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A Comparison of Tariffs and Quotas
in a Strategic Setting

by

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Abstract

We model the situation where two large countries impose either tariffs or quotas and a third large country remains passive. The introduction of the third country overturns results from two-country models. Stable quota equilibria are capable of reproducing the equilibrium price under tariffs, and Nash equilibria with quotas can result in positive amounts of trade. Using a linear partial equilibrium model, we show that world welfare may be higher under Nash quotas than under Nash tariffs. However, simulation results suggest that tariffs are likely to result in higher welfare than quotas.

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Executive Summary of
"A Comparison of Tariffs and Quotas in a Strategic Setting"

There is a large literature that compares trading equilibria
when nations use either tariffs or quotas. The purpose of that
literature is to provide general recommendations for the choice
of policy instruments. Various models have focused on different
aspects of the problem, and the conclusions are typically
ambiguous.

Two-nation, deterministic models have, however, suggested
that tariffs are superior to quotas. This conclusion holds
whether or not nations select the optimal value of the
instrument. Stable equilibria under quotas must lie on the lens
formed by the nations' offer curves. Tariff equilibria, on the
other hand, can lie in the interior of the lens. Thus, a much
larger set of stable equilibria can be sustained under tariffs.
In a Nash game, the use of quotas eliminates trade, whereas the
use of tariffs merely reduces trade.

This paper investigates whether these results continue to
hold if a third, passive, agent is introduced. The presence of
the third nation implies that the quota-ridden offer curve facing
one of the other nations is no longer perfectly inelastic. This
implies that interior (to the lens) stable equilibria are
possible under quotas, and that a Nash equilibrium under quotas
does not result in 0 trade. Therefore the results of the two-
country model no longer hold generally. Simulation exercises
indicate that world welfare may be higher under Nash quotas than
under Nash tariffs, but that this is unlikely.

A COMPARISON OF TARIFFS AND QUOTAS
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I. INTRODUCTION

Despite the lack of a universally valid welfare ranking between trade restrictions based on quantity controls and those based on price intervention, there is at least a strong sentiment that favors tariffs above quotas. The General Agreement on Tariffs and Trade (GATT) rules, which permit tariffs and discourage quotas, are an expression of this sentiment. This note discusses one of the arguments which form the basis for the preference for tariffs.[1]

There are at least two distinct types of reasons for favoring tariffs. In the presence of uncertainty, tariffs allow greater flexibility than do quotas if there are many states of nature in which the latter are binding. This flexibility tends to make welfare higher under a tariff than under a quota which is equivalent in some sense (e.g., both result in the same average level of imports). Although plausible, the universality of this view has been challenged (Fishelson and Flatters [1975]; Young [1979]; Young and Anderson [1980 and 1982]). It is now widely recognized that the presence of uncertainty is not a sufficient condition for tariffs to dominate quotas.

A second and perhaps more compelling argument in favor of tariffs is based on a comparison, in a deterministic environment, of the equilibria that result when nations use either tariffs (taxes) or quotas. Tower [1975] studied this issue using a two-country two-good general equilibrium model. He concludes that *"all countries should choose tariffs over quantitative restrictions, or else be indifferent between them"* [1975, p. 630].

The clarity of the result relies on the fact that a nation's offer curve becomes completely inelastic at the point at which its quota becomes binding. If the rival takes the quota as given, as under the Nash equilibrium, it believes that it is able to obtain a substantial improvement in the terms of trade at the expense of a negligible reduction in imports. This causes it to preempt the original policy by making its own quota slightly more stringent than its rival's. Since both nations act in this way, the only Nash equilibrium under quotas results in zero trade. If, on the other hand, nations use tariffs, there always exists a Nash equilibrium which involves trade. Since some trade is better than no trade, for both nations, the tariff equilibrium dominates the quota equilibrium.

More recently, Melvin [1986] compared the equilibria that result under arbitrary tariffs and quotas. He points out that under import quotas any stable equilibrium must lie on the envelope of the lens formed by the two nations' offer curves; a tariff equilibrium with positive tariffs must lie inside the lens. Therefore, the two sets of possible equilibria are disjoint. However, any quota equilibrium can be approximated arbitrarily closely by a tariff equilibrium; the converse does not hold. In this sense the set of possible equilibria is much larger under tariffs; this provides an informal, but plausible, basis upon which to prefer tariffs over quotas. Melvin's [1986] conclusions, which are closely related to Tower's [1975], follow from the fact that, if two countries use import quotas, their offer curves are perfectly inelastic over a region.

The purpose of this note is to question whether these conclusions survive the introduction of a third agent whose policies are given. This agent, denoted R, represents the rest of world; we assume that its combined policies cannot be described by a single quota. When the (original) two

countries are small relative to R, the former's policies do not affect the world equilibrium price. Therefore, the Nash equilibrium results in free trade whether the choice variable is a tariff or quota. When R is small relative to the two countries, Tower's [1975] and Melvin's [1986] conclusions hold, at least approximately.

The interesting situation occurs when the two countries and R are of the same order of magnitude. Trade in many commodities is characterized by the presence of a few large importers and exporters and a large number of small agents who collectively are significant. In these situations it is important to determine whether it makes sense to proscribe quantity restrictions and to permit tariffs.

The next section modifies Melvin's [1986] analysis by including R in a two-good general equilibrium model. It is no longer true that all stable quota equilibria lie on the envelope of the lens formed by the relevant offer curves. Tariff and quota equilibria may result in the same world price, although the trade flows need not be the same under the two types of policies. The following section compares Nash equilibria under tariff (tax) policies and under quotas in a partial equilibrium model. We show by example that, in the presence of R, world welfare may be higher when quotas are used, contrary to the two-country model. The conclusion summarizes the results and suggests some policy implications.

II. GENERAL EQUILIBRIUM

This section demonstrates why the presence of a third agent (whose policies are given) makes the comparison between quotas and tariffs ambiguous. Figure I describes the model. For relevant prices, country H imports good y and country F imports good x. The relative price of x is P.
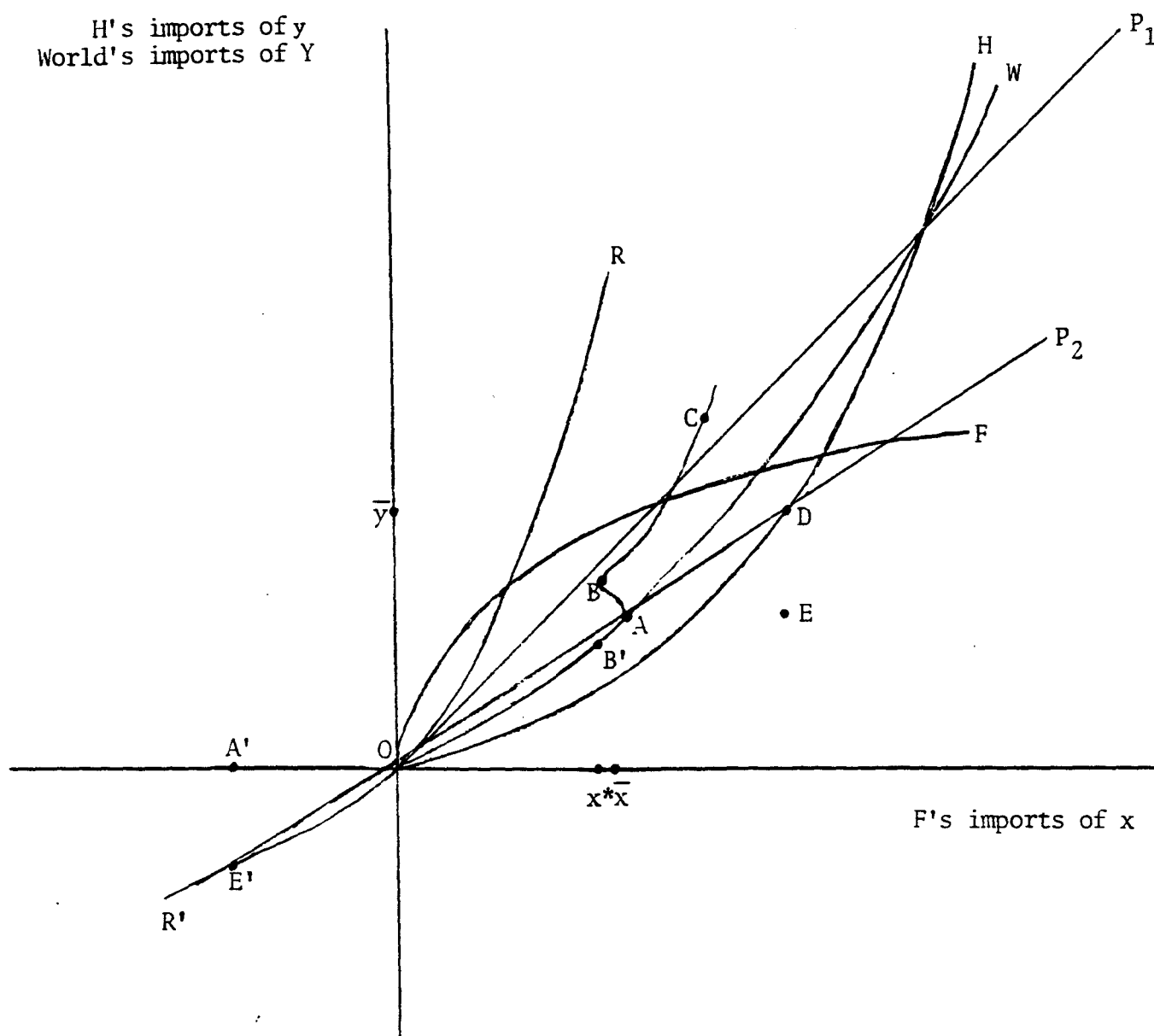
H's imports of y
World's imports of Y

R

H
W

P₁

P₂

C

F

$\overline{y}$

D

B

E

A

B'

A'

O

x*$\overline{x}$

F's imports of x

E'

R'

FIGURE I

The General Equilibrium Model

For $P < P_1$, R imports x and exports y; define x_R and y_R as R's imports of x and exports of y, respectively. Country H's offer curve is OH, and R's offer curve is R'R. The curve OW gives the net imports of y and exports of x by R and H for a given price. For prices less than P_1, this lies above the curve OH since for those prices R exports y to H. For example, at P_2, R imports AE = OA' units of x and exports DE = A'E' units of y. We assume that R's autarky price, P_1, lies between the autarky prices of H and F, as shown in Figure I.

Let H impose an import quota of $\bar{y}$. The quota is binding for $P > P_2$, and the offer curve facing F is now OABC. Define

$$\varepsilon = \frac{-dx_R}{dP} \frac{P}{x_R}$$

R's elasticity of demand for imports x; $y_W = \bar{y} - y_R$, the net demand for imports of y by R and H when H's quota is binding; and $x_W = x_H - x_R$, the net supply of exports of x by R and H. For $P > P_2$, the elasticity of the offer curve facing F is

$$\phi \equiv \frac{dy_W}{dx_W} \frac{x_W}{y_W} = \frac{\varepsilon - 1}{\varepsilon - x_H/x_R} = \frac{(\varepsilon - 1)x_R/P}{-dx_R/dP - \bar{y}/P^2}.$$

In order to reduce the number of cases we need consider, we adopt

Assumption 1a   for $P < P_1, \varepsilon > 1$ and

1b $d^2 x_R/dP^2 \leq 0$.

Assumption 1a ensures that the numerator of ϕ is nonnegative,[2] and 1b implies that the denominator is an increasing function of P (1b is sufficient but not necessary for this result).

Assumption 1 implies that, if the quota-ridden offer curve facing F bends toward the y axis, it does so at the price at which the quota is binding (point A in Figure I). This requires

$$\frac{-dx_R}{dP} < \frac{\bar{y}}{P^2},$$

evaluated at $P = P_2$. That is, unless R's demand for imports is sufficiently elastic, F faces an inelastic demand for its exports at prices near P_2. It is obvious from the expression for ϕ that, for P sufficiently large, the offer curve facing F has a positive slope; this does not require Assumption 1. However, the assumption guarantees that there will be at most two turning points (A and B in Figure I) and that the offer curve facing F never approaches the x axis (i.e., F's level of imports is a single-valued function of its exports).

In the absence of R, the quota-ridden offer curve facing F is $OD\bar{y}$, which is horizontal for $P > P_2$. In the presence of R, when both F and H use import quotas, it is no longer the case that all stable equilibria lie on the envelope of the lens formed by the nondistorted offer curves. Interior stable equilibria are clearly possible. Such an equilibrium can also be achieved by means of tariffs, although H and F's trade flows will typically not be the same under the two types of policies. There may be multiple stable equilibria. For example, the vertical line from $\bar{x}$ in Figure I intersects AB. If H imposes the quota $\bar{y}$ and F imposes the quota $\bar{x}$, there are two stable and one unstable equilibria. At the interior stable equilibria, both quotas are binding.

If both nations use import quotas, the Nash game may not be well defined due to the possibility of multiple price equilibria for a pair of

quotas.[3] To avoid this ambiguity we consider the game in which both nations impose a quota on the same good. For concreteness, suppose that H imposes an import quota and F imposes an export quota on y. Assumption 1 guarantees that, for any combination of import and export quota, a unique price and, consequently, a unique pair of payoffs results. There are two additional reasons for assuming that both nations impose a quota on the same good. First, this assumption is consistent with the partial equilibrium framework adopted in the next section. Second, if H uses an import quota, F (weakly) prefers to use an export quota. For example, if F's offer curve intersects OABC at B (Figure I), the best that F can guarantee itself using an import quota is to set the quota at x^*, causing price to fall to OB'. (If F chooses an import quota greater than x^*, B is a stable equilibrium. B, rather than the stable equilibrium that lies between B' and A, may occur; see footnote 1.) If, however, F chooses an export quota, it can achieve any equilibrium between B' and A.

If F chooses an arbitrary export quota y^*, the offer curve facing H has a positive slope given Assumption 1a. This is intuitively obvious; in the absence of R, F's export quota causes H to face a flat offer curve where the quota is binding. The presence of R with elastic demand for imports increases the slope of the curve, i.e., makes it positive. To verify this intuition, define $\hat{y} = y^* + y_R$, the supply of imports facing H when the export quota is binding, and $\hat{x} = x_F + x_R$, the net demand for imports from H. The inverse of the elasticity of the offer curve facing H when the export quota is binding is

$$\rho \equiv \frac{d\hat{y}}{d\hat{x}} \frac{\hat{x}}{\hat{y}} = \frac{(\varepsilon - 1)x_R}{x_F + \varepsilon x_R},$$

which is positive given Assumption 1a.

We are now able to state

PROPOSITION 1. Suppose that the nondistorted offer curves of H and F are positively sloped over an interval that includes the origin, as shown in Figure I, and that Assumption 1 holds. If H imposes an import quota and F imposes an export quota, then there exists a Nash equilibrium in pure strategies at which both countries trade.

Proof. The proof uses Figure II, which graphs H's best response function, ABCD, and F's best response function, A'B'C'D'. (Several features of these graphs appear arbitrary and are discussed in the following section; these features[4] are not used in the present argument.) If H chooses a zero quota, F's optimal quota is strictly positive because of the presence of R: point A' is bounded away from zero. If H's quota is sufficiently large, it is not binding, so small changes do not affect F's optimal response; this is represented by the interval C'D'. Since the offer curve OW lies to the right of OR, F's optimal quota when H's quota is not binding is larger than when H's quota is zero: point C' lies to the right of A'. F's best response function A'B'C'D' intersects the 45 degree line from below. By a similar argument, ABCD intersects the 45 degree line from above. Since the best response functions are continuous, they intersect at an interior point. Therefore, there exists an interior pure strategy Nash equilibrium.

Q.E.D.

This proposition is useful because it invalidates one argument used to show that tariffs dominate quotas. The basis for this argument is as follows: In the absence of R, when H imposes an import quota, it pays F to
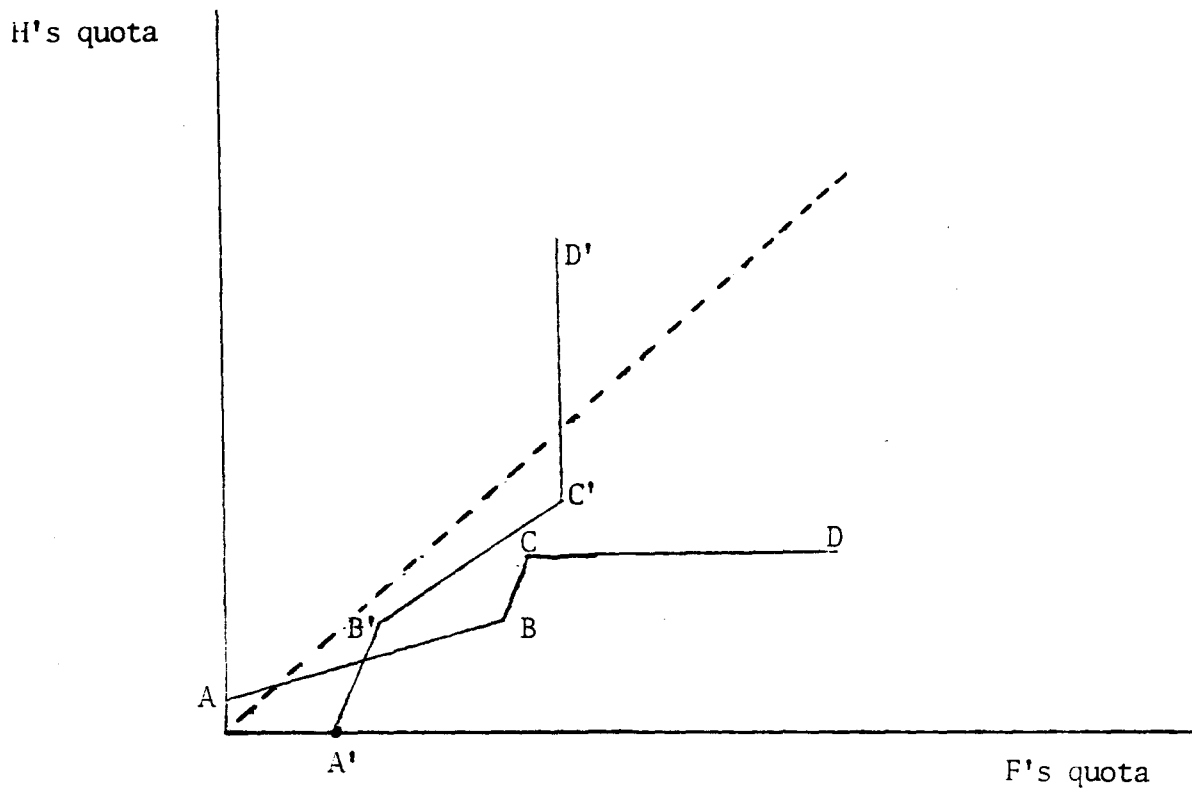
FIGURE II

Best-Response Functions of F and H

impose an export quota that is (at least) slightly more restrictive since this creates a negligible change in the level of imports and a nonnegligible improvement in the terms of trade. In order for F's best response function to be defined, we assume that, when H imposes an import quota of $\bar{y}$, F's export quota has no bite unless it is no larger than $\bar{y} - \delta$, where δ is a small positive constant.[5] This assumption can be motivated by F's belief that, unless its own quota is appreciably more restrictive than its rival's, there is a positive probability that its rival will capture all or part of the quota rents. Given this assumption, F's best response function lies strictly above the 45 degree line in Figure II, except possibly for an interval close to the origin; this interval can be made small by choosing δ small. Given an analogous assumption for H, its best response function lies below the 45 degree line in Figure II, except possibly near the origin. In this case a Nash equilibrium with quotas, in the absence of R, can result in at most a negligible amount of trade. Under the same circumstances, there exists a Nash equilibrium with tariffs that results in positive levels of trade. Therefore, both nations do better by committing to use tariffs rather than quotas. This is Tower's [1975] result.

III. PARTIAL EQUILIBRIUM

The previous section demonstrated that, in the presence of a third passive country, R, there exists interior price equilibria when each of two large countries impose quotas. If both countries impose a quota on the same good, there exists a Nash equilibrium with positive levels of trade. Therefore, it is not obvious that both countries would be willing to abjure the use of quotas and to adopt tariffs. This section shows by example that there are situations where tariffs do not dominate quotas in a Nash game. We

assess the likelihood of this occurrence and the probable magnitude in welfare loss due to use of the inferior form of trade restriction.

Since our chief objective is to find a counterexample to the conventional wisdom which favors tariffs, we use the simplest model available: a partial equilibrium linear model, described in Figure III. We assume that F's excess supply is given by cQ, that R's excess demand is $\alpha(1 - \beta Q)$, and that H's excess demand is $a(1 - bQ)$. Hereafter, we choose units of price and quantity so that $a = b = 1$; this leaves us three free parameters, α, β, and c. The excess demand facing F is ABC in the absence of an import quota and ABD when H imposes the quota $\bar{Q}$. The excess supply facing H is JKL in the absence of an export quota and JKM when F imposes the quota Q*.

Both F and H choose their quota to maximize the sum of quota rents and their consumer or producer surplus, taking their rival's quota as given. The construction of the Nash equilibrium for this model involves routine but lengthy calculations.[6] Figure II describes the principal features of the equilibrium. We discuss F's best response function; the description of H's is similar. If the import quota is sufficiently large, it is not binding, and F chooses its optimal export quota given by the intersection of C'D' and the horizontal axis. As the import quota becomes binding, F chooses to sell at the kink of the excess demand curve it faces (point B in Figure III). This results in the segment B'C' (Figure II). If the import quota is small enough, it is optimal for F to sell on the steep portion of the residual demand curve (BD in Figure III). This results in the segment A'B' in Figure II.

The relative slopes of the segments of A'B'C'D' in Figure II are explained in Figure IV. The curves ACD and ABE in Figure IV give the

II   P   I

a

A

M   B

L   cQ

α C

K

$a(1 - bQ)$ J $\alpha(1 - \beta Q)$ D
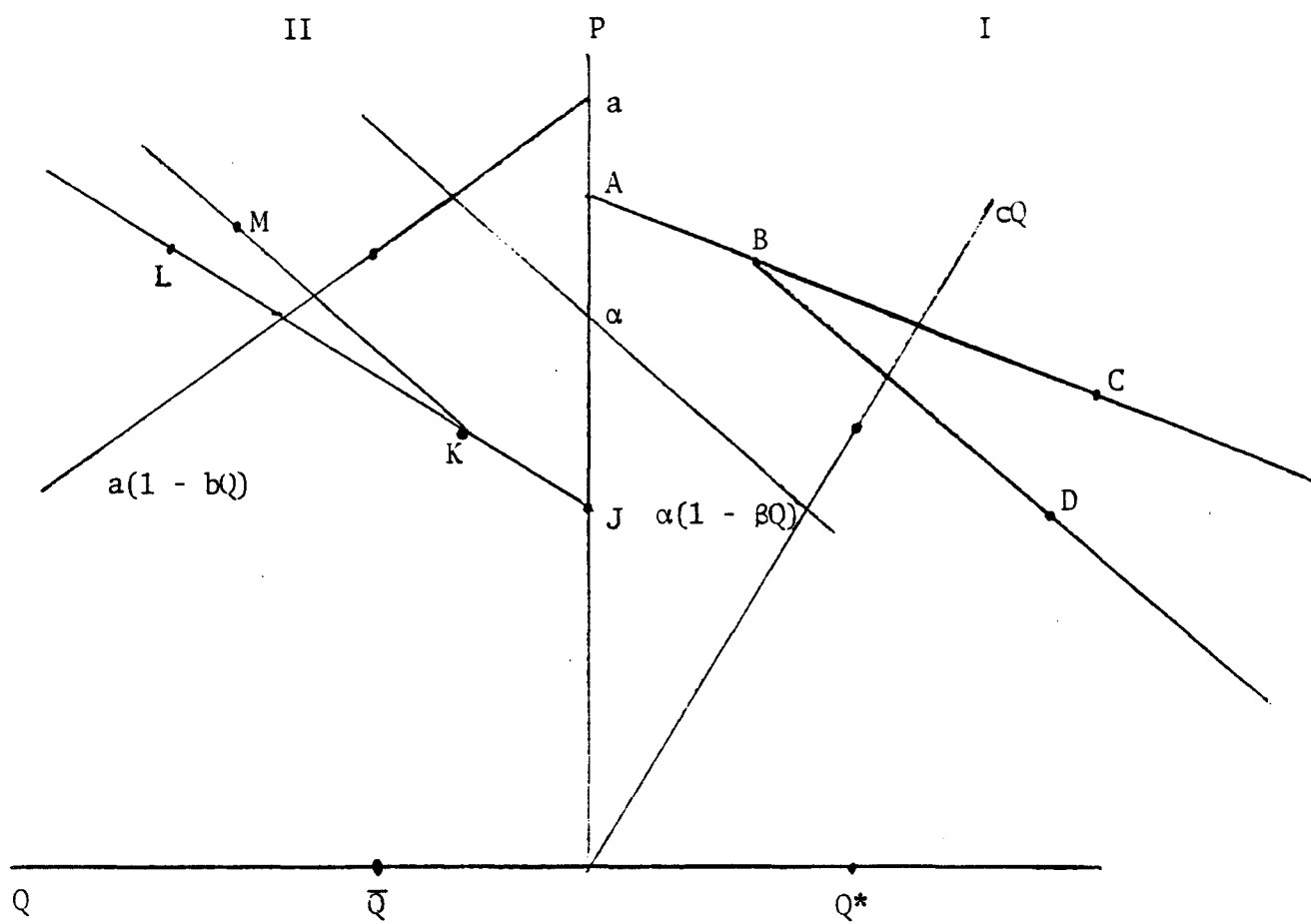
Q $\bar{Q}$ Q*

FIGURE III
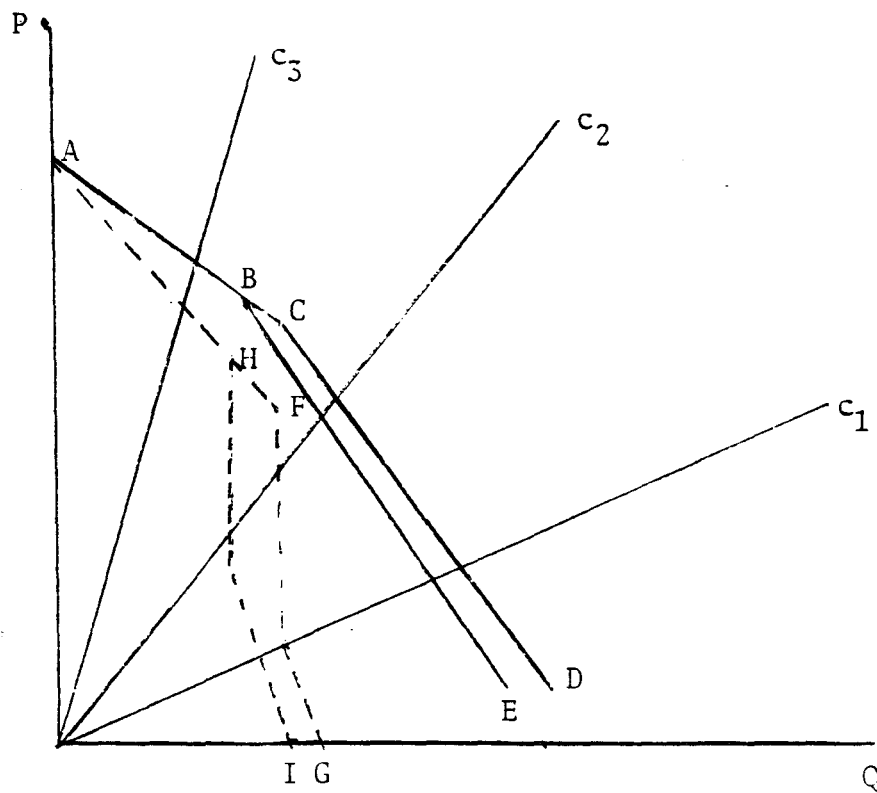
The Linear Parital Equilibrium Model

FIGURE IV

The Optimal Quota as a Function of Import Quota

excess demand curves facing the exporter for different levels of the import quota, and AFG and AHI show the corresponding marginal revenue curves. If the slope of the marginal cost curve is c_3, the change in the import quota has no effect on the optimal export quota. If the marginal cost curve intersects the marginal revenue curve in the vertical region, a change in the import quota has a larger effect on the optimal export quota than is the case when the marginal cost curve intersects the marginal revenue curve below the vertical region. This is because the distance GI is less than the horizontal distance between HI and FG where those curves are vertical.

The piecewise linearity of the best response functions is due to the linearity of the model. Other features of the response functions are preserved if the linear supply and demand functions are replaced by smooth nonlinear functions. The optimal export quota, for example, is insensitive to changes in the import quota where the latter is sufficiently large. As the import quota becomes binding, the optimal export quota occurs at a kink and is relatively sensitive to changes in the import quota. For sufficiently small import quotas, where it is optimal to export so that price is below the kink, the optimal export quota is less sensitive to changes in the import quota.

Inspection of Figure II also reveals

PROPOSITION 2. For the linear model described in Figure III, there is a unique stable Nash equilibrium at which both quotas are positive and binding.

Proof. From the shape of the best response functions in Figure II, it is clear that there exists either one or three Nash equilibria[7] at which the

quotas are positive. Suppose, contrary to the proposition, that there are three equilibria so that two are stable. Then, it is evident from Figure II that one stable equilibria occurs on either CD or C'D'. With no loss of generality, suppose that it occurs on C'D'. At this equilibrium, a small change in the import quota does not affect F's optimal export quota, which implies that a change in the import quota does not affect the world price. However, since the importer faces an upwardly sloping excess supply curve, it is optimal for it to impose a binding import quota, i.e., one which affects the world price. This contradiction establishes the proposition.

Q.E.D.

In the absence of R, each country wants to undercut its rival's quota so that only its own quota is binding and it captures all of the quota rents. In the presence of R, F's exports and H's imports are not equal in general. Country F, for example, may want to export either more or less than H is willing to import. When H's import quota is small (i.e., lies below C' in Figure II), it costs F too much, in foregone sales to R, to want to make H's quota slack. Similarly, when F's quota is small, it costs H too much, in foregone purchases from R, to want to make F's quota slack.

Calculation of the Nash equilibrium *ad valorem* tariffs for the linear model requires solving a quadratic equation (see note 6). Given parameter values for α, β, and c, the normalization a = b = 1 and the assumption that the exporter's cost curve intersects the origin, it is straightforward to compare welfare at the Nash equilibrium under quotas and tariffs. The assumption that R's autarkic price lies between that of F and H requires that $0 < \alpha < 1$; β and c can be any positive number.

As $\beta \to 0$, H and F face a fixed world price; with either policy instrument they permit free trade, and world welfare is the same. As $\beta \to \infty$, the influence of R on the behavior of H and F becomes negligible; therefore, the amount of trade and the magnitude of world welfare approaches zero under a Nash equilibrium with quotas. The welfare comparison is ambiguous when β is of the same order of magnitude as the other parameters of the model.

Since our principal objective is to demonstrate that tariffs do not necessarily dominate quotas (and in the interests of simplicity), we present only a comparison of world welfare (the sum of welfare in R, H, and F) and of welfare in R under quotas and under tariffs. If, for a particular set of parameter values, world welfare is higher under the quota, but R's welfare is higher under the tariff, then combined welfare in H and F must certainly be higher under the quota.

The welfare comparison for R is also of intrinsic interest. We can think of R as representing the less developed nations and H and F as representing the large trading powers. Given noncooperative behavior amongst the large countries, is it in the developing countries' collective interest that the former be restricted to using price rather than quantity controls? The answer to this clearly depends on the parameter values of the model. For example, if the Nash equilibrium under tariffs results in a world price of α, R's welfare gain from trade is zero; R cannot be worse off if quotas are used instead.

Tables I and II present welfare comparisons for a range of values of α and β and for c = 1.5, 2.5. The first element in each cell gives the ratio of world welfare under the tariff to world welfare under the quota; the second element gives the ratio of R's welfare under the tariff to R's welfare under

TABLE I

Welfare Comparisons for c = 1.5^a

α \ β	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0.25	7.72	2.42	1.51	1.21	1.08	1.02	0.998	0.993	1.000	1.01
	163.99	31.57	14.43	9.01	6.53	5.16	4.32	3.74	3.35	3.02
0.50	5.37	1.62	1.19	1.10	1.11	1.14	1.19	1.25	1.31	1.38
	771.11	135.71	58.40	40.33	19.67	15.50	17.00	10.00	6.00	3.00
0.75	3.87	1.38	1.18	1.20	1.26	1.35	1.44	1.54	1.64	1.74
	69.90	2.43	0.00	0.26	0.69	1.09	1.40	1.64	1.88	2.08

[a]The first element in each cell is the ratio of world welfare under the Nash tariff to world welfare under the quota; the second element in each cell is the ratio of R's welfare under the Nash tariff to R's welfare under the quota.

TABLE II

Welfare Comparisons for c = 2.5[a]

β / α	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0.25	9.41	2.84	1.66	1.25	1.06	0.97	0.92	0.89	0.88	0.88
	154.54	30.53	14.07	8.83	6.46	5.17	4.35	3.79	3.42	3.13
0.50	7.53	1.90	1.20	1.03	0.99	0.99	1.02	1.05	1.09	1.14
	261.94	47.81	21.62	13.72	9.86	7.73	6.22	5.43	4.50	3.80
0.75	6.09	1.55	1.14	1.08	1.11	1.16	1.22	1.29	1.36	1.43
	749.67	28.09	2.69	0.13	0.07	0.37	0.75	1.00	1.27	1.47

[a]The first element in each cell is the ratio of world welfare under the Nash tariff to world welfare under the quota; the second element in each cell is the ratio of R's welfare under the Nash tariff to R's welfare under the quota.

the quota. For β in the range of 3-5 and for small values of α, world welfare is greater under the (Nash equilibrium) quotas than under the tariffs. In these cases R does better under the tariff, so the combined welfare of H and F is greater under the quota.

Although there are cases where world welfare is lower under the tariffs, these are relatively infrequent, and the welfare loss due to using tariffs is usually not substantial. In all cases reported in the tables, welfare under the tariff is at least 88 percent of welfare under quotas. The most unfavorable case for tariffs that we were able to find led to a welfare ratio of approximately .84.[8] In most cases world welfare is higher under Nash tariffs, in many cases by a factor between 5 and 10.

As we remarked above, it is clear that there may be situations where R prefers for the large countries to use Nash quotas rather than tariffs. For the examples reported in the tables, this occurs in just over 10 percent of the cases. For the most part, R does substantially better when F and H use tariffs.

IV. CONCLUSION

This note has investigated the relevance of the conventional wisdom which favors tariffs over quotas. The intuition behind this preference is based on two-country models. We have shown that the presence of a third passive country expands the type of stable price equilibria that can be achieved by means of quotas. If the large countries adopt Nash strategies, welfare may be higher when quotas rather than tariffs are used. These conclusions cast some doubt on the conventional wisdom and suggest that the welfare ranking of tariffs and quotas is an empirical question. However, the results of numerical experiments suggest that it is at least

likely that tariffs dominate quotas and that, when they fail to do so, the loss in welfare is probably not large. Therefore, as a guiding principle, the GATT rules that permit tariffs and discourage quotas seem sensible.

There are several important issues that we have neglected. Why do nations choose one policy instrument over another? One possible explanation involves the different insurance properties of different instruments. There is a large literature on this subject where a single country takes the rest of world behavior as given (e.g., the papers cited in the Introduction), but we are unaware of work in the trade area involving both strategic behavior and uncertainty. Klemperer and Meyer [1986] consider the choice between price and quantity competition in a duopoly; this problem is very similar to the situation studied here. Their results, taken in conjunction with those of the single-country models which rank tariffs and quotas (especially Young [1979]), suggest that we are unlikely to find general conditions which determine whether tariffs or quotas emerge in equilibrium.

Our discussion of strategic considerations was exclusively based on the one-shot noncooperative Nash game. It is worth considering how matters change if instead the countries play a cooperative game or a noncooperative supergame. Suppose that there are only the two countries, H and F. It is well known that free trade may not Pareto dominate the Nash equilibrium with tariffs (Mayer [1981]); free trade certainly dominates (our version of) the Nash equilibrium with quotas. If we assume that the two countries play a noncooperative supergame and that each believes that deviation from a reference equilibrium causes its rival to adopt their one-shot noncooperative Nash policy level,[9] then it may be the case that free trade is sustainable as a perfect equilibrium under quotas but not under

tariffs. Similarly, free trade will be in the bargaining set of a cooperative game with quotas but may not be in the bargaining set in the game with tariffs.

The introduction of uncertainty or of more sophisticated strategic behavior increases the ambiguity of the welfare ranking between quotas and tariffs; this ranking is already uncertain when there is a third nation involved in trade. Nevertheless, it seems reasonable to require the burden of proof to rest on those who advocate quotas above tariffs.

APPENDIX: CONSTRUCTION OF THE QUOTA AND TARIFF NASH EQUILIBRIA FOR THE LINEAR MODEL

We outline the construction of the exporter's best response function A'B'C'D' (Figure II) for the linear model of Figure III. The construction of the importer's best-response function is similar.

Define

$$\gamma_0 = \frac{\beta + 1}{\beta}, \quad \gamma_1 = \frac{\alpha\beta + 1}{\alpha\beta}$$

Suppose that import quota is Q^i; then the quantity of exports by F that makes the import quota binding is Q^D, given by

(A.1)
$$Q^D = \gamma_0 + \gamma_1(Q^i - 1),$$

which uses the normalization $a = b = 1$. If the import quota is not binding, the exporter solves

$$P1 \max_{Q \leq Q^D} (\gamma_0 - Q)\frac{Q}{\gamma_1} - \frac{cQ^2}{2}.$$

The first-order condition is $\gamma_0 \geq (2 + c\gamma_1)\,Q$. This holds with equality if

$$\frac{\gamma_0}{2 + c\gamma_1} \leq Q^D,$$

which, using (A.1), requires

$$Q^i \geq \rho \equiv \left(1 - \frac{\gamma_0 + c\gamma_1\gamma_0}{(2 + c\gamma_1)\gamma_1}\right).$$

Therefore, the coordinates of C' of Figure II are $(\gamma_0 + \gamma_1(\rho - 1), \rho)$.

When the import quota is binding, the exporter's problem is

$$P2 \quad \max_{Q \geq Q^D} \alpha \left[1 - \beta(Q - Q^i) \right] Q - \frac{c Q^2}{2}.$$

The first-order condition is $\alpha(1 + \beta Q^i)/(2\alpha\beta + c) \leq Q$. This holds with equality if $\alpha(1 + \beta Q^i)/(2\alpha\beta + c) \geq Q^D$, which, using (A.1), requires

$$Q^i \leq \frac{c(1 - \alpha) + \alpha\beta(2 - \alpha)}{c(\alpha\beta + 1) + \alpha\beta(\alpha\beta + 2)} \equiv \sigma.$$

Therefore, the coordinates of B' in Figure II are $(\gamma_0 + \gamma_1(\sigma - 1), \sigma)$.

The coordinates of A' in Figure II are $(\alpha/(2\alpha\beta + c, 0)$, which is obtained from the first-order condition to P2, setting $Q^i = 0$.

To verify the relative slopes of A'B' and B'C' in Figure II, note that over the interval B'C' the export quota is given by (A.1), so that the slope of the reaction function is

$$\frac{dQ}{dQ^i} = \gamma_1 = \frac{\alpha\beta + 1}{\alpha\beta}.$$

Over the interval A'B', the first-order condition to P2 is satisfied with equality, so the slope of the reaction function is

$$\frac{\alpha\beta}{2\alpha\beta + c} < \frac{\alpha\beta + 1}{\alpha\beta}.$$

We now outline the construction of the Nash equilibria with *ad valorem* tariffs for the linear model of Figure III. Define t as the importer's *ad valorem* tariff and $\tau = t + 1$, so that the domestic price for the importer is τP. Define $\hat{\gamma} = (\alpha\beta\tau + 1)/\alpha\beta$, so that the inverse demand facing the exporter is $P = (\gamma_0 - Q)/\hat{\gamma}$, where Q is the exporter's level of sales. The exporter solves

$$P3 \max_{Q} \frac{\gamma_0 - Q}{\hat{\gamma}} Q - \frac{c}{2} Q^2.$$

The solution is $Q = \gamma_0/(2 + c\hat{\gamma})$. In order to enduce the level of exports using an export tax s, the domestic price in the exporting country must be SP, where $S \equiv 1 - s$ and $S = c\hat{\gamma}/(1 + c\hat{\gamma})$.

The importer takes S as given and faces the inverse excess supply given by $P = \alpha c(1 + \beta Q)/(S\alpha\beta + c)$, where Q is the level of imports. Given this function, we can find the level of imports that maximizes the sum of consumer surplus and tariff revenues; designate this quantity as Q^*. The optimal tariff is given by the inverse of the elasticity of excess supply, evaluated at Q^*. This provides a formula for t as a function of s. Substituting the expression for S obtained above into this formula gives a quadratic in t. This quadratic has a single root which gives positive levels of t and s.

FOOTNOTES

* I would like to thank Emiko Hashida for computing assistance.

[1]See Bhagwati and Srinivasan [1983, Chapter 10] for a discussion of the nonequivalence of tariffs and quotas.

[2]This assumption may appear very restrictive since it suggests that at least a substantial number of the countries that constitute R do not use quotas. However, as the partial equilibrium example of the next section demonstrates, it is the existence of R, and not its sensitivity to price, that is essential for the existence of a Nash equilibrium with quotas which results in trade.

[3]Without additional assumptions, the best response functions may not be defined when both nations use import quotas. Suppose that when H imposes import quota $\bar{y}$ the offer curve facing F is as shown in Figure I. Suppose in addition that F's preferred point on this offer curve is given by the intersection of OA and the vertical line from $\bar{x}$. Without some mechanism for determining which of the stable price equilibria arises under the quotas $\bar{x}$ and $\bar{y}$, F's best response to $\bar{y}$ is not defined. In a one-shot game, any such mechanism is likely to seem very artificial.

[4]The inessential features include the number of kinks in each graph, the relative slopes of the segments, and the relative positions of the two graphs. In addition, we have shown each best response function as being single valued. Inspection of Figure I shows that this need not be the case. For example, if H imposes quota $\bar{y}$ and if F's offer curve had been higher, then F might be indifferent between a point between B and C and point A,

both of which could be strictly preferred to all other points on OABC. This raises the possibility of mixed strategies. This generalization does not add anything to our basic point. Therefore, we consider only pure strategies, and Figure II can be interpreted as an incomplete graph of the best response functions.

[5]Tower [1975] models a game in which nations alternate in adjusting their quotas. He assumes [1975, p. 625] that legislatures believe that a quota adjustment must be at least 1/nth of the previous quota where n is a large finite number. Our description of the one-shot Nash game in the absence of R is a variation of Tower's [1975] model.

[6]The construction of the Nash equilibria under quotas and under tariffs is described in an appendix which is available upon request.

[7]We ignore the possibility that there are two equilibria since such a situation can be eliminated by perturbing the parameters.

[8]We allowed β to take values between .001 and 50; c to take values between .01 and 50; and α to take values of .25, .5, and .75.

[9]This is not the most general type of punishment strategy (Fudenberg and Maskin [1986]), but it is simple and relatively plausible.

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