Title
Tariffs with Dynamic Supply Response

Author
Karp, Larry

Publication Date
1985

353

Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

Working Paper No. 353

TARIFFS WITH DYNAMIC SUPPLY RESPONSE

by

Larry S. Karp

California Agricultural Experiment Station
Giannini Foundation of Agricultural Economics
January 1985

TARIFFS WITH DYNAMIC SUPPLY RESPONSE

Abstract

This paper studies the optimal tariff in a dynamic framework. The effects of the supplier's rationality and of the type of strategy available to the importer are discussed. With rational sellers, the optimal tariff is dynamically inconsistent; the consistent tariff is extremely myopic and may be worse than free trade for the importer. The paper concentrates on the case in which the traded good is a reproducible commodity. This is compared to the situation in which the traded good is a nonrenewable resource. The plausibility of the consistent equilibrium, in the absence of binding commitments, is discussed.

TARIFFS WITH DYNAMIC SUPPLY RESPONSE

A well-known result from trade theory states that a country maximizes the gains from trade by imposing an ad valorem tariff equal to the inverse of the elasticity of world excess supply (Johnson [1972]). This result is obtained from a static model in which the short- and long-run elasticities of supply are identical. Intuition suggests that in a dynamic model the path of the optimal tariff lies between the inverse of the short- and long-run elasticities of excess supply. This intuition is correct but incomplete. The equilibrium tariff path depends on the information available to the seller and the type of strategy available to the buyer. Three different situations are modeled.

In the first situation, the seller expects the current world price to persist indefinitely. This is designated the "naive scenario" and the resulting tariff, the "naive tariff." The tariff begins lower than the inverse of the short-run elasticity of supply ($1/\varepsilon_s$) and asymptotically approaches a level greater than the inverse of the long-run elasticity of supply ($1/\varepsilon_{lr}$). The model is analogous to the standard renewable resource problem, e.g., the fishing problem as in Clark [1976]. The buyer treats the seller's naivete as a renewable resource which it "harvests" optimally by means of a tariff.

In the second situation, the seller has rational expectations (or perfect foresight), and the buyer is permitted to commit himself to a trajectory of tariffs at the initial time. This is referred to as the open-loop tariff. It begins at $1/\varepsilon_s$ and approaches $1/\varepsilon_{lr}$ asymptotically. The buyer begins with a large tariff but encourages the seller to maintain his productive capacity by promising that the tariff will be reduced later. Sufficient conditions are given for the importer to prefer facing either the naive seller or the seller with perfect foresight. Since the importer can affect the cost and quality of information available to the seller, he has some influence in determining how the seller behaves.

The open-loop tariff is dynamically inconsistent. The buyer would like to revise the tariff path he announced at the start of the problem. Simaan and Cruz [1973, p. 619] point out the inconsistency of open-loop policies, and Kydland and Prescott [1977] discuss the implications for policymaking. Hillier and Malcomson [1984] cite some of the recent literature on the subject, and Kemp and Long [1980] and Karp [1984] discuss the inconsistency of the open-loop tariff when the traded good is a nonrenewable resource.

The third model retains the assumption of perfect foresight but restricts the importer to a consistent tariff. The policymaker in the importing country is unable to commit his successors to tariffs that will be suboptimal from their vantage point. The equilibrium consistent tariff is $1/\epsilon_s$ (which, in general, is not constant). Returning to the fishing analogy, this model corresponds to the case in which the harvest is determined by competitive pressure rather than being optimally managed. The policymaker faces the common-property problem, but here the competition is between present and future agents rather than among agents in the present.

The consistent policy may be worse for the buyer than free trade. This raises the question whether, in the absence of binding commitments, the consistent policy is always a more plausible result than the open-loop policy. The conclusion is that it is not. There are situations when either solution concept is more reasonable.

The traded good in these models is a reproducible commodity. The results under the open-loop and consistent tariffs are compared to previously obtained results for the case where the traded good is a nonrenewable resource. For both goods, the open-loop tariff is inconsistent, but the nature of the inconsistency is different. The open-loop policy is considerably more plausible when used against a reproducible commodity than when used against a nonrenewable good. The consistent policy provides a reasonable outcome for a nonrenewable good, at least if rest-of-the-world (ROW) demand and demand elasticity are small. Under these demand conditions, the consistent policy against a reproducible commodity is likely to be worse for the buyer than free trade which, as suggested above, makes it a questionable equilibrium.

These considerations lead to two possible interpretations. The first is that, since the open-loop policy against a reproducible good can conceivably be sustained, one would expect institutions to be developed which would, in fact, sustain it. These institutions would be supported by both importers and exporters. Their incentive is that, in the absence of such institutions, the importer may be driven to the consistent policy; and this harms both agents. The second interpretation is that the worse the consistent policy is, the less likely it is to be employed; that is, the more likely an open-loop policy is to be self-enforcing and the less need there is of institutions which sustain it.

The conclusion contains a summary and suggests the implications for trade policy and for empirical work.

I. THE BASIC MODEL AND THE NAIVE TARIFF

The simplest and most common justification for a dynamic supply response is the existence of a nonlinear adjustment cost. This keeps firms from instantaneously adjusting production to meet changes in relative prices. Let the production function be linearly homogeneous and, for simplicity, assume that there is a single input, k. By the choice of units, set output equal to k. Generalizing the model by allowing additional inputs along the lines of Lucas [1967] would not alter the results. The producer's problem is

$$\text{(P)} \qquad \max_{I} \int_0^\infty e^{-rt}[p(t)k - vI - \frac{cI^2}{2}]\, dt$$

subject to

$$\text{(1)} \qquad \dot{k} = I - \delta k,\ k_0 \text{ given,}$$

where p(t) is the output price, v is the unit cost of capital, $cI^2/2$ is the adjustment cost, and δ is the rate of depreciation. The necessary conditions for an optimum require

$$\text{(2)} \qquad I = \frac{\lambda - v}{c},$$

$$\text{(3)} \qquad \dot{\lambda} = (r + \delta)\ \lambda - p,$$

and the transversality condition, $\lim_{t\to\infty} e^{-rt}\lambda(t) = 0$; $\lambda(t)$ is the shadow value of k.

Let the demand in ROW be given by g(p) so that the excess supply facing the tariff-imposing country is k - g(p). The short-run elasticity of excess supply is $\varepsilon_s = -g'p/(k - g)$, and the long-run elasticity of excess supply is $\varepsilon_{lr} = p/(k_\infty - g)\ c\delta(r + \delta) + \varepsilon_s$, where $k_\infty = p/(r + \delta)\ \delta c - v/\delta c$, the long-run supply. Define $s(p) \equiv 1/\varepsilon_{lr}(p)$, the "static strategy tariff."

If producers expect the current price to persist indefinitely, then (2), (3), and the transversality condition imply that $I^*(t) = [p(t)/(r + \delta) - v]/c$. Let $U[k - g(p)]$ be the utility the tariff-imposing nation receives from the consumption of imports. If domestic markets are competitive, the importer's problem when the producer is naive is[1]

$$\text{(N)} \qquad \max_{p} \int_0^\infty e^{-\rho t}\{U[k - g(p)] - p[k - g(p)]\}\, dt,$$

subject to

$$\dot{k} = I^*(p) - \delta k,\ k_0 \text{ given.}$$

Let domestic price be $U' = p^d$ and the ad valorem tariff be $\tau = p^d/p - 1$. The first-order conditions to (N) require

$$\text{(4)} \qquad \tau - \frac{1}{\varepsilon_s} = \frac{\eta}{c(r + \delta)\, pg'}$$

$$\text{(5)} \qquad \dot{\eta} = (\rho + \delta)\,\eta - \tau p$$

with the standard transversality condition; η is the importer's shadow value of k. Because $\eta > 0$ and $g' < 0$, (4) implies that the ad valorem tariff is always less than the inverse of the short-run elasticity of excess supply. If k converges, the stationary point must be a saddle point, so k adjusts monotonically (Kamien and Schwartz [1981], p. 159). Hereafter, convergence is assumed. A sufficient condition for the monotonicity of p is given in Appendix A.

Using the long-run equilibrium condition, $\dot{\eta} = 0$, and substituting from (5) into (4) gives the stationary value of τ, τ_{1r}:

$$\tau_{1r} = \frac{1}{\varepsilon_s[1 - 1/(r + \delta)(\rho + \delta)\, cg']}.$$

The functions ε_s and g' are evaluated at the steady-state price. It is straightforward to show that $\tau_{1r}(p) > s(p)$ and that $\tau_{1r}(p) \to s(p)$ as $\rho \to 0$. Equation (4) defines p^d implicitly as a function of p. If the excess supply is sufficiently convex, p^d may be decreasing in p; over that region, the import demand curve--generated by (4)--is increasing in p. If the excess supply curve intersects the import demand curve in such a region, it must do so from below (the inverse demand curve is steeper than the inverse supply curve). In the static model this is guaranteed by the second-order condition.[2] In the dynamic model it is implied by the stability assumption (Appendix A). Therefore, shifting the demand curve out must result in an increased equilibrium price. Because the demand curve under regime s(p) is to the right of that under $\tau_{1r}(p)$, it follows that the latter tariff results in a lower world price and supply, i.e., the steady-state naive tariff must be greater than s(p).

The same reasoning implies that, for any given capacity k, the world price and the level of imports are greater under the dynamic tariff than under the tariff given by $1/\varepsilon_s$. This is because $\tau(p, k) < 1/\varepsilon_s(p, k)$ and, at the intersection of supply and demand, the demand curve (under either tariff rule) either slopes down or, if it slopes up, is less steep than the supply curve. The initial rate of investment is greater under the dynamic tariff than under the tariff $1/\varepsilon_s(p, k)$.

This section confirms the intuition that, if producers have static price expectations, a dynamic tariff lies between the inverse of the short- and the long-run elasticity of supply. The importer does not maximize the current flow of rents because he considers the effect of his tariff on future supply. He does not maximize the steady-state flow of rents because he discounts the future.

An interesting version of the model emerges if g(p) is replaced by a constant so that the short-run elasticity of excess supply is zero. In this case, the optimal solution is "bang bang." If the initial capacity, k_0, is less than the equilibrium level, the importer subsidizes imports as much as its treasury permits. As soon as the capacity reaches the equilibrium level, the subsidy is converted to a tariff. This problem is discussed in Appendix B. It is compared to the problem in which the maximand is world welfare. In that situation, if the initial capacity is less than the long-run equilibrium capacity, it is optimal to begin with a tariff that eventually declines to zero. This keeps the producer from overinvesting in capacity, and it smooths adjustment.

II. THE OPEN-LOOP TARIFF

The previous model assumed that producers (exporters) had static price expectations. A polar assumption endows them with perfect foresight so that current investment decisions depend on the future trajectory of tariffs. This gives the government in the importing nation an incentive to use a high current tariff and promise future reductions in the tariff rate[3]. This strategy enables it to increase its current monopsony rents while lessening the effect of the tariff on the future availability of supply.

The open-loop policy is dynamically inconsistent because the planner at time t + dt faces the same situation as the planner at time t: he, also, would like to set a high current tariff and promise future reductions. He is tempted to renege on the previous planner's promise to set a lower tariff at t + dt. If the planner is able to commit his successors to a policy, the open loop tariff emerges. The difficulty of enforcing international contracts tends to make the open-loop policy a dubious solution. However, it is possible to use forums such as the General Agreement on Tariffs and Trade to bring pressure on nations to adhere to promised tariff reductions. The open-loop policy is more credible in the case under consideration here, in which the traded good is a reproducible commodity, than in the case of a nonrenewable resource.

The importer of a reproducible commodity may prefer to face either a naive seller or one with perfect foresight. Sufficient conditions for the two cases are given below. The importer can determine, to some extent, the amount of information the producer has and, consequently, how he behaves. The model suggests that, if the current world supply is large (in a sense to be made precise), the importer will prefer the seller with perfect foresight and will make information freely available to him.

If the seller has perfect foresight and the importer is able to convince him he will carry out his announced policy, the importer's problem is

$$\max_{p(t),I(t)} \int_0^\infty e^{-\rho t}\{U[k - g(p)] - [k - g(p)]\, p\}\, dt, \tag{0}$$

subject to (1), (2), and (3).

Let η_1 and η_2 be, respectively, the costate variables associated with k and the "state" λ. Use (2) to eliminate I(t) so that the problem has a single control, p(t). The first-order conditions are (1), (3), and

$$\tau - \frac{1}{\varepsilon_s} = -\frac{\eta_2}{pg'} \tag{6}$$

(7) $$\dot{\eta}_1 = (\rho + \delta)\, \eta_1 - \tau p$$

(8) $$\dot{\eta}_2 = (\rho - r - \delta)\, \eta_2 - \frac{\eta_1}{c}.$$

In this section, τ is used to designate the open-loop tariff in order to avoid notational clutter. Assume that $\rho - r - \delta < 0$, which is necessary for stability.

The initial state $\lambda(0)$ is free, which implies the boundary condition $\eta_2(0) = 0$. An increase in k shifts the short-run excess supply curve out; so η_1, the shadow value of k, must be positive. Therefore, $\eta_2 < 0$ for $t > 0$,[4] and (6) implies that the initial tariff equals $1/\varepsilon_s(p)$, the inverse of the short-run elasticity of supply; subsequent tariffs are less than $1/\varepsilon_s(p)$.

In the previous model, stability implied that k adjusted monotonically, and this led to sufficient conditions to insure monotonic price adjustment. Monotonicity of k need not hold here.[5] Characteristics of the solution paths cannot be determined analytically, but the initial and steady-state points of the naive and open-loop models can be compared. Equations (4) and (6) evaluated at $t = 0$ imply that the initial open-loop tariff is greater than the initial naive tariff. The steady-state open-loop tariff is less than the steady-state naive tariff;[6] that is, under the open-loop policy, world price begins at a lower level and asymptotically approaches a higher level than under the naive policy. The steady-state supply is greater under the open-loop policy. The steady-state open-loop tariff is greater (less) than the tariff under the static strategy, s(p), if ρ is less (greater) than r.

The economic explanation for the inconsistency of the open-loop policy was given above. The technical reason is that $\lambda(0)$ is free. The importer chooses the producer's shadow value of capacity by his choice of the trajectory of tariffs. If the importer at t is able to revise the trajectory announced at time zero, he will want to do so. This is apparent from the fact that $\eta_2(t) \neq 0$, so $\lambda(t)$ is not optimal from the standpoint of the importer at t. Therefore, the trajectory of tariffs over (t, ∞) is not optimal from the standpoint of the seller at t.

Inconsistency results when an open-loop tariff is used against either a nonrenewable resource or a reproducible commodity. However, the nature of the inconsistency in the two cases is very different. With the nonrenewable resource, the open-loop tariff functions as a threat; with the reproducible commodity, it functions as a promise. As discussed above, the current importer of a reproducible commodity promises future tariff reductions in order to diminish the effect of the current tariff on future availability of supply. For the nonrenewable resource, the current importer threatens a high future tariff in order to encourage current sales of the resource. This difference in strategy follows from the different characteristics of the goods. Increased current imports of a nonrenewable resource come at the expense of decreased future supply; increased current imports of a reproducible good encourage future supply.

This characterization of the importer's strategy in the case of a reproducible good is verified by the fact that η_2, the importer's shadow value of the seller's rent, is negative. At $t > 0$, the importer would like to lower the seller's rent, which implies that he would like to increase the trajectory of tariffs he announced at $t = 0$; he would like to renege on his promise.

The characterization of the importer's strategy in the case of a nonrenewable resource requires additional assumptions. Kemp and Long [1980] show that, if both the importer and ROW have the same utility for consumption (or, more generally, the same marginal utility as consumption goes to zero) and if costs of extraction are constant, the importer will want to decrease his announced tariff. Karp [1984] shows that, if ROW demand is zero (or, more generally, perfectly inelastic) and the costs of extraction are nonincreasing and convex in remaining stock, then for $t > 0$ the importer would like to reduce the trajectory of tariffs he announced at $t = 0$. In both of these models, the importer wants to avoid carrying out the threat he made at $t = 0$. A more general model, which incorporates the features of both the Kemp and Long [1980] and Karp [1984] models, is discussed in Appendix C. It is not established for the general model that the open-loop policy functions as a threat ($\eta_2 \geq 0$), but the model does provide intuition about why the result can be expected to hold.

It is difficult to imagine an exporter filing a complaint against an importer for failing to maintain high tariffs. There is a common interest in voiding the threat, which makes the open-loop policy very implausible in the case of a nonrenewable resource. This commonality of interest does not exist for a reproducible good; this sustains the open-loop policy by making it more likely that the promise will be enforced. Schelling (1956) provides a general discussion of the use of threats and promises in a game.

If the open-loop policy is credible, then whether the naive or the open-loop model is more appropriate depends on the information available to the producer. The importer has some control over the flow of information, so it matters which type of seller he prefers to confront. He may prefer to face either a naive seller or one with perfect foresight. Sufficient conditions for the two cases to hold are given in the following propositions.

<u>Proposition 1</u>. If the optimal world price in problem N is nondecreasing at all points in time, then the importer prefers to face the seller with perfect foresight.

Proposition 2. If the optimal world price in problem 0 is decreasing at all points in time, then the importer prefers to face the naive seller.

The intuition is as follows: If price rises along the optimal trajectory in Problem N, the importer cannot be hurt by the seller's recognition of this since that recognition would lead to increased investment and increased future supply on a given price trajectory. If, on the other hand, price falls along the optimal trajectory in Problem 0, the importer would prefer the seller not to know this since that knowledge would lead to decreased investment and decreased future supply on a given price trajectory.

Define $p^N(t)$ and $p^0(t)$ as the optimal price paths in problems N and 0, respectively. The proof of Proposition 1 uses the fact that, if $\dot{p}^N(t) \geq 0$, then there exists a function $p^*(t) \leq p^N(t)$ such that $m^0_{p^*}(t) \equiv m^N_{pN}(t)$ (in t), where $m^0_{p^*}(t)$ is the level of imports at t when the seller with perfect foresight faces the path p^*, and $m^N_{pN}(t)$ is the level of imports at t when the naive seller faces the path p^N. The existence of p^* follows from the fact that m^0_p is a continuous (in fact, monotonic) mapping from a connected set (the set of continuous price trajectories less than or equal to p_N) and so its image is connected. The above identity states that, if $\dot{p}_N(t) \geq 0$, it is possible for the importer in problem 0 to obtain the same level of imports as the optimal level in problem N but at a lower cost. Since this level may not be optimal for problem 0, it is clear that the importer does better facing the seller with perfect foresight. The proof of Proposition 2 proceeds along the same lines.

The conditions given in the propositions are sufficient, not necessary. The propositions do not cover the cases (i) $\dot{p}^N(t) < 0$, (ii) $\dot{p}^0(t) \geq 0$ or (iii) monotonicity does not hold. There is no obvious connection between the shape of the optimal price paths in problems N and 0. There are two situations in which it can be determined, without solving for the price paths, that the importer prefers the seller with perfect foresight. First, if in problem N the sufficient condition for price monotonicity holds (Appendix A) and the initial supply is greater than or equal to the steady-state supply ($k_0 \geq k_{N,\infty}$), then $\dot{p}^N \geq 0$ and Proposition 1 obtains. Second, if $k_0 = k_{N,\infty}$, then $\dot{p}^N \equiv 0$; and Proposition 1 obtains. This, and the fact that all functions are continuous in the initial supply, implies that the importer prefers the seller with perfect foresight whenever k_0 is in some neighborhood of $k_{N,\infty}$. It is also clear that a necessary condition for $\dot{p}^O(t) < 0$ is $k_0 < k_{N,\infty}$.

These comments suggest that, if k_0 is large, i.e., close to or greater than $k_{N,\infty}$, then the importer is likely to prefer the seller with perfect foresight. If k_0 is small, the importer is likely to prefer the naive seller. Whether a seller is more accurately described as abysmally naive or wonderfully prescient depends, in part, on the importer's behavior. The importer is able to influence the amount of information available to the seller and the cost of obtaining it. If the importer announces his future trade policy, the cost of information is low; and the seller is more likely to act as if he had perfect foresight. If the importer does not announce his future trade policy or behaves erratically, the seller's cost of attempting to anticipate the future may be prohibitive, and "naive" behavior may be rational. The model suggests that, if at a given point in time world supply is "large" (k_0 close to or greater than $k_{N,\infty}$), it is in the importer's interest to make his future policy known.

III. THE CONSISTENT TARIFF

The open-loop tariff is a reasonable equilibrium only if the seller believes that the buyer will adhere to his announced policy, and the buyer actually does so. A system of international laws provides an environment in which an open-loop policy can be sustained. This type of institutional framework is sufficient but not necessary for an open-loop policy since it is conceivable that such a policy is self-enforcing.

If the importer is not constrained, either by binding commitments or the logic of his position, to follow the announced policy, then it ceases to be a plausible equilibrium. An alternative in this case is the consistent policy. This emerges when the current policymaker takes as given the control rules of his successors, and these rules are optimal from the points at which the successors find themselves. Although this may appear to provide a reasonable description of policymaking in the absence of institutions which enforce contracts, this section suggests that it is based on too narrow a definition of consistency. Whether the consistent or some open-loop (optimal or otherwise) policy is more likely to emerge in the absence of binding commitments depends on the details of the problem and cannot be answered in general.

An obvious candidate for the consistent policy is to set the tariff at the inverse of the short-run elasticity of excess supply. If future policymakers follow this rule and if producers foresee this, the current policymaker has no incentive not to maximize the instantaneous flow of rents. The proposed candidate is clearly admissible; moreover, if consistency is required at every point in time, it is the only admissible policy.

To verify this, consider the following approximation to the consistent policy. Suppose that administrations in the importing country change every T years so that the planner at times 0, T, 2T, ..., can make a commitment that is enforceable for T years. Define $y = \dot{k}$ and replace the constraints (1), (2), and (3) by

$$\dot{k} = y, \; k_0 \text{ given} \tag{9}$$

$$\dot{y} = ry + \frac{(r + \delta)\,\delta k + (r + \delta)\,(p - v)}{c}. \tag{10}$$

Let the importer's present value at time zero of the productive capacity and its rate of change at T, k(T), and y(T) be $e^{-\rho T}\, J[k(T), y(T)]$. Because y(T) is free, it will be chosen so that $\partial J/\partial y_{|T} = 0$.

The importer's problem at t = 0 is

$$\max_{p(t),y(0)} \int_0^T e^{-\rho t}\{U[k - g(p)]\, p - [k - g(p)]\, p\}\, dt + e^{-\rho T}\, J[k(T), y(T)], \tag{C}$$

subject to (9) and (10). The first-order condition corresponding to (6) is

$$\tau - \frac{1}{\varepsilon_s} = - \frac{\eta_3}{pg'c}, \tag{11}$$

where η_3 is the shadow value of y. The boundary conditions require $\eta_3(0) = \eta_3(T) = 0$, so the initial and final tariff during the first (and every) administrator's tenure is $\tau = 1/\varepsilon_s$. By choosing T sufficiently small, the tariff is maintained arbitrarily close to $1/\varepsilon_s$ over $(0, \infty)$. In the limit, as $T \to 0$, the consistent tariff is $1/\varepsilon_s$, which maximizes the current flow of monopsony rents. (Appendix D compares this solution with the consistent tariff used against a nonrenewable resource.)

The importer's payoff under the consistent tariff may be greater or less than under the free-trade policy. As $c\delta \to 0$, the long-run elasticity of excess supply becomes infinite; as $c\delta \to \infty$, the long-run elasticity goes to the short-run elasticity. The speed at which supply adjusts to its long-run level is inversely related to c. For large c and $c\delta$, the consistent tariff approximates the open-loop policy and the importer's payoff is higher than under free trade. For small c and $c\delta$, the consistent tariff is much too large; long-run imports will be quickly driven close to zero, and the importer does worse than under free trade.

The possibility of a tariff reducing the welfare of a country was noted previously by Maskin and Newberry [1978]. They give an example of a two-period model with a finite stock of nonrenewable resource, and they show that the importer may lose from a consistent tariff. The free-trade policy is not consistent. Karp [1984] gives the consistent tariff for a nonrenewable resource in a continuous time framework and shows that the consistent tariff is at least as beneficial as a zero tariff. That model assumes $g \equiv 0$, so it is not directly comparable to the present model; generalizing that model by allowing g and $g' \neq 0$ appears to be difficult. However, by letting $g, g' \to 0$ in the reproducible goods model, the two become comparable. It is still true that the importer may gain or lose from using a consistent tariff (rather than a zero tariff) in the case of a reproducible good. He cannot lose when the traded good is a nonrenewable resource and $g \equiv 0$. Comparison of the Maskin and Newberry [1978] and Karp [1984] results suggests that a source of the possible loss from a consistent tariff against a nonrenewable resource is the existence of competing buyers in ROW. With the reproducible good, on the other hand, the source of possible loss is located on the supply side--in particular, with the speed of adjustment and the long-run elasticity of supply.

The obvious lesson from this model is that dominant importers as well as competitive exporters may benefit from the introduction of enforceable multinational agreements to permit free trade. There is, however, a second interpretation; this is that the notion of consistency is much too narrow. It is not difficult to see that a slightly more complicated and more realistic model saves the importer from himself. Suppose the importer announces a particular open-loop policy; this may be free trade, the policy given in the previous section, the rule given by the steady state naive tariff, or any number of other possibilities. Each of these is "inconsistent"; but, if the importer adheres to the policy, the exporter may believe that he will continue to do so. For example, the importer may know that, if he departs from his announced path, the exporter will expect him to move toward the myopic, consistent path. This may persuade him to adhere to his announced policy.

This does not dispute the point that "rules are better than discretion," (Kydland and Prescott, 1977) at least in a deterministic world. It does suggest that the meaning commonly associated with "discretion," i.e., that which leads to "consistent" behavior, may not be a reasonable characterization of the way policymakers behave. In the example given above, policymakers may need no institutional arrangement to sustain a particular open-loop policy. Failure to sustain it is too costly, and all agents know this. The distinction between "rules" and a broader definition of "discretion" may be finer than has been thought.

Much of the appeal of the consistent policy, as an equilibrium in the absence of binding commitments, rests on the (implicit) assumption that the game is of known finite duration. In that situation the policymaker has no incentive not to behave consistently in the "last period." Rational agents expect this; given this expectation, the policymaker has no incentive not to behave consistently in the next to last period and, thus, the open-loop policy unravels. This may be an indictment of finite horizon Stackelberg models rather than an indication that policymakers are apt to behave consistently. It suggests that a consistent policy provides a reasonable equilibrium only if at some point along the open-loop trajectory the policymakers would prefer to leave that trajectory and switch to the consistent trajectory. This occurs in the last period of the finite horizon game but may also occur in an infinite horizon game. The case of a tariff used against a nonrenewable resource, and an infinite horizon, provides an example. There the consistent policy seems more plausible than the open-loop policy both because of the reason discussed in the previous section and, because at some point on the open-loop trajectory, the importer would prefer to switch to the consistent trajectory (the competitive equilibrium in Karp's model).

The general conclusion is that, even in the absence of binding commitments, there is no presumption that the consistent equilibrium is more plausible than any number of open-loop equilibria. There may, however, be particular features of the problem, such as a finite horizon, which recommend the consistent equilibrium.

IV. CONCLUSION

Bhagwati [1977] pointed out that an exporting country can suffer a loss in welfare from the possibility of a future trade disruption. The importer also can be made worse off by such a possibility. If policymakers in an importing country know that there is nothing to restrain their successors, they have no incentive to restrain themselves. The result is extremely myopic behavior. This consistent policy always leads to a decrease in welfare for both producers and importers relative to the open-loop trajectory.[7] The importer may also be worse off under the consistent policy than under free trade. This is more likely to be true the greater is the long-run elasticity of supply and the smaller is the elasticity of the ROW demand and, also, the greater the speed of adjustment of production capacity.

This suggests that there is a basis for negotiation of phased tariff reductions monitored and enforced by forums such as the General Agreement on Tariffs and Trade. This basis, which does not rely on any quid pro quo, tends to be stronger in the reproducible commodities case and there where the consistent tariff is the most damaging. These results were obtained using the prevailing definition of consistency. This definition may be too narrow. A more reasonable definition would lead to a less myopic policy and a less pessimistic outcome. This would tend to weaken the importer's desire for an institutional arrangement such as the General Agreement on Tariffs and Trade but only to the extent that such an arrangement is superfluous because of the broader rationality of the importer. The relative plausibility of open-loop and consistent equilibria, in the absence of binding commitments, was discussed. There seems to be no general presumption in favor of either. If a tariff is used against a nonrenewable resource in which ROW demand is small and very inelastic, the consistent tariff leads to a reasonable equilibrium; this is not true if the traded good is reproducible.

This paper assumes that the tariff-imposing country exerts monopsony power. The results have no bearing when, for domestic policy reasons, a "small country" imposes a tariff.[8] Although this excludes a significant percentage of tariffs, there are a number of important cases in which the trade policies of large countries affect prices. An example occurs with agricultural trade. The European Community, Japan, and the U.S.S.R. are large importers of coarse grains, and all pursue policies that affect world prices. These policies are more complex than tariffs but have their "tariff equivalents." Because trade restrictions in agricultural goods are the subject of often acrimonious debate, particularly between the United States and the European Community and the United States and Japan, it is worth pointing out where the common interests in phased reduction of trade restrictions lie. An obvious corollary to this argument is that the importer's incentive to agree to such reduction is diminished to the extent that U. S. policies (e.g., the loan rate and deficiency payments) inhibit adjustment in U. S. agriculture.

Although nations use policies that turn the terms of trade in their favor, it is difficult to know if their motive is to increase domestic welfare or, more specifically, to increase the welfare of domestic producers. The question is of some interest as an importer's probable response to a change in the economic environment (e.g., exporter retaliation) depends on how he weights the interests of the various groups. Sarris and Freebairn [1983] use estimated supply and demand elasticities and observed tariff equivalents with the theory of revealed preference to estimate the welfare weights in the objective functions of policymakers in a number of countries. This procedure can be properly used only to estimate bounds on the weights because the optimal tariff for any set of weights depends on assumptions about exporter rationality (or foresight) and the practicality of commitments.

APPENDIX A. Technical Details of Problem N

Equations (4) and (5) are derived from

$$U'g' - [(k - g) - g'p] + \frac{\eta}{c(r + \delta)} = 0 \tag{A.1}$$

$$p - U' + (\rho + \delta)\,\eta = \dot{\eta}. \tag{A.2}$$

The Legendre condition is

$$S \equiv U''(g')^2 - U'g'' + 2g' + g''p \leq 0. \tag{A.3}$$

Strict inequality is assumed. Differentiating (A.1) implies

$$\frac{\partial p}{\partial k} = \frac{(U''g' + 1)}{S} < 0 \tag{A.4}$$

$$\frac{\partial p}{\partial \eta} = \frac{-1}{c(r + \delta)\,S} > 0. \tag{A.5}$$

Linearize the system given by $\dot{k} = I^*(p) - \delta k$ and (A.2) using (A.4) and (A.5), and write it in deviation form as

$$\begin{pmatrix} \dot{k} \\ \dot{\eta} \end{pmatrix} = \begin{pmatrix} a & b \\ m & \rho\text{-}a \end{pmatrix} \begin{pmatrix} k \\ \eta \end{pmatrix},$$

where

$$a \equiv \frac{1 + U''g' - \delta S}{S} < 0$$

$$b \equiv -\frac{1}{c(r + \delta)\,S} > 0$$

$$m \equiv \frac{(1 + U''g')^2}{S} - U''.$$

The sign of m is ambiguous. The two possible phase diagrams are given in Figures 1 and 2. In Figure 2, the relative slopes of the $\dot{k} = 0$ and $\dot{\eta} = 0$ isoclines are implied by the stability assumption. The optimal trajectories are given by the heavy lines. In Figure 1, η and k adjust monotonically in opposite directions. For this case, (A.4) and (A.5) imply that p adjusts monotonically; if capacity rises, price must fall. In Figure 2, where $m < 0$, nothing can be said about price adjustment. Therefore, $m > 0$ is sufficient but not necessary for price monotonicity.

Use (A.2), (A.4), and (A.5) to obtain $\partial\eta/\partial\rho < 0$ on the $\dot{\eta} = 0$ isocline. From Figures 1 and 2, a decrease in ρ results in a larger steady-state k. Because the "static strategy tariff" is obtained by letting $\rho \rightarrow 0$, the result in the text follows immediately.

APPENDIX B. The Tariff When $g \equiv 0$

If ROW demand is identically zero (or, more generally, $g' \equiv 0$), the importer's problem is linear in p and a bang-bang control is optimal. For the naive tariff, the importer's Hamiltonian and first-order conditions are

$$H = U(k) - kp + \eta\left[\frac{p/(r + \delta) - v}{c} - \delta k\right]$$

$$\frac{\partial H}{\partial p} = -k + \frac{\eta}{(r + \delta)\, c}\begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \Rightarrow \begin{Bmatrix} p = p^{max} \\ p = ? \\ p = p^{min} \end{Bmatrix}$$

$$\dot{\eta} = (\rho + \delta)\, \eta - U' + p.$$

The parameters p^{max} and p^{min}, which may be functions of k, can be regarded, respectively, as the price resulting when the importer offers as large an import subsidy as its treasury permits, and the cost of transporting the good. If the initial capacity is less than the long-run equilibrium value, it is optimal to set $p = p^{max}$. The importer bears the adjustment cost. The situation is reversed if the initial stock is larger than the long-run equilibrium. At the long-run equilibrium, the tariff is finite and greater than zero.

The open-loop problem is also straightforward. The solution is still bang bang but in the opposite direction. Whatever the initial stock, the initial tariff is at its upper bound [$p(0) = p^{min}$]. Price remains at that level until the free-trade equilibrium is reached at which time the tariff is reduced to zero. The producer bears all of the adjustment cost.

The consistent tariff is derived as in the text. Price is set at p^{min} until capacity is driven to zero and production and trade cease.

If the objective is taken to be the sum of exporter and importer welfare, the problem is formally equivalent to that of Pindyck [1982]. His results can be directly applied. If initial capacity is less than the free-trade level, the initial tariff is positive and finite. The tariff decreases asymptotically to zero.

APPENDIX C. The General Open-Loop Tariff with a Nonrenewable Resource

If a competitive seller has an initial stock of resource, $z(0)$, and an average cost of extraction, $c(z)$, $c'(x) \leq 0$, $c''(z) \geq 0$, its problem is

$$\max_{x} \int_0^\infty e^{-rt}[p - c(z)]\, x\, dt,$$

subject to

$$\dot{z} = -x, \; z(0), \text{ given},$$

where x is the rate of extraction and sales. The importer seeks to maximize

$$\int_0^\infty e^{-\rho t}\{U[x - g(p)] - p[x - g(p)]\}\, dt,$$

subject to the constraints implied by the seller's problem. His Hamiltonian is

$$H = U\{x - g[\lambda + c(z)]\} - [\lambda + c(z)]\, \{x - g[\lambda + c(z)]\}$$
$$- \eta_1 x + \eta_2(r\lambda + c'(z)\, x),$$

where p has been eliminated by substitution, λ is the seller's shadow value of z, and η_1 and η_2 are the costate variables associated with z and λ, respectively. A terminal inequality constraint, implied by the terminal value of λ, depends on the choke price of $g(p)$ and $c(0)$. The relevant first-order condition is

$$\dot{\eta}_2 = [U' - (\lambda + c)]\, g' + x - g = \tau p g' + x - g = pg'(\tau - \frac{1}{\varepsilon^*}),$$

where ε^* is defined as $-pg'/(x - g)$; the boundary condition is $\eta_2(0) = 0$. For $g' = 0$, the model reduces to Karp's [1984] model; and $\dot{\eta} = x - g > 0$ (for an importer) implies $\eta_2 > 0$ for $t > 0$. If $c'(z) = 0$ and the importer and ROW have the same choke price, the model reduces to that of Kemp and Long [1980], who show that at some point the importer will want to reduce the tariff trajectory he originally announced. If η_2 does not change sign over the horizon, η_2 is always nonnegative (strictly positive except at the end-points of the trajectory).

For the general problem, a necessary and sufficient condition for $\eta_2 > 0$ over an initial interval is $\tau < 1/\varepsilon^*$ over a (smaller) interval. If this condition fails, the importer is conserving the resource for the benefit of the ROW consumers. The implausibility of this strategy suggests that the inequality is likely to hold over an initial interval. Over some final interval of the trajectory, it may be that $\tau > 1/\varepsilon^*$ (this occurs in Kemp and Long's [1980] model); but this does not contradict $\eta_2 \geq 0$. Over such an interval, the importer is carrying out the threat of a high tariff, which is what induced the owner of the resource to sell it at a lower price early in the program.

APPENDIX D. Comparison of Consistent Tariffs for Reproducible and Nonrenewable Goods

The consistent tariffs for the reproducible good given above and for the nonrenewable resource given in Karp [1984] have different characteristics. The methods of obtaining them are also different, and they cannot be exchanged.

In the reproducible goods problem (hereafter, RGP), the seller's control, I(t), does not directly influence the buyer's payoff. [I(t) is not an argument of the integrand of (N).] When the constraint (2) is eliminated, the seller's costate variable, λ, is absent from the integrand of (N); but it does appear in the state equation through I*. It is possible to eliminate λ by introducing the new state, $y = \dot{k}$, as in problem (C). The n + 1th administration will choose y[(n + 1) T] optimally for its tenure (not for future administrations), so the shadow value of y is zero at the end of the tenure of the nth administration. Because y[(n - 1) T] is free, the shadow value of y at (n - 1) T also is zero. As T approaches zero, the shadow value of y over ([n - 1] T, nT) remains small because of the continuity of the functions over the interval. By choosing T sufficiently small, the solution can be brought arbitrarily close to the consistent controls.

In the nonrenewable resource problem (hereafter, NRP), the seller controls x(t), the rate of extraction; by the assumption of no storage, this equals the rate of sales and consumption. When the buyer's constraint implied by the seller's maximization of his Hamiltonian is eliminated by substitution, the seller's costate variable appears in the buyer's integrand but not in the state equations. (This situation is reversed in the RGP.) It is impossible to eliminate the seller's costate variable by introducing a new state such as y. However, because the buyer's integrand is linear in the seller's costate variable, the buyer's problem can be replaced by one containing a single state. [This cannot be done in the RGP because the seller's costate variable appears in the state equation, e.g., (2). Eliminating λ from (2) causes it to appear nonlinearily in the integrand.] By defining T as the amount of time it takes to consume a fixed amount of stock and making this amount arbitrarily small, the original integrand is replaced by the sum of the two integrands, one of which the buyer is unable to affect.

Formally, the consistent controls in the RGP are obtained from the necessary conditions to the open-loop problem altered by setting $\eta_2 \equiv 0$; the consistent controls in the NRP are obtained from the conditions necessary to the corresponding open-loop problem altered by setting the seller's shadow value, λ, equal to zero. These do not give equivalent results. The intuition for the difference hinges on the fact that the seller's shadow value appears in the integrand in the NRP but not in the RGP. For an arbitrarily small interval of time, the value of λ does not alter the buyer's payoff over that interval in the RGP; he acts as if he could continuously choose it (therefore, $\eta_2 \equiv 0$). For an arbitrarily small interval of time, the value of λ does alter the buyer's payoff over that interval in the NRP, but he is forced to act as if he could not affect that value (therefore, $\lambda \equiv 0$). The NRP studied by Karp [1984] assumes that $g \equiv 0$. Relaxing this assumption to make the problem analogous to the RGP considered here makes it impossible to use either of these methods to obtain the consistent tariff.

University of California, Berkeley.

FOOTNOTES

1. The importer may have domestic production that involves an adjustment cost. This cost is ignored here; to model it explicitly requires introducing an additional state. The resulting increase in realism does not seem to merit the increase in complexity.

2. The static problem is

$$\max_{p} U[h(p)] - h(p)\, p,$$

where h(p) is the excess supply. The first-order condition requires $p^d = p + h/h'$, which gives $p^d(p)$. The hypothesis that, at the solution, the demand curve is steeper than the supply curve implies that $U''h' > 2 - hh''/(h')^2$. The second-order condition implies the opposite inequality, so the hypothesis is false.

3. Throughout this section, a "reduction in the tariff rate" means a decrease in the rule by which the tariff is set, i.e., $\tau(p)$ is shifted in. If capacity expands and price falls, this implies that the actual tariff falls.

4. An exception occurs if the solution paths are constant cycles, in which case $\eta_2 = 0$ at regular intervals. This system is structurally unstable and is of little interest.

5. For example, suppose there exists a unique steady state (k_∞, p_∞) which is globally stable. If the initial supply is at k_∞, then, using the information about the initial and steady-state open-loop tariff, it must be the case that k initially decreases and subsequently increases on the optimal trajectory.

6. The steady-state open-loop tariff is

$$\frac{1}{\varepsilon_s}\left[1 - \frac{1}{(\rho + \delta)(r - \rho + \delta)\,cg'}\right].$$

Comparison with the steady-state naive tariff gives the stated result.

7. Consumers in the ROW will prefer the higher consistent tariff trajectory, but their gain will be less than the producers' loss.

8. This statement must be modified if a collection of small countries uses tariffs to pursue domestic policies, but the result of the combination of policies improves their terms of trade. Whalley suggests that this is the case for the LDC's as a group.

REFERENCES

Bhagwati, Jagdish N., "Market Disruption, Export Market Disruption, Compensation, and GATT Reform," in Jagdish N. Bhagwati, ed. The New International Economic Order: The North-South Debate (Cambridge, Mass.: Massachusetts Institute of Technology Press, 1977).

Clark, Colin W., Mathematical Bioeconomics (New York: John Wiley and Sons, Inc., 1976).

Hillier, Brian, and James M. Malcomson, "Dynamic Inconsistency, Rational Expectations and Optimal Government Policies," Econometrica 52 (1984), 1437-53.

Johnson, Harry G., Aspects of the Theory of Tariffs (Cambridge, Mass.: Harvard University Press, 1972).

Kamien, Martin I., and Nancy L. Schwartz, Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management (New York: North-Holland Publishing Co, 1981).

Karp, Larry, "Optimality and Consistency in a Differential Game with Nonrenewable Resources," Journal of Economic Dynamics and Control 8 (1984), 73-97.

Kemp, M. C., and N. V. Long, "Optimal Tariffs and Exhaustible Resources," in M. C. Kemp and N. V. Long, eds., Exhaustible Resources, Optimality, and Trade (Amsterdam: North-Holland Publishing Co., 1980).

Kydland, Finn, and Edward Prescott, "Rules Rather than Discretion: The Inconsistency of Optimal Plans," Journal of Political Economy 85 (1977), 473-91.

Lucas, Robert, "Adjustment Costs and the Theory of Supply," Journal of Political Economy 75 (1967), 321-34.

Maskin, Eric, and David Newberry, "Rational Expectations with Market Power--the Paradox of the Disadvantageous Tariff in Oil," Discussion Paper, Massachusetts Institute of Technology, Cambridge, 1978.

Pindyck, Robert S., "The Optimal Phasing of Phased Deregulation," Journal of Economic Dynamics and Control 4 (1982), 281-94.

Sarris, Alexander H., and John Freebairn, "Endogenous Price Policies and International Wheat Prices," American Journal of Agricultural Economics 65 (1983), 214-24.

Schelling, Thomas C, "An Essay on Bargaining," The American Economic Review 46 (1956), 281-306.

Simaan, M., and J. B. Cruz, Jr., "Additional Aspects of the Stackelberg Strategy in Nonzero-Sum Games," Journal of Optimization Theory and Applications 11 (1973), 613-26.

Whalley, John, "The North-South Debate and the Terms of Trade: An Applied General Equilibrium Approach," Review of Economics and Statistics 64 (1984), 224-234.

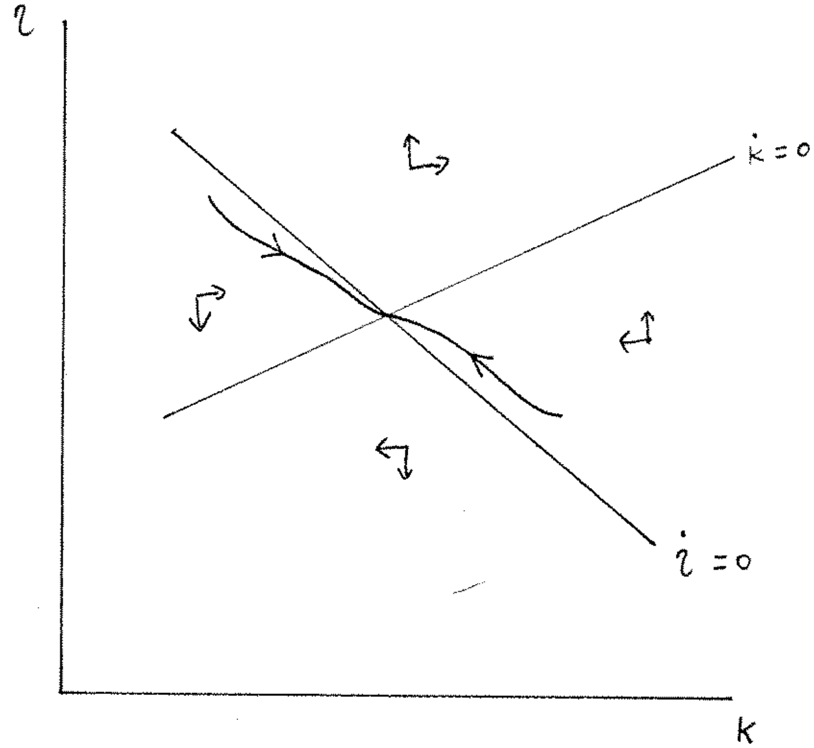

FIGURE 1. Phase plane for $m > 0$.

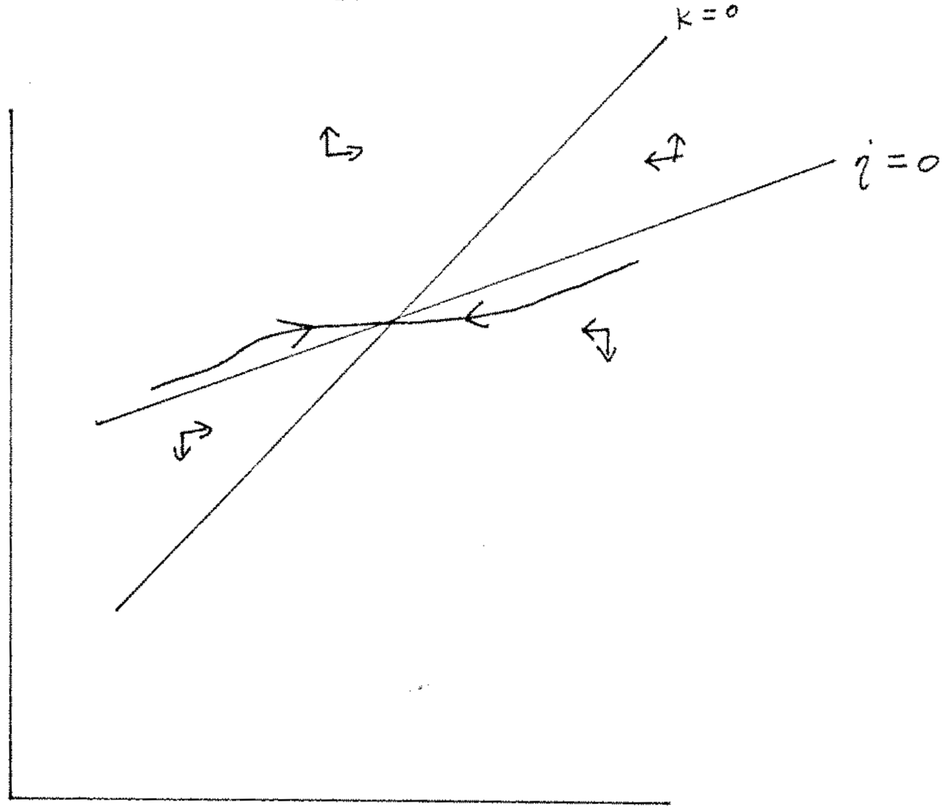

FIGURE 2. Phase plane for m < 0.