International Agricultural Trade
Research Consortium

Rational Incompatibility with International Product Standards

by

Christopher B. Barrett and Yi-Nung Yang*

Working Paper #99-9

The International Agricultural Trade Research Consortium is an informal association of University and Government economists interested in agricultural trade. Its purpose is to foster interaction, improve research capacity and to focus on relevant trade policy issues. It is financed by United States Department of Agriculture (ERS, and FAS), Agriculture and Agri-Food Canada and the participating institutions.

The IATRC Working Paper series provides members an opportunity to circulate their work at the advanced draft stage through limited distribution within the research and analysis community. The IATRC takes no political positions or responsibility for the accuracy of the data or validity of the conclusions presented by working paper authors. Further, policy recommendations and opinions expressed by the authors do not necessarily reflect those of the IATRC or its funding agencies. For a complete list of IATRC Working Papers, books, and other publications, see the IATRC Web Site ***http://www.umn.edu/iatrc***

A copy of this paper can be viewed/printed from the IATRC Web Site indicated above.

*Dr. Christopher Barrett is an Associate Professor in the Department of Agricultural, Resource, and Managerial Economics at Cornell University and Dr. Yi-Nung Yang is an Assistant Professor in the Department of International Trade at Chung Yuan Christian University in Tao Yuan, Taiwan.

Correspondence regarding this paper should be addressed to:

Christopher B. Barrett
Department of Agricultural, Resource and Managerial Economics
Cornell University
351 Warren Hall
Ithaca, NY, USA 14853-7801

.

September 1999
ISSN 1098-9218
Working Paper 99-9

Rational Incompatibility with International Product Standards

Christopher B. Barrett and Yi-Nung Yang

August 1999 revised version

The authors are Associate Professor in the Department of Agricultural, Resource and Managerial Economics, Cornell University (Ithaca, NY, USA), and Assistant Professor in the Department of International Trade, Chung Yuan Christian University, (Tao Yuan, Taiwan), respectively. Seniority of authorship is shared equally. We thank Terry Glover, Jimmye Hillman, Les Reinhorn, Oz Shy, Dawn Thilmany, Quinn Weninger and three anonymous referees for helpful comments and discussions. Barrett is the corresponding author, and can be reached at telephone (607) 255-4489, fax (607) 255-9984, or email cbb2@cornell.edu.

Rational Incompatibility with International Product Standards

JEL codes: F02, F13, F15, L11, L13, L51

Keywords: compatibility, international standardization, network effects, redesign costs, technical barriers to trade

Abstract: This paper considers the incentives of firms to conform to an exogenous international product standard. Product standardization enables traditional, price-based international competition. But the existence of redesign costs or network effects creates market frictions that diminish the incentive to standardize if there already exists a different technology in an established market. This leads to multi-attribute competition between products and will generally reduce trade flows. Not only do incumbent firms using a different technology have an incentive to deviate from the international standard, but a host country government that is also concerned for the welfare of consumers who own the old technology has no incentive to enforce the international standard. Indeed, the government may value deviation from the international standard more than the firm does, thereby creating incentives to adopt and enforce technical barriers to trade. The results highlight the challenge lock-in effects pose to the international standard-setting process.

Rational Incompatibility with International Product Standards

> "These days, it is differences in national regulations, far more than tariffs, that put sand in the wheels of trade between rich countries."
>
> *The Economist*, 24 May 1997, p.72

I. Introduction

Technical product standards are becoming key issues, both in corporate global business strategy and in government trade and technology policy. Sharp long-run reduction in average tariff levels, import quotas, and real international communications and transport costs have led to increased international economic integration. However, international diversity in product standards can lead to technical barriers to trade that threaten to limit further integration (Hillman 1991, Kende 1991, Sykes 1995, Thilmany and Barrett 1997). Internationally accepted product standards can facilitate international trade by reducing search and adjustment costs, cutting production costs where there are economies of scale or scope, and facilitating spatial arbitrage. For goods characterized by demand-side network externalities (e.g., electrical products with voltage standards, food safety standards[1]), the incentives to achieve compatibility may be especially pronounced (Katz and Shapiro 1985, 1994). Considerable effort is therefore being invested currently in developing international product (including product safety) standards through intergovernmental bodies — such as the International Organization for Standardization (ISO), Codex Alimentarius (Codex), the International Electrotecnical Comission (IEC), and the Asia Pacific Economic Cooperation (APEC) forum — as well as through private negotiation among firms. Meanwhile, trade treaties (e.g., NAFTA) increasingly incorporate language

[1] Network externalities may arise in the case of food safety standards because general acceptance of the product is taken as a signal of safety and quality. Put differently, network externalities are analytically equivalent to bandwagon effects common in consumer psychology.

designed to restrict nations' abilities to introduce technical barriers to trade (Sykes 1995, Wilson 1995).

Some nations and firms nonetheless choose not to adopt international standards. Automotive and machinery parts come in metric and non-metric sizes, railroad tracks and machinery exist in different gauges, fresh foods exporters use different controls against contamination (yielding potentially different *ex post* risks), and so on. Sometimes standards idiosyncratic to a particular firm or industrial cluster become mandatory in a particular economy (e.g., righthand-side-drive vehicles, food handling or storage practices) when governments convert voluntary standards into regulations. This is one source of technical barriers to trade, which appear to be increasing, both relative to quotas and tariffs and in absolute terms, as reflected in the quote that opens this paper.

This paper considers why a firm might choose not to comply with international product standards and why its host government might not enforce the international standard, and indeed might compel instead maintenance of a noncompliant, preexisting technology standard. If key market participants have incentive to maintain incompatible standards, then efforts to design uniformly agreeable international standards may prove futile. In this paper, we show that incentives to deviate from international standards may be significant under plausible assumptions. Our analytical findings are consistent with the dominant international pattern: countries typically do not recognize international standards. For example, the U.S. Congressional Research Service found that only 17 of approximately 89,000 standards recognized in the United States had international origins (USHR 1989).

The literature on networks explains incompatibility[2] as arising either from consumer heterogeneity that gives social value to variety, from stochastic technology quality that creates disincentives to betting everything on one standard of uncertain ultimate quality, or from firm asymmetries that cause one firm to be confident it will win a contest of competing standards (Farrell and Saloner 1986, Katz and Shapiro 1986, Matutes and Regibeau 1988, Katz and Shapiro 1994). Without recourse to any of those rationales, we show that international standards incompatibility will generally be a rational choice for firms and governments simply because product differences already exist. This finding obviously carries significant implications for costly expenditures on international product standardization agreements designed to facilitate trade. Important classes of prospective signatories may never find it in their interest to comply with standards. Our findings also offer some insight as to why governments wishing to maximize social welfare might impose technical barriers to trade.[3] As Matutes and Regibeau's (1996) recent review highlights, these international standardization choices and policies have been largely neglected in the literature to date.[4]

II. International Standards and the Domestic Network Market

Products in network markets generate some of their value through compatibility with others. Fax machines, computer software, and automobile parts are familiar examples. The network value of the good takes the form of an externality which is a function of the volume of the product in use,

[2] We have in mind either two-way (in)compatibility among alternative technologies or one-way incompatibility from the original domestic technology to the two new technologies.

[3] Hillman (1991), Sykes (1995) and Thilmany and Barrett (1997) discuss the political economy of technical barriers to trade.

[4] Gandal and Shy (1996) tackle related issues.

often referred to as the "installed base" of the network. Markets in goods characterized by network externalities are especially appropriate subjects for the study of international product standards because product standards and resulting compatibility influence consumers' valuation of a product. If production or exchange technologies exhibit nonconstant returns over any range, standards also influence production and transaction costs. Comparative advantage, international demand patterns, and trade flows in network products are thus affected by product standards.

Sykes (1995) defines a product "standard" as a specification or set of specifications that relate to a product's attributes. Standards commonly arise through the cooperation of firms, sometimes in partnership with government. There commonly develop multiple coalitions of firms, each coalition adhering to a different product standard, but each firm within the coalition adhering to exactly the same standard (Kindelberger 1983, Casella 1996, Economides and Flyer 1998).[5] In such cases, competition between coalitions can be modelled as oligopolistic, the path we follow here.

Compliance with standards is voluntary and may or may not be formally promulgated by a private or public standard-setting entity. A coalition can redesign its technology to suit an exogenously imposed standard or it can retain its existing technology standard. In some cases governments wish to enforce compliance with a standard by means of regulatory controls. When a standard is being enforced on a national market, the government typically must emplooy technical

[5] One example is the color television broadcasting case discussed by Pargal (1996), wherein reception and transmission standards must be common to work. Similarly, a nation's vehicle manufacturers must uniformly produce either righthand- or lefthand-side drive vehicles, not both, for local sale. Another example is food safety, sanitary and phytosanitary standards, which typically originate through cooperative, common definition by firms and government within a particular jurisdiction, but which vary across jurisdictions.

barriers to trade in order to ensure all imported products are also fully compatible with the mandated specifications. Standards choices are thus one means by which technical barriers to trade arise.

This section presents a simple, two-stage model of technology choice in a market for a product exhibiting network externalities. We draw on the pioneering work of Katz and Shapiro (1985), extending their approach to permit firms nondichotomous choice over standards compatibility. Like Jain (1989) and Shy (1996), we allow for *partial* compatibility in our model, reflecting the common phenomenon that some, but not all, key features may be compatible among products providing similar services.[6] Partially compatibile products (partly) contribute to each other's installed network base, thereby influencing market equilibria.

The scenario we model runs as follows. There exist two coalitions within which firms jointly decide on output quantities and product standards, i.e., the coalitions operate like oligopolistic cartels. While there are fixed costs associated with supplying the market and each firm within a coalition enjoys a monopoly in its particular brand of the standardized technology,[7] entry and exit into a coalition are free, so a monopolistic-competition equilibrium prevails within the coalition, and in long-run equilibrium, firms earn zero profits in spite of the oligopolistic competition between cartel-like coalitions (Shy 1995). Without loss of generality, assume one coalition is comprised of domestic firms and the other of foreign firms.

---

[6] For example, a software package might be able to access another application's format although their other characteristics may be decidedly different and imperfectly compatible (Gandal, 1995).

[7] Monopoly could be due to intellectual property rights conveyed by trademarks, copyrights, patents, etc. Or it could be due to brand proliferation in the face of fixed costs.

The domestic coalition offers a product with an original technology potentially incompatible with a subsequently chosen international technology standard belonging to the foreign coalition. So there may be two distinct technologies already in use when the domestic coalition makes its choice of whether or not to comply with the international standard. The potential differences between these two technologies are captured in a compatibility index, β, defined over the unit interval. The international product standard is fully compatible with the original domestic technology if $\beta=1$, they are totally incompatible if $\beta=0$, and they are partially compatible if $\beta\in(0,1)$. In the case where no prior domestic technology exists, $\beta=1$ *de facto*, since there is no incompatibility problem.

The market is in equilibrium when the foreign technology, β, becomes the international standard. The domestic coalition responds by potentially changing its technology. The index $\alpha\in[0,1]$ captures the compatibility between the coalition's new and old technologies. The domestic coalition's new and original technologies are totally incompatible if $\alpha=0$, they are perfectly compatible if $\alpha=1$, and they are partially compatible if $\alpha\in(0,1)$. At the same time, the domestic government decides whether to encourage or enforce either the international standard or the original domestic technology, i.e., to impose either $\alpha=\beta$ or $\alpha=1$ by regulatory fiat.

The timing of the game is as follows. In the first stage, the domestic coalition chooses a technology for its new product, i.e., decides α, given the installed base of both the original domestic technology and the international standard, and the compatibility of the international standard with the original domestic technology, as reflected by β. In the second stage, consumers form expectations about the network sizes of both technologies, given the domestic coalition's compatibility decision in stage one. We assume a fulfilled expectations equilibrium, following Katz and Shapiro (1985). Finally, the domestic coalition and its foreign competitor set quantities in a Cournot competition. We find that, save for unusual circumstances, neither the domestic coalition nor the social welfare-maximizing government have an incentive to adopt the international product standard. This result has obvious implications for negotiations over international product standards agreements.

A. Consumer Behavior

There are two classes of consumers in our model. The first group are consumers who previously purchased the original domestic technology. There are q_0 such established consumers making up the installed base of the domestic technology. Similarly, there are q_0* established consumers of the foreign technology. In order to keep the analysis simple, we do not permit established consumers to switch to the new technology.[8] Established consumers derive a discounted stream of benefits from the product equal to k + V(N), where N is the network size.

Coalitions make profits by selling to the second class of new, prospective consumers. Following Katz and Shapiro (1985), a prospective consumer of type r has a willingness to pay $r+v(N_e)$ for a product with expected network size N_e,where r represents her intrinsic valuation of the product and $v(N_e)$ reflects the network externality. For simplicity, we assume r is uniformly distributed with density one between minus infinity and A, a positive number. The network externality function, v(.), is assumed to be twice continuously differentiable, with v(0)=0, v' > 0, v'' < 0, and $\lim_{z \to \bar{N}} v'(z) = 0$ where there exists a large network size, $\bar{N}$. We should point out that $\bar{N}$ is not a

[8] When established consumers can switch, the installed network base becomes endogenous and one has to allow for prospective differences in the intrinsic value associated with the original and new technologies, as well as for consumer switching costs. Intuitively, when the gains from a better or more compatible technology are sufficiently large to justify incurring switching costs, consumers replace the old technology. The qualitative results of our simpler model carry through to this more refined setting, but the analysis gets messy. In the interests of clarity, we use the limiting assumption of no switching to simplify the model.

saturated market, merely one in which the marginal value to consumers of adding another user has vanished; contemporary fax, electronic mail, road, and utility networks are examples that spring immediately to mind.[9] The non-network services provided by the technologies are viewed as homogenous by all consumers, but the technologies may not be perfectly compatible. The only differences are the expectations about the sum of weighted network sizes since the networks might not be perfectly compatible.

Once the new domestic technology's standard has been established and becomes known, consumers form expectations about the weighted size of the new networks associated with the domestic and foreign products based on the known existing network sizes of both the original domestic technology and the international standard and on the expected sales of each, q_e and q_e*, respectively.[10] The expected weighted average network size for prospective consumers of the new domestic product is then

$$N_e = \alpha q_o + q_e + f(\alpha - \beta)(q_e^* + q_o^*) \tag{1}$$

where f(α-β) is a concave index function with support [0,1] that measures the compatibility deviation between the new domestic technology and the international standard. If α=β, the two new technologies are fully compatible with each other, although they might not be fully compatible with

[9] More complex network effects, in which the monotonicity and concavity assumptions on $V(N_e)$ are relaxed, can accomodate network overload or exclusivity effects — with v'<0 at very large or very small network sizes, respectively — but do not change the qualitative results of our analysis.

[10]Consumers care about the installed base in each technology because they may wish to network with others who purchased an earlier technology. This is a common phenomenon in, for example, automobiles, computer software, and facsimile machines. An alternative interpretation, appropriate to cases such as food safety, is that new consumers care about first generation consumption volumes as a signal about product quality or safety.

the original domestic technology (if $\alpha=\beta\neq 1$). Without loss of generality, assume $f'(.)>0$ when $\alpha-\beta<0$, $f(\alpha-\beta)=1$ and $f'(.)=0$ when $\alpha=\beta$, $f'(.) < 0$ when $\alpha-\beta>0$, and $f''(.) < 0$ for all α and β. If $\alpha=1$ consumers fully count the installed base of the original domestic technology since the domestic original and new technologies are fully compatible. Simply put, the more compatible the new domestic technology is with another product — whether the international standard or the original domestic technology — the more weight consumers give to the installed base of other (domestic or foreign) products in forming their expectations of the relevant network size for the new domestic technology. Consumers similarly form expectations of the weighted average network size for the imported product conforming to the international standard.

$$N_e^* = \beta q_o + f(\alpha - \beta)q_e + q_e^* + q_o^* \tag{2}$$

For network goods, compatibility creates value for consumers, whether established or prospective.

Each prospective consumer maximizes her surplus by purchasing one unit of either the new domestic or foreign product or by declining to purchase either product. In order to focus attention on the decision of whether or not to conform with the international standard, we assume the foreign coalition cannot unilaterally change its product's standard; it must satisfy the international standard. The foreign coalition can only choose the quantity it exports into the market, q*, in order to maximize its profits in the domestic market. Letting p denote the price of the new domestic product, an agent who purchases the new domestic technology must have

$$r + v(N_e) - p \geq 0 \tag{3}$$

Symmetrically, any agent who purchases the new foreign product must have

$$r + v(N_e^*) - p^* \geq 0 \tag{4}$$

Those prospective consumers whose reservation prices are less than either p or p* stay out of the network market. Therefore, if $r+v(N_e)-p > r+v(N_e^*)-p^*$ for all consumers, no one buys the imported international standard product. Analogously, no one buys the new domestic product if $r+v(N_e)-p < r+v(N_e^*)-p^*$ for all consumers. Under those two limiting situations, the domestic market has a single provider, either the domestic coalition or foreign producers.

If the domestic and international products are homogenous — i.e., $\alpha = \beta$, whether or not $\alpha = \beta = 1$ — then $v(N_e)=v(N_e^*)$, so the low-price producer captures the entire market. This is the textbook example of price-based division of a homogenous good's market, and a special case of our model of potentially heterogeneous (i.e., imperfectly compatible) goods. But in the more general case, the low price competitor does not necessarily capture the market if network effects confer an advantage on the producer offering the good at a higher price. In particular, the domestic coalition's choice of technologies influences control over the market. The next section describes the coalition's optimal technology choice. We will then subsequently revisit the possibility of market exclusion conditional on the coalition's optimal technology choice.

Our interest centers on the scenario in which both the imported international standard and the new domestic product exist in the domestic market in the second stage. In equilibrium, two coalitions both have positive sales only if

$$r + v(N_e) - p = r + v(N_e^*) - p^* \tag{5}$$

Equation (5) can be rearranged as follows

$$p - v(N_e) = p^* - v(N_e^*) \tag{6}$$

Equation (6) indicates that the expected hedonic prices must be equal if both coalitions have positive sales in the competitive domestic market. Let ϕ stand for the common value of the hedonic prices, i.e., $\phi = p - v(N_e) = p^* - v(N_e^*)$. Only those consumers whose intrinsic valuation of the product is greater than the hedonic price ($r \geq \phi$) will buy a new product. Since r is uniformly distributed between minus infinity and A with density one, A-ϕ consumers enter the product network. If the total sales of the products from two coalitions are (q+q*), then

$$A - \phi = q + q^* \tag{7}$$

Substituting for ϕ yields

$$A - (p - v(N_e)) = q + q^* \tag{8}$$

Rearranging equation (8), we find that the domestic coalition faces the downward-sloping inverse demand function

$$p = A + v(N_e) - (q+q^*) \tag{9}$$

Substituting instead $p^* - v(N_e^*)$ for ϕ in (7) and rearranging yields the inverse demand function for the imported product conforming to the international standard

$$p^* = A + v(N_e^*) - (q+q^*) \tag{10}$$

Coalitions make their own decisions knowing these inverse demand functions.

B. Coalition Behavior

The foreign coalition sells a product conforming to the predetermined international standard; it has no unilateral influence to change that standard. The foreign coalition enters the game actively only in the second period, as a quantity-setting Cournot competitor. The domestic coalition, on the other hand, chooses the degree of compatibility between its new and old products, α, in the first period, knowing the international standard (β), the installed network base under both the original domestic and the international standard technologies (q_0 and q_0^*, respectively), and the way in which consumers form expectations.

The domestic coalition offers an upgraded product in response to market entry by foreign coalitions selling the international standard only if total revenue is larger than the sum of variable, redesign and other fixed costs. The domestic coalition's redesign costs are a function of compatibility with its original technology, R(α). Assume R(α) is decreasing and convex in α and R(1)=R'(1)=0, and that R(α)=0 when q_0=0. In words, sticking with the original technology entails no redesign costs, which increase at an increasing rate with the deviation from the original design, while a completely new technology – i.e., one for which there are no established customers – entails no redesign costs no matter the technology choice. Without loss of generality, we assume the domestic coalition's other fixed costs have no influence at the margin. For simplicity, we also assume constant marginal cost of production and, without loss of generality, set this equal to zero.

The domestic coalition solves its multi-stage profit-maximization problem by backward induction. In the second stage, the domestic coalition chooses output volume so as to maximize profit, given consumers' expectations of network size and its prior compatibility decision, α.

$$\max_{q} \Pi(q^*\alpha,\beta) = q\,(A+v(N_e)-(q+q^*)) - R(\alpha) \qquad (11)$$

The foreign coalition's objective is likewise to maximize profits given α and consumers' expectations by

$$\max_{q^*} \Pi^*(q^{**}\alpha,\beta) = q^*\,(A+v(N_e^*) - (q+q^*)) \qquad (12)$$

Assume a fulfilled expectations Cournot equilibrium in which consumers' expectations about the sizes of the two domestic market product networks are fulfilled in equilibrium, i.e., $(N_e,N_e^*) = (N, N^*)$ and

$(q_e, q_e^*) = (q, q^*)$.[11] The second period first-order conditions for both coalitions' profit maximization are thus

$$\frac{\partial \Pi}{\partial q} = A + v(N) - (2q + q*) = 0 \tag{13}$$

$$\frac{\partial \Pi^*}{\partial q^*} = A + v(N^*) - (q + 2q*) = 0 \tag{14}$$

These two equations represent the reaction curves of the two competing coalitions and can be solved implicitly for the subgame perfect equilibrium quantities, $(\hat{q}(\alpha), \hat{q}^*(\alpha))$, conditional on the optimal first period compatibility choice of α.

Let us now consider the comparative static effects of the domestic coalition's first period choice of α on $(\hat{q}(\alpha), \hat{q}^*(\alpha))$. Differentiating (13) and (14) with respect to α gives the system of equations

$$\begin{pmatrix} \dfrac{\partial^2 \Pi}{\partial q^2} & \dfrac{\partial^2 \Pi}{\partial q \partial q^*} \\ \dfrac{\partial^2 \Pi^*}{\partial q \partial q^*} & \dfrac{\partial^2 \Pi^*}{\partial (q^*)^2} \end{pmatrix} \begin{pmatrix} \dfrac{\partial q}{\partial \alpha} \\ \dfrac{\partial q^*}{\partial \alpha} \end{pmatrix} = \begin{pmatrix} -\dfrac{\partial^2 \Pi}{\partial q \partial \alpha} \\ -\dfrac{\partial^2 \Pi^*}{\partial q^* \partial \alpha} \end{pmatrix} \tag{15}$$

Appropriate differentiation and algebra then establishes that

$$\frac{\partial q}{\partial \alpha} = \frac{f'(\alpha - \beta)(2v'(N)(q* + q_0*) - v'(N^*)q) + 2v'(N)q_0 - 2R'(\alpha)}{3} \tag{16}$$

We will need this expression to solve the coalition's optimal (stage one) technology choice, below. But in addition to that instrumental value, the result in (16) sheds light on the relationship between

[11] Katz and Shapiro (1985) also demonstrate another case, in which consumers form expectations of network size after coalitions have selected their output level.

sales volume and the coalition's prior technology choice. This relationship can be summarized in two propositions (proofs of which are in the appendix).

Proposition 1: *If and only if there is an installed base in the original domestic technology, then the domestic coalition's sales are increasing in the degree of its product's compatibility with the original domestic technology, i.e., by deviating from the international product standard if it is not identical to the original domestic technology*.

Proposition 1 tells us that when there exists a set of established consumers of the original technology, the coalition's profit-maximizing sales quantity will be greater if it has chosen a new technology positioned between the international standard and the original domestic technology than if its new technology conforms perfectly to the international standard. Because prospective consumers value compatibility, the coalition's market share is greater when it occupies a central location on the continuum of existing technologies (β,1), analogous to the Hotelling (1929) result.

For immature networks, wherein new sales generate marginal network effects ($v'>0$), the first term in the numerator of (16) is of indeterminant sign when $\alpha \neq \beta$, so we have only the local result offered in proposition one. However, for mature networks, wherein the marginal value of adding participants vanishes, we can derive somewhat more general results.

Proposition 2: *When the installed bases for both the original and international standard technologies are large, then sales of the new technology are increasing in* α.

Intuitively, the domestic coalition can increase its sales and profits by increasing the degree of compatibility with a mature technology's network. When both the international standard and the original domestic networks are mature, however, sales are maximized by maintaining the original domestic technology (i.e., at $\alpha = 1$) because this minimizes coalition redesign costs, enabling the domestic producer to offer a lower price and generate greater sales. As the existing literature on switching costs emphasizes (Klemperer 1995), the friction introduced by nonzero technology switching costs creates lock-in effects. In the present case, this phenomenon is manifest in the domestic coalition's incentive to deviate from an international product standard in the direction of a preexisting domestic technology.

The first stage compatibility choice of α reinforces this finding. Given the second-stage fulfilled expectations Cournot equilibrium, reflected in the optimal quantities $(\hat{q}(\alpha), \hat{q}^*(\alpha))$, the coalition maximizes profit by choosing α so as to

$$\max_{\alpha} \Pi\,(\hat{q}(\alpha), \hat{q}^*(\alpha), \alpha^* \beta) = \hat{q}(\alpha)(A + v(N) - (\hat{q}(\alpha) + \hat{q}^*(\alpha))) - R(\alpha) \qquad (17)$$

The first-order necessary condition for an optimum is thus

$$\hat{q}\ \{v'(N)[q_0 + f'(\alpha - \beta)(\hat{q}^* + q_0^*)] - (\partial \hat{q}^* / \partial \alpha)\} - R'(\alpha) \ \leq (\geq)\ 0 \qquad (18)$$

$$\{\text{with} <0 \text{ only if } \alpha = 0 \text{ and } >0 \text{ only if } \alpha = 1\}$$

The first-stage problem thus relates the coalition's technology choice, α, to profits in a fashion analogous to the relationship between α and the coalition's sales volume, $\hat{q}(\alpha)$, derived earlier through comparative statics analysis of the solution to the coalition's second stage problem. The necessary condition for profit maximization in (18) permits us to derive the necessary conditions for the domestic coalition to choose the international standard voluntarily.

Proposition 3: *The domestic coalition voluntarily produces a good perfectly compatible with the international standard* ($\hat{\alpha}=\beta$) *only if the international standard is itself perfectly compatible with the domestic original-technology or there was no preexisting domestic technology* ($\beta=1$). *Otherwise it chooses a technology more compatible with the original domestic technology than is the international standard* ($\hat{\alpha}>\beta$).

Again, the proof is in the appendix. The intuition of this proposition runs as follows. Although there may be multiple subgame perfect equilibria since there will not necessarily be a unique profit-maximizing combination ($\hat{\alpha}$, $\hat{q}$), two effects each cause the domestic producer to deviate from the international product standard unless it is perfectly compatible with the original domestic technology or no such original technology existed. First, positioning the new technology between the old domestic technology and the international standard can increase the consumer's expected network size, thereby securing a higher equilibrium price attributable to the technology's superior compatibility. Second, the closer the new technology to the old, the lower the redesign costs incurred. Both effects cause deviation away from the international standard toward the original technology. An established customer base and technology thereby creates a degree of path-dependence in coalition technology choice.

Technology choice will have trade volume effects since, by Proposition 1, the domestic coalition's equilibrium quantity is increasing in α and the foreign coalition's sales volume is decreasing in α. Where an established consumer base confers some advantage on incumbent domestic producers, international product standardization would then indeed stimulate international trade flows.

Coalitions' rational noncompliance with standards therefore reduces trade volumes relative to the scenario of full compliance.[12]

Proposition 3 implicitly highlights the importance of *ex ante* versus *ex post* standardization, where *ex ante* standardization represents the designation of an international standard, β, before the establishment of a competing domestic technology (i.e., $q_0=0$), and under *ex post* standardization, β is set after a domestic technology has been installed (i.e., $q_0>0$). Coalitions have incentives to comply with *ex ante* standards, but not necessarily with *ex post* standards. The problem with *ex ante* standardization, however, is that if research and development is stochastic, then it is impossible to know the optimal design *ex ante*, so widespread compliance may be gained at the price of a potentially suboptimal standard. On the other hand, once there is an installed base in a particular technology, voluntary coalition compliance can only be ensured if the international standard adopted *ex post* is the original domestic technology, $\beta=1$. In other words, only *ex ante* standardization can work under the conditions imposed in our model. This obviously bodes poorly for *ex post* standardization of technologies developed independently in more than one importing nation, e.g., for mature products subject to intra-industry trade. As a rule of thumb, these results suggest that self-enforcing, technologically desirable international product standards can be achieved only if there is a clear leader, who develops a technology successfully and before anyone else has developed a competing standard. Under such a scenario, international product standards must go hand-in-hand with intellectual property rights.

We earlier considered the conditions under which the domestic and foreign coalition share the market. Having now shown that domestic coalitions will, under fairly general conditions, choose a

[12] This issue is studied further in section IIc.

technology more compatible with the original domestic technology than the international standard (i.e., $\alpha > \beta$), let us return to consider the effect of the preexisting domestic network size, q_0, on the division of the market between the two suppliers. Recalling the earlier expressions of consumer's willingness to pay for the new domestic technology and the international standard (relations 3 and 4, respectively), we can now derive conditions under which the domestic coalition will exclude imports in equilibrium.

The necessary condition[13] for the domestic coalition to supply the whole market is

$$[v(N) - v(N^*)] + [p^* - p] \geq 0 \tag{19}$$

In words, the price differential between the products using domestic and international standards must not exceed the sum of the benefits to consumers from a larger network externality. In long-run equilibrium under monopolistic competition, price equals average cost, implying $p=R(\alpha)/q$ and $p^*=0$ under our assumption of zero and constant marginal costs. Conditional on the optimal technology choice, $\alpha > \beta$ for $\beta \neq 1$, the lefthand side of (19) is then increasing in the installed base of the original domestic technology, q_0. In simpler terms, the more mature the domestic industry, as manifest in a larger established consumer base for its original technology, the more likely the domestic coalition can exclude foreign rivals in equilibrium.

Proposition 4: *The larger the established base of the original domestic technology, q_0, the larger the price markup the domestic coalition enjoys relative to the imported international standard, and the more likely it is to exclude the international standard from the domestic market in equilibrium.*

[13] The sufficient condition is simply a strict inequality.

The intuition of Proposition 4 runs as follows. The larger the population of established consumers of the original domestic technology, the greater the unit value to new consumers of a technology that is relatively more compatible to established consumer's technology than is the international standard. In equilibrium, the price falls to average fixed cost as new brands are introduced to increase supply until the domestic coalition fully controls the market. The core point is that product standardization enables traditional, price-based international competition. But the existence of technology redesign costs or network effects creates market frictions that diminish the incentive to standardize if there already exists a different technology in a reasonalby large market. This leads to multi-attribute competition between products and will, generally reduce trade flows.

An intriguing prospective extension of this model emerges from the case where there is no original domestic technology, so a start-up coalition with market power in a network good (i.e., a coalition given an exclusive concession by the government, but for which $q_0=0$) optimally chooses the international standard in order to take advantage of the broader international standard network. The innovation would then be to introduce learning-by-doing dynamics which could lead to the new coalition acquiring comparative advantage in this product. This stylized scenario seems to resemble many cases in East Asia in the 1950s and 1960s, where active government industrial policy went hand-in-hand with rapid adoption of foreign technology standards and trade expansion. Contrast this experience with that of several Latin American economies in which incumbent industries secured considerable tariff and regulatory protection against foreign technologies. Extensions of the present model might prove helpful in such comparative analysis.

C. Competing for Third Markets

One can also think of this model in a slightly different way, in which two distinct coalitions have independently captured their home markets, q_0 and q_0*, and are competing for the rest of the world market. In this scenario, our model can be reinterpreted to consider how home market size affects technology choice in the competition for third-country export markets in the presence of international standards. In particular, maintaining the assumption that the two standards coalitions are Cournot competitors for the third-country export market, the first-order condition for profit-maximizing technology choice, (18), yields the following comparative statics relationships via the implicit function theorem:

$$\frac{\partial\alpha}{\partial q_0} = \frac{-\hat{q}\left[v''(N)\left(q_0 + f'(\alpha-\beta)(\hat{q}^* + q_0^*)\right)^2 + v'(N)\right]}{\hat{q}\left[v''(N)\left(q_0 + f'(\alpha-\beta)(q^* + q_0^*)\right)^2 + \left(v'(N)f''(\alpha-\beta)(q^* + q_0^*)\right)\right] - R''(\alpha)} \tag{20}$$

$$\frac{\partial\alpha}{\partial q_0^*} = \frac{-\hat{q}\left[v''(N)\left(q_0 + f'(\alpha-\beta)(\hat{q}^* + q_0^*)\right)^2 + v'(N)f'(\alpha-\beta)\right]}{\hat{q}\left[v''(N)\left(q_0 + f'(\alpha-\beta)(q^* + q_0^*)\right)^2 + \left(v'(N)f''(\alpha-\beta)(q^* + q_0^*)\right)\right] - R''(\alpha)} \tag{21}$$

These expressions lead to a fifth, intuitive propostion, proof of which is in the Appendix.

Proposition 5: *If the international standard is not the original domestic technology standard, then so long as the market is not fully mature, the larger the established market in the international standard technology, the less the optimal deviation of the coalition's new technology from the international standard.*

As with earlier propositions, a large but not-yet-mature existing market induces increased compatability by the new technology because firms wish to take advantage of consumers' preference for access to a larger network in the international product standard.[14] Once the network is mature, however, the marginal value of increased compatibility goes to zero, so this effect exists only over a limited range. When the new international standard's established market is large, the optimal technology choice therefore approaches β, meaning that the optimal deviation from the international standard is weakly decreasing in the size of the established market for the international technology standard. Optimal deviations will be less from international standards that have well established markets than from those that are not yet well established.

III. Government Incentives: International Standards Or Regulatory Barriers To Trade?

The preceding model generates clear predictions regarding the incentives faced by the domestic coalition not to comply with the international product standard voluntarily. But a powerful government might be able to compel the coalition's compliance by regulatory fiat. Alternatively, an interventionist government might constrain the coalition's ability to modify the original technology by imposing regulatory product standards different from the international standard, in particular, the original technology.[15] A government that seeks to maximize consumer welfare would need to consider both the consumer surplus of new consumers who enter the market and any induced change

[14] While the effect on optimal technology choice of the international standard's installed base is unambiguous, the effect of the installed base of the original domestic technology, by contrast, turns on an unintuitive comparison between the slope and (scaled) curvature of the network externality function. Details are reported in the Appendix under the proof of Proposition 5.

[15] The government obviously has a *laissez faire* option which demands no analysis.

in the consumer surplus enjoyed by the established consumers who own the original technology but do not purchase the new technology.[16] The previous section explored the effects of the coalition's choice of technology, α, on firm incentives. Now we explore how a desire to maximize aggregate consumer surplus might influence the government's incentive to influence the coalition's technology choice.

The economic surplus enjoyed by a consumer joining a network depends on the network size and price, both of which are affected by the coalition's technology choice. By equation (7), a new consumer whose intrinsic valuation of the product, r, is greater than the hedonic price, ϕ, joins the network and derives a surplus of r + q + q* -A from joining a network with sales of Q=q+q*. Integrating over the A-Q consumers who enter the market yields aggregate new consumers' surplus

$$S_n = \int_{A-Q}^{A} (\tau + Q - A)\, d\tau = Q^2/2 \tag{22}$$

This is the first part of the consumer surplus about which the government is concerned.

The cohort of established consumers is the other group about which the government is concerned. Technology choice can affect established consumers in either of two ways. First, by changing the size of the network, it changes their valuation of the product they already own, bestowing gross welfare benefits on them for free. Second, a change in the network product technology may impose gross switching costs on established consumers. For example, not only would a population of consumers owning metric-sized mechanical equipment not derive network externality benefits from industry adoption of a completely incompatible English-sized parts

[16] Given that firm profits equal zero in monopolistic competitive equilibrium, consumer surplus represents full social welfare in this model.

technology standard ($\alpha=\beta=0$), they would suffer costs due to the added inconvenience of finding correct parts and tools. Similarly, owners of electronic equipment suddenly may have to check voltage compatibility when an alternative technology is introduced with different standards.[17]

The welfare effects of the technology choice on the subpopulation of q_0 established consumers can therefore be represented as

$$S_e = q_0\,[v(N) - v(q_0+\beta q_0^*) - SC(\alpha)] \tag{23}$$

where the difference between the first and second bracketed terms represents the increase in an established consumer's network externality benefits and the third term captures the gross switching costs incurred. $SC(\alpha)$ is assumed to be nonegative, with $SC'<0$ and $SC(1)=SC'(1)=0$. In words, established consumers' switching costs decrease with the degree of compatibility of the new technology with the original domestic technology they own, going to zero when the technology does not change.[18]

Aggregate consumer surplus in the economy is the sum of these two components, $S=S_n+S_e$. In order to see whether the government is inclined to support the international product standard, we evaluate the change in aggregate consumer surplus around the point $\alpha=\beta$.

$$\begin{aligned} \left.\frac{\partial S}{\partial \alpha}\right|_{\alpha=\beta} &= Q\frac{\partial Q}{\partial \alpha} + q_0\big[v'(N)q - SC'(\alpha)\big] \\ &= Q\big[q_0 v'(N) - R'(\alpha)\big] + q_0\big[v'(N)q - SC'(\alpha)\big] \\ &= q_0 v'(N)[2q + q*] - R'(\alpha)Q - SC'(\alpha)q_0 \;>\; 0 \end{aligned} \tag{24}$$

---

[17] Some of us who purchased laptop computers in the early 1990s when they were only manually-switchable between voltage regimes learned the hazards of partial compatibility the hard way. A jet-lagged traveller incurred large "failure to switch" costs if he plugged in a unit prematurely.

[18] Klemperer (1995) offers an excellent survey of the microeconomic literature on consumer behavior in the presence of switching costs.

Unless there is no installed base in the original domestic technology (q_0=0) – in which case consumer surplus is invariant with respect to α around the firm optimum of α=β=1 – then consumer surplus is increasing in α when evaluated in the neighborhood of α=β because the network externality function, v(N) is monotonically increasing in N, and because switching costs and redesign costs (and therefore equilibrium price) are monotonically decreasing in α. A government concerned about consumer welfare will therefore have an interest in maintaining compatibility with the original domestic technology quite apart from the incentives faced by private producers. This yields Proposition 6.

Proposition 6: *A government concerned exclusively about the welfare of domestic parties will not require compliance with the international product standard if there is already an established base of consumers of the original domestic technology.*

One final important finding emerges in the case where the product network is mature, so the marginal network externality benefit equals zero for either new or established consumers. In this case, when $v'(\bar{N})=0$,

$$\frac{\partial S}{\partial \alpha} = -R'(\alpha)Q - SC'(\alpha)q_0 > 0 \tag{25}$$

In the case of mature network technologies – e.g., right or left-hand-side drive vehicles, voltage standards in power grids, color television broadcasting specifications – because consumers have to pay for technological change, both directly through covering firms' redesign costs and indirectly through switching costs, consumer welfare is best served by strict compliance with the old technology. A consumer-minded government therefore has a strong incentive to impose regulatory barriers, including trade barriers, to ensure compliance with the old domestic technology standard. Hence our next proposition .

Proposition 7: *In the case of mature network products, government maximizes consumer surplus if it enforces compliance with the old domestic technology rather than permitting firms to alter the technology to increase compatibility with a different international standard.*

Propositions 6 and 7 are robust to most redefinitions of the means by which government determines policy since any political economy model based on votes or contributions that depend on domestic groups' welfare will generate an optimal policy choice of $\alpha>\beta$ unless $\beta=1$. An interventionist government will not compel compliance with the international product standard. Gandal and Shy (1996) study governement choice with respect to the recognition of foreign standards and find the desirability of recognition is inversely related to the conversion costs a coalition must incur to comply with a foreign standard, akin to our redesign costs, $R(\alpha)$. This paper shows similar results emerge from the consumer side: greater switching costs and lower additional network externality benefits for established consumers reduce the government's incentive to enforce an international product standard. The general inference drawn from both papers is that the greater the frictions in technology conversion — on either the consumer or producer side — the less likely is a government to recognize foreign product standards. This broad principle applies to a variety of standards, potentially including metric versus nonmetric measures, sanitary and phytosanitary standards on agricultural commodities, voltage and other electronics standards, etc. Indeed, a consumer-oriented or social welfare maximizing government would more likely consider introducing regulatory barriers to trade in an effort to resolve the private technology choice externality evident in relations (24) and (25).[19] This analytical result appears consistent with the casual observation that regulatory barriers to trade invariably arise from pressure by import-competing coalitions, consumer groups, or both (Hillman 1991, Thilmany and Barrett 1997).

Together, Propositions 3-7 raise serious questions about the international standards-setting process. Incumbent producers have little incentive to comply with an international product standard that deviates from their current technology, indeed they may be able to exclude foreign competitors from their home market by deviating. Meanwhile, a host nation government has no incentive to force the coalition to comply with the international standard. Indeed, it may even wish to restrict the coalition's ability to approach the international standard and, especially in the case of a mature technology, to compel compliance with the original technology. A government from a country that imports network products can thus credibly insist that prospective foreign suppliers conform to the preexisting domestic technology standard, else it will refuse to use regulatory powers to enforce the international product standard and might even, in the interests of consumer welfare, obstruct entry of the international standard. While there is only one importing country in our model, the suggestion is clear that if multiple standards exist, stalemates over *ex post* standardization and reciprocal regulatory barriers to trade would be likely. This seems consistent with experience to date.

[19] Such regulatory barriers may cause foreign coalitions to incur extra conversion, testing or certification costs in order to meet the differential standard, thus having an effect equivalent to a specific tariff. An unusual characteristic of this quasi-protectionism is that, as the present model shows, it might be desired by consumers more than by producers.

IV. Conclusions

There is widespread belief that harmonized international product standards promote trade and economic welfare globally. Considerable government and corporate human and financial resources are thus committed to the process of negotiating and enforcing international standards. However, the diversity of original technologies among potential trading coalitions and countries makes standards-setting a difficult process.

The simple model presented in this paper suggests that establishing an international standard that governments and private coalitions or firms will honor may be formidable for an important class of goods, those characterized by network externalities — for which compatibility is central to market performance — technology redesign costs, or consumer switching costs. First, if an importing country already has a significant network size under its original domestic technology, the domestic producer has an incentive to deviate from any international product standard that is not fully compatible with its own original technology. This clearly suggests a problem of path-dependence or lock-in effects, whereby a technology persists whether or not it is technically superior to other available technologies. Second, the consumer welfare maximizing government of an importing country has no incentive to force its producers to comply with the international standard. Indeed, the coalition's profit maximizing choice to deviate from the international product standard in the direction of the original domestic technology generates additional domestic consumer surplus because it reduces established consumers' switching costs and increases their added network externality benefits. Knowing this, governments from economies not possessing comparative advantage in a product (i.e., prospective importers) have incentives to credibly resist product standardization, thereby potentially frustrating multilateral efforts to negotiate technologically superior standards. Moreover, heterogeneity in standards gives rise to technical barriers to trade.

Our generally pessimistic conclusions about the prospects for global harmonization in network product standards should nonetheless be interpreted cautiously. Ours is a parsimonious model that does not include the dynamic evolution of international standards, uncertainty about emerging technologies, strategic interaction among the parties negotiating standards, or the potential for market power exercised by exporting coalitions. The rapidly advancing literature on networks suggests uncertainty and strategic interaction can be of considerable importance. It would also be fruitful to establish explicitly exporting coalitions' and governments' incentives to adopt international product standards. This paper neverheless offers an intruiging first look at the economics of international product standardization.

REFERENCES

Casella, Alessandra, “Product Standards Coalitions In A Market Without Borders,” NBER Working Paper 5853, December 1996.

Economides, Nicholas and Frederick Flyer, “Technical Standards Coalitions for Network Goods,” *Annales d’Economie et de Statistique*, 1998, 49/50, 361-380.

Farrell, Joseph and Garth Saloner, "Standardization and Variety," *Economics Letters*, 1986, 20, 71-74.

Gandal, Neil, "Competing Compatibility Standards And Network Externalities in The PC Software Market," *Review of Economics and Statistics*, November 1995, LXXVII, 599-608.

Gandal, Neil and Oz Shy, "Standardization Policy and International Trade," mimeo, 1996.

Hillman, Jimmye S., *Technical Barriers to Agricultural Trade*. Boulder, CO: Westview Press, 1991.

Jain, Subhash C., "Standardization of International Marketing Strategy: Some Research Hypotheses," *Journal of Marketing*, January 1989, 53, 70-9.

Katz, Michael L., and Carl Shapiro, "Network Externalities, Competition, and Compatibility," *American Economic Review*, June 1985, 75, 424-40.

Katz, Michael L. and Carl Shapiro, "Product Compatibility Choice in a Market with Technological Progress," *Oxford Economic Papers*, November 1986,

Katz, Michael L. and Carl Shapiro, "Systems Competition and Network Effects," *Journal of Economic Perspectives*, Spring 1994, 8, 93-115.

Kende, Michael, "Strategic Standardization in Trade with Network Externalities," mimeo, 1991.

Kindleberger, Charles, “Standards as Public, Collective and Private Goods,” *Kyklos*, 6, 377-396.

Klemperer, Paul, "Competition When Consumers Have Switching Costs: An Overview With Applications to Industrial Organization, Macroeconomics and International Trade," *Review of Economic Studies*, 1995, 62, 515-539.

Matutes, Carmen and Pierre Regibeau, "Mix and Match: Product Compatibility Without Network Externalities," *Rand Journal of Economics*, Summer 1988, 19, 221-234.

Matutes, Carmen and Pierre Regibeau, "A Selective Review of the Economics of Standardization: Entry Deterrence, Technological Progress and International Competition," *European Journal of Political Economy*, 1996, 12, 183-209.

Pargal, Sheoli, "Do Incompatible Network Standards Lead To Domestic Benefits? The Case of Color Television," *Information Economics and Policy*, 1996, 8, 205-227.

Shy, Oz, *Industrial Organization: Theory and Applications* (Cambridge: MIT Press, 1995).

Shy, Oz, "Technology Revolutions in the Presence of Network Externalities," *International Journal of Industrial Organization*, October 1996, 14, 785-800.

Sykes, Alan O., *Product Standards for Internationally integrated Goods Markets*, Washington: Brookings Institution, 1995.

Thilmany, Dawn D., and Christopher B. Barrett, "Regulatory Barriers In An Integrating World Food Market," *Review of Agricultural Economics*, Spring/Summer 1997, 19, 91-107.

U.S. House of Representatives Committee on Science, Space, and Technology, "International standardization: the federal role: Hearing before the Subcomittee on Science, Research, and Technology," Washington: Government Printing Office, 1989.

Wilson, John S., Standards and APEC; An Aciton Agenda, Washington: Institute for International Economics, 1995.

APPENDIX

Proof of Proposition 1

When evaluated around the point $\alpha=\beta$, $f'(\alpha-\beta) = 0$, and thus equation (16) becomes

$$\partial q/\partial\alpha = 2/3[v'(N)q_0 - R'(\alpha)] > 0 \qquad \text{(A1)}$$

But since $R'(\alpha)= 0$ only when $q_0=0$ or $\alpha=1$, then $\partial q/\partial\alpha^*{}_{\alpha=\beta\neq1} =0$ if and only if $q_0 = 0$.

Proof of Proposition 2

When $v'(\bar{N})=v'(\bar{N}^*)=0$, equation (16) reduces to

$$\frac{\partial q}{\partial\alpha} = -\frac{2}{3}R'(\alpha) \qquad \text{(A2)}$$

which is positive for all $\alpha <1$.

Proof of Proposition 3

There are two parts to the proof of this proposition.

(a) If $q_0=0$ and $\hat{q}>0$, then the left-hand side of (18) reduces to $\hat{q}\,[\,v'(N)\,f'(\hat{\alpha}-\beta)\,(\hat{q}^*+q_0^*)] - \partial\hat{q}^*/\partial\alpha$, for which the optimum obtains if and only if $\hat{\alpha}=\beta=1$.

[Note, (i) if $q_0=0$, then $v'(N)>0$, and (ii) the logic of Proposition 1 can be repeated to derive $\partial\hat{q}^*/\partial\alpha<0$.]

(b) If not $q_0=0$, then when equation (18) is evaluated around $\alpha=\beta$, it becomes

$$\frac{\partial\Pi}{\partial\alpha}\Big|_{\alpha=\beta} = q\left[v'(N)(q_0) - \frac{\partial\hat{q}^*}{\partial\alpha}\right] - R'(\alpha) > 0 \qquad \text{(A3)}$$

Hence the necessity of $\beta=1$ for $\hat{\alpha}=\beta$.

Proof of Proposition 4

Proposition 4 cannot be proved generally without imposing considerable, arbitrary structure on f(.) and v(.), but we can prove that it holds for both infant and mature technologies. Given that we are relying on a sequence of sufficient conditions, the unproven suggestion is that the relation holds more generally. Call the lefthand side of (19) Λ. Assume long-run equilibrium under monopolistic competition, i.e., $p^*-p = -R(\alpha)/q$. Then partial differentiation of Λ with respect to q_0 yields:

$$\partial\Lambda/\partial q_0 = (\alpha - \beta) + R(\alpha)/q^2 \cdot \partial q/\partial q_0$$

Since the term in parentheses is positive given the optimal technology choice ($\alpha>\beta$) and $R(\alpha)/q^2 \geq 0$, a sufficient condition for $\partial\Lambda/\partial q_0 > 0$ is

$$\partial q/\partial q_0 \geq 0$$

Comparative static analysis of (13) and (14) reveals that

$$\partial q/\partial q_0 = [2v'(N)\alpha - v'(N^*)\beta]/3$$

Without imposing specific functional forms on f() and v(.), this expression cannot be signed unambiguously. But the sufficient condition is satisfied at either end of the continuum relevant to v(.), i.e., for large or small q_0. For large q_0, or more precisely $\partial q/\partial q_0|_{q0=\bar{N}/\beta} = 0$, since both v'(N) and $v'(N^*)\rightarrow 0$. For small q_0, $\partial q/\partial q_0|_{q0=0} \geq 0$ if $q< q^* + q_0^*$. This can be seen by rearranging the righthand side above so that the sufficient condition is $v'(N)/v'(N^*) \geq \beta/(2\alpha)$, for which a sufficient condition is that $N<N^*$. Using (1) and (2), with $q_0=0$, we find that $q< q^* + q_0^*$ is a sufficient condition, i.e., if the installed base in the international standard technology is relatively large.

Proof of Proposition 5

The denominator is negative for both (20) and (21), regardless of network size. For a mature network, $\partial\alpha/\partial q_0 = \partial\alpha/\partial q^*_0 = 0$ since $v'(N^*) = v''(N^*) = 0$. So network size only matters in immature networks in which network size affects consumers' marginal valuation of the new product. For an immature network, and since we have already established that $\alpha>\beta$ for any $\beta\neq 1$, we restrict analysis to the only interesting region, when $\alpha>\beta$. Then, the numerator of (21) is always positive, so $\partial\alpha/\partial q^*_0 < 0$. The divergence of the new technology from the international standard is therefore (weakly) decreasing in the size of the installed base under the international standard.

No such unambiguous relation exists between α and q_0. The numerator of (20) is positive if and only if $v'(N) > | v''(N)[(q_0 + f'(\alpha-\beta)(q^*+q_0^*)]^2 |$.

September 1999

OTHER RECENT WORKING PAPERS OF THE
INTERNATIONAL AGRICULTURAL TRADE RESEARCH CONSORTIUM*

IATRC Working Paper	**TITLE:**	**Author(s):**
99-8	Distinguishing Between Equilibrium and Integration in Markets Analysis	Jau Rong Li Christopher B. Barrett
99-7	Competition Policy and International Agricultural Trade	Donald MacLaren Tim Josling
99-6	The Economics of TRQ Administration	David W. Skully
99-5	Regionalism and Trade in Agrifood Products	Crescenzo dell'Aquila Rakhal Sarker Karl D. Meilke
99-4	Is the WTO Still Relevant to the Global Economy?	Henryka Bochniarz
99-3	The Problems and Pitfalls in Modeling International Dairy Trade Liberalization	Karl Meilke Sylvain Larivière
99-2	Economic Costs of the U.S. Wheat Export Enhancement Program: Manna from Heaven or from Taxpayers?	Jeffrey M. Peterson Bartholomeus J. Minten Harry de Gorter
99-1	What is the Cause of Growth in Regional Trade: Trade Liberalization of RTA's? The Case of Agriculture	Xinshen Diao Terry Roe Agapi Somwaru
98-6	Import Rules for FMD Contaminated Beef	Philip L. Paarlberg John G. Lee
98-5	Modeling the U.S. Sweetner Sector: An Application to the Analysis of Policy Reform	Stephen L. Haley
98-4	Implementation of the WTO Agreement on the Application of Sanitary and Phytosanitary Measures: The First Two Years	Donna Roberts

*See the IATRC Web Site for a complete listing of all publications, programs and members addresses: **http://www.umn.edu/iatrc**