-collusive effect. Interestingly, this result holds no matter whether trade costs take the form of tariffs or transportation costs; therefore, trade liberalization and market integration are not substitutes for active competition policy. In contrast, when barriers are initially high, trade liberalization is welfare-improving because cartel members find it less appealing to specialize in selling to their local markets; that is, it is more difficult for firms to engage in geographic collusion. In short, the relationship between national welfare and trade barriers is non-monotonic.

Our results on the effects of reciprocal trade liberalization differ from those obtained when home and foreign firms collude in a single market. A prominent paper in this area is Davidson (1984), which examined the impact of tariff policy on collusion with firms interacting in quantities in a single homogeneous goods market. In this setting, tariffs affect firm incentives asymmetrically because they render deviations more attractive for the home country firm but not for the foreign firm. To maintain collusion, a unilateral tariff reduction requires cartel output to be reallocated from home firms to foreign firms. Assuming that firms adjust quantities to maintain total output at the monopoly level, Davidson showed that a tariff reduction at high tariff levels facilitates collusion. The reason for this is that foreign firms do not earn enough profits at such tariff levels to be able to compensate domestic firms for their increased incentive to violate the cartel agreement; however, at low tariff rates they do.[3] Our analysis differs from Davidson's in that, with multimarket contact, reciprocal trade liberalization affects collusive incentives symmetrically, with each firm thus being favorably affected in its export market but not in its home market. Reciprocal tariff changes do not have redistributive effects within the cartel, but they may change the efficient market-sharing agreement. Our model also

[3] In similar spirit, Rotemberg and Saloner (1989) compared the effects of tariffs and quotas with repeated price interactions between a domestic and a foreign firm. Placing cost asymmetries between firms at center stage, Fung (1992) studied the effects of economic integration (captured by a unilateral tariff reduction) on critical discount rates and through that on collusive conduct in a differentiated-goods model with price competition. Syropoulos (1992) examined how tariffs and quotas affect the sustainability of collusion among quantity-setting foreign oligopolists (with no domestic producers).

extends existing work on multimarket collusion by providing a comprehensive analysis of how trade liberalization affects the profitability of cartels and welfare. Bernheim and Whinston (1990) established that the presence of trade barriers between markets may render multimarket agreements more profitable than agreements arranged on a market by market basis.[4] Our analysis differs in that we take as given the benefits of multimarket collusion and consider how market shares, profits and welfare respond to changes in the level of trade barriers.[5]

Section II of the paper presents the basic model for the case of homogeneous goods. We begin by analyzing the case of an international duopoly under very weak restrictions on punishment schemes. In this setting, we generate two main results. The first is that the minimum discount factor (i.e., the smallest discount factor that is capable of sustaining the monopoly profit level) is discontinuous at zero trade costs. This is important because it implies the existence of a range of actual discount factors under which the elimination of trade barriers enables firms to sustain full collusion. The second result is that the minimum discount factor approaches zero when trade barriers approach their prohibitive level. These results establish a *collusion facilitating effect* of trade liberalization at low levels of trade barriers and a *collusion undermining effect* at sufficiently high trade barrier levels. To ascertain the robustness of these findings, we then extend the analysis

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[4] Pinto (1986) extended the Brander-Krugman framework to study how repeated firm interactions may affect collusive conduct and showed that, in the presence of trade costs, the monopoly payoffs can be sustained by geographic allocation of markets.

[5] In a related paper, Colonescu and Schmitt (2000) investigated how the move from a regime of "market segmentation" (where firms can price discriminate between domestic and export markets) to a regime of "economic integration" (where price discrimination is impossible) affects competitive conduct via its impact on minimum discount factors. Their analysis revealed that the transition to market integration is pro-competitive or anti-competitive depending on the degree of (dis)similarity of product markets. Our analysis differs in that we are concerned with the implications of reciprocal cuts in trade costs on incentive constraints and collusive outcomes, and consider circumstances under which collusion does not necessarily lead to the elimination of trade flows. Lommerud and Sørgard (2000) also investigated the effects of reciprocal tariff cuts on multimarket collusion under repeated quantity- and price-setting games by symmetric homogeneous good duopolists. However, these authors were mainly concerned with the effects of trade liberalization on minimum discount factors and did not study the exact circumstances under which incentive constraints are binding for firms and what that may mean for geographic collusion and welfare. Olson and Mason (1996), considered a model similar to ours to explore the effects of a price ceiling in one market on multimarket collusion when incentive constraints are binding. They showed that a mild price ceiling in one market can cause firms to behave more collusively in the unregulated market.

to the oligopoly case with an arbitrary number of firms in each country. We conclude Section II with a simulation analysis (using permanent reversion to the Nash equilibrium of the single-period game as punishment) that illustrates further the effects of trade liberalization on minimum discount factors, global profit levels, and national welfare. Section III extends the analysis to the case of imperfect substitutes, and Section IV concludes. The formal proofs of propositions can be found in the Appendix.

II. The Model with Homogeneous Goods and Quantity Competition

To examine the issue of reciprocal trade liberalization with multimarket contact, we consider a symmetric two-country Cournot oligopoly model of trade. For clarity, we label the two countries "home" and "foreign". We begin with the case in which there is a single firm in each country producing a homogeneous good. Later we extend the analysis to consider more firms and product differentiation. Our assumption of symmetry is embodied in the assumptions that all firms have constant and identical marginal costs, and each country *i* has a linear inverse demand function $p_i = A - Q_i$, where Q_i represents the total quantity sold in it. Without loss of generality, we normalize marginal costs to zero. However, a firm's involvement in world trade is costly: for each unit of output a firm ships abroad, it incurs a trade cost *t*.[6] The important point is that trade barriers segment national markets and introduce an asymmetry in the costs of delivering goods at home and abroad.

Let q_i denote the quantity a firm from country *i* sells in its own market and x_i the quantity it sells in its export market. It readily follows that firm *i* will earn a profit of $[A - (q_i + x_j)]q_i$ in its own market and $[A - (q_j + x_i) - t]x_i$ in its export market, for given quantities (q_j, x_j) chosen by its rival firm $j \neq i$. In a non-cooperative equilibrium, firm *i* chooses (q_i, x_i) to maximize global profits, given (q_j, x_j). It is straightforward to show that, under the above assumptions, we will have $q_i = q_j$ and $x_i = x_j$ in the one-shot Nash equilibrium,

[6] Trade costs could be identified either with specific import tariffs or with transportation costs. We abstract from the unilateral use of trade barriers for strategic policy purposes and assume that changes in trade costs are due to either due to technological change or to reciprocal tariff reductions that affect trade partners symmetrically.

so we may drop country subscripts and focus on the output decisions of a representative firm. Thus, letting superscript N identify Nash equilibrium values, we obtain

Lemma 1: *The Nash equilibrium outputs, $q^N(t)$ and $x^N(t)$, and global profits, $\Pi^N(t)$, can be described as follows:*

a) *If* $t < \bar{t}^N \equiv \dfrac{A}{2}$, *then* $q^N(t) = \dfrac{A+t}{3}$ *and* $x^N(t) = \dfrac{A-2t}{3}$. *Furthermore,* $\Pi^N(t)$ *is strictly convex in* t *and minimized at* $t^N_{\min} = \dfrac{A}{5}$.

b) *If* $t \geq \bar{t}^N = \dfrac{A}{2}$, *then* $q^N(t) = \dfrac{A}{2}$, $x^N(t) = 0$, *and* $\Pi^N(t) = \dfrac{A^2}{4}$.

As in Brander and Krugman (1983), the Nash equilibrium is characterized by the cross-hauling of identical products, provided, of course, the trade cost t is less than the prohibitive level, $\bar{t}^N$. For low trade cost levels, an increase in t reduces global profits because export markets are sufficiently important to firms. However, when trade cost levels are high, firms earn most of their profits in their home market and thus benefit from increased protection. Global profits are maximized when the trade cost level is at or beyond $\bar{t}^N$ because firms are better off with a monopoly in their own market than with a duopoly in every market.

A. Collusion with Multimarket Contact - The Duopoly Case

We now consider the possibility of tacit collusion with firms setting quantities in domestic and export markets. As in Bernheim and Whinston (1990), we suppose firms engage in multimarket collusion by allocating to each firm a pair (q, x) that reflects the outputs q and x targeted for sale in the domestic and export markets, respectively.[7] Since all firms face identical conditions in the two markets, once again, we may treat firms from

[7] Spagnolo (2001) showed that, in cases where a deviation in one market raises the payoff to deviation in another market, multimarket agreements may yield lower profits than single market collusive arrangements. This possibility does not arise in our model because the assumption of constant marginal costs makes deviation payoffs independent across markets.

different countries symmetrically and focus on the payoff of a representative firm. In particular, if a firm deviates from the collusive arrangement in any one market it gets punished in all markets.

The global profit of a firm under an agreement (q, x) is

$$\Pi^A(q, x, t) = [A - (q + x)](q + x) - tx, \tag{1}$$

where Π^A is concave in (q, x) and decreasing in t. It is straightforward to verify that, in the special case of no trade barriers (i.e., when $t = 0$), cartel profits are maximized for any combination of output levels that satisfy $q + x = A/2$. However, for any $t > 0$, cartel profits are maximized by choosing $q = A/2$ and $x = 0$. Since under this arrangement every firm produces the monopoly output is its home market and sells nothing abroad, we refer to it as *maximal geographic collusion*. A key benefit of multimarket contact is that firms can reallocate shares across markets to the lowest cost producer so as to minimize total cartel costs.

If firm i deviates from a collusive agreement in its own (export) market that specifies an output of x (q) for its rival, firm i's deviation profit in that market will be $\max_{q_i} [A - q_i - x] q_i = \frac{1}{4}(A - x)^2$ ($\max_{x_i} [A - q - x_i - t] x_i = \frac{1}{4}(A - q - t)^2$). Since a firm that violates a collusive agreement has an incentive to do that in all markets, its payoff to deviating from a cartel output pair (q, x) can be obtained by summing the deviation payoffs across all markets; that is,

$$\Pi^D(q, x, t) = \frac{1}{4}[(A - x)^2 + (A - q - t)^2]. \tag{2}$$

Clearly, Π^D is decreasing in t and strictly convex in (q, x) for all output pairs that yield non-negative profits in each market.

We assume that, in the event of a deviation, an agreement calls for a "credible" punishment in which firms switch to a subgame perfect equilibrium of the repeated game that forces the deviating firm to attain a lower payoff. Denote with $\delta > 0$ the representative firm's discount factor, and with $\Pi^P(t)$ its per period global payoff during the punishment phase. Then, for a given t, an agreement (q, x) will be sustainable if

$$Z(q, x, t, \delta, \Pi^P) \;=\; \Pi^A(q, x, t) \;-\; (1-\delta)\Pi^D(q, x, t) \;-\; \delta\,\Pi^P(t) \;\geq\; 0. \tag{3}$$

The Nash equilibrium payoff characterized in Lemma 1 is a natural punishment. However, as has been emphasized by Abreu (1988) and others, the cartel could support more profitable agreements by choosing more severe punishments. In order to identify results that do not depend on the particular form of punishment considered, at this point we assume that the chosen punishment payoff satisfies $\Pi^P \leq \Pi^N$. (We examine the case of Nash punishments later.)

An efficient cartel agreement will maximize the payoff to a representative firm over the set $F(t, \delta, \Pi^P) \;=\; \{(q, x) \,|\, Z(q, x, t, \delta, \Pi^P) \geq 0 \text{ and } q, x \geq 0\}$ of incentive-compatible output levels. The following result, proven in the Appendix, establishes that efficient agreements can be characterized using standard Lagrangian methods and provides some useful properties of efficient cartel agreements.

Lemma 2: *If* $\Pi^P(t) \leq \Pi^N(t)$ *for* $t < \bar{t}^N$, $F(t, \delta, \Pi^P)$ *is a convex set and contains a collusive agreement* (q, x) *with* $Z(q, x, t, \delta, \Pi^P) \geq 0$.

a) *The first-order conditions (FOCs) for maximizing*

$$\mathfrak{L}(q, x, \lambda, t, \delta, \Pi^P) \;\equiv\; \Pi^A(q, x, t) \;+\; \lambda Z(q, x, t, \delta, \Pi^P). \tag{4}$$

are necessary and sufficient for a cartel agreement to be efficient.

b) *The efficient cartel agreement,* (q^*, x^*), *has the following properties:*

(i) *If* $t > 0$, *then* $q^* > x^* \geq 0$.

(ii) *If* $t = 0$, *then* $q^* = x^* \geq A/4$, *with strict equality if* $\lambda > 0$.

c) *The maximum sustainable profits for a cartel member,* $\Pi^*(t, \delta) \equiv \Pi^A(q^*(t), x^*(t), t)$, *is continuous in t.*

At an interior solution with a binding incentive constraint, the FOCs associated with the Lagrangian in (4) require $\Pi_q^A / \Pi_x^A = \Pi_q^D / \Pi_x^D$. (Subscripts q and x denote partial derivatives.) It can be seen from direct differentiation of Π^A in (1) and of Π^D in (2) that $q^* = x^*$ when $t = 0$. Intuitively, this is so because the strict convexity of the deviation payoff in (q, x) makes it attractive for the cartel to "smooth" outputs across markets when the incentive constraint is binding. As a result, there is cross-hauling of identical products in a collusive agreement when $t = 0$ and the incentive constraint is binding. When $t > 0$, this cross-hauling becomes costly and thus the cartel finds it more profitable to assign larger output shares to the domestic firm in each market. However, for small trade costs, the no deviation constraint may prevent the representative firm from going all the way to the most profitable collusive agreement associated with complete geographic specialization. This suggests the existence of a trade-off between incentive compatibility and profitability in the allocation of market shares when $t > 0$. The continuity of global profit, $\Pi^*(t)$, in t follows from Berge's maximum theorem.

Having established the existence and form of profitable cartel agreements, we now turn to the question of how the sustainability and profitability of cartels are affected by the level of trade costs. We begin by examining how the trade cost level affects the ability to sustain the monopoly profit level, $\Pi^M \equiv A^2/4$, in each market. When $t > 0$, cross-hauling is costly and the only way to capture the monopoly profit level is to choose maximal geographic collusion, i.e., $q = A/2$ and $x = 0$. Since $Z(q, x, t, \delta, \Pi^P)$ is increasing in δ for $\Pi^D > \Pi^P$, it follows from (3) that the monopoly output will be sustainable for $\delta \geq \delta^c(t) \equiv$

$[\Pi^D(A/2, 0, t) - \Pi^M]/[\Pi^D(A/2, 0, t) - \Pi^P(t)]$. We refer to $\delta^c(t)$ as the minimum discount factor that is necessary to sustain the monopoly output level. For the case in which punishment involves permanent reversion to the Nash equilibrium, $\delta^c(t) = 9(A - 2t)/(13A + 22t)$. In that case the minimum discount factor is monotonically decreasing in t, with $\delta^c(t) \to 0$ as $t \to \bar{t}^N$ $(= \frac{A}{2})$. For the more general case, where the punishments are only required to be continuous in t and to satisfy $\Pi^P(t) \leq \Pi^N(t)$, the minimum discount factor will not necessarily be monotonic in t. However, we can establish that, even in this more general case, we will have $\delta^c(t) \to 0$ as $t \to \bar{t}^N$.[8]

The result that $\delta^c(t) \to 0$ as $t \to \bar{t}^N$ establishes a sense in which very high trade cost levels facilitate collusion. For any $\delta > 0$, it is possible to find a trade cost level in the neighborhood of $\bar{t}^N$ that allows firms to attain the maximal collusive profits. High trade costs facilitate collusion because they discourage the foreign firm from entering the market when the home firm charges the monopoly price. The observation that very high trade costs (tariffs) facilitate multimarket collusion is in line with the conventional wisdom about protectionism and collusion. What may be more surprising is that there is also a sense in which trade liberalization can facilitate collusion when trade barriers are low. To see this note that, for $t = 0$, cross hauling of goods is costless and Π^M can be attained with any allocation that satisfies $q + x = A/2$. Lemma 2b(ii) shows that with $t = 0$, the most efficient cartel agreement requires setting $q = x = A/4$ when the no deviation constraint is binding. This means that at $t = 0$ the minimum discount factor for supporting Π^M is $\delta^c(0) \equiv [\Pi^D(A/4, A/4, 0) - \Pi^M]/[\Pi^D(A/4, A/4, 0) - \Pi^P(0)]$. It follows from the strict convexity of Π^D and

[8] If $\Pi^P(\bar{t}^N) < \Pi^N(\bar{t}^N) = \Pi^M$, then $\delta^c(\bar{t}^N) = 0$ follows from the observation that $\Pi^D(A/2, 0, \bar{t}^N) = \Pi^M$. If $\Pi^P(\bar{t}^N) = \Pi^N(\bar{t}^N)$, then $\lim_{t \to \bar{t}^N} \delta^c(t) = 0$ follows from the fact that $\Pi^D_t(A/2, 0, \bar{t}^N) = 0$ and $\Pi^P_t(\bar{t}^N) \geq \Pi^N_t(\bar{t}^N) > 0$.

its symmetry at $t = 0$ that $\Pi^D(A/4, A/4, 0) < \Pi^D(A/2, 0, 0)$. Therefore, $\delta^c(0) < \underline{\delta} \equiv \lim_{t \to 0} \delta^c(t)$. With Nash punishments, we have $\delta^c(0) = 0.5294 < 0.692 = \underline{\delta} \equiv \lim_{t \to 0} \delta^c(t)$. The downward jump in the minimum discount factor at $t = 0$ reveals a sense in which trade liberalization may facilitate collusion: collusion can be sustained for a wider range of discount factors at $t = 0$ than for positive tariff rates in the neighborhood of $t = 0$.

Since some transportation cost frictions are likely to remain even when tariff barriers are completely eliminated, one might be tempted to view this discontinuity in the minimum discount factor at $t = 0$ as a theoretical curiosum. However, this discontinuity reflects the fact that cross-hauling of goods makes a collusive agreement easier to sustain. When the incentive constraint is binding and t is not too high, the efficient collusive agreement characterized in Lemma 2 will involve $x > 0$. As a result, a reduction in t should make the collusive agreement more profitable for the cartel in this region. This intuition can be formalized by considering $\delta \in \left[\delta^c(0), \underline{\delta}\right)$. Since $\delta \geq \delta^c(0)$, $\Pi^*(0, \delta) = \Pi^M$ in this interval. However, the fact that $\delta < \underline{\delta}$ and $\Pi^*(t, \delta)$ is continuous in t means that there will exist a $\hat{t}(\delta) < \bar{t}^N$ such that $\Pi^*(t, \delta) < \Pi^M$ for $t \in (0, \hat{t}(\delta))$;[9] thus, starting from any t in this interval, the elimination of trade costs will raise cartel profits.

We may summarize these results as follows:

Proposition 1: *Assume that $\Pi^P(t)$ is continuous in t and $\Pi^P(t) \leq \Pi^N(t)$. Then,*

a) *for any discount factor $\delta > 0$, there will exist an $\varepsilon > 0$ such that the monopoly profit, Π^M, is sustainable for $t > \bar{t}^N - \varepsilon$;*

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[9] The continuity of $\delta^c(t)$ and the result that $\delta^c(t) \to 0$ as $t \to \bar{t}^N$ ensures the existence of a t such that $\delta^c(t) = \delta$. Choosing $\hat{t}(\delta)$ to be the smallest value of t satisfying this condition, it follows from the definition of the minimum discount factor that monopoly profits will be unsustainable for $t \in (0, \hat{t}(\delta))$.

b) *there exists a set of discount factors,* $\Delta \equiv (\delta^c(0), \lim_{t\to 0}\delta^c(t))$, *and a non-empty interval of trade costs,* $\mathrm{T}(\delta) \equiv (0, \hat{t}(\delta))$ *for any* $\delta \in \Delta$, *such that* $\Pi^M(t)$ *is sustainable for* $t = 0$ *but not for* $t \in T(\delta)$. *The elimination of trade barriers will raise cartel profits if* $\delta \in \Delta$ *and* $t \in T(\delta)$.

The intuition for part (b) follows from the fact that the easiest agreements to sustain are those that involve cross-hauling of goods in order to reduce the deviation incentives, which follows from the convexity of the deviation payoffs. If trade costs are not too high, the firm will still find it profitable to engage in cross-hauling in an efficient agreement. Trade liberalization will thus benefit the cartel members by reducing the cost of this cross-hauling. When trade costs become sufficiently high, however, the cartel will find it profitable to use maximal geographic collusion. With only one firm in each market, maximal geographic collusion can be used to sustain Π^M for sufficiently high t.

It is important to point out that Proposition 1 is robust to relaxation in the assumption that the demand curve is linear. For the case of a general inverse demand function, $f(X)$, we can express a firm's deviation payoff as $\pi^D(Y, t) = \max_y [f(Y + y) - t)]y$, where Y is the aggregate output of all other firms, and y and t are the firm's output and trade cost, respectively, in a given market. Let $\tilde{y}(Y, t)$ denote the firm's optimal deviation. Differentiation of π^D yields $\partial\pi^D/\partial Y = f'(Y + \tilde{y})\tilde{y} < 0$ since $f' < 0$. When demand is linear, the convexity of the deviation payoff follows from the fact that f' is constant and $\tilde{y}$ is decreasing in Y. In the general case, $\partial^2\pi^D/\partial Y^2 = -(f')^2/(2f' + \tilde{y}f'') > 0$ because the denominator is negative by the second-order condition on the choice of y. It follows that the deviation payoff will be convex in the general demand case as well. Thus, as long as the inverse demand function is such that $\Pi^A(q, x, t)$is concave, the results of Lemma 2 and Proposition 1 will hold.

We can also use Lemma 2 to say something about the effect of trade liberalization on profits in the neighborhood of $t = 0$ for $\delta < \delta^c(0)$. Lemma 2(b) establishes that the efficient cartel agreement will have $q^* = x^* > A/4$ when $t = 0$ and $\delta < \delta^c(0)$. Through appropriate differentiation of the Lagrangian in (4), the effect of a change in trade costs on global profits is

$$\mathfrak{L}_t^* = (1 + \lambda)\Pi_t^A - \lambda(1 - \delta)\Pi_t^D - \lambda\delta\Pi_t^P, \tag{5}$$

where payoffs are evaluated at the constrained efficient pair (q^*, x^*). The first two terms of the above expression are conflicting when $x^* > 0$. An increase in trade costs reduces the payoff under the collusive agreement, but it also reduces the incentive to deviate from it. We know from the first-order condition for the choice of q that $\Pi_q^A/\Pi_q^D = \lambda(1-\delta)/(1+\lambda)$. If we substituted this expression into the first two terms and evaluated expressions in the neighborhood of the efficient cartel at free trade, we would obtain

$$\left[(1+\lambda)\Pi_t^A - \lambda(1-\delta)\Pi_t^D\right]\Big|_{q=x,\,t=0} = -3(1+\lambda)[q^N(0) - q]. \tag{6}$$

Clearly, the above expression will be negative for cartel output levels that are below the Nash equilibrium level. Therefore, in the neighborhood of unimpeded free trade, the negative effect of the trade cost increase on the agreement payoff dominates the effect on the deviation payoff. It then follows from (5) that an increase in the trade cost, t, will reduce global profits as long as t does not force the punishment payoff to fall too rapidly. Stronger results on the effects of tariff on cartel payoffs require explicit assumptions about the punishment payoffs.

B. Collusion with Multimarket Contact - The Oligopoly Case

The analysis above can be readily extended to the case in which there are $n > 1$ firms operating in each country. We retain symmetry by assuming that the number of firms in each country is the same, and let q (x)

denote the output of a representative firm from each country in its domestic (export) market. The total output in each market will then be $Q = n(q + x)$. In this section we indicate how the results of Proposition 1 are affected when $n > 1$.

Lemma 3: *The Nash equilibrium with* $n \geq 1$ *firms can be characterized as follows:*

a) *If* $t < \bar{t}^N \equiv \dfrac{A}{1+n}$, *then* $q^N(t) = \dfrac{A+tn}{1+2n}$, $x^N(t) = \dfrac{A-(n+1)t}{1+2n}$ *and* $\Pi^N(t) = \dfrac{2A(A-t)+(1+2n+2n^2)t^2}{(1+2n)^2}$

b) *If* $t \geq \bar{t}^N \equiv \dfrac{A}{1+n}$, *then* $q^N(t) = \dfrac{A}{1+n}$, $x^N(t) = 0$ *and* $\Pi^N(t) = \left(\dfrac{A}{1+n}\right)^2$.

As in the duopoly case, profits in the Nash equilibrium will be convex in t and the maximum Nash profit will occur when $t = \bar{t}^N$. Furthermore, firms may benefit from multimarket collusion whenever the Nash equilibrium profit Π^N is less than the monopoly profit Π^M. The primary difference from the findings in Lemma 1 is that $\Pi^N(\bar{t}^N) < \Pi^M$ when $n > 1$. This means that there will continue to exist gains from collusion even when the tariff is prohibitive, because there is still room for the domestic firms to coordinate their production plans (i.e., reduce domestic output).

The agreement and deviation payoffs for this case are given by

$$\begin{aligned} \Pi^A(q, x, t, n) &= \left[A - n(q+x)\right](q+x) - tx\,; \\ \Pi^D(q, x, t, n) &= \frac{1}{4}\left\{[A - ((n-1)q + nx)]^2 + [A - (nq + (n-1)x) - t]^2\right\} \end{aligned} \tag{7}$$

The agreement payoff, Π^A, is concave in (q, x) and the deviation payoff, Π^D, is convex in (q, x). It is shown in the Appendix that the results of Lemma 2 extend directly to the case of $n > 1$ firms in each country. In particular, when the no deviation constraint is binding, the efficient cartel will have $q^* = x^* > A/(4n)$ for $t = 0$. Cross-hauling of goods will continue to be a component of efficient cartel agreements when trade costs are low in order to facilitate collusion. This suggests that trade-liberalization will continue to have a pro-collusive effects when tariffs are low and the no deviation constraint is binding on the cartel. It can be shown that $\lim_{t\to 0} \delta^c(t) > \delta^c(0)$ for $n > 1$. Thus, as in Proposition 1(b), we can construct an interval such that the elimination of trade barriers will raise cartel profits.[10]

The result that a trade costs allow the cartel to sustain monopoly profits in an international duopoly was obtained by showing that $\delta^c(t) \to 0$ for n=1 and sufficiently high t. This result followed from the fact that a prohibitive tariff eliminates the incentive to deviate from the cartel equilibrium with maximal geographic collusion when $n = 1$ (i.e., $[\Pi^D(A/2, 0, t, 1) - \Pi^A(A/2, 0, t, 1)] \to 0$ as $t \to \bar{t}^N$). With $n > 1$, a deviating firm will earn profits by cheating both on its allocation in the export market and on its allocation in the domestic market. A sufficiently high trade cost can drive the gain to deviating in the foreign market to zero, but there will still exist gains from deviating against the other domestic firms in the local market. As a result, δ must be sufficiently high to sustain collusion between domestic firms even when trade costs are prohibitive. Because the cartel has to worry only about deviations by the n domestic firms when dividing up the market, this does suggest a sense in which prohibitive tariffs make collusion easier. This idea can be formalized if we assume

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[10] For $t = 0$, the cartel that yields Π^M allocates each firm $A/(4n)$ units in each market and the minimum discount factor is $\delta^c(0) \equiv [\Pi^D(A/(4n), A/(4n), 0, n) - \Pi^M]/[\Pi^D(A/(4n), A/(4n), 0, n) - \Pi^P(0)]$. When $t > 0$, the efficient cartel allocates each firm $A/(2n)$ units in its domestic market and 0 in the export market. In this case, the minimum discount is $\delta^c(t) \equiv [\Pi^D(A/(2n), 0, t, n) - \Pi^M]/[\Pi^D(A/(2n), 0, t, n) - \Pi^P(t)]$. The result $\lim_{t\to 0} \delta^c(t) > \delta^c(0)$ follows from the convexity of Π^D in (q, x). It should be noted that the construction of an interval $T(\delta)$ analogous to the one in Proposition 1(b) involves a slightly different argument for $n > 1$, because we cannot be sure that there exists a t satisfying $\delta^c(t) = \delta$ for all $\delta \in \left(\delta^c(0), \underline{\delta}\right)$. If no such δ exists, then $\hat{t}(\delta) = \bar{t}^D$.

that the punishment involves permanent reversion to the Nash equilibrium. With $t = 0$, we can use Lemma 3 and (7) to obtain $\delta^c(0) = (1+2n)^2/(4n^2+12n+1)$. The trade cost required to deter deviations is $\bar{t}^D = A/2$, which yields $\Pi^D(A/(2n), 0, \bar{t}^D, n) = A[1-(n-1)/(2n)]^2/4$. Utilizing this result and $\Pi^N(\bar{t}^D)$ from Lemma 3 yields $\delta^c(\bar{t}^D) = (1+n)^2/(1+6n+n^2)$. Comparing these two discount factors we have $\delta^c(0) - \delta^c(\bar{t}^D) = 4n(2n^2-1)/[(1+6n+n^2)(4n^2+12n+1)] > 0$ for $n \geq 1$, so Π^M is easier to sustain for sufficiently high tariffs.

The above ideas can be used to obtain the following result on the pro-collusive effects of trade liberalization when trade costs are low, and the collusive effects of protectionism when trade costs are high.

Proposition 2: *Suppose there are $n > 1$ firms in each country.*

a) *If $\Pi^P(t) = \Pi^N(t)$, the monopoly profit, Π^M, is easier to sustain for $t \geq \bar{t}^D = A/2$ than for $t = 0$.*

b) *If $\Pi^P(t) \leq \Pi^N(t)$ and $\Pi^P(t)$ is continuous in t, there will exist a set of discount factors, $\Delta \equiv \left(\delta^c(0), \lim_{t\to 0}\delta^c(t)\right)$, and a non-empty interval of trade costs, $T(\delta) \equiv (0, \hat{t}(\delta))$ for any $\delta \in \Delta$, such that $\Pi^M(t)$ is sustainable for $t = 0$ but not for $t \in T(\delta)$. The elimination of trade barriers will raise cartel profits if $\delta \in \Delta$ and $t \in T(\delta)$.*

It is worth noting that the trade costs that is required to deter deviation in the export market with $n = 1$ is equal to the prohibitive tariff in the Nash equilibrium (i.e., $\bar{t}^D = \bar{t}^N = A/2$). In contrast, when $n > 1$, the tariff required to deter deviation in the export market exceeds the tariff that prohibits trade in the Nash equilibrium described in Lemma 3 (i.e., $\bar{t}^D = A/2 > A/(n+1) = \bar{t}^N$). This follows from the fact that $\Pi^N(\bar{t}^N) < \Pi^M$ with $n > 1$.

C. Multimarket Collusion with Nash Punishments

The results so far have concentrated on the analysis of the effects of trade barriers on collusion in the neighborhood of the extreme value of $t = 0$ and $t = \bar{t}^D$. It is clear from (5) that in order to derive results on the effects of trade barriers on firm profits for $t \in (0, \bar{t}^D)$ we must make a specific assumption about the punishment payoffs. In this section, we suppose the punishment takes the form of permanent reversion to the Nash equilibrium of the one-shot game. We first establish that trade liberalization facilitates collusion in the neighborhood of $t = 0$. Then, we use simulations to illustrate how changes in trade costs, t, affect the minimum discount factor that supports the maximum sustainable global profit, Π^M, and the level of national welfare for $t \in [0, \bar{t}^D]$. Since tariffs generate revenues while transportation costs do not our discussion of welfare explicitly considers both types of trade costs.

Proposition 3: *If the no deviation constraint is binding and punishments take the form of permanent reversion to the Nash equilibrium of the one shot game, then the constrained-efficient global profit is decreasing in t in the neighborhood of t = 0 (i.e.,* $\partial\Pi^*(0,\delta)/\partial t < 0$*).*

Fig. 1(a) illustrates how the minimum discount factor varies with t for $n = 1, 2, 3$ under the assumption that $A = 10$. For $n = 1$, the minimum discount factor is discontinuous at $t = 0$, and $\delta^c(\bar{t}^N) = 0$, as pointed out in Proposition 1. With Nash punishments, we obtain the further result that the minimum discount factor is monotonically decreasing in $t \in (0, A/2)$ for $n = 1$. Fig. 1(a) also illustrates that there is also a discontinuity at $t = 0$ when $n = 2, 3$, as noted in Proposition 2. However, the size of the range of this discontinuity decreases with n.[11] This suggests that, with Nash punishments, the favorable effect of trade liberalization on collusion

[11] For example, when $n = 5$, the aforementioned range becomes (.7515, .7538).

is most important when the number of firms in the market is fairly small. Furthermore, Fig. 1(a) reveals that, for n = 2, 3, the minimum discount factor at $A/2$ is less than that at t = 0, as indicated by Proposition 2(a). Note, however, that $\delta^c(t)$ is not monotonic on (0, $A/2$) for n = 2, 3. The reason for this can be seen by differentiating $\delta^c(t)$ in the case of complete geographic specialization, which yields

$$\frac{\partial \delta^c}{\partial t} = \frac{(\Pi^A - \Pi^N)\Pi_t^D + (\Pi^D - \Pi^A)\Pi_t^N}{(\Pi^D - \Pi^N)^2} \tag{8}$$

Since there is no trade with geographic specialization, increases in t have no effect on Π^A. Higher levels of t reduce the gains from cheating by selling in the export market, and this tends to reduce the minimum discount factor. However, this effect could be offset if the punishment payoff is increasing in t. It can be seen from Lemma 3 that the Nash equilibrium payoff is increasing in t in the neighborhood of the prohibitive tariff, $\bar{t}^N \equiv A/(n+1)$, in the Nash equilibrium. This accounts for the spikes in the minimum discount factor at $A/(n+1)$ for n = 2, 3. For $t \in (\bar{t}^N, \bar{t}^D)$, the minimum discount factor must be decreasing in t because $\Pi_t^D < 0$ and $\Pi_t^P = 0$.

A second way to characterize the effect of trade costs on collusion is to identify the dependence of (constrained optimal) global profits, $n\Pi^*(t)$, on trade costs t. Fig. 1(b) illustrates the relationship between $n\Pi^*(t)$ and t for a sufficiently low discount factor $(\delta = .5)$ that ensures the monopoly output is not sustainable at t = 0. This value lies below the ranges identified in Propositions 1(b) and 2(b) under which the elimination of trade barriers raises profits for some interval of t. The impact of trade barriers on profits in this case was identified in (5) and (6), which showed that an increase in t will reduce profits in the neighborhood of t = 0 if the punishment payoff is non-decreasing in t. However, Lemmas 1 and 3 showed that the Nash equilibrium payoff is strictly decreasing in t for $t \in (0, t^N_{\min}]$. Therefore, these two effects are conflicting in the case of Nash punishments. Numerical analysis reveals that profits are decreasing in t in this region, so the former effect dominates. The simulations also reveal that the negative effect of trade costs on cartel profits is strongest when the number of firms is small. This is consistent with the result obtained for the minimum discount factors that the pro-collusive effect of trade liberalization is largest when the number of firms is small.

The efficient agreements underlying the payoffs in Fig. 1(b) involve export sales for $t = 0$, as established in Lemma 2. The optimal level of export sales will be decreasing in t up to the point where exports are eliminated, which occurs at $t = .775$ for $n = 1$ and $t = .275$ for $n = 3$. Since $\Pi^A_t = 0$ for t exceeding the value for which exports are eliminated, it can be seen from (5) that a sufficient condition for global cartel profits to be increasing in t when firms sell only in their own market is that the punishment payoff be non-increasing in t. Since the Nash payoffs are decreasing in t in the neighborhood of these critical values for t, cartel profits will be increasing in t. This is captured in Fig. 1(b) by the fact that increases in trade costs raise cartel profits for intermediate values of trade cost levels. For n=1, geographic specialization yields the monopoly profit level for $t \geq 0.9$. For n=2 monopoly profits can also be attained for some values of t, but for n=3 the incentive to deviate is sufficiently large that constrained-efficient profits are below the monopoly profit level for all t. Also note that for n=2 and n=3, profits have a local minimum at the respective values of $\bar{t}^N = A/(n+1)$. This is due to the sharp increase in the punishment payoff in the neighborhood of $\bar{t}^N$ for $n > 1$, which was also responsible for the local maximum in $\delta^c(t)$ in Fig. 1(a) for $n > 1$.

Overall, these results indicate a non-monotonic relationship between the level of trade costs and the maximum sustainable profits under collusion when firms use reversion to the static Nash equilibrium as the punishment. One feature of these figures is the U-shaped relationship between profits and trade costs suggested by the discussion of (6) for cases where the effects of tariffs on punishments is not too large. Trade cost increases reduce profits in the neighborhood of $t = 0$, where there is significant trade, but raise profits when t is sufficiently high and, as a consequence, there is substantial geographic specialization.

The simulations also illustrate an additional effect resulting from the use of Nash punishments for $n > 1$, which is that profits have a local minimum at $\bar{t}^N$. In this neighborhood, the punishment effect in (5) dominates the first two terms. Finally, the simulations capture the idea that the global maximum for the cartel will occur at trade costs that are sufficiently high to permit a large degree of geographic collusion.

We conclude our analysis by considering the impact of reciprocal trade liberalization on national welfare when firms engage in multimarket collusion. These results can then be compared with the benchmark case of the one-shot Nash equilibrium explored in Brander and Krugman (1983). We consider two cases: one in which the trade cost t represents tariffs, and another in which t represents transportation costs.

When trade barriers take the form of tariffs, national welfare, W, can be expressed as the sum of consumer surplus, global profits, and tariff revenue:

$$W = \int_{A - n(x+q)}^{A} (A - u)du + n\Pi^A(q, x, t) + ntx = \int_{0}^{n(x+q)} (A - u)du \tag{9}$$

The second equality in (9) is due to the fact that, with symmetric countries, the tariff revenues collected by the home country government from foreign firms is exactly equal to the loss of export profits to the foreign treasury in the export market. Thus, in equilibrium, the aggregate welfare measure is simply the area under the home market demand curve. Trade liberalization will raise domestic welfare if and only if it results in a reduction in the domestic price. It immediately follows from Lemmas 1 and 3 that welfare in the one-shot Nash equilibrium is monotonically decreasing in t, because industry output $Q^N = n(q^N + x^N)$ is decreasing in t.

Fig. 2 illustrates the relationship between welfare and tariff levels under constrained efficient multimarket collusion using the same parameter values as in Fig. 1. One particularly interesting feature is that for $n \leq 2$, national welfare is maximized at a positive tariff. In the neighborhood of $t = 0$, increases in the tariff have two conflicting effects on output. One is that the total cost of exports rises, which tends to reduce output. The other is that the tariff makes it more difficult to sustain the cartel, which tends to increase output. The simulations illustrate that, for $n \leq 2$, this effect is non-monotonic, with total output initially falling and then rising to a higher level as the tariff increases. This non-monotonicity is also present for $n \geq 2$, but in these cases global welfare is maximized at $t = 0$. These results yield a significant difference between the non-cooperative case, where welfare is monotonically decreasing in t, and the constrained-collusive case because of the effects of changes in tariffs on the sustainability of collusion.

In the case where trade barriers take the form of transportation costs, national welfare will equal the value in (9) less the transportation costs associated with imports; that is, $\tilde{W} = W - ntx$. The cross-hauling of goods is more costly to national welfare in this case, because trade uses up real resources and no longer transfers revenues to the government. Brander and Krugman (1983) find that this yields a non-monotonic relationship between welfare and trade barriers under non-cooperation. In this case, trade is beneficial because it makes markets more competitive; however, trade is also socially costly because it absorbs resources for two-way trade in identical products. Brander and Krugman prove that: (i) the former effect dominates when t is low (thus, welfare is decreasing in t in the neighborhood to $t = 0$); (ii) the latter effect dominates for transportation costs close to the prohibitive level (thus, welfare is increasing in t in the neighborhood of $\bar{t}^N$); and (iii) welfare is maximized at $t = 0$.

The relationship between national welfare and transportation costs under multimarket collusion is depicted in Fig. 2 for the same parameter values considered in Fig. 1. When trade costs are sufficiently high, so that firms choose to engage in maximal geographic collusion, there is no essential distinction between tariffs and transportation costs because there are no tariff revenues. Consequently, in this case, the relationship between national welfare and transportation costs is identical to the obtained earlier with tariffs. However, when trade costs are sufficiently low, so that cross-hauling is absent (i.e., $x^* > 0$), welfare in the presence of transportation costs is strictly lower than welfare in the presence of tariffs, as indicated in Fig. 2 by the thinner curves labeled $\tilde{W}$. As in Krugman and Brander (1993), welfare is increasing in t in the neighborhood of the prohibitive level. However, unlike Krugman and Brander, welfare is not necessarily maximized at $t = 0$, or decreasing in transportation costs in the neighborhood of $t = 0$ because, as was pointed out earlier, trade liberalization at low trade costs facilitates collusion.[12]

Fig. 2 reveals that, when firms engage in multimarket collusion and the number of firms is small, totally free trade may not yield the highest level of welfare, regardless of whether trade barriers take the form of tariffs or transportation costs. This contrasts with the case in which firms behave non-cooperatively (where welfare is maximized at $t = 0$), and thus substantiates the potentially adverse welfare effect of globalization due to its pro-collusive effect when t is small. Of course, these exercises have assumed the absence of a competition policy aimed at deterring collusion. If an effective competition policy, capable of detecting collusion is in place, the Nash equilibrium quantities described in Lemma 1 will be observed and welfare will be maximized at $t = 0$.[13] These results suggest that reciprocal trade liberalization will not be a substitute for competition policy in the presence of collusive behavior of this type. To realize the gains from trade liberalization countries will have to use an appropriate competition policy.

[12] For the simulations with $n = 1$, the point that minimizes global profit occurs when transportation costs are 7.9% of the collusive price. The maximum welfare point occurs when transportation costs are 11.7% of the monopoly price. These values are above the average freight rates that are typically calculated for the U.S. (for example, Hummels (2001) calculates a weighted average freight rate of 3.8% for all U.S. trade), which suggests that current transport cost barriers are sufficiently low for this effect to be important.

[13] An even higher welfare level than under free trade could be achieved by using subsidies that induce firms to produce at the competitive level, A/n.

III. Imperfect Substitutes

We now extend the model to consider the case in which products are imperfect substitutes on the demand side. As before, there are two countries with n firms in each country and each firm having a zero marginal production cost. The inverse demand function of good i sold in market k is $p_{ik} = A - q_{ik} - \gamma \sum_{j \neq i} q_{jk}$, where $\gamma \in (0, 1)$ captures the degree of substitutability between any two goods. This demand function maintains the equal size of the two markets and imposes symmetry between home and foreign firms by requiring an equal degree of substitutability between all products.

The following lemma summarizes the key properties of the payoff functions:

Lemma 4: *In the Cournot oligopoly model with symmetric trade barriers and* $\gamma \in (0, 1)$,

a) *global profits* $\Pi^N(t)$ *in the Nash equilibrium, are strictly convex in t and minimized at*

$$t_{\min} = \frac{A(2-\gamma)^2}{[2+(n-1)\gamma]^2 + n^2\gamma^2};$$

b) $\Pi^N(0) \gtreqless \Pi^N(\bar{t}^N)$ as $\gamma \lesseqgtr 2/(\sqrt{2}n + 1)$;

c) *global profits* $\Pi^A(q, x, t)$ *under an agreement* (q, x) *are strictly concave in* (q, x)*;*

d) *global profits* $\Pi^D(q, x, t)$ *under the optimal deviation from an agreement* (q, x) *are strictly convex in* (q, x).

Lemma 4 indicates that the convexity and concavity properties of the payoff functions are preserved when we allow for imperfect substitutability. However, there are two differences that deserve some emphasis here because they play an important role in the results we report below. The first is that, with imperfect substitutability, the Nash equilibrium profits could be maximized at free trade if γ is sufficiently small. When products are relatively poor substitutes, the gain in profits on domestic sales from a prohibitive tariff is not as great as the loss of sales in the foreign market. The second difference is that, for $t > 0$, the agreement that maximizes cartel profits will not necessarily involve complete geographic specialization. Specifically, the profit-maximizing cartel outputs are

$$q^M(t) = \frac{A(1-\gamma) + \gamma n t}{2(1-\gamma)[1+\gamma(2n-1)]}, \quad x^M(t) = \frac{A(1-\gamma) - [1+\gamma(n-1)]t}{2(1-\gamma)[1+\gamma(2n-1)]}, \quad \text{for } t < \bar{t}^M \equiv \frac{A(1-\gamma)}{1+\gamma(n-1)}$$

$$q^M(t) = \frac{A}{2[1+\gamma(n-1)]}, \qquad x^M(t) = 0, \qquad \text{for } t \geq \bar{t}^M \tag{10}$$

The strict concavity of Π^A for $\gamma \in (0, 1)$ makes it desirable for the representative firm to continue selling in both markets when t is not too large. In this case, the elimination of trade is more costly for the cartel because the goods of domestic suppliers are imperfect substitutes for the goods of foreign suppliers. It can be shown that, with $\gamma \in (0, 1)$, the Nash equilibrium quantities will exceed the constrained-efficient quantities for all n and t.

As in the previous section, we can define $F(t, \delta, \Pi^P)$ to be the set of $(q, x) \in \mathbb{R}^2_+$ pairs satisfying the no deviation constraint (3). Arguments similar to those used in Lemma 2 can also be used here to establish that there will exist a unique agreement that maximizes cartel profits subject to the incentive constraint. This agreement will have the property that $q^* > x^*$ if $t > 0$, and $q^* = x^* \geq q^M$ if $t = 0$. With imperfect substitutability and $t = 0$ there are two reasons for firms to equalize their market shares: deviation incentives are lower and payoffs are maximized when market shares are equal. For $t > 0$, the cartel will choose to allocate larger output shares to domestic firms in each market, as in the case with perfect substitutability.

One difference that arises between the results of Propositions 1 and 2 and those obtained with $\gamma < 1$ is that the minimum discount factor that is necessary to support the most profitable level of collusion no longer has a discontinuity at $t = 0$. However, we can identify similar effects by illustrating how the minimum discount factor varies with t in the case of Nash punishments. Increases in tariffs facilitate collusion if they reduce the minimum discount factor. It can be shown, by differentiating the expression for the minimum discount factor, that if n=1, $\delta^c(t)$ will have a local minimum at $t = 0$, so that trade liberalization will facilitate collusion in this case. For $n > 1$, the minimum discount factor will attain a local minimum (maximum) at $t = 0$ for $\gamma > (<)\ 2(n-1)/(2n-1)$. Fig. 3(a) shows the relationship between the minimum discount factor $\delta^c(t)$ and trade costs t for γ = .95, .8, .65, when n=2. For γ values of .95 and .8, there is a local minimum at t = 0 and a local maximum at the value of t for which $x^*(t) = 0$. At the value of t at which $x^*(t) = 0$, increases in the trade costs will not affect the agreement payoff but will deter deviations from the collusive outcomes and reduce the Nash punishment. Therefore, increases in the trade costs must unambiguously facilitate collusion in this region. For γ=.65 the minimum discount factor has a local maximum at $t = 0$. The decline in the minimum discount parameter becomes quite rapid at the point where $x^*(t) = 0$. In summary, these results indicate that trade liberalization will facilitate collusion in the neighborhood of $t = 0$ if n=1 or if $n > 1$ and the degree of product differentiation is not too large with linear demand.

A second aspect of the effect of tariffs on collusion that can be examined is the effect on the (constrained) efficient profit level when the discount factor is less than the minimum discount factor. With imperfect substitutability a result analogous to (6) will hold: profits will be decreasing in the neighborhood of $t = 0$ when the incentive constraint binds. Fig. 3(b) illustrates the impact of trade barriers on profits for the values of γ illustrated in Fig. 3(a). Since the maximum profit levels attainable under collusion will vary with

γ, these results have been normalized by dividing the agreement profits by the maximum sustainable profits available at $t = 0$. In all cases there is a pronounced U-shaped relationship between protection and cartel profits, because profits initially decline with tariffs but eventually increase as complete geographic specialization becomes optimal. The simulations indicate that when γ is close to 1 the global maximum for profits occurs with geographic specialization of firms, so that the most collusive agreement involves trade barriers high enough to keep foreign sellers out of the market. When γ is lower, the global maximum occurs at $t = 0$. When product differentiation becomes sufficiently large, geographic specialization in sales in substantially lower profits.

A comparison of Figs 3(a) and 3(b) illustrates the importance of considering both the minimum discount factor and the level of cartel profits in considering the effects of the tariff on cartel activity. Fig. 4 illustrates how $W(t)/W(0)$ varies with t under the assumption that trade barriers take the form of tariffs. For reasons similar to those associated with Figs. 2(a), and 2(b), the relationship between welfare and trade costs is non-monotonic. Note, however, that in all of the cases illustrated the welfare level is decreasing in the trade cost in the neighborhood of free trade.

IV. Concluding Remarks

In this paper, we have established that in general there is a non-monotonic relationship between the level of trade barriers and the profitability of cartels in the case of symmetric Cournot oligopolies. Thus, the relationship between tariffs and cartel activity is more subtle than suggested by Havemeyer's remark.

One sense in which high tariffs facilitate collusion is that they generally make it easier to sustain agreements with maximal geographic collusion in which firms specialize in selling in their own market. This is reflected in the result that the minimum discount factor associated with maximal geographic collusion is decreasing in the level of trade barriers as long as trade barriers do not have too large an effect on the punishment payoff. When the goods produced by cartel members are very good substitutes, the cartel profits will be highest when trade costs are high enough to facilitate the sustainability of maximal geographic collusion. However, geographic collusion is not attractive when the degree of substitutability between goods is low because profits are relatively low when firms sell only in their own markets. Therefore, cartel members will not benefit from high tariffs in this case, even though the minimum discount factor may be relatively low.

We also established that collusion is easier to support at free trade when cartel members have equal market shares across markets. This finding accounted for the result that cartel profits are decreasing in the level of the trade costs in the neighborhood of free trade when the no deviation constraint is binding. An increase in the trade cost level reduces the profit of cartel members for two reasons: (i) it taxes trade, and (ii) it makes it more difficult for firms to sustain collusion. If the latter effect is sufficiently large, the trade cost increase may result in a reduction in domestic price and an increase in national welfare. Numerical analysis indicated that this case is most likely to occur when goods are very close substitutes and the number of firms is small.

Our findings unveil the important role of substitutability in determining the linkage between trade liberalization and collusion. For homogeneous product cartels, profits will be highest in the extreme cases of free trade and high tariffs. When products are more heterogeneous, however, the highest profits will most likely be earned under free trade because the benefits of high tariff protection to geographically segmented markets are relatively small.

Our findings also unveil several questions concerning cartel activity that should be addressed. The observation that cartel deviation incentives are smallest when firms have symmetric costs suggest that firms might have an incentive to locate plants in each market in order to make collusion easier to sustain. This could give rise to a interesting relationship between foreign direct investment and the level of collusion. A second issue to be addressed is the extent to which the benefits of symmetric market shares extend to the case in which firms compete in prices rather than quantities. These remain areas for future research.

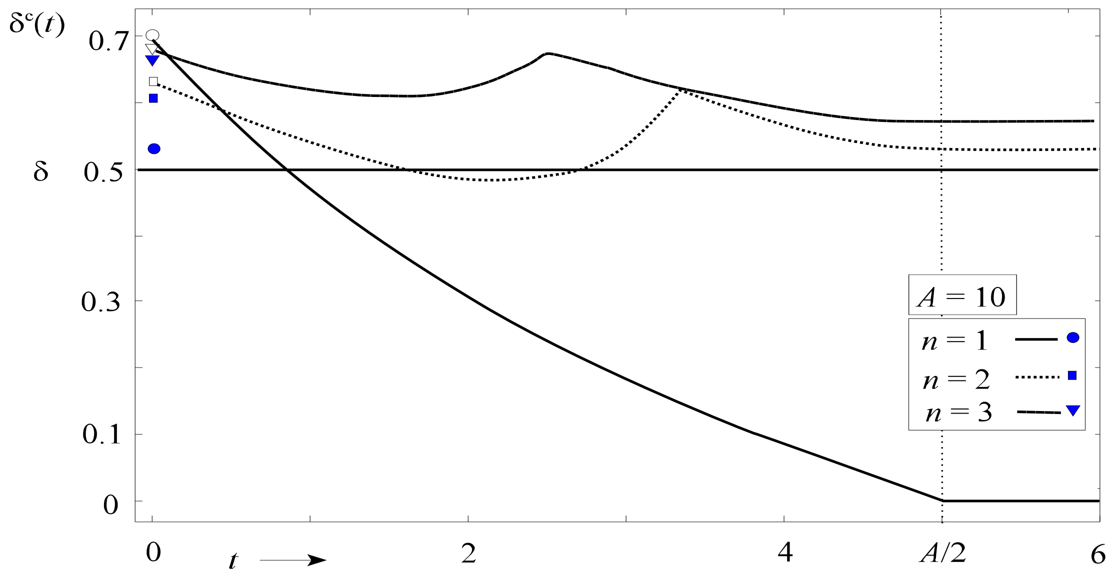


Figure 1a: Minimum Discount Factors as Functions of Trade Costs (Homogeneous Goods)

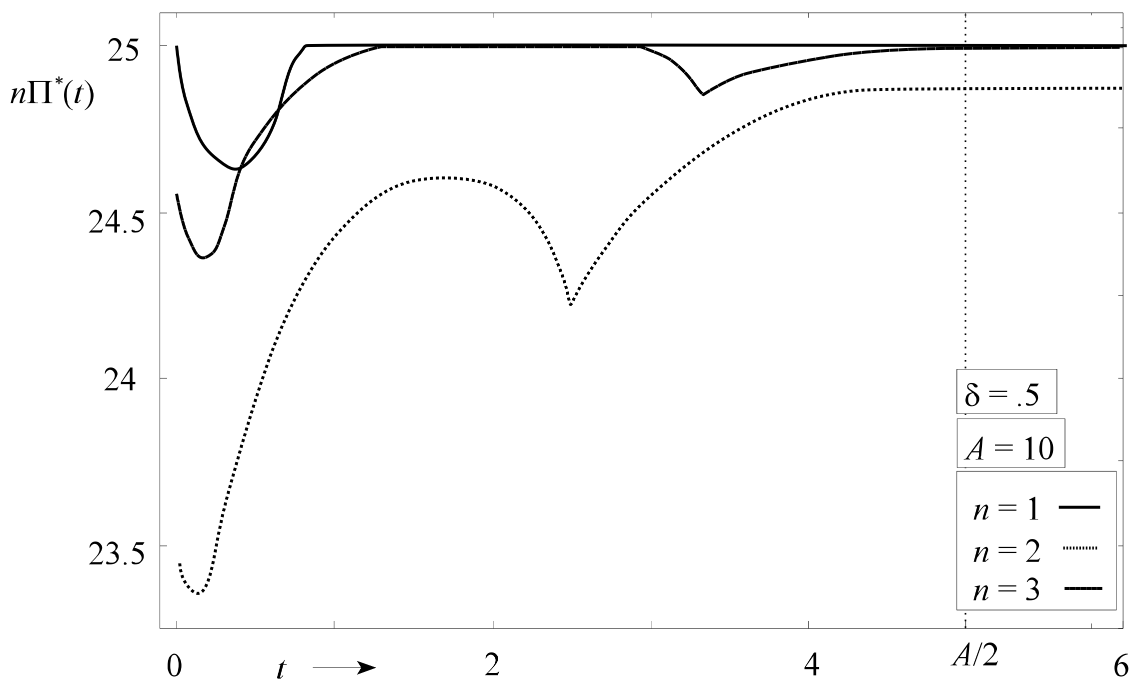


Figure 1b: Constrained-Efficient Global Profits and Their Dependence on Trade Costs (Homogeneous Goods)

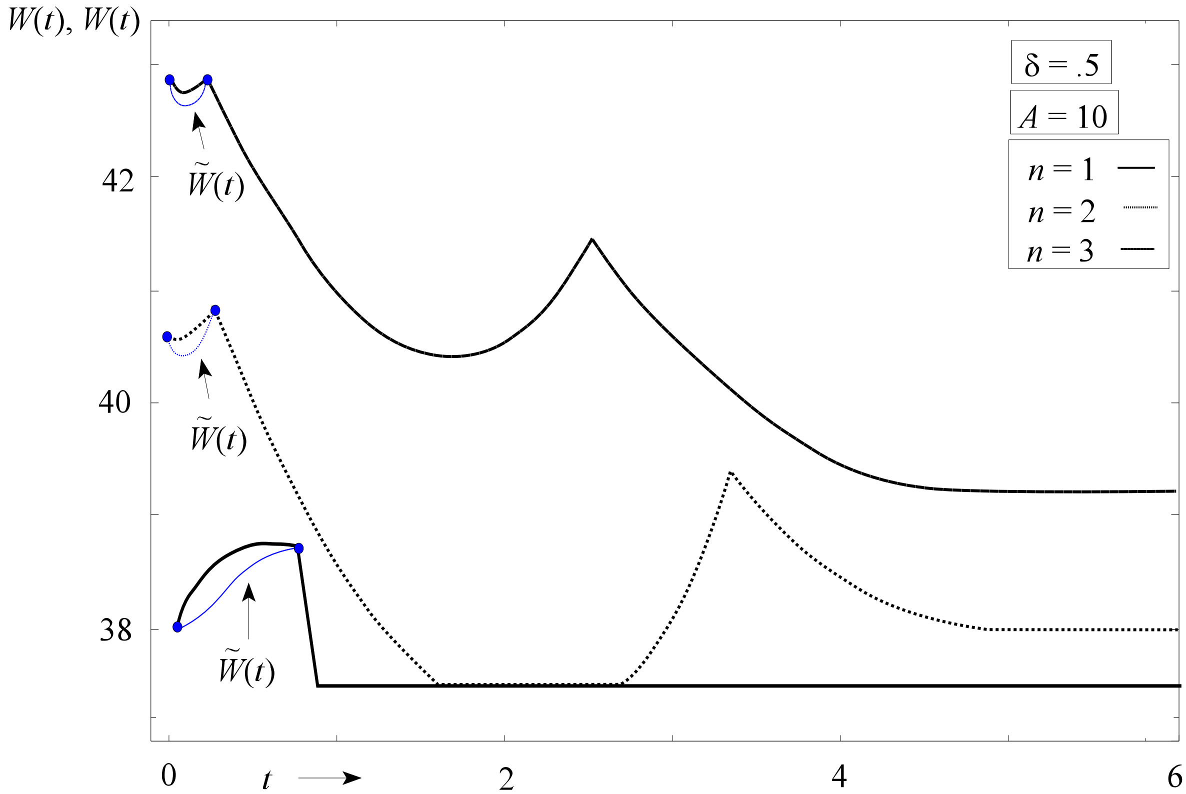
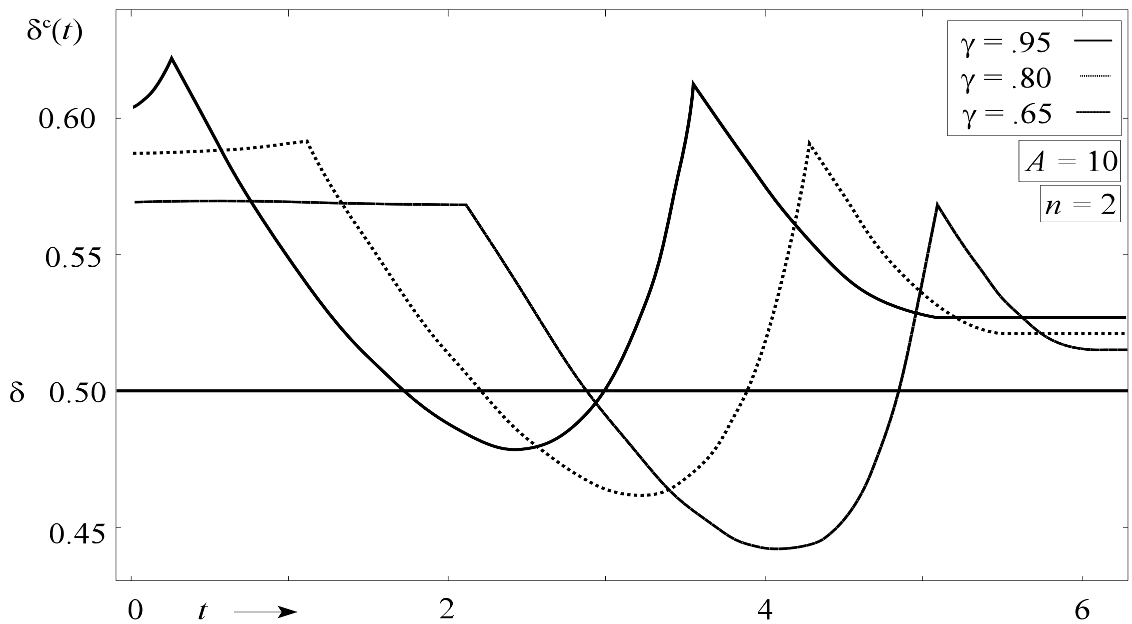


Figure 2: Welfare as a Function of Reciprocal Tariffs and Transport Costs (Homogeneous Goods)

Figure 3a: Minimum Discount Factors as Functions of Trade Costs (Imperfect Substitutes)



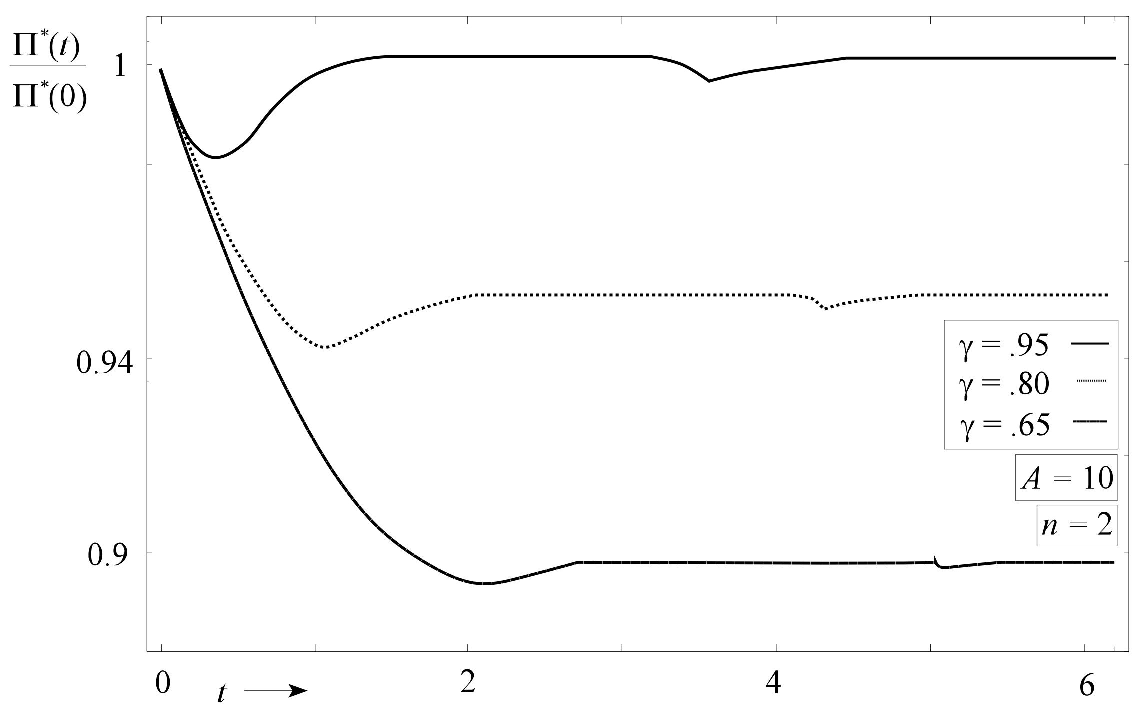
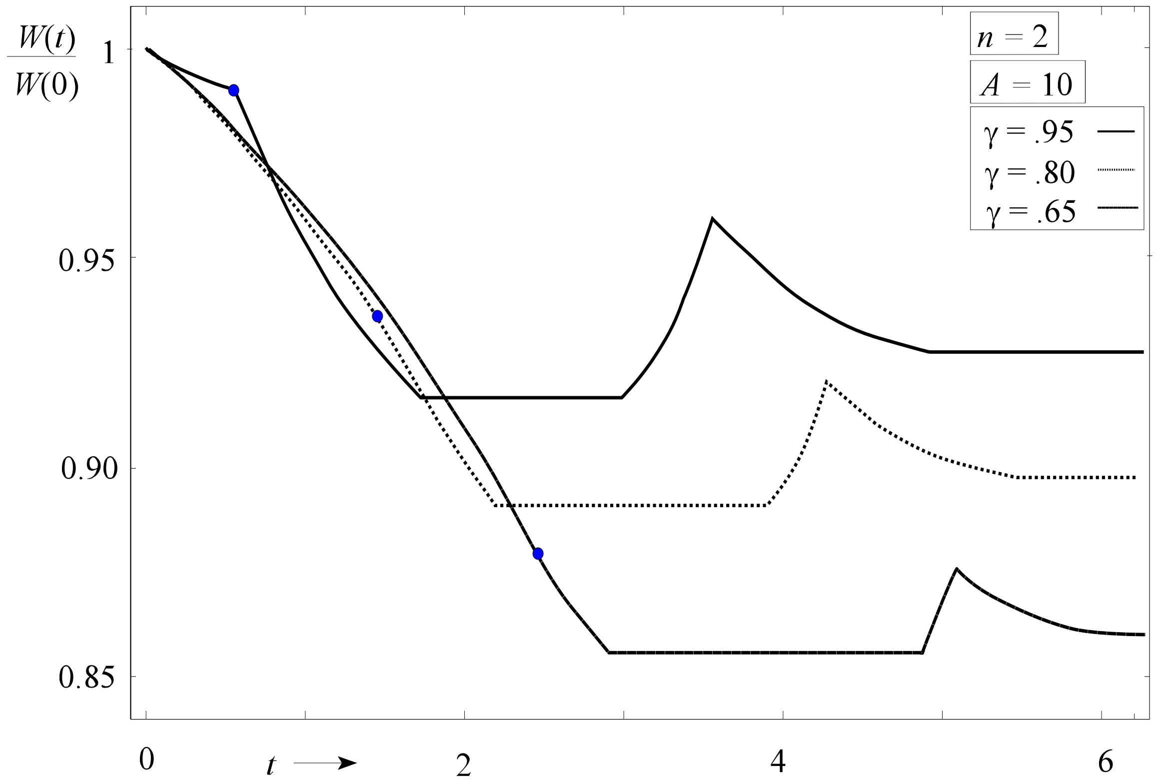


Figure 3b: Constraint-Efficient Relative Profits as Functions of Trade Costs
(Imperfect Substitutes)



Appendix

The proofs in this section will be derived for the general demand function $p_{ik} = A - q_{ik} - \gamma \sum_{j \neq i} q_{jk}$ for the most general case with $n \geq 1$ and $\gamma \in [0, 1]$. The results of Section II.A are obtained from the special case with $\{\gamma = 1, n = 1\}$ and those for II.B with $\{\gamma = 1, n > 1\}$.

Proof of Lemmas 1, 3, 4: Let $\pi(y, Y, c) = (A - y - \gamma Y - c)y$ be the profit of a representative firm with output y when all other firms produce Y and marginal cost is c. The best response function is $\tilde{y}(Y, c) = (A - \gamma Y - c)/2$ and maximum profit is $\tilde{\pi}(Y, c) = \pi(\tilde{y}, Y, c) = (A - \gamma Y - c)^2/4$. Solving $\tilde{y}((n-1)q + nx, 0) - q = 0$ and $\tilde{y}(nq + (n-1)x, t) - x = 0$ with the requirement that $x \geq 0$, we can characterize the Nash equilibrium outputs. This yields:

- If $t \leq \bar{t}^N = \dfrac{A(2 - \gamma)}{2 + (n-1)\gamma}$, then $q^N(t) = \dfrac{A(2 - \gamma) + nt\gamma}{(2 - \gamma)[2 + \gamma(2n - 1)]}$

$$x^N(t) = \frac{(A - t)(2 - \gamma) - \gamma nt}{(2 - \gamma)[2 + \gamma(2n - 1)]}$$

$$\Pi^N(t) = \frac{2A(A - t)(2 - \gamma)^2 + t^2[(2 + (n - 1)\gamma)^2 + n^2\gamma^2]}{(2 - \gamma)^2[2 + \gamma(2n - 1)]^2} \tag{A.1}$$

- If $\bar{t}^N > \dfrac{A(2 - \gamma)}{2 + (n-1)\gamma}$, then $q^N(t) = \dfrac{A}{2 + \gamma(n - 1)}$, $x^N(t) = 0$, $\Pi^N(t) = q^N(t)^2$.

The proofs to all parts of these lemmas readily follows from the above. ||

To prepare the ground for proof of Lemma 2, we first establish the following properties of the functions Π^A and Z in Lemma A.1 below.

Lemma A.1:

a) *If* $t \geq 0$ and $\gamma \in (0, 1]$, *then* $\Pi^A(q, x, t)$ *is concave in* (q, x).

If $t > 0$, *then* $\Pi^A(q, x, t)$ *is strictly quasi-concave.*

If $\gamma < 1$, *then* $\Pi^A(q, x, t)$ *is strictly concave.*

b) $Z(q, x, t, \delta, \Pi^P)$ *is concave.*

c) *For* $\delta > 0$, *there exists* (q, x) *such that* $Z(q, x, t, \delta, \Pi^P) > 0$ *if either (i)* $n > 1$ *or (ii)* $n = 1$ *and* $t < \bar{t}^N$.

Proof: Using the definition of $\pi(y, Y, c)$ and $\tilde{\pi}(y, Y, c)$, we have

$$\Pi^A(q, x, t) = \{A - q - \gamma[(n-1)q + nx]\}q + \{A - x - \gamma[(n-1)x + nq]\}x - tx$$

$$\Pi^D(q, x, t) = \frac{1}{4}\{A - \gamma[(n-1)q + nx]\}^2 + \frac{1}{4}\{A - \gamma[nq + (n-1)x] - t\}^2. \tag{A.2}$$

Parts (a) and (b) follow from evaluation of Π^A and Π^D from (A.2). The concavity of Π^A and the convexity of Π^D also imply the concavity of Z in $\{q, x\}$, and hence the convexity of the feasible set F. To establish part (c), note that $Z(q^N, x^N, t, \delta, \Pi^P) \geq 0$ since $\Pi^A(q^N(t), x^N(t), t) = \Pi^D(q^N(t), x^N(t), t) = \Pi^N(t)$. Differentiation of the payoff functions gives $\Pi^A_q(q^N, x^N, t) = \Pi^D_q(q^N, x^N, t) = -\gamma[(n-1)q^N + nx^N]$, which from (A.1) will be negative if $n \geq 1$ and $t < \bar{t}^N$. Similarly, $\Pi_x^A(q^N, x^N, t) = \Pi_x^D(q^N, x^N, t) = -\gamma\,[nq^N + (n-1)x^N] < 0$. For $\delta > 0$ and $x^N > 0$, $Z_q(q^N, x^N, t, \delta, \Pi^P) = -\delta\Pi_q^D(q^N, x^N, t) > 0$ and $Z_x(q^N, x^N, t, \delta, \Pi^P) = -\delta\Pi_x^D(q^N, x^N, t) > 0$, so there will exist an $\varepsilon > 0$ such that $Z(q^N - \varepsilon, x^N - \varepsilon, t, \delta, \Pi^P) > 0$ by the continuity of Z. On the other hand, if $\delta > 0$ and $x^N = 0$, then there will exist an $\varepsilon > 0$ such that $Z(q^N - \varepsilon, 0, t, \delta, \Pi^P) > 0$ when $n > 1$.

||

Proof of Lemma 2:

Part (a): Lemma A.1 showed that our optimization problem (4) satisfies the conditions for Theorems 2.1-2.2 in Takayama (1993). Since Π^A is a concave function and F is a convex set satisfying the Slater condition, the FOCs are necessary and sufficient for an agreement (q, x) to be a global maximum to the efficient cartel problem. In the case of Lemma 2 where $\gamma = 1$, the solution will also be unique if $t > 0$ by the strict quasi-concavity of Π^A. In the case of Section III with $\gamma < 1$, the solution will be unique from the strict concavity of Π^A.

Part (b): The necessary conditions for a maximum of the Lagrangian at an interior solution can be expressed as

$$\frac{\Pi_q^A}{\Pi_q^D} = \frac{\Pi_x^A}{\Pi_x^D} = \frac{\lambda(1-\delta)}{1+\lambda} < 1 \tag{A.3}$$

where $\lambda > 0$ is the Lagrange multiplier. Using the fact that

$$\Pi_x^A = \Pi_q^A - t + 2(1-\gamma)(q-x) \quad \text{and} \quad \Pi_x^D = \Pi_q^D - \frac{\gamma}{2}[t + \gamma(q-x)], \tag{A.4}$$

the first equality in (A.3) can equivalently be written as

$$-\Pi_q^A(\frac{\gamma}{2})[t + \gamma(q-x)] = \Pi_q^D[2(1-\gamma)(q-x) - t]. \tag{A.5}$$

Since Π_q^A and Π_q^D will both be negative at an interior solution where the no deviation constraint binds, (A.5) will require that $q = x$ if $t = 0$. For the case of $\gamma = 1$ monopoly profits are attained with an allocation $A/(4n)$. Solving (A.3) with $\gamma = 1$ and $t = 0$ yields $q^* - A/(4n) = \lambda A(4n^2 - 1)[4n(\lambda(4n^2+1) + 4n(2 + \lambda(1+\delta)))/(1-\delta)] \geq 0$, with strict equality holding for $\lambda > 0$. For $t > 0$, (A.5) can be rewritten as

$$\frac{\Pi_q^A}{\Pi_q^D} = \frac{[t - 2(1-\gamma)(q-x)]}{[t + \gamma(q-x)](\gamma/2)} < 1 \tag{A.6}$$

where the inequality follows from (A.3). In order for the right-hand side to satisfy the inequality for $t > 0$, we must have $q > x$.

This characterizes the quantities at interior solutions. We conclude by showing that there cannot be a corner solution with $q = 0$. If a corner solution with $q = 0$ is a maximum to the optimization problem, there will exist a λ and an x such that $(1+\lambda)\Pi_x^A(0, x, t) - \lambda(1-\delta)\Pi_x^D = 0$ and $(1+\lambda)\Pi_q^A(0, x, t) - \lambda(1-\delta)\Pi_q^D \leq 0$.

Subtracting the former condition from the latter and using (A.4), we have that a corner solution with $q = 0$ requires $\Phi \equiv (1+\lambda)[t + 2(1-\gamma)x] + \lambda(1-\delta)\gamma(\gamma x - t)/2 \leq 0$. Simplifying this expression and rearranging terms gives $\Phi = (1+\lambda)[2(1-\gamma) + \lambda(1-\delta)\gamma^2/2]x + [(1+\lambda) - \lambda(1-\delta)\gamma/2]t$ which is clearly positive. This contradicts our supposition that $q = 0$; therefore, $q = 0$ cannot be part of an efficient cartel agreement. ||

Proof of Proposition 3: Noting that $\Pi^P(t) = \Pi^N(t)$ and that the Lagrangian in (4) is valid for $n \geq 1$, we may solve the constrained optimization problem for t=0 to obtain

$$q^*(0,\delta) = x^*(0,\delta) = \left[\frac{4\delta + (1-\delta)(1+2n)^2}{8\delta n + (1-\delta)(1+2n)^2}\right] q^N(0)$$

$$\lambda^*(0,\delta) = \frac{-8\delta n + (1-\delta)(1+2n)^2}{\delta[8\delta n + (1-\delta)(1+2n)^2]} \geq 0 \quad \textit{since} \quad \delta \leq \delta^c(0) = \frac{(1+2n)^2}{8n + (1+2n)^2}.$$

It can be verified that $q^*_\delta < 0$. Moreover, $q^*(0,0) = q^N(0)$ and $q^*(0,\delta^c(0)) = q^M$, as expected. Substituting the expressions for $q^*(0,\delta)$ and $\lambda^*(0,\delta)$ in (5) and manipulating the resulting expression yields

$$\mathfrak{L}^*_t = -\left(\frac{2}{1+2n}\right)\left[\frac{16\delta n^2 + (1-\delta)(1+2n)^2}{8\delta n + (1-\delta)(1+2n)^2}\right] q^*(0,\delta) < 0$$

for all $\delta \leq \delta^c(0)$, which implies $\partial\Pi^*(0,\delta)/\partial t < 0$. ||

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