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Abstract: We examine quality choice in a duopoly model with one foreign and one domestic firm, where consumers show similar preferences for quality but different preferences for brands. Firms set quality prior to choosing price; and, the interaction between firms and policymakers assumes several forms. Our conclusions differ depending on whether firms face "set-up" costs in establishing higher quality levels. When these costs are absent, both domestic and foreign firms typically set quality at socially optimal levels. When these costs are present, the foreign firm [and often the domestic firm] sets quality below the socially optimal level. These results change when firms use their quality choices to signal cost information to policymakers or rivals.

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Quality Choice, Trade Policy, and Firm Incentives

1. Introduction

In the past few years, the international trade literature has examined the role of quality decisions in firm behavior, along with the associated implications for social welfare and trade policy. Among the shortcomings of this literature are that it addresses competitive or monopolistic markets almost exclusively [with the exception of Das and Donnenfeld (1989)], and that products are solely differentiated on the basis of quality.[1]

Prior models thus ignore the possibility that oligopolistic behavior may arise in those markets where successful entry requires the development of specific technological assets [or substantial sunk-cost investment]. Moreover, products in those markets may be differentiated on the basis of both horizontal [i.e., brand] and vertical [i.e., quality] attributes. Consumers may hold diverse preferences for some of these attributes, but not for others. By allowing consumers to differ only in their valuation of quality, prior models discount the possibility that consumer diversity instead depends on other factors. When consumer diversity does not depend on varied preferences for quality, a firm still uses its quality choice to induce changes in consumer purchasing behavior and rival pricing behavior. Hence, the quality decisions of firms have important welfare implications in these types of oligopolistic markets.

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[1] See Rodriguez (1979), Falvey (1979, 1983), Santoni and Van Cott (1980), Mayer (1982), Das and Donnenfeld (1987), Krishna (1987, 1990), Donnenfeld (1988), and Bond (1988).

This paper considers these issues by analyzing a duopoly with one domestic and one foreign firm, where products possess both quality and brand attributes. Consumers show similar preferences for quality but diverse preferences for brands.[2,3] This assumption may describe behavior in many markets. For instance, consumers may assign similar values to a product's "reliability", but have diverse preferences for its "styling". Consumers in other markets may have similar incomes; hence, they may show similar tastes for the "luxury" of a product, but not for other attributes.

Using this assumption to describe tastes, we examine social welfare and optimal trade policy in a subgame-perfect Nash equilibrium where quality decisions are made before price decisions. In addition, firms may face "set-up" and "development" costs in improving product quality. We consider several types of interaction between policymakers and firms, and our results differ depending on the role played by set-up costs.

In the absence of set-up costs, private quality choices typically maximize social welfare unless a welfare maximum requires that a firm be constrained to a "minimal" presence in the market. If firms choose quality in anticipation of the policymaker's imposition of a subsidy or tariff, and if they possess perfect information concerning the policymaker's objectives, then welfare-maximizing quality levels are still selected. This result may apply even when the policymaker's weighting of producer and

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[2] Das and Donnenfeld (1989) use a duopoly model where consumers are diversified in their preferences for the sole product attribute, quality.

[3] Product attributes are perfectly observable before purchase. Another strand of the literature examines trade policy when consumers face informational imperfections in observing quality [see Mayer (1982), Bond (1984), Donnenfeld, Weber, and Ben-Zion (1985), Donnenfeld (1986), Donnenfeld and Mayer (1987), Falvey (1989), and Bagwell and Staiger (1989)].

consumer surplus differs from the "true" social welfare function.

Our conclusions change markedly, however, if there are informational imperfections in the market. We find that in a situation where firms use their quality choices to signal cost information, the incentives created by signalling may cause either overcommitment or undercommitment to quality depending on the "receiver" of the signal. If a rival receives the cost signal prior to setting price, then a given firm sets its quality below the socially optimal level. This tendency may be reversed when the policymaker observes the cost signal prior to the imposition of a subsidy or tariff.

In the presence of set-up costs, firms typically choose suboptimal quality levels from a welfare-maximizing standpoint. The foreign firm underinvests in quality whenever it is socially optimal for that firm to maintain a significant market presence. The domestic firm behaves similarly unless a preimposed subsidy [or tariff] is relatively large. When the policymaker can adjust the quality of each firm and impose a subsidy [or tariff], optimal policy mandates that domestic and foreign quality be set typically at different levels [even if firms face identical costs]. If institutional constraints preclude the policymaker from imposing different quality standards, we find that a uniform standard may raise welfare under many conditions [in contrast to results from other models]. When applied by itself, or in tandem with a uniform quality standard, we find that the optimal subsidy or tariff may be negative in sign. This result differs from policy recommendations contained in most price-setting models that ignore quality [e.g., Eaton and Grossman (1986)].

When quality decisions precede the imposition of a subsidy [or tariff], and the policymaker's objectives are known, the foreign firm still sets quality below the socially optimal level in the presence of set-up costs. The domestic firm, however, may overinvest in quality depending on the policymaker's weighting of producer surplus, consumer surplus, and government revenue.

We organize the paper as follows. Section 2 describes the elements of the model. Section 3 examines an equilibrium where the policymaker may set a subsidy or tariff prior to the quality decision. Section 4 analyzes first-best policy and other alternatives when the policymaker may adjust quality directly and impose a subsidy [or tariff]. Section 5 examines an equilibrium where firms choose quality in anticipation of a future subsidy or tariff. In Section 6, the domestic quality choice signals cost information to either the policymaker or a foreign rival. This signal may either influence the imposed subsidy [or tariff] or a rival's price.

2. The Model

In our model, two firms and a continuum of uniformly distributed consumers are located along a circle. The firms, one foreign and one domestic, have chosen locations to maximize the distance between them.[4]

[4] If firms simultaneously choose locations prior to other stages of the game, then each firm reacts to its rival's locational choice by selecting that location which yields the highest expected payoff in the subsequent post-location subgame. In the case of linear transportation costs, an assessment of this payoff is not without complications. In particular, D'Aspremont, Jaskold-Gabszewicz, and Thisse (1979) have shown that a pure-strategy Nash equilibrium in prices may not exist when firms locate at close proximity. Under these circumstances, some other equilibrium concept [possibly a mixed-strategy result] must be used to determine payoffs based on location.

Salop (1979) and others have presumed that a symmetric locational equilibrium is relevant for examination. Further, Economides (1984) has shown that our assumption of maximum firm separation conforms with a locational equilibrium in the case of quadratic transportation costs. Our qualitative results are scarcely changed if we convert to this assumption.

Since we measure distances in units of 2π radians, the circle is of unit circumference and the distance separating the firms equals 1/2. The locations of firms and consumers can be identified by their equivalent arc measures [in units of 2π radians].

Each consumer may purchase a variable amount of a homogeneous good and a single, nondivisible unit of a differentiated good that is obtainable from either of the two firms along the circle. The utility function is additively separable, and any consumer receives subutility m from consuming m units of the homogeneous good. The subutility from consuming the differentiated product depends on the consumer's "location" and the "quality" of the product. For consumer w, the subutility from consuming the domestic(foreign) variety is $h(q)-td(w)(h(q^*)-t[(1/2)-d(w)])$, where $q(q^*)$ is the domestic(foreign) "quality" level, t is unit transport cost, and d(w) is the shortest arc distance between consumer w and the domestic firm. We assume that the potential quality choices of each firm are bounded above and below, implying that $q(q^*) \in [\underline{q},\bar{q}]([\underline{q}^*,\bar{q}^*])$.

This utility specification presumes that all consumers assign the same value to "quality" attributes, expressed by h(Q) [where $Q = q,q^*$]. Consumers assign different values to "locational" [or "brand"] attributes, expressed by td(w).[5] A consumer experiences a utility loss that arises

[5] Prior literature has often assumed that quality is the only basis of product differentation, and that consumers show different preferences for quality. Some of these models [see, for example, Das and Donnenfeld (1987, 1989)] are based on the construct of Shaked and Sutton (1982), where the marginal value of quality rises as a consumer's income increases. In terms of this formulation, our specification can be justified if consumers have similar income levels. This does not necessarily constitute an extreme assumption. Even in industries such as automobiles, where there are "economy" and "luxury" varieties, the actual "markets" may essentially be stratified on the basis of consumer income [with little crossover purchasing]. Alternatively, other markets may exist where consumers of

from any distance she must cover to reach a specific producer's location. We characterize this loss as a "transport" cost that rises linearly with distance. Our qualitative results would be unchanged fundamentally if we instead used a quadratic representation of transport costs.

Without losing generality, we assume that the price of the homogeneous good equals one, and the price of the differentiated domestic (foreign) good equals $p(p^*)$. To ensure that every consumer purchases one unit of the differentiated product, we only examine equilibria where $[h(q)-p],[h(q^*)-p^*] > t/4$. Consumer w maximizes her utility by purchasing from the domestic(foreign) firm if $h(q)-p-t(d(w)) >(<) h(q^*)-p^*-t[(1/2)-d(w)]$. A consumer that is indifferent between the two varieties is located at distance x from the domestic firm, where

$$x = (1/2t)[(h(q)-h(q^*)) - (p-p^*)] + 1/4. \qquad (1)$$

Hence, the market segment for the domestic(foreign) firm equals $x((1/2)-x)$ in each direction.

The domestic and foreign cost functions can be described as

$$C(q,X) = c(q)X + f(q), \quad C^*(q^*,X^*) = c^*(q^*)X^* + f^*(q^*),$$

where $X(X^*)$ is domestic(foreign) output, $c(q)(c^*(q^*))$ is domestic(foreign) marginal cost, and $f(q)(f^*(q^*))$ is non-output-related domestic(foreign) quality cost. We restrict the behavior of the cost functions and the consumer valuation of quality as follows:

$$c_q, c^*_{q^*} > 0, \ c_{qq}, c^*_{q^*q^*} \geq 0; \ f_q, f^*_q \geq 0, \ f_{qq}, f^*_{q^*q^*} \geq 0;$$

$$h_Q > 0, \ h_{QQ} < 0.$$

An increase in quality potentially creates two sources of increased costs.

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different incomes share similar preferences for quality. Our construct parallels that used by Riordan (1986) to examine an incentive-compatible quality equilibrium under consistent consumer expectations.

First, as firms raise their quality input, their marginal production costs increase at a nondecreasing rate. Second, an increase in quality may create costs that are not related directly to output [i.e., "set-up" and "development" costs]. In our future discussion, we say that "set-up" costs are absent(present) when $f_q, f^*_{q^*} =(>) 0$. If these costs are present, we assume that they either increase or remain unchanged as quality increases. Finally, an increase in quality raises the utility received by consumers, but at a decreasing rate.

Let $Z(q) = h(q)-c(q)$ and $Z^*(q^*) = h(q^*)-c^*(q^*)$. Based on the above conditions, these functions are at least twice differentiable. Further, $Z_{qq}, Z^*_{q^*q^*} < 0$. We also assume the following:

$$Z(\underline{q}), Z^*(\underline{q}^*) > 0, \quad Z_q(\underline{q}), Z^*_{q^*}(\underline{q}^*) > 0, \quad Z_q(\bar{q}), Z^*_{q^*}(\bar{q}^*) < 0. \qquad \text{(ii)}$$

The first inequality ensures that a quality level exists where the value of the product to consumers exceeds the cost of providing the product. The second inequality ensures that, at some quality levels, the marginal value of additional quality exceeds the marginal cost of providing that quality. The third inequality ensures that the opposite situation prevails at some higher quality levels.

In an earlier stage, both firms have decided to enter the market based on their expectation of nonnegative profits in the subsequent equilibrium. Given these entry decisions, our analysis examines a multistage game where firms determine the quality of their product prior to setting its price. We allow policymakers to impose trade policies at one of two possible stages: (1) before the quality-setting stage, or (2) after this stage but before the price-setting stage. Both firms use Cournot conjectures [i.e., zero conjectural variations] in the quality-setting and price-setting stages.

In examining subgame-perfect Nash equilibria, we use backward induction and initially consider the price-setting stage. Each firm's profits are denoted as follows [given that $X(X^*) = 2x(2((1/2)-x))$]:[6]

$$\pi = 2(p-c(q)+s)x - f(q) \qquad (1)$$

$$\pi^* = 2(p^*-c^*(q^*)-v)[(1/2)-x] - f(q^*), \qquad (1^*)$$

where $s \in [\underline{s},\bar{s}]$($v \in [\underline{v},\bar{v}]$) is the level of the domestic production subsidy(import tariff). Using equation (1) to replace x [assuming that $0 < x < 1/2$], the following first-order conditions are obtained with respect to price:

$$\pi_p = 2[x - ((p-c(q)+s)/2t)] = 0 \qquad (2)$$

$$\pi^*_{p^*} = 2[((1/2)-x) - ((p^*-c^*(q^*)-v)/2t)] = 0 \qquad (2^*)$$

or,

$$p - c(q) + s = 2tx \qquad (2')$$

$$p^* - c^*(q^*) - v = 2t((1/2)-x). \qquad (2^{*\prime})$$

Equations (2') and (2*') will prove useful to our analysis.

We only consider those cases where each firm has a positive market share in equilibrium. Letting x^N refer to the equilibrium value of x, we thus assume that $0 < x^N < 1/2$.[7] A unique Nash equilibrium in prices exists

[6] Without losing generality, we normalize the marginal density function, $f(w) = k$, so that $k = 1$.

[7] This assumption excludes the possibility of a prohibitive import tariff or domestic tax. Removing this assumption complicates the exposition while only minor modifications occur in our qualitative results. It also implies that a firm may have acted nonoptimally by deciding to enter the market. In this model, the price and quality choices of a given firm are significantly different in the absence of entry than if a rival firm enters and serves a minute [or zero] share of the market.

based on the solutions to (2) and (2*).[8] If we solve these equations simultaneously, the following equilibrium prices are derived:

$$p^N(q,q^*,s,v) = (1/3)\{[h(q)+2(c(q)-s)] - [h(q^*)-(c^*(q^*)+v)]\} + t/2 \quad (3)$$

$$p^{*N}(q,q^*,s,v) = (1/3)\{[h(q^*)+2(c^*(q^*)+v)] - [h(q)-(c(q)-s)]\} + t/2. \quad (3^*)$$

By substituting these prices into equation (1), x^N is also obtained:

$$x^N(q,q^*,s,v) = (1/6t)\{[h(q)-(c(q)-s)] - [h(q^*)-(c^*(q^*)+v)]\} + 1/4$$

or,

$$x^N(q,q^*,s,v) = (1/6t)[Z(q) - Z^*(q^*) + (s+v)] + 1/4. \quad (4)$$

Given that equations (3) and (3*) depend on q and q*, a firm can manipulate equilibrium prices through its quality choice:

$$dp^N/dq = [h_Q(q)+2c_q(q)]/3, \qquad dp^{*N}/dq = -[h_Q(q)-c_q(q)]/3 \quad (5)$$

$$dp^{*N}/dq^* = [h_Q(q^*)+2c^*_{q^*}(q^*)]/3, \qquad dp^N/dq^* = -[h_Q(q^*)-c^*_{q^*}(q^*)]/3 \quad (6)$$

It can be easily shown that a given firm's profits rise when its rival increases price.[9] Hence, quality is considered to possess positive(zero, negative) "<u>strategic value</u>" if increased quality input causes a rival's

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[8] It can be shown that each firm's profit function is continuous and concave with respect to its own price. Reaction functions are thus continuous, and also linear with a positive slope. Since the reaction functions are continuous, an equilibrium exists. Given that they are linear, they satisfy a single-crossing condition. Hence, the equilibrium is unique.

The equilibrium is also stable. By differentiating (2) and (2*), we obtain $\pi_{pp} = \pi^*_{p^*p^*} = -2/t < 0$ and $\pi_{pp^*} = \pi^*_{p^*p} = 1/t > 0$. Stability is established by observing that $B = \pi_{pp}\pi^*_{p^*p^*} - \pi_{pp^*}\pi^*_{p^*p}$ [$= 3/t^2$] > 0.

[9] After substituting for x from (1), we obtain $\pi_{p^*} = (1/t)[p-c(q)+s]$ and $\pi^*_p = (1/t)[p^*-c^*(q^*)-v]$. Each of these expressions is positive, since a profit-maximizing domestic(foreign) firm sets $p(p^*) > c(q)-s(c^*(q^*)+v)$ [see (2') and (2*')].

price to rise(remain unchanged, fall). Referring to equations (5) and (6), we now assess the "strategic value" of quality:

<u>Lemma 1.</u> There exists $q' \in (\underline{q}, \bar{q})$ $(q^{*\prime} \in (\underline{q}^*, \bar{q}^*))$ that satisfies $Z_q (Z^*_{q^*}) = 0$. For the domestic(foreign) firm, increased quality input has negative[zero, positive] strategic value if $q(q^*) <[=,>]\ q'(q^{*\prime})$.

Proof: Consider the domestic firm. Given that Z_{qq} is defined, Z_q is continuous. By condition (ii), $Z_q(\underline{q}) > 0$ and $Z_q(\bar{q}) < 0$. Continuity thus implies that $Z_q(q) = 0$ for some $q \in (\underline{q}, \bar{q})$. Hence, q' exists.

From equation (5), we obtain $dp^{*N}/dq = -Z_q/3 \lesseqgtr 0$ if $Z_q \gtreqless 0$ [where $Z_q(q) = h_Q(q) - c_q(q)$]. Since $Z_q(q') = 0$ and $Z_{qq} < 0$, it follows that $Z_q \gtreqless 0$ if $q \lesseqgtr q'$. Hence, $dp^{*N}/dq \lesseqgtr 0$ if $q \lesseqgtr q'$. The results in the lemma follow based on the definition of strategic value. Analagous reasoning applies to the foreign firm. QED

We can differentiate equation (4) with respect to a change in quality, which leads to the following:

<u>Lemma 2.</u> For the domestic firm, $dx^N/dq = Z_q/6t \gtreqless 0$ if $q \lesseqgtr q'$. For the foreign firm, $dx^N/dq^* = -Z^*_{q^*}/6t \lesseqgtr 0$ if $q^* \lesseqgtr q^{*\prime}$. Holding rival quality constant, x^N reaches a maximum(minimum) at $q'(q^{*\prime})$.

Proof: The results for dx^N/dq and dx^N/dq^* follow directly from differentiation, given that $Z_q(Z^*_{q^*}) \gtreqless 0$ if $q(q^*) \lesseqgtr q'(q^{*\prime})$. Since dx^N/dq is defined everywhere, $x^N(q, q^*, s, v)$ is a continuous function. Based on the above behavior of dx^N/dq, the mean-value theorem establishes that $x^N(q', q^*, s, v) > x^N(q, q^*, s, v)$ for $q \neq q'$. Similar reasoning shows that $x^N(q, q^{*\prime}, s, v) > x^N(q, q^*, s, v)$ for $q^* \neq q^{*\prime}$. QED

From Lemma 2, it is apparent that domestic(foreign) output reaches a minimum at $\underline{q}(\underline{q}^*)$ or $\bar{q}(\bar{q}^*)$. We use this result to form the following definition, which aids our subsequent analysis:

Definition. A given firm has minimal market presence if its quality lies at either extreme. If this condition does not hold, then that firm has significant market presence.

We now analyze each firm's optimal quality choice, assuming that the government has previously committed to a given subsidy or tariff [or to free trade]. This assumption is modified later. As described above, a firm's quality choice affects prices and outputs in the subsequent Nash equilibrium. Substituting these prices and outputs [from equations (3)-(4)] into each firm's profit function, and differentiating, we obtain:[10]

$$\pi_q = 4x^N(Z_q/3) - f_q \tag{7}$$

$$\pi\star_{q\star} = 4((1/2)-x^N)(Z\star_{q\star}/3) - f\star_{q\star}. \tag{7*}$$

Using Lemma 2 and our prior assumptions, we can assert that π_{qq} and $\pi\star_{q\star q\star}$ exist. Hence, π_q and $\pi\star_{q\star}$ are continuous functions.

In order to focus on internal equilibria, we assume that $\pi_q(\underline{q},q\star',s,v) > 0$ and $\pi\star_{q\star}(q',\underline{q}\star,s,v) > 0$.[11] These conditions necessarily hold if $f_q(q)(f\star_{q\star}(q\star))\Rightarrow 0$ as $q\Rightarrow\underline{q}(q\star\Rightarrow\underline{q}\star)$, a requirement that is always met in the absence of set-up costs.

We express the Nash equilibrium in qualities as $(q^N(s,v),q\star^N(s,v))$,

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[10] The following shortcut is helpful. In equilibrium, the domestic (foreign) price must satisfy $p-c(q)+s(p\star-c\star(q\star)-v) = 2tx^N(2t((1/2)-x^N))$ [see equations (2') and (2*')]. Substituting these results into (1) and (1*), it follows that $\pi = 4t(x^N)^2 - f(q)$ and $\pi\star = 4t[(1/2)-x^N]^2 - f\star(q\star)$. Equations (7) and (7*) can be obtained by differentiating these equations, using Lemma 2.

[11] Refer to equations (7) and (7*). Since $x^N((1/2)-x^N)$ reaches a minimum when $q\star(q) = q\star'(q')$, these conditions ensure that $\pi_q(\underline{q},q\star,s,v) > 0$ $(\pi\star_{q\star}(q,\underline{q}\star,s,v) > 0)$ for all $q\star(q)$.

and respectively denote the domestic and foreign reaction functions as $q^r(q*,s,v)$ and $q*^r(q,s,v)$. Based on equations (7) and (7*), we obtain the following:

Lemma 3. Let $f_q, f*_{q*} = 0$. Profit-maximizing behavior requires that $q^r(q*,s,v)\{q*^r(q,s,v)\} = q'(q*')$ for all $q*(q)$. A unique Nash equilibrium occurs at $(q^N(s,v), q*^N(s,v)) = (q', q*')$, where quality has zero strategic value.

Proof: Let $f_q = 0$. Equation (7) shows that $\pi_q \gtreqless 0$ if $Z_q \gtreqless 0$, and we have previously shown that $Z_q \gtreqless 0$ if $q \lesseqgtr q'$. Since $\pi_q \gtreqless 0$ if $q \lesseqgtr q'$, the mean-value theorem establishes that $\pi(q',q*,s,v) > \pi(q,q*,s,v)$ for all $q \neq q'$. Hence, profit-maximizing behavior requires that $q^r(q*,s,v) = q'$ for all $q*$. By similar reasoning, $q*^r(q,s,v) = q*'$ for all q. Thus, $(q',q*')$ is the unique Nash equilibrium; and, quality has zero strategic value in equilibrium [Lemma 1]. QED

Lemma 4. Let $f_q, f*_{q*} > 0$. Profit-maximizing behavior requires that $q^r(q*,s,v)\{q*^r(q,s,v)\} < q'(q*')$ for all $q*(q)$. Any Nash equilibrium requires that $(q^N(s,v), q*^N(s,v)) < (q', q*')$, implying that quality has negative strategic value.

Proof: Let $f_q, f*_{q*} > 0$. Equation (7) shows that $\pi_q < 0$ if $Z_q \leq 0$, and we have previously shown that $Z_q \leq 0$ if $q \geq q'$. Since $\pi_q < 0$ for $q \geq q'$, and since π_{qq} is defined, continuity implies that there exists $\delta(\epsilon) > 0$ such that $\pi_q < 0$ for $q > q'-\delta(\epsilon)$. It follows from the mean-value theorem that $\pi(q'-\delta(\epsilon),q*,s,v) > \pi(q,q*,s,v)$ for all $q > q'-\delta(\epsilon)$. Hence, profit-maximizing behavior requires that $q^r(q*,s,v) \leq q'-\delta(\epsilon) < q'$. Similarly, $q*^r(q,s,v) < q*'$. Hence, any Nash equilibrium requires that $(q^N(s,v), q*^N(s,v)) < (q',q*')$, implying that quality has negative strategic value in equilibrium [Lemma 1].

Lemmas 3 and 4 provide interesting insights. When set-up costs are absent [i.e., $f_q, f^*_{q^*} = 0$], the equilibrium in qualities implies that $Z_q(q^N(s,v)), Z^*_{q^*}(q^{*N}(s,v)) = 0$. Each firm sets quality at a level where the marginal value of quality to each consumer equals the associated increase in marginal production cost. When set-up costs are present [i.e., $f_q, f^*_{q^*} > 0$], the equilibrium in qualities implies that $Z_q(q^N(s,v))$, $Z^*_{q^*}(q^{*N}(s,v)) > 0$. Hence, each firm sets quality at a level where the marginal value of quality to each consumer exceeds the associated increase in marginal production cost.

Since the quality behavior of each firm depends on the existence of set-up costs, the ability of policymakers to manipulate quality may also depend on these costs. When set-up costs are absent, each firm's quality choice is independent of its expected output level [as proxied by x^N]. Policymakers cannot alter quality choices by using instruments that merely change each firm's expectation of x^N. When set-up costs are present, quality choices do depend on x^N [since, from (7) and (7*), the optimal choices satisfy $4x^N(Z_q/3) = f_q > 0$ and $4((1/2)-x^N)(Z^*_{q^*}/3) = f^*_{q^*} > 0$].[12] Given that the expected level of x^N can be altered by changing a subsidy [or tariff] or a rival's quality choice, a policymaker can manipulate quality through a variety of instruments.

<u>Lemma 5.</u> Consider a marginal increase from equilibrium in the quality of the low-quality firm. If $f_q, f^*_{q^*} =(>) 0$ (and if $\pi_{qq}, \pi^*_{q^*q^*} < 0$ globally when $f_q, f^*_{q^*} > 0$), then: (i) the high-quality firm does not change(lowers)

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[12] Consider the domestic firm. From Lemma 4, $q^r(q^*,s,v)$ must satisfy $\underline{q} < q$ [$< q'$] $< \bar{q}$ [since, by our prior assumption, $\pi_q(\underline{q},q^*,s,v) > 0$ for any q^*]. Given that $q^r(q^*,s,v) \in (\underline{q},\bar{q})$, profit maximization requires that $\pi_q(q^r(q^*,s,v),q^*,s,v) = 0$ and $\pi_{qq} < 0$. A similar result applies for the foreign firm.

its quality, (ii) profits remain unchanged(rise) for the low-quality firm, and (iii) profits remain unchanged(fall) for the high-quality firm.

Corollary. Let $f_q, f^*_{q^*} = 0$. Any significant [i.e., nonmarginal] quality standard that is only binding for the low-quality firm will lower the profits of the low-quality firm and raise the profits of the high-quality firm. Let $f_q, f^*_{q^*} > 0$. A significant standard can be imposed that raises the profits of the low-quality firm and lowers the profits of the high-quality firm.

Proof: See Appendix.

In Das and Donnenfeld (1989) [i.e., D&D], where consumers display heterogeneous preferences for quality and set-up costs equal zero, the imposition of a quality standard causes profits to rise for the low-quality firm and fall for the high-quality firm. In our model, when set-up costs equal zero, an imposed standard produces the opposite effect on profits. When set-up costs are positive, the standard's impact on profits is qualitatively similar to that found in D&D [although the standard causes the high-quality firm to lower its quality in our model and raise its quality in the D&D model].

3. Welfare and Quality

In this section and the next section, we consider welfare-maximizing quality choices when the policymaker sets the subsidy [or tariff] level prior to the quality decision. Unless otherwise noted, all proofs are contained in the Appendix.

Social welfare consists of a positively weighted average of producer surplus, consumer surplus, and any government revenues [or costs] that flow from an imposed trade policy. The following expression describes social welfare [W^S], where the respective weights for producer surplus, consumer surplus, and government revenue equal b_1, b_2, and 1.[13]

$$W^S(b_1,b_2) = b_1\pi + 2b_2\left(\int_0^x [h(q)-p-tz]dz + \int_x^{1/2} [h(q^*)-p^*-t((1/2)-z)]dz \right)$$

$$+ 2[v((1/2)-x) - sx],$$

or, using the definition of x,

$$W^S(b_1,b_2) = b_1\pi + b_2[2tx^2 + (h(q^*)-p^*) - (t/4)] + v - 2(s+v)x. \qquad (8)$$

Since the quality decisions determine the outcome of the Nash price subgame, we can substitute equations (3)-(4) into equation (8). Partial differentiation with respect to domestic quality yields the following:

$$W_q^S = [b_1(4x^N) + b_2(2x^N+1) - ((s+v)/t)](Z_q/3) - b_1f_q. \qquad (9)$$

Further, we obtain the following by subtracting $b_1\pi_q$:[14]

$$W_q^S - b_1\pi_q = [b_2(2x^N+1) - ((s+v)/t)](Z_q/3) \qquad (10)$$

Consider the term, $b_2(2x^N+1)(Z_q/3)$. This term indicates that a marginal increase in domestic quality benefits(harms) consumers if

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[13] Let B_1, B_2, and B_3 represent the original weights attached to producer surplus, consumer surplus, and government revenue, respectively. Without affecting the maximization of the welfare function, we can normalize the original specification by dividing by B_3. This yields the specification in (8) [where $b_1 = B_1/B_3$ and $b_2 = B_2/B_3$].

[14] When it maximizes π, the domestic firm also maximizes $b_1\pi$.

$q <(>) q'$. When $q <(>) q'$, an increase in domestic quality results in lower(higher) prices to the $1-2x^N$ consumers of the foreign good [because $dp*^N/dq = -(Z_q/3) <(>) 0$] and higher(lower) surplus to the $2x^N$ consumers of the domestic good [because $d[h(q)-p^N]/dq = (2Z_q/3) >(<) 0$]. Consumer surplus thus reaches a maximum at q'. An increase in quality also affects tariff revenue and subsidy expenditures, as captured by the term, $-((s+v)/t)(Z_q/3)$. Using (9) and (10), we can compare the private domestic quality choice with the welfare-maximizing quality choice:

Proposition 1. Whenever $s+v \le(>) tb_2$, a welfare maximum does(may not) require a significant market presence by the domestic firm. Assuming that a significant presence is necessary to maximize welfare, the following results can be obtained: (i) if $f_q = 0$, then the domestic firm sets quality at the socially optimal level; (ii) if $f_q > 0$ and if $s+v \le tb_2$, then the domestic firm sets quality below the socially optimal level; and, (iii) if $f_q > 0$ and if $tb_2 < s+v < tb_2(2x^{N''}+1)$ $(s+v > tb_2(2x^{N''}+1))$, where $x^{N''} = x^N(q^N(\cdot),q*^N(\cdot),s,v)$, then welfare can be raised by increasing (decreasing) domestic quality from its privately chosen level [holding foreign quality constant].

Corollary. Assume that free trade exists [i.e., $s,v = 0$]. A welfare maximum requires a significant market presence, and if $f_q =(>) 0$, the domestic firm sets quality at(below) the socially optimal level.

Next, we turn to the welfare analysis of the foreign quality choice. By partially differentiating the welfare function, we obtain:

$$W^S_{q*} = [-b_1(4x^N) + b_2(2-2x^N) + ((s+v)/t)](Z*_{q*}/3). \qquad (11)$$

Notice that foreign set-up costs do not influence price; hence, they do not appear in equation (11). Consider the term, $b_2(2-2x^N)(Z\star_{q\star}/3)$. This term indicates that a marginal increase in foreign quality benefits(harms) consumers if $q\star <(>) q\star'$. When $q\star <(>) q\star'$, an increase in foreign quality results in lower(higher) prices to the $2x^N$ consumers of the domestic good [because $dp^N/dq\star = -(Z\star_{q\star}/3) <(>) 0$] and higher(lower) surplus to the $1-2x^N$ consumers of the foreign good [because $d[h(q\star)-p\star^N]/dq\star = (2Z\star_{q\star}/3) >(<) 0$]. Consumer surplus thus reaches a maximum at $q\star'$.

When $q\star < q\star'$, an increase in foreign quality causes some consumers to divert their purchases to the foreign firm [since $dx^N/dq\star = -Z\star_{q\star}/6t < 0$]. Given that the domestic price-cost differential is positive, this shift in demand creates an efficiency loss. This price-cost differential becomes larger as the domestic market share grows in equilibrium [since, from (2'), $p^N-c(q)+s = 2tx^N$]. If the domestic market share is sufficiently large, then an increase in foreign quality may create losses for domestic producers that overwhelm the gains to domestic consumers. Due to this possibility, it is not always welfare-maximizing for the foreign firm to increase quality above its minimum level.

Proposition 2. If $f\star_{q\star} =(>) 0$, and if a welfare maximum requires a significant market presence, then the foreign firm sets quality at(below) the socially optimal level.[15]

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[15] With a positive ad-valorem tariff $[v^{ad}]$, the foreign firm sets its quality below the socially optimal level when $f\star_{q\star} = 0$. The foreign firm chooses $q\star''$, which satisfies $h\star_Q(q\star) - (1+v^{ad})c\star_{q\star}(q\star) = 0$. [Hence, a tariff increase leads to quality downgrading.] Although this quality choice maximizes consumer surplus, a marginal increase in quality would improve social welfare by raising price and boosting tariff revenue while leaving consumer surplus unaffected. Under an ad-valorem tariff, the

Remark. Assume that free trade exists [i.e., s,v = 0], and that producer and consumer surplus are equally weighted in the social welfare function. If the foreign market share is less than 1/3 in equilibrium, then welfare can be increased by constraining the foreign firm to a minimal market presence.

Other models have noted that welfare may be improved by eliminating a firm from the market, or reducing its importance.[16] In general, output expansion by a less-efficient producer may reduce welfare by causing a contraction in the output of a more-efficient producer. The associated efficiency loss may overwhelm the consumer gain. When output is shifted from domestic to foreign firms, an efficiency loss necessarily occurs if price exceeds domestic marginal cost.

4. First-Best Policy and Other Alternatives

Under first-best policy, a benevolent policymaker maximizes social welfare by setting optimal levels for the domestic production subsidy, the import tariff, and for domestic and foreign quality. The quality of each firm can be adjusted either upward or downward from its privately chosen level.

To determine the optimal subsidy(tariff) under first-best policy, we partially differentiate W^S with respect to s(v):

$$W_s^S = [(4b_1 + 2b_2 - 6)x^N + b_2 - (s+v)/t](1/3) \qquad (12)$$

domestic firm does set a socially optimal quality level when $f_q = 0$.

[16] See Dixit (1986), Schwartz (1988), and Farrell and Shapiro (1990).

$$W^S_v = [(4b_1 + 2b_2 - 6)x^N + (3 - 2b_2) - (s+v)/t](1/3). \qquad (13)$$

Let $B = 4b_1 + 2b_2 - 6$. We assume that $W^S_{ss} = W^S_{vv} = (-1/18t)(6-B) < 0$; hence, $B < 6$.

From (12) and (13), it follows that $W^S_s \lesseqgtr W^S_v$ if $b_2 \lesseqgtr 1$. Only one of the first-order conditions will hold from these equations [except when $b_2 = 1$]. We now describe the optimal subsidy-tariff combination, referred to as (s',v'):

Lemma 6. Let $W^S_s(q,q^*,\underline{s},\underline{v}), W^S_v(q,q^*,\underline{s},\underline{v}) > 0$ and $W^S_s(q,q^*,\bar{s},\underline{v}), W^S_v(q,q^*,\underline{s},\bar{v}) < 0$. For any given quality pair, the welfare-maximizing subsidy-tariff combination satisfies the following:

(a) $s' + v' = t[Bx^N(q,q^*,s',v') + (3-2b_2)]$, $s' = \underline{s}$; if $b_2 < 1$,

(b) $s' + v' = t[Bx^N(q,q^*,s',v') + 1]$ if $b_2 = 1$,

(c) $s' + v' = t[Bx^N(q,q^*,s',v') + b_2]$, $v' = \underline{v}$; if $b_2 > 1$. (14)

If b_2 <(=,>) 1, the welfare effect from a given subsidy increase is inferior(equal,superior) to that from an equal tariff increase.

From the above results, it is apparent that s'+v' depends on the chosen values of q and q*. This functional relationship is crucial to the analysis in the next section, where firms recognize that their quality choices will influence the subsequently imposed level of protection. In this section, the policymaker imposes her policies before quality is chosen.

Based on our prior results, we now derive the first-best policy combination:

Lemma 7. Let the maximization of social welfare require that each firm establish a significant market presence. If the conditions hold from

Lemma 6, then first-best policy requires that: (i) $q^* = q^{*\prime}$, (ii) q satisfy the first-order condition from (9), and (iii) s and v satisfy (14).

Proposition 3. Let $f_q, f^*_{q^*} = 0$. Private quality choices maximize social welfare under a first-best outcome; hence, no quality standards are needed.

Let $f_q, f^*_{q^*} > 0$ [and $\pi_{qq} < 0$ globally]. In order to attain a first-best outcome, the policymaker imposes a standard on foreign quality. Given that all other policy instruments are at their optimal levels, the policymaker adjusts domestic quality as follows: (i) if $b_2 \geq 1$, and if $b_1 <(=,>) 3/2$, then she must raise(not change,lower) domestic quality; and, (ii) if $b_2 < 1$ and if $b_1 <(\geq) 3/2$, then she may either raise, lower, or leave unchanged (must lower) domestic quality.

Corollary. When all components of social welfare are equally weighted [i.e., $b_1 = b_2 = 1$], if $f_q, f^*_{q^*} =(>) 0$, then the policymaker does not change(raises) the quality of each firm to attain a first-best outcome.

The above result admits the possibility that welfare may be enhanced by using a standard to raise the quality of the low-quality firm. Nonetheless, we have only examined first-best policy where domestic and foreign quality levels can be adjusted individually. In most cases, a uniform standard must be applied to all firms regardless of their nationality. In the Appendix [included in the proof of Proposition 3], we show that if set-up costs are positive, then imposing a uniform quality standard [in combination with an optimal subsidy and tariff] still raises welfare whenever the foreign firm is the low-quality firm. Moreover, if the domestic firm is the low-quality firm, a uniform standard will raise welfare whenever $b_2 \geq 1$ and $b_1 < 3/2$. This conclusion contrasts with many results obtained in prior models [e.g., Das and Donnenfeld (1989), where a uniform standard lowers welfare].

When the policymaker can only impose a uniform quality standard, or is constrained from imposing any quality standard, she still possesses policy tools that can alter the quality choices of an unconstrained firm. For example, without any quality constraints, an increase in the subsidy or tariff raises domestic quality and lowers foreign quality when set-up costs are positive.[17]

The trade tax recommendations of previous price-setting models that ignore quality [e.g., Eaton and Grossman (1986)] may be reversed when quality effects are considered. Prior models have often recommended imposing an import tariff for domestic markets, and a domestic production tax [i.e., export tax] for pure export markets. In addition to improving the terms of trade, an import tariff leads to gains in domestic efficiency when price exceeds marginal cost. A domestic production tax causes domestic firms to raise their prices which, in turn, causes foreign rivals to raise their prices. This reaction by rivals enhances domestic profits in pure export markets.

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[17] This result presumes that the quality equilibrium is initially stable, which requires that $Y = \pi_{qq}\pi^*_{q^*q^*} - \pi_{qq^*}\pi^*_{q^*q} > 0$. By totally differentiating π_q and $\pi^*_{q^*}$, we obtain $dq/ds = (-\pi_{qs}\pi^*_{q^*q^*} + \pi^*_{q^*s}\pi_{qq^*})/Y$ and $dq^*/ds = (-\pi^*_{q^*s}\pi_{qq} + \pi_{qs}\pi^*_{q^*q})/Y$. Further, $\pi_{qs} = (2/9t)Z_q$, $\pi^*_{q^*s} = -(2/9t)Z^*_{q^*}$, and $\pi_{qq^*} = \pi^*_{q^*q} = -(2/9t)Z_q Z^*_{q^*}$. Using Lemma 4, it follows that $Z_q(q^N(s,v)), Z^*_{q^*}(q^{*N}(s,v)) > 0$ if $f_q, f^*_{q^*} > 0$. Hence, under optimal behavior, $\pi_{qs} > 0$, $\pi^*_{q^*s} < 0$, $\pi_{qq^*} = \pi^*_{q^*q} < 0$, and as required by second-order conditions, $\pi_{qq}, \pi^*_{q^*q^*} < 0$. It follows that $dq/ds > 0$ and $dq^*/ds < 0$. Since $\pi_{qs} = \pi_{qv}$ and $\pi^*_{q^*s} = \pi^*_{q^*v}$ [because $dx^N/ds = dx^N/dv = 1/6t$], we can also assert that $dq/dv = dq/ds$ and $dq^*/dv = dq^*/ds$.

When set-up costs are positive in our model, the imposition of an import tariff lowers foreign quality which creates losses for domestic consumers. The imposition of a domestic production tax raises foreign quality which creates losses for domestic producers in a pure export market. When these impacts are sufficiently large, we conclude as follows:[18]

Remark. Assume that foreign and domestic quality levels cannot be controlled individually, and both firms sell solely to the domestic market. The welfare-maximizing policy may require an import subsidy [or domestic production tax].

For a pure-export market [where the foreign quality level cannot be directly controlled], the welfare-maximizing policy may require a domestic production subsidy.

The above results still apply when all components of social welfare are equally weighted.

5. Anticipated Ex-Post Trade Taxes or Subsidies

Let the policymaker impose tariffs or subsidies after quality is chosen, but before the price-setting stage. This characterization of behavior may be particularly applicable when set-up and development costs are incurred in raising quality. If set-up costs increase significantly as the length of the set-up period collapses, then a substantial interval may arise between the quality-setting and price-setting stages. Firms are assumed to make their quality choices in anticipation of the subsequent

[18] Formal proof available from author.

imposition of a subsidy and tariff. We also assume that both firms possess complete information concerning the policymaker's objective function.

By assumption, the policymaker's objective function [W^P] also consists of a positively weighted average of producer surplus, consumer surplus, and government revenue. This function is analagous to that used in equation (8), except that $a_1(a_2)$ replaces $b_1(b_2)$ as the weight for producer(consumer) surplus. We thus permit the policymaker's objectives to differ from "true" social objectives.

Solving by backward induction, we first derive the policymaker's optimal subsidy-tariff combination [(s",v")]. The policymaker maximizes her objective function after quality is chosen. The first-order conditions are thus identical to (12) and (13), except that $a_1(a_2)$ replaces $b_1(b_2)$. Thus, the policymaker's optimal subsidy and tariff choices parallel those described in (14),

$$s'' + v'' = t[Ax^N(q,q^*,s'',v'') + k''], \qquad (15)$$

where $A = 4a_1 + 2a_2 - 6$, and $k'' = a_2(3-2a_2)$ if $a_2 \geq (<) 1$. We assume that $A < 6$ [i.e., $6-A > 0$] in order to satisfy second-order conditions.

By substituting (4) into (15), and then totally differentiating, we assess the impact of a quality change on the policymaker's choices for a subsidy and tariff:

$$d(s''+v'')/dq = [A/(6-A)]Z_q \qquad (16)$$

$$d(s''+v'')/dq^* = [-A/(6-A)]Z^*_{q^*}. \qquad (16^*)$$

A quality change by either firm can alter the policymaker's assessment of the domestic market share, which is proxied by $x^N(q,q^*,s'',v'')$. In response, the policymaker may adjust the total subsidy-tariff level [i.e., the level of protection]. Since they possess complete knowledge of the policymaker's reaction function, both firms know that their quality choice will influence the subsidy-tariff level in a manner consistent with equations (16) and (16*).

In assessing the marginal value of its quality, the domestic firm now adds the term, $\pi_{s+v}(d(s''+v'')/dq)$, to equation (7).[19] This term captures the change in domestic profits arising from the quality-induced change in the level of protection. Noting that $\pi_{s+v}[d(s''+v'')/dq] = [A/(6-A)]4x^N(Z_q/3)$, the private marginal value of quality equals:

$$\pi_q = [6/(6-A)]4x^N(Z_q/3) - f_q. \tag{17}$$

Further, the marginal social value of domestic quality includes the welfare effect arising from the quality-induced change in the level of protection. We thus add the term, $W^S_s(ds''/dq) + W^S_v(dv''/dq)$, to equation (9). Using (15), we derive:

$$W^S_q = [b_1(4x^N) + b_2(2x^N+1) - k'' - Ax^N](Z_q/3) - b_1f_q + W^S_s(ds''/dq) + W^S_v(dv''/dq) \tag{18}$$

In evaluating the above expression, we use the following definition:

Definition. If the policymaker's objectives are socially consistent, then $W^P = W^S$. Hence, $a_1 = b_1$ and $a_2 = b_2$.

When policy is socially consistent, the following results hold:

(i) $W^S_s(ds''/dq) + W^S_v(dv''/dq) = 0$,[20] (ii) $A = B$, and (iii) $k'' = b_2(3-2b_2)$ if

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[19] Since $\pi = 4t(x^N)^2 - f(q)$ in equilibrium [see footnote 10], and given that $dx^N/dv = dx^N/ds = 1/6t$, we obtain $\pi_s = \pi_v = (4/3)x^N$. Hence, we can refer to π_{s+v}. A similar result holds for the foreign firm.

[20] If $W^P = W^S$, then $(s'',v'') = (s',v')$. Hence, $W^S{}_s(ds''/dq) + W^S_v(dv''/dq) = W^S_s(ds'/dq) + W^S_v(dv'/dq)$. Let $b_2 < 1$. From (13) and (14), (s',v') solves $W^S_v(s',v',q,q^*) = 0$, where $s' = \underline{s}$. Since $W^S_v(s',v',q,q^*) = 0$

$b_2 \geq(<) 1$. Incorporating these results in (17) and (18), we obtain:

Proposition 4. Assume that the policymaker's objectives are socially consistent, and that the domestic firm possesses complete information concerning these objectives. Let $f_q = 0$. If a welfare maximum requires a significant market presence, then the domestic firm sets quality at the socially optimal level. [When $b_2 \geq(<) 1$, a welfare maximum does(may not) require a significant market presence.]

Let $f_q > 0$. If $b_2 \geq 1$ and $b_1 <(=,>) (3/2) - (b_2/4)$, then the domestic firm sets quality below(at,above) the socially optimal level. If $b_2 < 1$ and $b_1 <(\geq) (3/2) - (b_2/4)$, then the domestic firm sets quality (above) either below, at, or above the socially optimal level.

Corollary. When the policymaker's objectives are socially consistent and all components of social welfare are equally weighted, if $f_q =(>) 0$, then the domestic firm sets quality at(below) the socially optimal level.

When set-up costs are absent, the domestic firm continues to choose quality optimally under socially consistent policy. The domestic firm can only influence the chosen subsidy-tariff level by changing the policymaker's assessment of x^N. Given that $dx^N/dq = Z_q/6t$, any quality-induced changes in the level of protection depend directly on Z_q. Thus, the private marginal value of domestic quality still bears the same sign as Z_q [from (17), since $f_q = 0$ and $6\text{-}A > 0$]. Domestic profits must reach a maximum at q', even though the total level of protection may reach a

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and $ds'/dq = 0$, it follows that $W^S_s(ds'/dq) + W^S_v(dv'/dq) = 0$. By analagous reasoning, this result also pertains when $b_2 \geq 1$.

minimum at this quality level. This domestic quality choice maximizes both consumer and producer surplus, which implies that it is socially optimal.

When set-up costs are present, it is unlikely that the domestic firm chooses a socially optimal quality level under consistent policy. The domestic firm may even overinvest in quality, when producer surplus [and to a lesser extent, consumer surplus] carries a sufficiently large weight within the social welfare function. In this situation, the domestic firm has incentive to invest in quality for the purpose of raising the policymaker's assessment of its market share, which then induces the policymaker to raise the total level of protection. If producer surplus carries a relatively small weight, the domestic firm will underinvest in quality.

Of course, with fully anticipated policy, the foreign firm can also use its quality choice to influence the applied level of protection. As the weighting of consumer and producer surplus increases in magnitude [i.e., as A increases in value], the foreign firm derives increased benefit from appearing able to capture a large share of the market. If $A > 0$, and if set-up costs are positive, the policymaker's anticipated behavior provides the foreign firm with an enhanced incentive to invest in quality. This inducement remains insufficient, nonetheless, to push the foreign quality choice to its welfare-maximizing level.

<u>Proposition 5.</u> When the policymaker's objectives are socially consistent and the foreign firm possesses complete information concerning these objectives, if $f^*_{q*} =(>) 0$, then the foreign firm sets quality at(below) the socially optimal level.

Remark. When $f^*_{q^*} = 0$, the foreign firm can still set quality at the socially optimal level even if policy is socially inconsistent. This result necessarily occurs whenever $2b_2 + [(Ak'-6k")/(A-6)] > 0$ [where $(k',k") = (b_2,a_2)((3-2b_2,3-2a_2))$ if $a_2 \geq (<) 1$].

In this section, we see that firms continue to choose socially optimal quality levels in the absence of set-up costs. Moreover, they may still act optimally when the policymaker's objectives are socially inconsistent. In the next section, we see that the signalling incentives arising from private information alter these conclusions.

6. Rent Seeking, Signalling, and Quality Choice

Players in the market do not always possess complete information concerning conditions affecting the behavior of other players. In certain cases, a given firm can use its quality decision to convey private information concerning conditions facing that firm. We examine a firm's choice of quality when that choice signals private cost information to the policymaker prior to the imposition of protective policy. In a later example, cost information is signalled to a rival prior to its pricing decision. We determine whether the incentives from signalling are welfare-enhancing or welfare-worsening. Our methodology, a variant of Mailath (1987), uses the solution concept of an incentive-compatible separating equilibrium.

We initially consider a situation where the policymaker has incomplete information concerning domestic costs. The analysis can be readily extended to a case where these informational imperfections involve the foreign firm.

Assume that the domestic firm is a newcomer while the foreign firm is an incumbent. Set-up costs equal zero for both firms, implying that $f_q, f^*_{q^*} = 0$. For the domestic(foreign) firm, direct production costs equal $cqX(c^*q^*X^*)$, where $c(c^*) \in [\underline{c},\bar{c}]([\underline{c}^*,\bar{c}^*])$. Hence, $Z(q)(Z^*(q^*))$ is replaced by $Z(q,c)(Z^*(q^*,c^*)) = h(q)-cq(h(q^*)-c^*q^*)$. By definition, we let $q'(c)(q^{*\prime}(c^*))$ satisfy $Z_q(q,c)(Z^*_{q^*}(q^*,c^*)) = 0$.

Both firms know the true values of c and c*. The policymaker possesses complete [i.e., perfect] information concerning the foreign incumbent's costs, but she possesses incomplete information concerning the domestic entrant's costs. She believes, ex-ante, that the possible values of c are distributed across the support, $[\underline{c},\bar{c}]$. We expand our analysis later so that the foreign firm possesses incomplete information concerning domestic costs.

The policymaker obtains information by observing the domestic quality choice only. The foreign quality choice conveys no information because the foreign firm chooses $q^{*\prime}(c^*)$ regardless of cost conditions facing the domestic firm [see proof of Prop. 5].

We search for a <u>consistent, incentive-compatible, separating equilibrium</u> where the strategy used by the domestic firm uniquely reveals its cost "type". Thus, we posit that the optimal domestic strategy over all cost "types" can be described by a one-to-one mapping, $g:[\underline{c},\bar{c}]\Rightarrow[\underline{q},\bar{q}]$. The mapping, $y:[\underline{q},\bar{q}]\Rightarrow[\underline{c},\bar{c}]$, represents the policymaker's assessment of c based on its observation of q. If this assessment changes, then the policymaker may change the level of protection based on an altered estimate of x^N.

Let $e = y(q)$. The policymaker's estimate of x^N, known as $x^{NE}(e,q,q^*,s,v)$, is described by equation (4) where eq replaces $c(q)[=cq]$. Substituting this result into (15), and then differentiating, we calculate the impact on the combined subsidy-tariff level that arises from a change in the policymaker's assessment of domestic costs:[21]

$$d(s''(e,\cdot)+v''(e,\cdot))/de = [-A/(6-A)]q. \quad (19)$$

Again, second-order conditions require that $6-A > 0$. Due to its impact on the subsidy-tariff level, a change in e exerts the following effect on domestic profits:

$$\pi_e = \pi_{s+v}[d(s''(e,\cdot)+v''(e,\cdot))/de] = [-A/(6-A)]4x^N(q/3) \gtreqless 0 \text{ if } A \lesseqgtr 0. \quad (20)$$

For the domestic firm, the policymaker can hold no worse assessment than $e = \underline{c}(\bar{c})$ whenever $A <(>) 0$. This belief would lead to the lowest imposed level of protection.

In a <u>consistent</u>, <u>incentive-compatible</u>, <u>separating</u> equilibrium, the domestic firm must act optimally across all cost types. We require that $g(c) = \text{argmax}_q\ \pi(y(q),c,c^*,q,q^{*\prime}(c^*))$ for all c, noting that $e = y(q)$.[22] Consistency further requires that $y(q) = g^{-1}(q)$; hence, $g^{-1}(q=g(c)) = c$.

<u>Lemma 8.</u> If the domestic firm's strategy is incentive-compatible and continuous on $I \subset (\underline{c},\bar{c})$, then $g(c)$ is differentiable and satisfies the following condition under consistency:

$$dg/dc = -\pi_e(c,c,c^*,g(c),q^{*\prime}(c^*))/\pi_q(c,c,c^*,g(c),q^{*\prime}(c^*)) \quad (21)$$

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[21] For notational convenience, we let $(e,\cdot)$ refer to (e,q,q^*). Hence, $s''+v''$ is now dependent on e as well as q, and q^*.

[22] Domestic profits $[\pi(e,c,c^*,q,q^*)]$ are now dependent on the policymaker's cost assessment [e], actual domestic costs [c], actual foreign costs [c*], domestic quality [q], and foreign quality [q*].

Proof: See Mailath (1987).

The above result implies that $d\pi/dq = \pi_q + \pi_e(dg/dc)^{-1} = 0$, where $(dg/dc|_{c,e=g^{-1}(q)})^{-1} = dg^{-1}/dq$. Hence, equation (21) represents the domestic firm's first-order condition when its strategy is continuous and the policymaker's beliefs are consistent.

If an initial-value condition can be imposed in this example, and if g(c) is a continuous strategy, then the sign of dg/dc is constant and readily determinable. The initial-value condition relates to the domestic strategy when $c = c^w$, where c^w represents the worst belief that the policymaker can hold. The initial-value condition requires that $g(c^w)$ satisfy $\pi_q(c^w,c^w,c*,q,q*'(c*)) = 0$ [i.e. $[6/(6-A)]4x^N(Z_q/3) = 0$]; thus, the domestic firm's best strategy is to choose the same quality level, $q'(c^w)$, as in the perfect-information case.

We can indeed assert that $g(c^w) = q'(c^w)$. Assume that g(c) is one-to-one, $y = g^{-1}$, and $g(c^w) \neq q'(c^w)$. If $c = c^w$, then the domestic firm would raise its profits by switching to $q'(c^w)$. First, if the policymaker still believes that domestic costs equal c^w, then domestic profits increase because $\pi_q(c^w,c^w,c*,q,q*'(c*)) \gtrless 0$ if $q \lessgtr q'(c^w)$. Hence, an application of the mean-value theorem ensures that profits are highest at $q'(c^w)$. Second, if the policymaker's beliefs change, profits are further enhanced [due to an increase in the subsidy-tariff level induced by the revised cost assessment].

Now, let $g(c) = q'(c^w)$ when $c = c^o \neq c^w$. If $c = c^w$, then the domestic firm would gain by switching its quality level to $q'(c^w)$. The policymaker would infer $y(q^w) = c^o$, which leads to a higher subsidy-tariff level than that associated with c^w. Domestic profits would thus rise.

Given that the initial-value condition holds, we can describe g(c) as follows:

Lemma 9. If g(c) is everywhere continuous, then dg/dc < 0 and $dy/dq = dg^{-1}/dq\ [= (dg/dc)^{-1}|_{c,e=g^{-1}(q)}] < 0$ in a consistent, separating equilibrium.[23]

The domestic firm sets a lower quality level as its costs increase. Conversely, the policymaker's estimate of domestic costs increases as the observed quality level declines.

We are now able to assess the effect of incentive compatibility on the domestic firm's quality choice. Since the domestic quality choice affects the policymaker's assessment of its costs, the domestic firm's first-order condition becomes as follows [see Lemma 8]:

$$d\pi/dq = \pi_q + \pi_e(dg^{-1}/dq)$$
$$= [(1/(6-A))(4/3)x^N][6Z_q - A(g^{-1}(q)-c)] + \pi_e(dg^{-1}/dq) = 0. \qquad (22)$$

The term, $[(1/(6-A))(4/3)x^N](6Z_q)$, follows directly from (17). The term, $-[(1/(6-A))(4/3)x^N]A(g^{-1}(q)-c)$, represents the effect on domestic profits that results from any inconsistency in the policymaker's estimate of domestic costs as it is applied to the subsidy-tariff level. Under consistent expectations, where $g^{-1}(q)|_{q=g(c)} = c$, this term vanishes. The term, $\pi_e(dg^{-1}/dq)$, describes the effect on profits resulting from any quality-induced change in the policymaker's estimate of domestic costs.

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[23] Mailath has shown that g(c) is continuous everywhere if the sign of π_{cq} remains constant [for all (c,c,g(c))].

Using equation (20) and Lemma 9, we obtain $\pi_e(dg^{-1}/dq) = -[(1/(6-A)) \times (4/3)x^N Aq](dg^{-1}/dq) \lesseqgtr 0$ if $A \lesseqgtr 0$. Based on this result, we draw the following conclusion:

Proposition 6. Assume that $f_q, f^*_{q^*} = 0$, $W^P = W^S$, and $g(c)$ is continuous everywhere. Consider a consistent, incentive-compatible, separating equilibrium where the policymaker is incompletely informed concerning domestic costs. Compared to the outcome under perfect information, the domestic firm sets lower(equal,higher) quality whenever $B <(=,>) 0$. If $b_2 \geq 1$ and $B <(=)(>) 0$, then welfare can(not) be raised by increasing (changing)(decreasing) domestic quality from its privately chosen level. If $b_2 < 1$ and $B =(\lessgtr) 0$, then welfare cannot(may) be raised by changing domestic quality from its privately chosen level.

When its quality choice signals cost information to the policymaker, the domestic firm does not typically choose a welfare-maximizing quality level even if set-up costs are absent. When $A = B > 0$, the domestic firm benefits from a higher level of protection if the policymaker lowers its estimate of domestic costs. This provides incentive for the domestic firm to set quality above $q'(c)$, the level chosen under perfect information. If $A = B < 0$, then the opposite situation applies.

As the policymaker's assessment of domestic costs approaches the true cost level, the imposed subsidy-tariff combination approaches the welfare-maximizing combination [assuming policy is socially consistent]. Thus, if a change in domestic quality leads to a more accurate cost assessment by the policymaker, certain welfare benefits naturally arise. These benefits, however, may be overwhelmed by the negative impact on consumer surplus resulting from the quality change. Although the policymaker estimates domestic costs correctly when $q = g(c)$, both consumer surplus and total welfare would rise if domestic quality moved closer to $q'(c)$.

For the domestic firm, any incentive to overinvest in quality may be reversed when the foreign firm is incompletely informed. Consider a situation where neither firm can observe its rival's price but quality choices are observed prior to the price-setting stage. The foreign firm possesses incomplete information concerning domestic costs, but the domestic firm possesses complete information concerning foreign costs.

An incentive-compatible equilibrium is attainable where the foreign firm sets price at the Nash equilibrium level based on its expectation of rival costs, its own costs, and the observed quality choices.[24] Thus, the foreign price conforms with equation (3*), except that the foreign firm estimates domestic costs at $e'q$ instead of cq for each unit of output. Let $p^{*NE}(e',q,q^*,s,v)$ refer to this foreign price. By replacing $c(q)$ with $e'q$ in equation (3*), and then differentiating, we obtain $dp^{*NE}/de' = q/3 > 0$. Since the foreign firm raises price when its estimate of domestic costs increases in magnitude, the domestic firm has incentive to raise the foreign firm's estimate of its costs. The domestic firm attempts to achieve this outcome by lowering its quality, since $de'/dq = dg^{-1}/dq < 0$ in a consistent, incentive-compatible equilibrium [see proof of Lemma 9]. Due to this behavior, we reach the following conclusion:

<u>Proposition 7.</u> Assume that $f_q, f^*_{q^*} = 0$, $g(c)$ is continuous everywhere, and a free-trade regime is in effect. Consider a consistent, incentive-

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[24] The domestic firm sets its price as a best response to this foreign price behavior.

compatible separating equilibrium where the foreign firm is incompletely informed concerning domestic costs, and rival prices are not immediately observable. Compared to the outcome under perfect information, the domestic firm sets lower quality. Furthermore, the domestic firm sets quality below the socially optimal level.

7. Concluding Remarks

In formulating trade policy for markets with quality aspects, the nature of diversity among consumers is crucial to any analysis. Although consumers exhibit different preferences for "brands" in our model, they exhibit uniform preferences for "quality". These assumptions yield results that differ markedly from those models where consumers exhibit diverse preferences for quality. In those models, the addition of quality is more valuable to certain types of consumers than others. This facet of consumer behavior implies that each firm can use its quality choice to gain an advantage in serving a specific part of the market. Hence, each firm attempts to set a different quality level than its rivals have chosen. This outcome holds even if all firms face the same cost function in providing a product of a given quality.

In our model, we eliminate the role of quality in determining a firm's "position" in the market, and instead let a firm's brand choice perform this function. Firms can potentially utilize a cost advantage in providing quality so that they can court those customers where they have a positional [i.e., brand] disadvantage. However, when firms face the same costs, they choose the same quality levels [unless costs are effectively changed by the prior imposition of a subsidy or tariff].

We also show that the role of set-up costs is crucial to any welfare analysis of quality choice. For instance, we find that firms usually make socially optimal quality choices in the absence of set-up costs. When these costs are present, foreign firms and, often domestic firms, underinvest in quality.

An examination of market behavior becomes even more complicated if firms choose quality in anticipation of ex-post policy changes. In this situation, a given firm's choice of quality may influence the levels of subsidies or tariffs even when all participants are completely informed. This quality choice may also serve as a signalling device when policymakers or rivals are incompletely informed. If set-up costs are absent, we find that the incentives posed by signalling create welfare losses. If set-up costs are present, the welfare impact of these incentives is more difficult to predict.

Appendix

Proof of Lemma 5 [and corollary]

Consider a marginal increase from equilibrium in the quality of the foreign firm; analagous reasoning applies to the domestic firm.

Let $f_q, f^*_{q^*} = 0$. From Lemma 3, $(q^N(s,v), q^{*N}(s,v)) = (q', q^{*\prime})$. Further, $q^r(q^*, s, v) = q'$ for all q^*; domestic quality does not change when foreign quality increases. Turning to domestic profits, $\pi = 4t(x^N)^2 - f(q)$, and $\pi_{q^*} = 8tx^N(dx^N/dq^*) = -(4/3)x^N Z^*_{q^*}$ [see footnote 10 and Lemma 2]. Since $Z^*_{q^*}(q^{*N}(\cdot)) = Z^*_{q^*}(q^{*\prime}) = 0$, we obtain $\pi_{q^*}(q^N(\cdot), q^{*N}(\cdot), s, v) = 0$. Thus, domestic profits are unchanged. Turning to foreign profits, $\pi^* = 4t[(1/2)-x^N]^2 - f^*(q^*)$, and $\pi^*_{q^*} = (4/3)(1/2-x^N)Z^*_{q^*}$ [see eq. (7*)]. Given that $Z^*_{q^*}(q^{*N}(\cdot)) = Z^*_{q^*}(q^{*\prime}) = 0$, it follows that $\pi^*_{q^*}(q^N(\cdot), q^{*N}(\cdot), s, v) = 0$. Thus, foreign profits are also unchanged.

Let $f_q, f^*_{q^*} < 0$. From Lemma 4, $(q^N(s,v), q^{*N}(s,v)) < (q', q^{*\prime})$, implying that $Z_q(q^N(\cdot)), Z^*_{q^*}(q^{*N}(\cdot)) > 0$. Domestic profit maximization requires that $\pi_q(q^r(q^*,s,v),q^*,s,v) = 0$ [see footnote 12]. By total differentiation and the implicit function theorem: $dq^r/dq^* = -\pi_{qq^*}/\pi_{qq}$. Hence, $dq^r(q^{*N}(\cdot),s,v)/dq^* < 0$ [given that $q^r(q^{*N}(s,v),s,v) = q^N(s,v)$, $\pi_{qq^*}(q^N(\cdot),q^{*N}(\cdot),s,v) = -(2/9t)Z_q(q^N(\cdot))Z^*_{q^*}(q^{*N}(\cdot)) < 0$, and $\pi_{qq} < 0$]. Domestic quality falls when foreign quality increases from equilibrium.

Turning to domestic profits, $d\pi/dq^* = \pi_{q^*} + \pi_q(dq^r/dq^*) = \pi_{q^*} = -(4/3)x^N Z^*_{q^*}$ [noting that $\pi_q = 0$]. Since $Z^*_{q^*}(q^{*N}(\cdot)) > 0$, it follows that $d\pi(q^r(q^{*N}(\cdot),\cdot),q^{*N}(\cdot),s,v)/dq^* < 0$. Domestic profits fall. Turning to foreign profits, $d\pi^*/dq^* = \pi^*_{q^*} + \pi^*_q(dq^r/dq^*) = \pi^*_q(dq^r/dq^*) = -[(4/3)((1/2)-x^N)Z_q](dq^r/dq^*)$. Since $Z_q(q^r(q^{*N}(\cdot),s,v)) = Z_q(q^N(s,v)) > 0$ and $dq^r(q^{*N}(\cdot),s,v)/dq^* < 0$, it follows that $d\pi^*(q^r(q^{*N}(\cdot),\cdot),q^{*N}(\cdot),s,v)/dq^* > 0$. Foreign profits rise.

Consider the results in the corollary. Let $f_q, f^*_{q^*} = 0$, implying that $q^N(s,v), q^{*N}(s,v) = (q', q^{*\prime})$. From Lemma 3, a standard that raises foreign quality to $q^{*\prime}+\delta^*$ does not affect the domestic quality choice, which remains at q'. Thus, we can express the standard's effect on domestic profits as $\pi(q',q^*+\delta^*,s,v) - \pi(q',q^*,s,v)$, or:

$$\int_{q^{*\prime}}^{q^{*\prime}+\delta^*} \pi_{q^*}\, dq^* = -(4/3) \int_{q^{*\prime}}^{q^{*\prime}+\delta^*} x^N Z^*_{q^*}\, dq^* > 0$$

[because $Z^*_{q^*} < 0$ for $q^* > q^{*\prime}$]. Hence, domestic profits rise. Similar reasoning shows that foreign profits fall. When $f_q, f^*_{q^*} > 0$, our prior discussion showed that $d\pi(q^r(q^{*N}(\cdot),\cdot),q^{*N}(\cdot),s,v)/dq^* > 0$. By continuity, these qualitative effects still hold for a small but significant increase in foreign quality. QED

<u>Proof of Proposition 1 [and corollary]</u>

Let $f_q = 0$. Consider W^S_q from eq. (9). Letting $T = (s+v-tb_2)/t(4b_1+2b_2)$, and noting that $dx^N/dq = Z_q/6t \gtreqless 0$ if $q \lesseqgtr q'$ [see Lemma 2], we assert that W^S_q behaves as follows as q increases:

(i) $W^S_q <(=)[>]\ 0$ if $q < q'$ and $x^N(q,q^*,s,v) <(=)[>]\ T$,

(ii) $W^S_q = 0$ if $q = q'$,

(iii) $W^S_q <(=)[>]\ 0$ if $q > q'$ and $x^N(q,q^*,s,v) >(=)[<]\ T$.

Given the above behavior of W^S_q, social welfare can attain a local [or global] maximum at only q', $\underline{q}$, or $\bar{q}$ [proof via mean-value theorem]. Of these choices, only q' is associated with a significant market presence. Since $q^N(s,v) = q'$ [Lemma 3], the private quality choice is socially optimal when a significant market presence is needed to maximize welfare.

Let $s+v \le tb_2$. Hence, $T \le 0$, and necessarily $x^N(q,q^*,s,v) > T$ for all q. Referring to (i)-(iii) above, $W^S_q \gtreqless 0$ if $q \lesseqgtr q'$. Welfare must reach a global maximum at q'; thus, a significant presence must be socially optimal. Let $s+v > tb_2$, which implies that $T > 0$. Further, assume that $x^N(q',q^*,s,v) < T$. Under this condition, $x^N(q,q^*,s,v) < T$ for all q [see Lemma 2]. Referring to (i)-(iii) above, $W^S_q \lesseqgtr 0$ if $q \lesseqgtr q'$. Welfare can reach a global maximum at only $\underline{q}$ or $\bar{q}$; thus, a minimal presence is socially optimal. This possibility must always be considered whenever $s+v > tb_2$.

Let $f_q > 0$. From Lemma 3, $q^N(s,v) < q'$, which implies that $Z_q(q^N(s,v)) > 0$. The results in the proposition follow directly from (10). For example, let $s+v < tb_2$. Given that $Z_q(q^N(\cdot)) > 0$, and that $\pi_q(q^N(\cdot),q^{*N}(\cdot),s,v) = 0$ [see footnote 12], we obtain from (10) that $W^S_q(q^N(\cdot),q^{*N}(\cdot),s,v) > 0$. By continuity, there exists $\delta(\epsilon) > 0$ such that $W^S_q(q,q^{*N}(\cdot),s,v) > 0$ for $q^N(\cdot) < q < q^N(\cdot)+\delta(\epsilon)$. Hence, by the mean-value theorem, there exists $q > q^N(\cdot)$ such that $W^S(q,q^{*N}(\cdot),s,v) > W^S(q^N(\cdot),q^{*N}(\cdot),s,v)$. It can also be shown that a global maximum exceeds $q^N(s,v)$ [proof available from author]. A similar argument establishes our results for $s+v \ge tb_2$. The corollary follows directly since, under free trade, $s+v = 0 < tb_2$. QED

<u>Proof of Proposition 2 [and remark]</u>

Consider $W^S_{q^*}$ from eq. (11). Letting $T^* = (s+v+2tb_2)/t(4b_1+2b_2)$, and noting that $dx^N/dq^* = -Z^*_{q^*}/6t \gtreqless 0$ if $q^* \gtreqless q^{*\prime}$ [see Lemma 2], we observe that the behavior of $W^S_{q^*}$ parallels that of W^S_q from the preceding proof. Social welfare can attain a local [or global] maximum at only $q^{*\prime}, \underline{q}^*$, or $\bar{q}^*$; and, only $q^{*\prime}$ is associated with a significant presence. Since $q^{*N}(s,v) =(<) q^{*\prime}$ when $f^*_{q^*} =(>) 0$ [see Lemma 3(4)], we can assert that if a significant market presence is required to reach a welfare maximum, then the private foreign quality choice is at(below) the socially optimal level.

Consider the remark. Define $G(q,q^*,s,v) = (s+v+2tb_2) - t(4b_1+2b_2)x^N$, where $x^N = x^N(q,q^*,s,v)$. Note that $G \gtreqless 0$ if $x^N \lesseqgtr T^*$.

Let $x^{N\prime\prime} = x^N(q^N(\cdot),q^{*N}(\cdot),s,v) \ge T^*$. Given that $q^{*N}(s,v) \le q^{*\prime}$ [see

Lemmas 3-4], and that $dx^N/dq^* < 0$ for $q^* < q^{*\prime}$ [see Lemma 2], it follows that $x^N(q^N(\cdot), q^*, s, v) > T^*$ for $q^* < q^{*N}(\cdot) \leq q^{*\prime}$. Thus, $G(q^N(\cdot), q^*, s, v) < 0$ and by extension, $W^S_{q^*}(q^N(\cdot), q^*, s, v) < 0$ for $q^* < q^{*N}(\cdot)$ [since from (11), $W^S_{q^*}(q, q^*, s, v) = G(q, q^*, s, v)(Z^*_{q^*}/3t)$, and given that $Z^*_{q^*}(q^*) > 0$ for $q^* < q^{*N}(\cdot)$]. By the mean-value theorem, $W^S(q^N(\cdot), q^{*N}(\cdot), s, v) < W^S(q^N(\cdot), \underline{q}^*, s, v)$. Hence, if $x^{N''} \geq T^*$, social welfare increases when the foreign firm becomes a minimal market presence [i.e., when foreign quality falls to $\underline{q}$].

Assume that free trade exists [i.e., $s, v = 0$], and that producer and consumer surplus are equally weighted [i.e., $b_1 = b_2$]. Thus, $T^* = 1/3$, and a minimum foreign presence is socially desirable when $x^{N''} \geq T^* = 1/3$. The corollary follows directly, since the foreign market share is $2[(1/2) - x^{N''}]$ in equilibrium. QED

Proof of Lemma 6

By assumption, $W^S_{ss}(=W^S_{vv}) < 0$. If $b_2 = 1$, then $W^S_s = W^S_v$. A global maximum is attained when $W^S_s = W^S_v = 0$. The combination, (s', v'), from (14b) solves this first-order condition.

If $b_2 \neq 1$, then the first-order conditions [f.o.c.'s] based on (12) and (13) cannot be satisfied simultaneously. Let $b_2 < 1$, and consider the combination, (s', v'), from (14a). Using (12) and (13), it follows that $W^S_s(\cdot, s', v') < 0$, $W^S_v(\cdot, s', v') = 0$, and $s' = \underline{s}$. We demonstrate that these conditions must be satisfied for a global maximum, and that (s', v') is the unique solution.

Let $(s, v^o) \in [\underline{s}, \bar{s}] X [\underline{v}, \bar{v}]$ satisfy $W^S_v(s, v^o)) = 0$; hence, $W^S_s(\cdot, s, v^o) < 0$ [by substituting (13) into (12)]. Since $W^S_{vv} < 0$, a unique v^o satisfies $W^S_v(\cdot, s, v^o) = 0$ for each value of s. Thus, we define $v^o: [\underline{s}, \bar{s}] \Rightarrow [\underline{v}, \bar{v}]$ as the mapping that satisfies $W^S_v(\cdot, s, v^o) = 0$. Since $W^S_v(\cdot, s, v^o(s)) = 0$ and $W^S_{vv} < 0$, the mean-value theorem shows that $W^S(\cdot, s, v^o(s)) > W^S(\cdot, s, v)$ for $v \neq v^o(s)$. A global maximum thus occurs in the graph of $v^o(s)$. By differentiation, we obtain $dW^S(\cdot, s, v^o(s))/ds = W^S_s(\cdot, s, v^o(s)) + W^S_v(\cdot, s, v^o(s))(dv^o/ds) = W^S_s(\cdot, s, v^o(s)) < 0$. Since $dW^S(\cdot, s, v^o(s))/ds < 0$ globally, W^S reaches a global maximum at $s = \underline{s}$ [$= s'$]. Since $v^o(\underline{s}) = v^o(s') = v'$, a unique global maximum occurs at (s', v'). Similar reasoning shows that for $b_2 > 1$, the welfare-maximizing policy combination must satisfy (14c) [implying that $W^S_s(\cdot, s', v') = 0$, $W^S_v(\cdot, s', v') < 0$, and $v' = \underline{v}$]. The results concerning tariff dominance follow directly from (12) and (13). QED

Proof of Lemma 7

Under first-best policy, q, q*, s, and v are set individually. When it is socially optimal to maintain a significant market presence, the quality choices are internal. Given this result, and that the conditions from Lemma 6 are satisfied, a maximum requires that $W^S_{q*} = 0$, $W^S_q = 0$, and W^S_s [or W^S_v] = 0 [see prior proof]. Furthermore, $W^S_{q*} = 0$ and $W^S_{q*q*} < 0$ only if $q* = q*'$. Noting that $W^S_q = 0$ if the f.o.c. from eq. (9) is satisfied, and that W^S_s(or W^S_v) = 0 if eq. (14) is satisfied, we obtain the result in the lemma. QED

Proof of Proposition 3 [and remark in text]

If $f_q, f*_{q*} = 0$, then a first-best welfare maximum occurs at (q',q*') [from Lemma 7, noting that $W^S_q = 0$ and $W^S_{qq} < 0$ only if $q = q'$]. This quality combination is identical to the private quality choices [Lemma 3].

If $f_q, f*_{q*} > 0$, then q*' represents the welfare-maximizing foreign quality level. Since $q*^N(s,v) < q*'$ [Lemma 4], the policymaker must raise foreign quality. To calculate the welfare-maximizing domestic quality choice, we set $W^S_q(q,q*',s',v') = 0$ after substituting for the optimal subsidy-tariff combination from (14). The welfare-maximizing choice, q^s, must satisfy $W^S_q(q^s,\cdot) = [2x^N + (1/3)(b_2-k')]Z_q - b_1 f_q = 0$, where $(b_2-k') = 0(3b_2-3)$ if $b_2 \geq(<) 1$. From (7), we obtain $\pi_q(q^s,\cdot) = (4/3)x^N Z_q - f_q$. Substitute $W^S_q(q^s,\cdot) = 0$ into $\pi_q(q^s,\cdot)$. When $b_2 \geq 1$ [and thus $(b_2-k') = 0$], it follows that $\pi_q(q^s,\cdot) \lesseqgtr 0$ if $b_1 \lesseqgtr 3/2$. Given that profit-maximizing behavior requires that $\pi_q(q,\cdot) = 0$, and that $\pi_{qq} < 0$, the private quality choice would be lower(equal,higher) than q^s. When $b_2 < 1$ [and thus $(b_2-k') < 0$], $\pi_q(q^s,\cdot) > 0$ if $b_1 \geq 3/2$. Hence, the private quality choice would be higher than q^s. When $b_2 < 1$ and $b_1 < 3/2$, the sign of $\pi_q(q^s,\cdot)$ depends on the magnitude of x^N.

Suppose that the policymaker can only impose a uniform quality standard, and the domestic firm is the low-quality firm. Welfare can be adjusted by imposing a subsidy [and tariff], and a uniform standard that only constrains the domestic firm's quality choice. Although unconstrained by the standard, the foreign firm's optimal quality choice is affected by the imposed standard and the applied subsidy and tariff.

If $b_2 \geq 1$, then the welfare-maximizing policy combination must now satisfy the f.o.c.'s from (9) and (12), where the term, $W^S_{q*}(dq*^r/dq)$ $\{W^S_{q*}(dq*^r/ds)\}$, would be added to (9)\{(12)\}. Further, $dq*^r/dq = Z_q(dq*^r/ds)$ [because $dq*^r/dq\{dq*^r/ds\} = -\pi*_{q*q}/\pi*_{q*q*}\{-\pi*_{q*s}/\pi*_{q*q*}\}$ and $\pi*_{q*q} = Z_q\pi*_{q*s}$, given that $\pi*_{q*q} = -(2/9t)Z_qZ*_{q*}$ and $\pi*_{q*s} = -(2/9t)Z*_{q*}$]. By substituting the optimal subsidy-tariff combination [based on the modified f.o.c. from (12)] into the modified f.o.c. from (9), it follows that the welfare-maximizing domestic quality choice must satisfy $dW^S(q,q*^r(q,s',v'),s',v')/dq = 2x^NZ_q - b_1f_q = 0$. Let this condition be satisfied at q^s. Since $\pi_q = (4/3)x^NZ_q - f_q$, it follows that $\pi_q(q^s,\cdot) < 0$ whenever $b_1 < 3/2$ and $f_q > 0$. Since $\pi_q(q,\cdot) = 0$ under profit-maximizing behavior, the domestic firm would choose less than the socially optimal quality level. Hence, a quality standard is needed.

Let the policymaker impose an optimal subsidy [and tariff], and a <u>uniform</u> standard that only constrains the [low-quality] <u>foreign</u> firm. The welfare-maximizing policy combination must satisfy the f.o.c.'s from (11) and (12)[(13) when $b_2 < 1$], where the term, $W^S_{q*}(dq^r/dq*)\{W^S_{q*}(dq^r/ds)\}$, would be added to (11)\{(12)\}.

Given that the subsidy-tariff combination satisfies its modified f.o.c., we obtain the following result by differentiating social welfare with respect to foreign quality:

$$dW^S(q^r(q*,s'(\cdot),v'(\cdot)),q*,s'(q*),v'(q*))/dq* = [(1/3)(2b_2+k') - 2x^N]Z*_{q*},$$

where $2b_2+k' = 3b_2\{3\}$ if $b_2 \geq\{<\} 1$ [note: $W^S_q(\partial q^r/\partial q*) = -Z*_{q*}W^S_q(\partial q^r/\partial s)$ $(= -Z*_{q*}W^S_q(\partial q^r/\partial v))$ because $\partial q^r/\partial q* = -Z*_{q*}(\partial q^r/\partial s)$ $(= -Z*_{q*}(\partial q^r/\partial v))$]. Since $[(1/3)(2b_2+k') - 2x^N] > 0$, it follows that $dW^S/dq* \gtreqless 0$ if $q* \lesseqgtr q*'$. The welfare-maximizing foreign quality choice remains at $q*'$; hence, a uniform standard would raise welfare whenever $f*_{q*} > 0$ [see Lemma 3]. QED

<u>Proof of Proposition 4</u>

Given that results (i)-(iii) apply under consistent policymaking [see text discussion prior to Prop. 4], we substitute into eq. (18) to obtain:

$$W^S_q = [2x^N + (1/3)(b_2-k'')]Z_q - b_1f_q, \text{ where } b_2-k'' = 0\{3b_2-3\} \text{ if } b_2 \geq\{<\} 1.$$

Let $f_q = 0$. When $b_2 \geq 1$ [and thus $b_2-k'' = 0$], it follows that $W^S_q = 2x^NZ_q \gtreqless 0$ if $Z_q \gtreqless 0$. Since $Z_q \gtreqless 0$ if $q \lesseqgtr q'$, social welfare reaches a maximum at q'. When $b_2 < 1$ [and thus $b_2-k'' < 0$], the behavior of W_q^S parallels that described in the proof of Prop.1 [where $T = -(b_2-k'')/6 > 0$]. Based on our prior discussion, q' is the only internal maximum. From (17), $\pi_q \gtreqless 0$ if $Z_q \gtreqless 0$ [since $A = B < 6$]. Domestic profits also reach a maximum at q'. Hence, the private quality choice is socially optimal.

Let $f_q > 0$. Without loss of generality, the domestic firm chooses q to maximize $b_1\pi$. From (17), it follows that $b_1\pi_q = [6/(6-B)](4/3)b_1x^N Z_q - b_1 f_q$. Subtracting from W_q^S, we obtain, $W_q^S - b_1\pi_q = \{[2-(8/(6-B))b_1]x^N + (1/3)(b_2-k'')\}Z_q$.

Let $b_2 \geq 1$, implying that $(b_2-k'') = 0$. Hence, for any $q < q'$, $W_q^S - b_1\pi_q \gtreqless 0$ if $2 \gtreqless [8/(6-B)]b_1$. Since optimal firm behavior implies that $q^r(q^*,b_1,b_2) < q'$ and $\pi_q(q^r(q^*,\cdot),\cdot) = 0$ for all q^* [proof follows that of Lemma 4 and footnote 12], we assert that $W_q^S(q^r(\cdot),\cdot) >(=,<) 0$ if $2 >(=,<) [8/(6-B)]b_1$. Consequently, we can only attain a local [and global] maximum by raising(leaving unchanged,lowering) domestic quality from its privately chosen level. The results in the proposition follow, given that $2 \gtreqless [8/(6-B)]b_1$ implies $6-B \gtreqless 4b_1$, or $6-b_2 \gtreqless 4b_1$, or $b_1 \lesseqgtr (3/2)-(b_2/4)$.

Let $b_2 < 1$, implying that $(b_2-k'') = 3b_2-3 < 0$. By similar reasoning to that used above, $W_q^S(q^r(\cdot),\cdot) < 0$ if $2 \leq [8/(6-B)]b_1$. If $2 > [8/(6-B)]b_1$, the sign of $W_q^S(q^r(\cdot),\cdot)$ depends on the magnitude of x^N. QED

<u>Proof of Proposition 5 [and remark]</u>

If policy is consistent, then $W_s^S(ds''(\cdot)/dq^*) + W_v^S(dv''(\cdot)/dq^*) = 0$ [see footnote 20], $A=B = 4b_1 + 2b_2 - 6$, and $k'' = b_2(3-2b_2)$ if $b_2 \geq(<) 1$. $W_{q^*}^S$ is again expressed by (11), where $s''(\cdot)+v''(\cdot) = t[Bx^N(q,q^*,s''(\cdot),v''(\cdot))+k'']$. Substituting, we obtain $W_{q^*}^S = [-2x^N + (1/3)(2b_2+k'')]Z^*_{q^*}$. Since $(1/3)(2b_2+k'') \geq 1$ [because $b_2+k'' = 3b_2(3)$ if $b_2 \geq(<) 1$] and $0 < 2x^N < 1$, it follows that $W_{q^*}^S \gtreqless 0$ if $Z^*_{q^*} \gtreqless 0$. Given that $Z^*_{q^*} \gtreqless 0$ if $q^* \lesseqgtr q^{*\prime}$, social welfare reaches a maximum at $q^{*\prime}$.

To assess the marginal private value of its quality, the foreign firm now adds $\pi^*_{s+v}(d(s''(\cdot)+v''(\cdot))/dq^*) = [B/(6-B)]4((1/2)-x^N)(Z^*_{q^*}/3)$ to (7*). It follows that $\pi^*_{q^*} = [6/(6-B)]4((1/2)-x^N)(Z^*_{q^*}/3) - f^*_{q^*}$. Let $f^*_{q^*} = 0$. Once again, $\pi^*_{q^*} \gtreqless 0$ if $Z^*_{q^*} \gtreqless 0$ [noting that $B < 6$]. Hence, foreign profits reach a maximum at $q^{*\prime}$. The private quality choice is socially optimal. Let $f^*_{q^*} > 0$. Referring to $\pi^*_{q^*}$, and using reasoning analagous to that in the proof of Lemma 4, it follows that $q^{*r}(q,\cdot) < q^{*\prime}$ for all q. The foreign firm sets quality below the social optimum.

When policy is inconsistent, $A \neq B$. To assess W^S_{q*}, we add the term, $W^S_s(ds''(\cdot)/dq^*) + W^S_v(dv''(\cdot)/dq^*)$ to the specification in (11), where $W^S_s\{W^S_v\}$ is expressed by (12){(13)} and $d(s''(\cdot)+v''(\cdot))/dq^*$ is expressed by (16) [noting that $ds''(\cdot)/dq^*\{dv''(\cdot)/dq^*\} = 0$ if $a_2 <\{\geq\} 1$ --refer to (14) for similar result]. After including these changes, $W^S_{q*} = (Y + gx^N)(Z^*_{q*}/3)$, where $Y = 2b_2 + [(Ak'-6k'')/(A-6)]$ and $(k',k'') = (b_2,a_2)\{(3-2b_2,3-2a_2)\}$ if $a_2 \geq\{<\} 1$.

Assume that $f^*_{q*} = 0$. Let $Y > 0$. Given that $g > 0$, it follows that $W^S_{q*} \gtreqless 0$ if $q^* \lesseqgtr q^{*\prime}$. Social welfare reaches a maximum at $q^{*\prime}$, which is the same as the private quality choice. When $g < 0$, the behavior of W^S_{q*} is analagous to that of W^S_q in Proposition 1. Hence, social welfare can only reach an internal maximum at $q^{*\prime}$. QED

Proof of Lemma 9

Assume that g(c) is continuous. Lemma 8 asserts that g(c) is necessarily differentiable. By inverting g(c), we obtain $dg^{-1}/dq = (dg/dc|_{c,e=g^{-1}(q)})^{-1}$. Further, g(c) must satisfy equation (21), which represents the f.o.c. for the domestic firm. From (21), it follows that

$$\pi_q(g^{-1}(q),g^{-1}(q),c^*,q,q^{*\prime}(c^*)) + \pi_e(g^{-1}(q),g^{-1}(q),c^*,q,q^{*\prime}(c^*))(dg^{-1}/dq) = 0.$$

By totally differentiating this condition, we obtain the following:

$$(\pi_{ce}+\pi_{ee})(dg^{-1}/dq)^2 + (\pi_{cq}+2\pi_{eq})(dg^{-1}/dq) + \pi_{qq} + \pi_e(d^2g^{-1}/dq^2) = 0. \quad (A1)$$

The function, g(c), must also satisfy second-order conditions:

$$d^2\pi/dq^2 = \pi_{ee}(dg^{-1}/dq)^2 + 2\pi_{eq}(dg^{-1}/dq) + \pi_{qq} + \pi_e(d^2g^{-1}/dq^2) < 0. \quad (A2)$$

Substituting (A1) into (A2), we obtain the following:

$$d^2\pi/dq^2 = -[\pi_{ce} + \pi_{cq}(dg/dc)](dg^{-1}/dq)^2 < 0. \quad (A3)$$

By equation (21), $dg/dc = -\pi_e/\pi_q$. Our initial-value condition ensures that $g(c^w) = q'(c^w)$, where $q'(c^w)$ solves $\pi_q(c^w,c^w,c^*,q,q^{*\prime}(c^*)) = [6/(6-A)]4x^N(Z_q/3) = 0$. Thus, $|dg/dc| \Rightarrow |\infty|$ as $c \Rightarrow c^w$. As $c \Rightarrow c^w$, (A3) cannot be satisfied unless $\pi_{cq}(dg/dc) > 0$, which requires that dg/dc has the same sign as π_{cq}. By differentiation, $\pi_{cq} = -[4/3(6-A)][6x^N+(qZ_q/t)]$. As $c \Rightarrow c^w$, $g(c) \Rightarrow q'(c^w)$ which implies that $Z_q \Rightarrow 0$. Hence, $\pi_{cq} \Rightarrow -(4/3)[6/(6-A)]x^N < 0$ as $c \Rightarrow c^w$; it follows that $dg/dc < 0$ near c^w.

Mailath (1987) shows that g(c) is continuous, and also monotonic, when the initial-value condition holds and π_{cq} is constant in sign. If π_{cq} changes sign along (c,c,g(c)), then g(c) is discontinuous. Hence, if g(c) is continuous, then dg/dc < 0 everywhere. QED

Proof of Proposition 6 [and corollary]

An equilibrium with consistent beliefs requires that $e = g^{-1}(q)|_{q=g(c)} = c$. Using this result, and referring to (22), the optimal domestic quality choice must satisfy the following in equilibrium: $d\pi/dq = \pi_q + \pi_e(dg^{-1}/dq) = [6/(6-A)]4x^N(Z_q/3) + \pi_e(dg^{-1}/dq) = 0$. Under perfect information, the domestic firm chooses q'(c) as its quality level [see proof of Prop. 4], where $Z_q(q'(c),c) = 0$ and $[6/(6-A)] \times 4x^N(Z_q(q'(c),c)/3) = 0$. Based on this result, if q=q'(c) in our example with incomplete information, then $d\pi(q'(c),\ldots)/dq = \pi_e(dg^{-1}/dq)$. From (20) and Lemma 9, $\pi_e(dg^{-1}/dq) = [-A/(6-A)]4x^N(q/3)(dg^{-1}/dq) \gtreqless 0$ if $A \lesseqgtr 0$. Hence, $d\pi(q'(c),\ldots)/dq \gtreqless 0$ if $A \lesseqgtr 0$. Since incentive compatibility requires that $d^2\pi/dq^2 < 0$ globally [see Mailath], domestic profits must reach a maximum at a quality level less than(equal to,greater than) q'(c) whenever A <(=,>) 0.

Under socially consistent policy, $a_1 = b_1$ and $a_2 = b_2$. Thus, under complete information, $s''(\cdot)=s'(\cdot)$ and $v''(\cdot)=v'(\cdot)$, as described by (14) [where we now define · as (q,q*)]. Under incomplete information, the policymaker's choices for a [combined] subsidy and tariff, represented as $s''(e,\cdot)+v''(e,\cdot)$ $[=s'(e,\cdot)+v'(e,\cdot)]$, are described by (14), except that $x^{NE}(e,q,q^*,s,v)$ replaces $x^N(q,q^*,s,v)$ [where $x^{NE}(e,q,q^*,s,v)$ is specified by (4), except that eq replaces c(q)]. Under consistent beliefs, it follows that if q=g(c), then $e = g^{-1}(q=g(c)) = c$, and $x^{NE}(c,\ldots) = x^N(\ldots)$. Hence, if q=g(c), $s''(e,\cdot)+v''(e,\cdot) = s''(\cdot)+v''(\cdot)$, which equals $s'(\cdot)+v'(\cdot)$ because policy is socially consistent. From this, we conclude that if q=g(c), then $W^S_s[(\partial s''/\partial e)(de/dq)+(ds''/dq)] + W^S_v[(\partial v''/\partial e)(de/dq)+(dv''/dq)] = 0$ [see footnote 20].

If q=g(c), we can substitute $s''(\cdot)+v''(\cdot)[=s'(\cdot)+v'(\cdot)]$ from (14) into (9). By differentiating social welfare with respect to domestic quality, and recognizing that $W^S_s[(\partial s''/\partial e)(de/dq)+(ds''/dq)] + W^S_v[(\partial v''/\partial e)(de/dq) +(dv''/dq)] = 0$, we obtain the familiar result [demonstrated in the proof of Prop. 4] that $dW^S(g(c),\ldots)/dq = W^S_q = [2x^N + (1/3)(b_2-k'')]Z_q(g(c),c)$, where

b_2-k" = 0($3b_2$-3) if $b_2 \geq (<) 1$.

We have shown that $g(c) \gtreqless q'(c)$ if $A - B \gtreqless 0$. Since $Z_q(q'(c),c) = 0$ and $Z_{qq} < 0$, it follows that $Z_q(g(c),c) \gtreqless 0$ if $A - B \lesseqgtr 0$. Using this result in the expression for $dW^S(g(c),\ldots)/dq$, we can assert that if $b_2 \geq 1$ and $A - B <(=)(>) 0$, then $dW^S(g(c),\ldots)/dq >(=)(<) 0$. Hence, welfare can(not) be raised by increasing(changing) (reducing) domestic quality from g(c). If $b_2 < 1$ [implying that b_2-k" = $(3b_2-3) < 0$], then $dW^S(g(c),\ldots)/dq = 0$ when $A - B = 0$. Welfare cannot be raised by changing domestic quality [since if A=B=0, then the optimal subsidy and tariff are independent of x^N and x^{NE}]. If $A - B \neq 0$, then the sign of $dW^S(g(c),\ldots)/dq$ depends on the magnitude of x^N. QED

<u>Proof of Proposition 7</u>

Under a free-trade regime, s,v = 0. For the domestic firm, $b_1(d\pi/dq) = b_1[\pi_q + \pi_{p*}(\partial p*^{NE}/\partial e')(de'/dq)] = b_1[(4/3)x^E Z_q + 2x^N(\partial p*^{NE}/\partial e')(de'/dq)]$, where $x^E = x(p^r(p*^{NE}),p*^{NE})$, $p^r(p*)$ is the domestic reaction function in prices [based on equation (2)], and $p*^{NE} = p*^{NE}(e',q,q*,s,v)$ is specified by (3*) except that e'q replaces c(q). Since $de'/dq = dg^{-1}/dq < 0$ under consistent, incentive-compatible behavior [proof follows that of Lemma 9], and $\partial p*^{NE}/\partial e' = q/3 > 0$ [see text], it holds that $(\partial p*^{NE}/\partial e')(de'/dq) < 0$. Given this result, and that $Z_q \leq 0$ for $q \geq q'(c)$, it follows that $d\pi/dq < 0$ for $q \geq q'(c)$. From this, we can infer that $g(c) < q'(c)$. Hence, $Z_q(g(c),c) > 0$ for all $c \neq c^w$, and the foreign firm must assume that $Z_q(q,g^{-1}(q)) > 0$ for {q: q=g(c) and $c \neq c^w$}.

When the domestic quality choice influences the foreign assessment of domestic costs, it follows that $dW^S/dq = W^S_q + [W^S_{p*} + W^S_p(\partial p^r(p*^{NE})/\partial p*^{NE})]$ X $[(\partial p*^{NE}/\partial e')(de'/dq)]$. Using (8), we can partially differentiate W^S with respect to q, p* and p [evaluated at $p*^{NE}$ and $p^r(p*^{NE})$]: (i) $W^S_q = b_1\pi_q + (b_2)[(1+2x^E)(Z_q(q,g^{-1}(q))/3) + (g^{-1}(q)-c)(x^E/2)]$ (ii) $W^S_{p*} = b_1\pi_{p*} - b_2(1 - 2x^E)$, and (iii) $W^S_p = -b_2(2x^E)$.

From prior results, we can assert that $(\partial p*^{NE}/\partial e')(de'/dq) < 0$ and $(\partial p^r(p*^{NE})/\partial p*^{NE})(\partial p*^{NE}/\partial e')(de'/dq) < 0$ [since $\partial p^r/\partial p*^{NE} = -\pi_{pp*}/\pi_{pp} = 1/2$ --see eqs. (2) and (1)]. Also, $Z_q(q,g^{-1}(q)) > 0$ for all $q \leq g(c)$ ($<q'(c)$) [except at $q'(c^w)$ where $Z_q(q,g^{-1}(q)) = 0$], and $e = g^{-1}(q) \geq c$ for $q \leq g(c)$ [since $g^{-1}(q=g(c)) = c$ and $dg^{-1}(q)/dq < 0$]. We can incorporate all the above results into the specification for dW^S/dq, and then subtract $b_1(d\pi/dq)$. For $q \leq g(c)$, it holds that $dW^S/dq - b_1(d\pi/dq) > 0$. Since $d\pi(g(c))/dq = 0$ [see Lemma 8], we obtain $dW^S(g(c))/dq > 0$. Hence, a local welfare maximum [and also global maximum, since $d\pi/dq > 0$ implies that $dW^S/dq - b_1(d\pi/dq) > 0$ for $q \leq g(c)$] is attained by raising domestic quality from g(c). QED

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