The (Non) Equivalence of Tariff and Quota Policy in the Presence of Search Costs

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March 2013

Abstract

This study compares the economic effects of tariffs and quotas in an environment where exporters must expend resources to find foreign consumers. Within a sequential search model, we find the policies to be (with rare exceptions) nonequivalent in domestic price. The relative impact of the two policies on domestic prices depends crucially on the magnitude of the two policies with prices more likely to be higher under tariff policy at lower tariff rates. The study adds to the 'equivalence' literature by identifying another, and empirically relevant, factor which would result in the breakdown of equivalence between tariff and quota policy.

Keywords: Search; tariffs; quotas

JEL Classification: F12; F13

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I. Introduction

Among the most enduring lines of research in the theoretical analysis of international trade policy is the so-called equivalence analysis comparing the effects of import tariffs to quantitative restrictions. Beginning with Bhagwati's (1965) demonstration that tariff policy and an import equivalent quota produce identical economic effects under conditions of universal competition within a partial equilibrium framework, equivalence analysis has evolved by progressively expanding the conditions under which the two policies are compared as well by incorporating new modeling techniques. Over time, researchers have introduced elements of imperfect competition {Shibata (1968), Hwang and Mai (1988)}, general equilibrium {Falvey (1975), Melvin (1986)}, (directly) unproductive activities {Bhagwati and Srinivasan (1982), Larue and Lapan (2002)}, regional trade agreements {Panagariya and Duttagupta (2002)} and informational failures {Fishelson and Flatters (1975), Matschke (2003)} into equivalence analysis in an effort to identify the conditions under which equivalence breaks down.[1]

The ongoing interest in equivalence analysis is, in good part, motivated by the importance to trade policy formation of understanding the comparative effects of the two sets of policies. Indeed, this issue is especially significant today in light of the widespread 'tariffication' of quantitive restrictions that has resulted from multilateral trade negotiations – the most notable example being the recent conversion of global textile and apparel quantitative restrictions to tariffs.

The objective of the present study is to extend this body of work still further by conducting an equivalence analysis of import tariffs and quotas in an environment where a foreign exporter holds less than full information on domestic buyer preferences and, as a result, must expend resources to find a buyer who is willing to purchase the product at the posted price. The presence of search costs is likely to be particularly germane for international markets where buyers and sellers are separated by distance, culture and jurisdictional borders. The question to be addressed is does the introduction of a search process result in a breakdown of, what would otherwise be, equivalent economic effects.

We employ a standard sequential search model where a foreign monopolist exports to domestic consumers. The monopolist, ex ante, knows the distribution of individual domestic consumer valuations, but not the amount that any individual consumer is willing to pay. To find buyers with a valuation greater than price, set at the outset, the monopolist must engage in costly search. To the best of our knowledge no previous study has examined either policy in a formal model of search, much less carried out an equivalence analysis.[2]

With monopolistic foreign supply, absent search costs, Shibata (1968) demonstrated that an import tariff and an import quota, set at a level equal to the import quantity achieved under the tariff, will produce identical domestic prices. Here, we demonstrate that the equivalence of domestic price is a rare exception in the presence of search activity on the part of the foreign monopolist. Moreover, the exact nature of nonequivalence varies in terms of which policy produces the highest domestic price and depends on the relative magnitude of the policies. In general, the lower the tariff rate the greater the likelihood that the domestic price under the quota is higher than under the tariff policy.

The underlying source of nonequivalence is the difference between the exporter's perception of the duration of the search process under each policy which, in turn, results in a difference in the exporter's expected search costs. Under quota policy the exporter perceives search activity to be a finite process constrained by the number of allowable units of imports so that search costs are specific to each unit. Under tariff policy, in contrast, search is perceived to be ongoing so that search costs are not associated with individual units of output, but rather with individual (potential) domestic buyers. These differences in perceived time horizons generate the nonequivalence in pricing behavior.

Section II develops the basic sequential search model used to analyze the pricing behavior of the foreign exporter. The assumption of monopolistic supply of exports streamlines the analysis and facilitates the identification of the mechanism by which search activity alters the pricing behavior of the exporter. Section III prefaces the application of the search model to the formal analysis of the two policies by describing the impact of each policy on the exporter's perception of the duration of search. Sections IV and V apply the model to examine the effects of import tariff and quota policy, respectively. In Section VI we compare the effects of each policy on the domestic price of the importing country and demonstrate the general result of nonequivalence. Section VII concludes with remarks on the policy implications of the results.

II. Model

Consider a standard infinite horizon, sequential search process whereby a foreign monopolist expends c per unit of (continuous) time to search for a potential domestic buyer. Search costs result from the exporter's efforts to inform domestic importers of the availability and characteristics of its products. Expenditures on search generate a stream of potential buyers who "arrive" according to a Poisson process at rate λ per unit of time.[3]

Each potential buyer seeks to purchase a single unit of the good and holds a valuation based on his/her preferences for the exporter's product. From the exporter's perspective, the valuation of individual domestic consumers is a random variable, v, described by cumulative distribution function $F(v)$ with continuous density function $f(v)$: $E(v) < \infty$.

The "posted price" model developed by Arnold and Lippman (2001) serves as the basis for the analysis. The exporter selects a price, p, prior to the arrival of buyers. The price is invariant over time, so that if an arrival rejects p once there will be no sale to that same arrival at a later date.[4] The first buyer with individual valuation, $v \geq p$, purchases a unit of the product. Upon completion of a sale, the exporter immediately produces another unit and resumes search. The length of time between the point when search is initiated (or, equivalently, when the previous unit is sold) and the point when a domestic buyer accepts the posted price and purchases the unit is defined as the sales period.

The arrival of buyers willing to pay p is a Poisson process with parameter $\lambda\overline{F}(p)$ where $\overline{F}(p) = 1 - F(p)$. With a Poisson process, the sales period is an exponential random variable, τ, with parameter $\lambda\overline{F}(p)$, characterized by "lack of memory." That is, the sales period for an individual unit is independent of the sales period for the previous unit so that the expected sales period for all units is identical.

To derive expected profits for a single sales period, first recognize that because the exporter's revenue derived from selling a single unit equals its posted price, expected discounted revenue equals $pE[e^{-\delta\tau}] = p\lambda\overline{F}(p)/(\delta + \lambda\overline{F}(p))$.[5] Expenditures on search costs, in contrast to revenue, are a continuous flow until a sale is made so that the expected discounted value of search costs required to find a buyer willing to pay p equals

$$cE\int_0^{\tau} e^{-\delta\tau dt} = cE(1 - e^{-\delta\tau})/\delta = c/(\delta + \lambda\overline{F}(p)).$$

Suppose the domestic country imposes a per-unit import tariff, *t*. Under such a policy the exporter's expected single period profit, discounted to the beginning of the sales period, equals:

$$\pi(p) = [(p-t)\lambda\overline{F}(p) - c]/(\delta + \lambda\overline{F}(p)) \tag{1}$$

The domestic exporter sets a posted price, *p*, at time $t = t_0$ which maximizes the sum of the expected discounted value of profits associated with selling each of *n* units:

$$\Pi = \pi + \beta\pi + ... + \beta^{n-1}\pi = \pi(1-\beta^n)/(1-\beta) \tag{2}$$

where $\beta = \lambda\overline{F}/(\delta + \lambda\overline{F})$ represents the discounted expected value of a sales period.

The intuition underlying expression (2) can be gleaned by examining the case where $n = 2$. Search for a buyer of the first unit begins at t_0 so that the expected discounted value of profits obtained from selling the first unit, π, is given by expression (1). Because the expected sales period for the second unit equals that of the first unit, the expected discounted value of second-unit profits, measured at the beginning of the second-unit sales period, also equals π. To obtain the expected discounted value of second-unit profits at t_0, π must then be discounted by β to obtain $\beta\pi$. For $n > 2$ the recursive process continues to yield expression (2). The first-order condition for profit maximization equals:

$$\partial\Pi/\partial p = \{\partial\pi/\partial p(1-\beta^n)(1-\beta) + \pi(\partial\beta/\partial p)[1-\beta^n(1-n) - n\beta^{n-1}]\}/(1-\beta)^2 = 0 \tag{3}$$

where $\partial\pi/\partial p = \lambda[\overline{F}(\delta + \lambda\overline{F}) - f((p-t)\delta + c)]/(\delta + \lambda\overline{F})^2$ and $\partial\beta/\partial p = -\lambda f \delta/(\delta + \lambda\overline{F})^2 < 0$.

III. Perceived Duration of Search and the Exporter's Pricing Decision

Before applying the sequential search model to the question of equivalence, it will prove useful to first consider the exporter's perception of the duration of the search process under each policy. Tariff policy does not prohibit the foreign exporter, upon completion of the sale of a single unit, from producing, instantly and costlessly, another unit and resuming search for a domestic buyer of that unit. Here, as with free trade, the exporter perceives search as an ongoing process whose duration extends indefinitely.

The implication of ongoing search activity for subsequent analysis is that the foreign monopolist perceives the maximal (potential) number of sales as approaching infinity. Although the actual quantity of sold units for any specified time period is constrained by the number of arrivals, λ, the monopolist's pricing decision is made over an infinite time horizon, or equivalently, an infinite number of finite time periods, where the cumulative number of arrivals approaches infinity so that potential sales, n, are not constrained.

Under the quota policy, the maximal number of sold units for any specified time period is set at some finite value, $\tilde{n}$, regardless of the number of arrivals. When all $\tilde{n}$ units are sold search ceases (until the next time period). Here, search activity is perceived to be finite in duration and the exporter sets price accordingly – to maximize the profits of selling a specified number of units of the good within a finite time period. The finite pricing horizon holds, even if quota policy were in place for multiple periods, as long as the quota quantity holds for each period. In effect, the foreign exporter sets price at the beginning of each period for which quantity is constrained and the price for each period is identical because of the independence of the expected length of each sales period.

The difference in the exporter's perception of the duration of search under each policy manifests itself analytically in the cost to the monopolist of raising price as measured by forgone revenue. Under tariff policy, each arrival represents p-t of potential revenue. If an individual arrival rejects a posted price once, they will continue to reject it for all time so that the perceived cost to the exporter is p-t of lost revenue. Here, the costs of increasing the posted price is specific to each arrival.

With quota policy, in contrast, potential revenue is specific to each of the $\tilde{n}$ allowable units (per time period). Thus, when a current arrival rejects the posted price, p, the exporter does not perceive forgone revenue to be the *full* price. Instead, the monopolist perceives that it can continue search and ultimately find a buyer willing to pay p for the previously rejected unit. Here, the costs to the monopolist is the reduction in the discounted value of price generated by the delay in finding a buyer of the specific unit.

IV. Tariff Policy

Because the foreign monopolist perceives search as an ongoing process under tariff policy, the exporter sets price, p, as if potential sales, n, approaches infinity. Thus, profits over an infinite time horizon can be expressed as $\Pi(n \rightarrow \infty) = \pi / (1-\beta)$ with first-order condition:

$$\partial\Pi / \partial p(n \rightarrow \infty) = [(\partial\pi / \partial p)(1-\beta) + \pi(\partial\beta / \partial p)] / (1-\beta)^2 = 0 \tag{4}$$

Substituting for $\partial\pi / \partial p$ and $\partial\beta / \partial p$ yields:

$$1 = (p-t)h(p) = MC_t \tag{5}$$

where $h(p) = f(p)/\overline{F}(p)$ – the hazard rate function for valuations. Because of the equality of price and marginal revenue, the increase in revenue that results from a buyer purchasing the unit at a higher price equals one.

The right-hand side of (5) can be interpreted as the expected marginal costs associated with a price increase. With ongoing sales, if the exporter fails to make a sale at a higher $\tilde{p} > p$ when the domestic buyer would have purchased the item at price p, the price increase costs the exporter the full amount of the lost sale: $p-t$. Expected marginal costs, MC_t, are obtained by multiplying, $p-t$, by the hazard rate function, $h(p)$, which measures, roughly, the probability that a randomly arriving domestic consumer who would have purchased the product at the original price now rejects the new, higher price.

It is also interesting to note that c, δ and λ are absent from the exporter's marginal costs. This follows from the fact that the search process continues forever, regardless of the length of the sales period for an individual unit, so that the discounted value of the exporter's search costs equals c/δ, regardless of the price.

Second-order (and stability) conditions require expected marginal costs to increase with respect to price: sgn $\partial MC_t/\partial p = \text{sgn}\ (h(p)+(p-t)\partial h/\partial p) > 0$. A sufficient condition for $\partial MC_t/\partial p > 0$ is $\partial h/\partial p > 0$. Recognizing that the behavior of hazard functions varies widely over possible distributions of consumer valuations, we assume that $\partial h/\partial p$ is not too negative so that second-order conditions hold.[6]

To determine the impact of tariff policy on price, totally differentiate first-order condition (5):

$$dp/dt = h(p)/(h(p)+\partial h/\partial p(p-t)) > 0 \tag{6}$$

which is positive when second-order conditions hold. An increase in the tariff rate, t, lowers the net price of the exporter and thus lowers expected costs in terms of the forgone revenue of a lost sale due to a price increase. Since expected opportunity costs decline, the exporter is more willing to "absorb" the costs of delay associated with a price increase.

The impact of an import tariff is shown in Figure 1 which depicts expected marginal revenue and search costs of the foreign exporter with respect to price. Imposition of the import tariff lowers marginal search costs from MC_o to MC_t. As a result, the monopolist raises its price to domestic consumers from p_o to p_t.

It is also interesting to note the possibility that $dp/dt > 1$. That is, an import tariff can potentially raise the net costs of imports to the importing nation. A necessary condition for a "deterioration" in the importing nation's terms of trade is $\partial h / \partial p < 0$ – the likelihood that an arriving buyer, who would have purchased a unit at the lower price, but reject the higher price, declines. Such an outcome is possible under reasonable specifications of consumer valuations.[7]

Although higher tariff rates increase the domestic price of imports just as in standard (non-search) models, the mechanism by which tariff policy works under search is quite distinct from standard models. Here, tariffs lower search costs which result in higher prices, while in standard models, tariffs raise the supply costs of foreign exporters who respond by raising prices.

V. Import Quota Policy

Traditional equivalence analysis solves for the equilibrium quantity of imports under tariff policy and then proceeds to examine the effects of an import quota set at this level. In the sequential search model developed above, the exporter sets its price based on the expected number of arrivals who are willing to pay the posted price. Since the analysis does not solve for the actual number of units sold during any specified time period, traditional equivalence analysis is not strictly applicable. However, it is still possible to demonstrate that import-equivalent tariff and quota policies are, in general, non-equivalent in price for any quantity of imports realized under the tariff.

Suppose that the exporter, facing tariff rate t, sells $\tilde{n}$ units to domestic buyers at posted price, p_t, over a specified time period. If, instead, the exporter were faced with an import quota equal to $\tilde{n}$ units per time period, the exporter's profit function is represented by expression (2) with $n = \tilde{n}$ and $t = 0$. The analysis assumes quota licenses for the $\tilde{n}$ units are issued free of charge to the monopolist exporter. First-order condition, expression (3), can be expressed as:

$$1 = h(p)((p\delta + c)/(\delta + \lambda \overline{F})) - \pi_q[(\tilde{n}\,\beta^{\tilde{n}-1}(1-\beta) + \beta^{\tilde{n}} - 1)/(1-\beta^{\tilde{n}})] = MC_q \qquad (7)$$

where π_q equals $\pi(t = 0)$. Just as in the case of tariff policy, the left-hand side of expression can be interpreted as the marginal revenue of selling a single unit to a domestic buyer at the higher price. The right-hand side measures the expected, discounted value of marginal costs (MC_q) associated with a price increase and has two components. First, when a current arrival rejects the higher price, the cost to the monopolist is the discounted, expected reduction in revenue caused by the delay in finding a buyer for this unit: $p\delta/(\delta + \lambda \overline{F})$.[8] In addition, the delay increases the direct expenditure required to locate another buyer willing to pay the higher price for this unit: $c/(\delta + \lambda \overline{F})$. Second, the discounted costs associated with delaying the start of search for buyers of subsequent units, due to the longer sales period of previous units, increase: $\pi_q[.]$.

For subsequent equivalence analysis, it is important to note that marginal costs associated with a price increase are higher as the quota quantity increases: $dMC_q / d\tilde{n} > 0$.[9] This result is easily explained by the fact that with a greater quota, the costs associated with the delay caused by a price increase now affect a greater number of units.

VI. (Non) Equivalence Analysis

Because marginal revenue associated with a price increase is identical under both policies (equal to one), the difference in prices under the two policies is determined exclusively by differences in marginal search costs. The key to understanding this result is the difference in the exporter's perception of the duration of the search process under each policy. Recall that under tariff policy the exporter perceives the search process as ongoing so that there is no limit to the potential quantity of sales over the pricing horizon. Realized sales are only limited by potential domestic buyers rejecting a higher posted price. Here, search costs are, in essence, specific to individual arrivals. The revenue forgone from a lost sale – a rejection of the posted price by an individual arrival – can never be recovered, even partially. Thus, each lost sale reduces revenue by the full amount of the net price, $(p-t)$.

Under quota policy, in contrast, when the monopolist is attempting to sell a finite number of units realized sales are restricted by the quota quantity, $\tilde{n}$. Thus, search is perceived to be specific to each individual unit. Here, the monopolist views the revenue lost from a rejection as partially recoverable when the specific unit is sold at a later date to another arrival, albeit at a lower present value: $p\lambda\overline{F}(p)/(\delta+\lambda\overline{F}(p))$.

Of course, under the quota the exporter must also contend with the increase in transaction-specific search costs associated with delay. In contrast, under tariff policy a price increase does not impact the exporter's direct search costs since search continues forever regardless of how many individual units are sold per time period. The remaining source of higher costs under the quota, the reduction in the discounted value of all units resulting from the extended (cumulative) time period required to sell all $\tilde{n}$ units, is absent under tariff policy.

The (excess) reduction in revenue associated with a lost sale under tariff policy is of course inversely related to the size of the tariff rate, *t*. This relation is captured by expression (8) which compares marginal costs under each policy (measured at a given price):

$$MC_t \text{ ¤ } MC_q \text{ if } t \text{ £ } \pi_q[\tilde{n}\beta^{\tilde{n}-1}(1-\beta)/(1-\beta^{\tilde{n}})] \tag{8}$$

If, for example, an importing country, starting at free trade, were to impose a "small" tariff, marginal costs under a tariff would exceed those under any quota policy (value of $\tilde{n}$). At the other extreme when the tariff rate approaches its prohibitive value $(t = \pi_q / \beta)$, $MC_t > MC_q$.[10]

Define the critical value of the tariff rate, t_c, as the tariff rate which equates MC_t to MC_q – measured at identical prices – for a given quota quantity, $\tilde{n}$. The critical tariff rate and quota quantity must be inversely related. As described above, as the quota quantity increases MC_q also rises. Thus, to maintain $MC_t = MC_q$ the tariff rate must be lower in value. This relation is summarized in Figure 2 which shows the locus of $t_c, \tilde{n}$ values which equate marginal search costs for any given price.[11] For combinations below (above) the $MC_t = MC_q$ curve, $MC_t > (<) MC_q$.[12]

As previously shown an increase in the marginal costs of search under both policies results in the exporter reducing its price, *p*, in an effort to reduce the time required to find a domestic buyer. Thus, since marginal revenue equals one under both policies, price will be greater (lower) under that policy with the lower (higher) marginal cost. Referring to Figure 2, for $t, \tilde{n}$ combinations below (above) the $MC_t = MC_q$ locus, the equilibrium price under the quota, p_q, will be greater (less) than the equilibrium price under the tariff, p_t. In terms of the value of the tariff rate, *t*, we can generalize the (non) equivalence of price under both policies:

$$t \le t_c \rightarrow p_q \neq p_t \tag{9}$$

At $t < t_c$ failure to sell a unit to a current buyer is more costly when *potential* sales are unrestricted over the pricing time horizon as under a tariff, versus the case where search is specific to each unit, as under the quota, and so provides a greater incentive to the exporter to avoid those costs under tariff policy by reducing price. Thus, the exporter sets a lower price under tariff policy than under the import-equivalent quota policy.

VII. Concluding Remarks

This study has identified an additional, and empirically relevant, source of nonequivalence between import tariffs and quotas – search activity on the part of exporting firms. Although the market structure modeled is stylized, the analysis serves to illustrate that the fundamental cause of the breakdown of equivalence is the differential impact that each policy has on the exporter's perception of the duration of the search process which, in turn, causes the exporter's search costs to differ under each policy. Amending the search process, so that the firm sets a price equal to *v* for each arrival (greater than some reservation price) or by allowing the firm to reset prices at a later date would not alter this fundamental result.

It is worth noting that the treatment of the exporter's pricing decision is not dependent on the time period attached to each policy. As long as the number of arrivals, λ, exceeds the quota quantity, $\tilde{n}$, the exporter's constraint on sales is the quota quantity itself with maximal potential revenue equal to $\tilde{n}p$. The delay in selling a specific unit resulting from a rejection reduces potential revenue by the discounted value of *p*. This holds even if the quota policy were in place for multiple periods so long as λ exceeds $\tilde{n}$ for each period. Moreover, it is possible to demonstrate that quota policy can be tightened or loosened by either changing the quota quantity or the time period associated with the quota quantity with identical effects on domestic price.[13]

Tariff policy, in contrast to quota policy, is typically imposed without reference to a specified time period which is consistent with the analytical treatment of search under tariff policy presented above whereby the exporter perceives search as ongoing. However, even if tariff policy were set for a specified time period, the exporter's perception of search costs would remain unchanged. Potential sales per time period would continue to be constrained by the number of arrivals, λ, so that maximal potential revenue per time period would equal $(p-t)\lambda$. When a current arrival rejects the posted price, that rejection lowers maximal revenue by $(p-t)$ and represents the potential costs of raising price. Again, this lost revenue cannot be recovered, even partially.

The analysis demonstrates that domestic prices are unlikely to be equal under each policy. Moreover, it is not possible to predict, a priori, which policy will produce higher domestic prices. We show, however, that the relative impact of each policy on domestic price depends crucially on the magnitude of the two policies. The combination of lower tariff rates and lower quota quantities are more likely to generate lower domestic prices under the tariff than the quota. Of course, policymakers need to recognize not only the other economic effects that follow from differences in price, including differences in domestic production, consumption and welfare, but also that their decisions on the magnitude of the policies determine the nature of nonequivalence.

Our analysis also demonstrates how the introduction of search activity alters the mechanism by which trade policy works with a consequent change in standard economic effects. Higher tariff rates, for example, result in higher domestic prices, just as in standard tariff analysis, but via an entirely different mechanism. Here, higher tariff rates reduce search costs which results in the exporter raising its price. Also, higher tariff rates may actually increase the exporter's net price (world price of imports). These results, as well as the nonequivalence results, suggest the importance of recognizing the role of search activities in international settings when evaluating trade policy.

Notes

1. These listed studies are meant to be illustrative, not exhaustive.

2. Several recent studies recognize that informational barriers may force international traders to engage in costly search to find "compatible" commercial partners located in foreign countries (e.g. Rauch and Cassella (2003), Cassella and Rauch (2002)), but do not consider trade policy.

3. The notion of 'arrival' does not necessarily imply that potential buyers physically travel to meet the monopolist (as in consumers arriving at a retail outlet). Perhaps a more satisfactory interpretation would be to think of the exporter contacting prospective foreign consumers, sequentially, at a rate of λ per period.

4. The posted price model is implicitly a model without recall, since the monopolist cannot lower its price to arrivals who previously rejected a posted price.

5. $E[e^{-\delta\tau}]$ equals the expected discounted time of receipt of the first valuation greater than p. The time until the arrival of a customer willing to pay $p, \tau,$ is exponentially distributed according to density function $\lambda\overline{F}e^{-(\lambda\overline{F})\tau}$. Thus,

$$E[e^{-\delta\tau}] = \int_0^\infty e^{-\tau(\delta+\lambda\overline{F})} d\tau$$ which yields the expression for $pE[e^{-\delta\tau}]$ in the text.

6. The properties of hazard rate functions vary significantly over familiar distribution functions. For example, the hazard rate function for a uniform distribution is increasing with respect to valuations. The Weibull distribution (the most commonly used distribution in the reliability literature) has a hazard rate function which can be either increasing or decreasing. For a more detailed discussion of the behavior of hazard rate functions see Arnold and Lippman (2000).

7. A simulation, assuming a Weibull distribution of consumer valuations, which illustrates a case where a higher import tariff raises the net price of imports to the domestic country is available upon request.

8. The reduction in the present value of the posted price that results from delay, $\delta p/(\delta+\lambda\overline{F}(p)) = p-(p\lambda\overline{F}(p)/(\delta+\lambda\overline{F}(p))$ where p equals present value when the good is purchased at time zero.

9. See Appendix for a formal derivation.

10. At the prohibitive tariff value, expression (1) for π equals zero. The prohibitive tariff exceeds the critical value of *t* that equates $MC_t = MC_q$ (see expression 8) for $0 \le \beta \le 1$.

11. The $MC_t = MC_q$ locus provides no information on the equilibrium locus of *t* and *n* values. Indeed, the equilibrium value of *n* under tariff policy is endogenous to the tariff policy. However, as noted above, tariff policy is based on expected sales and the realized value of *n* can take on any value (for any given tariff rate, *t*). The $MC_q = MC_t$ locus simply compares the value of costs under both policies for any given *p*. The relative equilibrium values of *p* can be inferred from the differences in *MC* since marginal revenue is the same under each policy.

12. Another way of presenting the comparison of marginal costs under the two policies is graphically with the aid of Figure 1. Saying that $MC_q > (<) MC_t$ is equivalent to saying that the marginal cost curve under the quota lies above (below) MC_t curve in Figure 1 for all prices.

13. A demonstration of this result is available from the author. Also, Arnold and Lippman (2001) derive a qualitatively equivalent result for the impact of imposing a finite time horizon on a supplier of *n* units.

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APPENDIX

Proof: $dp/d\tilde{n} < 0$ (or $dMC_q/d\tilde{n} > 0$).

For analytical convenience, we take an indirect approach to show that increases in the quota quantity, $\tilde{n}$, reduce the posted price, p (versus employing comparative statics based on first-order condition (7)). From expression (2) in the text it follows that total expected discounted profits for n units (Π_n) can be written as:

$$\Pi_n = \Pi_{n-1} + \beta^{n-1}\pi \tag{A1}$$

Differentiating (A1) with respect to p yields:

$$\partial\Pi_n/\partial p = \partial\Pi_{n-1}/\partial p + \beta^{n-2}((n-1)\pi\,\partial\beta/\partial p + \beta(\partial\pi/\partial p)) \tag{A2}$$

The objective is to demonstrate that $\partial\Pi_n/\partial p < 0$ when evaluated at the price that maximizes $\Pi_{n-1}(p_{n-1})$. With concave profit functions this is equivalent to showing $p_n > p_{n-1}$.

At p_{n-1}, $\partial\Pi_{n-1}/\partial p = 0$. Therefore, a sufficient condition for $\partial\Pi_n/\partial p < 0$ is $Z = \beta^{n-2}[(n-1)\partial\beta/\partial p\pi + \beta(\partial\pi/\partial p)] < 0$. Begin by solving for $\partial\pi/\partial p$ from first-order conditions for $\Pi_{n-1} = \pi(1-\beta^{n-1})/(1-\beta)$. From $\partial\Pi_{n-1}/\partial p = 0$ it follows that:

$$\partial\pi/\partial p(p = p_{n-1}) = (\partial\beta/\partial p)\pi((n-1)\beta^{n-2}(1-\beta) - (1-\beta^{n-1}))/(1-\beta)(1-\beta^{n-1}) \tag{A3}$$

Substituting (A3) into Z yields:

$$Z = \beta^{n-2}(\partial\beta/\partial p)\pi)/(1-\beta)(1-\beta^{n-1}))[n(1-\beta) + (\beta^n - 1)] \tag{A4}$$

If $V = (n(1-\beta) + (\beta^n - 1)) > 0$ then $Z < 0$ (since $\partial\beta/\partial p < 0$). First note that $\partial V/\partial\beta = n(\beta^n - 1) \leq 0$ for $0 \leq \beta \leq 1$. Thus, because $V = 0$ at $\beta = 1$, it follows that $V > 0$ for $0 \leq \beta \leq 1$.

<u>FIGURE 1</u>

Price Effects of Import Tariff Policy

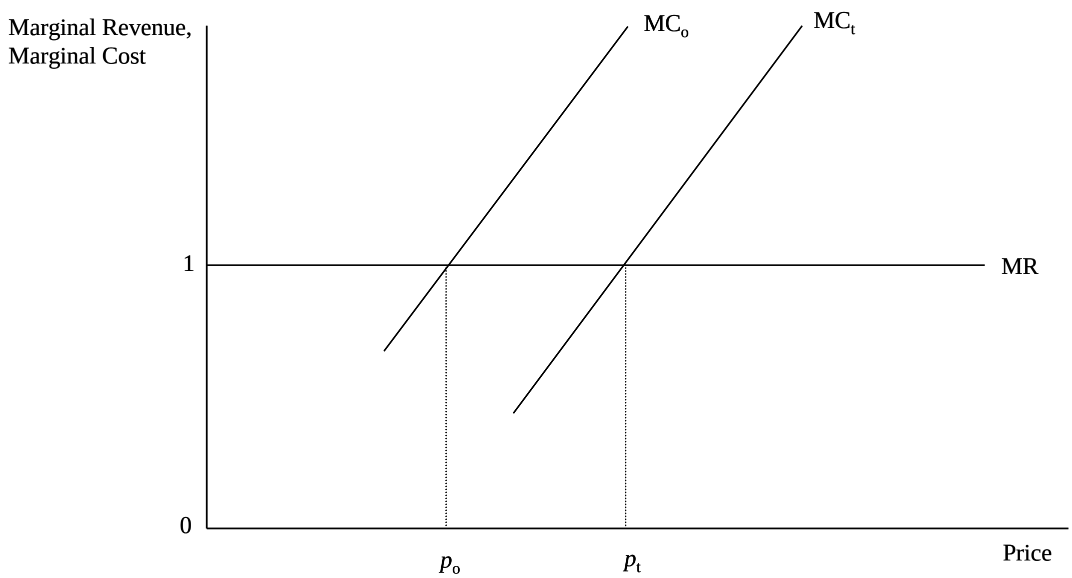

FIGURE 2

Locus of Tariff-Quota Combinations which Equate
Marginal Search Costs