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Christopher B. Barrett and Yi-Nung Yang

ABSTRACT

This paper considers the private incentives of an import-competing firm and the social incentives of a technology-importing country to conform to an exogenous international standard for a product characterized by network externalities. We find that the domestic firm has an incentive to deviate from the international standard under fairly general conditions. Moreover, the social incentive of an importing country to deviate from the international standard is even greater than the private one, providing incentives to adopt and enforce technical barriers to trade. The results confirm the challenge lock-in effects pose to the international standard-setting process.

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

Key words: international standardization, network effects, technical barriers to trade
I. Introduction

Technical product standards are becoming key issues in government trade and technology policy and in corporate global business strategy. Sharp long-run reduction in average tariff levels, import quotas, and relative international communications and transport costs has 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 (Kende 1991, Sykes 1995, Thilmany and Barrett forthcoming). Internationally accepted product standards, on the other hand, can facilitate international trade and foreign direct investment 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, the incentives to achieve compatibility are especially pronounced (Katz and Shapiro 1985, 1994). Voltage standards for consumer electrical products are a clear example. Considerable effort is therefore being investigated currently in developing international standards through intergovernmental bodies such as the International Organization for Standardization (ISO), Codex Alimentarius (Codex) 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 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. Many

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1The authors are assistant professor and graduate student, respectively. Seniority of authorship is shared equally. We thank Dr. Terry Glover and Dr. Quinn Weninger for helpful comments and discussions. Dr. Barrett is the corresponding author and can be reached at email: cbarrett@b202.usu.edu, telephone: (435) 797-2306, or fax: (435) 797-2701. This work was supported by the Utah Agricultural Experiment Station and approved as journal paper 6010.
telephone systems cannot be linked by direct dialing, some nations use righthand-side-drive vehicles while others use lefthand-side-drive, automotive and machinery parts come in metric and non-metric sizes, railroad tracks and machinery exist in different gauges, and so on. Sometimes idiosyncratic standards become mandatory in a particular economy (e.g., righthand-side-drive vehicles) when governments convert voluntary standards into regulations. This is a primary source of technical barriers to trade, which appear to be increasing in both relative (to quotas and tariffs) and absolute terms (Sykes 1995, Thilmany and Barrett forthcoming).

This paper considers why an import-competing firm or an importing nation more generally might choose not to comply with international product standards. If maintaining incompatible standards is sometimes in the interest of important market participants, this has important implications for the likely success of efforts to design uniformly agreeable international standards. The modeling strategy we employ makes these findings especially relevant to industrializing nations that have a tradition of state-sanctioned monopoly in network industries (e.g., telecommunications, automobiles, electronics, utilities), but are now looking to open their economies to trade and foreign investment.

The literature on networks explains incompatibility 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 import-competing domestic firms and importing country
governments. 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.²

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, 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 the installed base of, and thus 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. Compliance with standards is voluntary and may or may not be formally promulgated by a private or public standard-setting entity. In some cases governments wish to enforce compliance with a standard by means of regulatory controls. Technical barriers to trade are

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a means by which national governments ensure all imported products are fully compatible with particular specifications.

This section presents a simple, static model of oligopoly in a domestic market 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 are compatible among products providing similar services.\(^3\) Partially compatible products (partially) contribute to each other’s installed network base, thereby influencing market equilibria.

The scenario we model runs as follows. A domestic monopolist offers a product with an original technology potentially incompatible with the newly established international technology standard, with which (at least some) foreign producers have long conformed. The potential differences between the two technologies are captured in a compatibility index, \(\beta\), 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 \(\beta \in (0,1)\). The domestic market is in equilibrium when a foreign firm enters the domestic market offering a product conforming to the international standard characterized by \(\beta\). The domestic firm responds by producing a new product evincing compatibility with its original technology as characterized by the index \(\alpha \in [0,1]\). The domestic firm’s new and original technologies are fully compatible if \(\alpha = 1\), they are totally incompatible if \(\alpha = 0\), and they are partially compatible if \(\alpha \in (0,1)\). At the same time, the domestic government decides whether to encourage or enforce the

\(^3\) For example, a software package might be able to access another application’s format although their other characteristics may be decidedly different (Gandal 1995).
international standard. What we find is that, save for unusual circumstances, neither the domestic firm nor the social welfare-maximizing government have an incentive to adopt the international product standard.

A. Consumer Behavior

Following Katz and Shapiro (1985), a 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 the consumer's 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 $v' > 0$, $v'' < 0$, and $\lim_{z \to \infty} v'(z) = 0$. The services provided by the technologies are viewed as homogenous by all consumers. The only differences are the expectations about the sum of weighted network sizes since the networks might not be perfectly compatible.

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 expected sales of each. Let $q_e$ and $q_e^*$ denote the expected sales of the domestic and foreign new products, respectively. The expected weighted average network size for those who want to buy the new domestic product is then described by

$$N_e = \alpha q_o + q_e + f(\alpha - \beta)(q_e^* + q_o^*)$$

where $q_o$ and $q_o^*$ are the preexisting domestic and worldwide network sizes, respectively, and $f(\alpha - \beta)$ is a concave index function with support $[0,1]$ that measures the compatibility deviation between the new domestic technology and the international standard. If $\alpha = \beta$, the two new technologies are fully
compatible with each other. Without loss of generality, assume \( f'(.) > 0 \) when \( \alpha - \beta < 0 \), \( f(\alpha - \beta) = 1 \) and \( f'(.) = 0 \) when \( \alpha = \beta \), and \( f'(.) < 0 \) when \( \alpha - \beta > 0 \). 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.

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

Each consumer maximizes his 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 technology is supplied competitively in the world market at a price \( p^* \). Letting \( p \) denote the price of the new domestic product, an agent who purchases the new domestic technology must have

\[
r + v(N_e) - SC(\alpha) - p \geq 0 \tag{3}
\]

where \( SC(\alpha) \) is the cost of switching from the original domestic technology to the new domestic technology. \( SC(\alpha) \) is assumed to be decreasing in \( \alpha \), i.e., the larger degree of compatibility with the original technology, the less switching cost accruing to the consumers. Symmetrically, any agent who purchases the new foreign product must have

\[
r + v(N_e^*) - SC^*(\beta) - p^* \geq 0 \tag{4}
\]

where \( SC^*(\beta) \) is the cost of switching from the original domestic technology to the international
standard. Those consumers whose reservation prices are less than either $p$ or $p^*$ stay out of the network market. Therefore, if $r + v(N_e) - SC(\alpha) - p > r + v(N_e^*) - SC^*(\beta) - p^*$ for all consumers, no one buys the imported international standard product. Analogously, no one buys the new domestic product if $r + v(N_e) - SC(\alpha) - p < r + v(N_e^*) - SC^*(\beta) - p^*$ for all consumers. Under those two limiting situations, the domestic market has a single provider, either the domestic firm or foreign producers.

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

$$r + v(N_e) - SC(\alpha) - p = r + v(N_e^*) - SC^*(\beta) - p^*$$

Equation (5) can be rearranged as follows

$$p - v(N_e) + SC(\alpha) = p^* - SC^*(\beta)$$

Equation (6) indicates that the expected hedonic prices must be equal if both firms have positive sales in the competitive domestic market. Let $\phi$ stand for the common value of the hedonic prices, i.e., $\phi = p - v(N_e) + SC(\alpha) = p^* - v(N_e^*) + SC^*(\beta)$. 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, $A - \phi$ consumers enter the product network. If the total sales of the products from two firms are $(q + q^*)$, then

$$A - \phi = q + q^*$$

Substituting for $\phi$ yields

$$A - (p - v(N_e) + SC(\alpha)) = q + q^*$$

Rearranging equation (8), we find that the domestic firm receives a price
\[ p = A + v(N_e) - SC(\alpha) - (q + q^*) \]  
(9)

Substituting instead \( p^* - v(N_e^*) + SC^*(\beta) \) for \( \phi \) in (7) and rearranging yields the imported quantity of the product conforming to the international standard

\[ q^* = A + v(N_e^*) - SC^*(\beta) - q - p^* \]  
(10)

B. The Import-Competing Firm’s Choice

Competitive foreign firms sell the product conforming to the predetermined international standard. They have no unilateral influence to change either the standard or the world market price. The domestic firm, on the other hand, chooses the degree of compatibility between its new and old products, \( \alpha \), and its output, \( q \), which influences the equilibrium price, \( p \), according to (9).

The domestic firm offers an upgraded product in response to market entry by foreign firms selling the international standard only if total revenue is larger than the sum of variable, redesign and other fixed costs. Without loss of generality, we assume the domestic firm’s redesign and other fixed costs have no influence at the margin. For simplicity, we also assume constant marginal cost of production and set it to zero. This simplification does not change the results of the model.

Given the international technology and the price of the product, the domestic firm maximizes profit based on consumer expectations of network size.

\[
\max_{\alpha, q} \Pi = q(A + v(N_e) - SC(\alpha) - (q + q^*))
\]  
(11)

Assume a fulfilled expectations Cournot equilibrium in which consumer’s expectations about the sizes of the two domestic market product networks are fulfilled in equilibrium, i.e., \((N_e, N_e^*) = (N, N^*)\) and \((q_e, q_e^*) = (q, q^*)\). The first-order conditions of the domestic firm’s profit maximization

\[ 4 \] 
Katz and Shapiro (1985) also demonstrate another case, in which consumers form expectations of network size after firms have selected their output level.
choice are thus

\[ \frac{\partial \Pi}{\partial \alpha} = q \left( v'(N) (q_0 + f'(\alpha - \beta) (q^* + q_0^*)) - SC'(\alpha) \right) = 0 \]  

(12)

\[ \frac{\partial \Pi}{\partial q} = (A + v(N) - SC(\alpha) - (q + q^*)) + q (v'(N) - 1) = 0 \]  

(13)

Since we will study the situation in which both firms have positive sales, \( q \) is positive and can be canceled out in equation (12). After rearranging terms, (12) becomes

\[ v'(N) q_0 - SC'(\alpha) + v'(N) f'(\alpha - \beta) (q^* + q_o^*) = 0 \]  

(14)

Equation (14) permits us to bound the firm’s choice of \( \alpha \), the parameter describing the compatibility of the domestic firm’s new and original technologies.

**Case I:** \( \alpha \leq \beta \)

If \( \alpha \leq \beta \), all terms in (14) are positive, implying that \( \partial \Pi / \partial \alpha > 0 \). This yields a corner solution, at which \( \hat{\alpha} = \beta \) is the firm’s optimal decision, where \( \hat{\alpha} \) denotes the optimal compatibility level (the \( \hat{\cdot} \) symbol is used to denote optimal values of choice variables).

**Case II:** \( \alpha > \beta \)

If \( \alpha > \beta \), then \( f'(\alpha - \beta) \) is negative. Assuming the second-order conditions are satisfied, there then exists an \( \hat{\alpha} \) that satisfies equation (14). Rearranging (14) yields

\[ v'(N) q_0 - SC'(\alpha) = -v'(N) f'(\alpha - \beta) (q^* + q_o^*) \]  

(15)

The first term on the left-hand side of (15) is the marginal value of the original network size, while the second term captures the marginal cost of switching from the original technology. The right-hand side of (15) can be interpreted as the marginal value of the international standard network size, adjusted by the marginal compatibility function \( f'(\cdot) \), which is negative when \( \alpha > \beta \).
The equilibrium condition in (15) shows that the firm equates the marginal value of the original technology's network size less the marginal switching cost with the marginal value of the international standard's network. The domestic firm is essentially balancing two distinct considerations. First, the greater the deviation from either the original domestic technology or the international standard, the smaller the firm's network size, thereby lowering its product's value to consumers. This is the attraction to compatibility highlighted in the literature on networks. But unless the original domestic technology conformed to the international product standard, one would intuitively expect the optimal new technology to be positioned somewhere between the two so as to maximize the new product's aggregate weighted network size. Second, greater deviation from the international standard (i.e., the closer the new domestic technology is to the old technology) gives the new domestic technology a price advantage over the imported product due to differences in the switching cost borne by potential consumers. Hence, there are potentially two reasons why the optimal technology choice, which is restricted to $\hat{\alpha} \in [\beta, 1]$, might diverge from the international product standard.

III. Private and Social Incentives to Adopt the International Product Standard

The preceding model generates clear predictions regarding the incentives faced by the domestic firm and the importing country as a whole to achieve compatibility with the international product standard. We characterize these in the following two propositions.

**Proposition 1:** Under the preceding assumptions, the domestic firm produces a good perfectly compatible with the international standard ($\hat{\alpha} = \beta$) if and only if (i) the international standard is coincidentally perfectly compatible with the domestic
original-technology ($\beta = 1$), or (ii) there was no preexisting domestic network ($q_0 = 0$).

This proposition’s proof runs as follows. If $q_0 = 0$, the first two terms in (14) equal zero and the firm’s optimal strategy is to set $f(\hat{\alpha} - \beta) = 0$, i.e., $\hat{\alpha} = \beta$. Meanwhile, since (14) rules out $\hat{\alpha} < \beta$, it must be that $\hat{\alpha} = \beta$ if $\beta = 1$; the corner solution of case I applies. Thus, the sufficiency of $q_0 = 0$ or $\beta = 1$ for $\hat{\alpha} = \beta$. Those conditions are also necessary because if $q_0 > 0$, (14) implies $\partial \Pi / \partial \alpha > 0$ for any $\alpha < \beta$, per case I above, and there exists an optimal solution $\hat{\alpha} > \beta$, as demonstrated in Case II. Thus only the corner solution of $\hat{\alpha} = \beta = 1$ would yield rational compatibility with the international product standard if there is positive installed base in the original domestic technology. Q.E.D.

This result indicates that a start-up firm with market power in a network good (i.e., a firm given an exclusive concession by the government, but for which $q_0 = 0$) will adopt the international standard, whatever it is, in order to take advantage of the broader international standard network. An established import-competing firm, however, will only conform to an international product standard that is itself perfectly compatible with the firm’s original technology. This is due to the twin considerations outlined earlier of maximizing network size by being compatible with both preexisting technologies and positioning the new technology between the old domestic technology and the international standard so as to secure a price advantage by reducing consumer switching costs.

We now consider the social welfare implications of the choice of $\hat{\alpha}$. The economic surplus enjoyed by a consumer joining a network depends on the network size. By equations (5) and (7), a consumer whose $r \geq \varphi$ derives a surplus of $r + q + q^* - A$ from joining a network with sales of
Q = q + q*. Only those whose r is greater than the hedonic price, \( \varphi = A - Q \), join a network. Integrating over all consumers who enter the market yields aggregate consumers’ surplus

\[
S = \int_{A-Q}^A (r + Q - A) dr = \frac{Q^2}{2}
\]

Let W denote the aggregate welfare in our fulfilled expectations Cournot equilibrium, i.e., the sum of producer and consumer surplus. Letting F denote the sum of redesign and other fixed costs,

\[
W = (\Pi - F) + S
\]

Suppose initially that \( \alpha = \beta \). The producer’s incentive to deviate from \( \beta \), evaluated around \( \alpha = \beta \) is

\[
\frac{\partial (\Pi - F)}{\partial \alpha} \bigg|_{\alpha = \beta} = \frac{\partial \Pi}{\partial \alpha} \bigg|_{\alpha = \beta} > 0
\]

as established earlier in case I of section II. Meanwhile, the change in consumers’ surplus with respect to \( \alpha \), evaluated in the neighborhood of \( \alpha = \beta \) is

\[
\frac{\partial S}{\partial \alpha} \bigg|_{\alpha = \beta} = \frac{\partial (Q^2/2)}{\partial \alpha} \bigg|_{\alpha = \beta} = \frac{Q \cdot \partial Q}{\partial \alpha} \bigg|_{\alpha = \beta}
\]

Using (1) and (8), equation (19) can be rewritten in the following form

\[
\frac{\partial S}{\partial \alpha} \bigg|_{\alpha = \beta} = Q \left[ v'(N) \bigg|_{\alpha = \beta} \left[ q_0 + f'(\alpha - \beta) \bigg|_{\alpha = \beta} (q^* + q_0^*) \right] - SC'(\alpha) \bigg|_{\alpha = \beta} \right] > 0
\]

Consumer surplus is increasing in \( \alpha \) when evaluated in the neighborhood of \( \alpha = \beta \) because the network externality function, \( v(N) \) is monotonically increasing in \( N \) and switching costs are

5 Since \( r - \varphi \geq 0 \), substitute \( \varphi \) from equation (7) to obtain this expression.

6 As long as F remains independent of the compatibility decision, \( \alpha \), it has no effect on the analysis.
monotonically decreasing in $\alpha$. This leads directly to a second proposition.

**Proposition 2:** *Under the preceding assumptions, the social incentive to deviate from the international product standard is greater than the private incentive.*

The proof of this proposition comes from combining (17), (18) and (20). Since the marginal change in welfare with respect to $\alpha$ equals the sum of the marginal changes in consumer and producer surplus with respect to $\alpha$, and since the former is positive by (20), it follows that

$$
\frac{\partial W}{\partial \alpha} \bigg|_{\alpha=\beta} > \frac{\partial \Pi}{\partial \alpha} \bigg|_{\alpha=\beta} \quad \text{Q.E.D.} \quad (21)
$$

Just as the domestic producer will generally choose not to introduce a new technology that is fully compatible with the international standard, unless $\beta=1$ or $q_o=0$, conformity with the international product standard, $\beta$, would likewise yield suboptimal social welfare in the importing country. A social welfare maximizing government recognizing this point might be predisposed to introduce technical barriers to trade in an effort to resolve the externality evident in (21).

Proposition 2 raises a serious challenge to the international standard-setting process. If an importing country government aims to maximize social welfare, it has no incentive to require domestic producers to conform (against their will, per Proposition 1) to the international standard. Indeed, the government has even greater incentives to deviate from the international standard than does the domestic firm. A government from a country that imports network products can 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 obstruct entry of the international standard for the sale of the consumer welfare. This obviously poses a serious challenge to the process of setting international product standards that will be honored globally.

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 firms and countries makes standards-setting a difficult process.

The simple model presented in this paper suggests the task may be harder than previously thought for an important class of goods, those characterized by network externalities, for which compatibility is central to market performance. 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 social welfare maximizing government of an importing country has no incentive to force its producer to comply with the international standard. Indeed, the firm’s profit maximizing choice to deviate from the international product standard generates additional domestic consumer surplus because it reduces consumers’ switching costs. 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 carefully. We employed 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 firms. 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 firms’ and governments’ incentives to adopt international product standards. This paper nevertheless offers an intriguing first look at the economics of international product standardization.
REFERENCES


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Some nations and firms nonetheless choose not to adopt international standards. Many telephone systems cannot be linked by direct dialing, some nations use righthand-side-drive vehicles while others use lefthand-side-drive, automotive and machinery parts come in metric and non-metric
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Sykes (1995) defines a product "standard" as a specification or set of specifications that relate to a product's attributes. Compliance with standards is voluntary and may or may not be formally promulgated by a private or public standard-setting entity. In some cases governments wish to enforce compliance with a standard by means of regulatory controls. Technical barriers to trade are a means by which national governments ensure all imported products are fully compatible with particular specifications.

¹ Sykes (1995) and Thilmany and Barrett (forthcoming) discuss the political economy of technical barriers to trade.
This section presents a simple, static model of oligopoly in a domestic market 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 are compatible among products providing similar services. Partially compatible products (partially) contribute to each other’s installed network base, thereby influencing market equilibria.

The scenario we model runs as follows. A domestic monopolist offers a product with an original technology potentially incompatible with the newly established international technology standard, with which (at least some) foreign producers have long conformed. The potential differences between the two technologies are captured in a compatibility index, $\beta$, 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 $\beta \in (0,1)$. The domestic market is in equilibrium when a foreign firm enters the domestic market offering a product conforming to the international standard characterized by $\beta$. The domestic firm responds by producing a new product evincing compatibility with its original technology as characterized by the index $\alpha \in [0,1]$. The domestic firm’s new and original technologies are fully compatible if $\alpha = 1$, they are totally incompatible if $\alpha = 0$, and they are partially compatible if $\alpha \in (0,1)$. At the same time, the domestic government decides whether to encourage or enforce the international standard. What we

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2 For example, a software package might be able to access another application’s format although their other characteristics may be decidedly different (Gandal, 1995).
find is that, save for unusual circumstances, neither the domestic firm nor the social welfare-maximizing government have an incentive to adopt the international product standard.

A. Consumer Behavior

Following Katz and Shapiro (1985), a 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 the consumer's 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 \( v' > 0 \), \( v'' < 0 \), and \( \lim_{z \to \infty} v'(z) = 0 \).

The services provided by the technologies are viewed as homogenous by all consumers. The only differences are the expectations about the sum of weighted network sizes since the networks might not be perfectly compatible.

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 expected sales of each. Let \( q_e \) and \( q_e^* \) denote the expected sales of the domestic and foreign new products, respectively. The expected weighted average network size for those who want to buy the new domestic product is then described by

\[
N_e = \alpha q_o + q_e + f(\alpha - \beta)(q_e^* + q_o^*)
\]  

(1)

where \( q_o \) and \( q_o^* \) are the preexisting domestic and worldwide network sizes, respectively, and \( f(\alpha - \beta) \) is a concave index function with support \([0,1]\) that measures the compatibility deviation between the new domestic technology and the international standard. If \( \alpha = \beta \), the two new technologies are fully
compatible with each other. Without loss of generality, assume \( f'(\cdot) > 0 \) when \( \alpha - \beta < 0 \), \( f(\alpha - \beta) = 1 \) and \( f'(\cdot) = 0 \) when \( \alpha = \beta \), and \( f'(\cdot) < 0 \) when \( \alpha - \beta > 0 \). 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.

\[
N_e^* = \beta q_o + f(\alpha - \beta)q_e + q_e^* + q_o^* \quad (2)
\]

Each consumer maximizes his 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 technology is supplied competitively in the world market at a price \( p^* \). Letting \( p \) denote the price of the new domestic product, an agent who purchases the new domestic technology must have

\[
r + v(N_e) - SC(\alpha) - p \geq 0 \quad (3)
\]

where \( SC(\alpha) \) is the cost of switching from the original domestic technology to the new domestic technology. \( SC(\alpha) \) is assumed to be decreasing in \( \alpha \), i.e., the larger degree of compatibility with the original technology, the less switching cost accruing to the consumers. Symmetrically, any agent who purchases the new foreign product must have

\[
r + v(N_e^*) - SC^*(\beta) - p^* \geq 0 \quad (4)
\]
where $SC^* (\beta)$ is the cost of switching from the original domestic technology to the international standard. Those consumers whose reservation prices are less than either $p$ or $p^*$ stay out of the network market. Therefore, if $r + v(N_e) - SC(\alpha) - p > r + v(N_e^*) - SC^* (\beta) - p^*$ for all consumers, no one buys the imported international standard product. Analogously, no one buys the new domestic product if $r + v(N_e) - SC(\alpha) - p < r + v(N_e^*) - SC^* (\beta) - p^*$ for all consumers. Under those two limiting situations, the domestic market has a single provider, either the domestic firm or foreign producers.

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

$$r + v(N_e) - SC(\alpha) - p = r + v(N_e^*) - SC^* (\beta) - p^*$$

Equation (5) can be rearranged as follows

$$p - v(N_e) + SC(\alpha) = p^* - SC^* (\beta)$$

Equation (6) indicates that the expected hedonic prices must be equal if both firms have positive sales in the competitive domestic market. Let $\phi$ stand for the common value of the hedonic prices, i.e., $\phi = p - v(N_e) + SC(\alpha) = p^* - v(N_e^*) + SC^* (\beta)$. 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 $\theta$ with density one, $A \cdot \phi$ consumers enter the product network. If the total sales of the products from two firms are $(q + q^*)$, then

$$A - \phi = q + q^*$$

Substituting for $\phi$ yields

$$A - (p - v(N_e) + SC(\alpha)) = q + q^*$$

Rearranging equation (8), we find that the domestic firm receives a price
\[ p = A + v(N_e) - SC(\alpha) - (q + q^*) \] (9)

Substituting instead \( p^* - v(N_e^*) + SC^*(\beta) \) for \( \phi \) in (7) and rearranging yields the imported quantity of the product conforming to the international standard

\[ q^* = A + v(N_e^*) - SC^*(\beta) - q - p^* \] (10)

**B. The Import-Competing Firm’s Choice**

Competitive foreign firms sell the product conforming to the predetermined international standard. They have no unilateral influence to change either the standard or the world market price. The domestic firm, on the other hand, chooses the degree of compatibility between its new and old products, \( \alpha \), and its output, \( q \), which influences the equilibrium price, \( p \), according to (9).

The domestic firm offers an upgraded product in response to market entry by foreign firms selling the international standard only if total revenue is larger than the sum of variable, redesign and other fixed costs. Without loss of generality, we assume the domestic firm’s redesign and other fixed costs have no influence at the margin. For simplicity, we also assume constant marginal cost of production and set it to zero. This simplification does not change the results of the model.

Given the international technology and the price of the product, the domestic firm maximizes profit based on consumer expectations of network size.

\[
\max_{\alpha, q} \Pi = q(A + v(N_e) - SC(\alpha) - (q + q^*))
\] (11)

Assume a fulfilled expectations Cournot equilibrium in which consumer’s expectations about the sizes of the two domestic market product networks are fulfilled in equilibrium, i.e., \( (N_e, N_e^*) = (N, N^*) \) and
The first order conditions of the domestic firm's profit maximization choice are thus

\[
\frac{\partial \Pi}{\partial \alpha} = q [v'(N)(q_0 + f'((\alpha - \beta)(q^* + q_0^*)) - SC'(\alpha))] = 0
\]  
(12)

\[
\frac{\partial \Pi}{\partial q} = (A + v(N) - SC(\alpha) - (q + q^*)) + q(v'(N) - 1) = 0
\]  
(13)

Since we are studying the situation in which both firms have positive sales, \(q\) is positive and can be canceled out in equation (12). After rearranging terms, (12) becomes

\[
v'(N) q_o - SC'(\alpha) + v'(N)f'((\alpha - \beta)(q^* + q_o^*)) = 0
\]  
(14)

Equation (14) permits us to bound the firm's choice of \(\alpha\), the parameter describing the compatibility of the domestic firm's new and original technologies.

**Case I: \(\alpha \leq \beta\).**

If \(\alpha \leq \beta\), all terms in (14) are positive, implying that \(\partial \Pi/\partial \alpha > 0\). This yields a corner solution, at which \(\hat{\alpha} = \beta\) is the firm's optimal decision, where \(\hat{\alpha}\) denotes the optimal compatibility level (the ^ symbol is used to denote optimal values of choice variables).

**Case II: \(\alpha > \beta\).**

If \(\alpha > \beta\), then \(f'(\alpha - \beta)\) is negative. Assuming the second order conditions are satisfied, there then exists an \(\hat{\alpha}\) that satisfies equation (14). Rearranging (14) yields

\[
v'(N) q_o - SC'(\alpha) = -v'(N)f'(\alpha - \beta)(q^* + q_o^*)
\]  
(15)

---

3 Katz and Shapiro (1985) also demonstrate another case, in which consumers form expectations of network size after firms have selected their output level.
The first term on the lefthand side of (15) is the marginal value of the original network size, while the second term captures the marginal cost of switching from the original technology. The righthand side of (15) can be interpreted as the marginal value of the international standard network size, adjusted by the marginal compatibility function $f(\cdot)$, which is negative when $\alpha>\beta$.

The equilibrium condition in (15) shows that the firm equates the marginal value of the original technology's network size less the marginal switching cost with the marginal value of the international standard's network. The domestic firm is essentially balancing two distinct considerations. First, the greater the deviation from either the original domestic technology or the international standard, the smaller the firm's network size, thereby lowering its product's value to consumers. This is the attraction to compatibility highlighted in the literature on networks. But unless the original domestic technology conformed to the international product standard, one would intuitively expect the optimal new technology to be positioned somewhere between the two so as to maximize the new product's aggregate weighted network size. Second, greater deviation from the international standard (i.e., the closer the new domestic technology is to the old technology) gives the new domestic technology a price advantage over the imported product due to differences in the switching cost borne by potential consumers. Hence there are potentially two reasons why the optimal technology choice, which is restricted to $\hat{\alpha} \in [\beta,1]$, might diverge from the international product standard.
III. Private and Social Incentives to Adopt the International Product Standard

The preceding model generates clear predictions regarding the incentives faced by the domestic firm and the importing country as a whole to achieve compatibility with the international product standard. We characterize these in the following two propositions.

**Proposition 1:** Under the preceding assumptions, the domestic firm produces a good perfectly compatible with the international standard ($\alpha = \beta$) if and only if (i) the international standard is coincidentally perfectly compatible with the domestic original-technology ($\beta = 1$), or (ii) there was no preexisting domestic network ($q_0 = 0$).

This proposition's proof runs as follows. If $q_0 = 0$, the first two terms in (14) equal zero and the firm's optimal strategy is to set $f(\alpha - \beta) = 0$, i.e., $\alpha = \beta$. Meanwhile, since (14) rules out $\alpha < \beta$, it must be that $\alpha = \beta$ if $\beta = 1$; the corner solution of case I applies. Thus the sufficiency of $q_0 = 0$ or $\beta = 1$ for $\alpha = \beta$. Those conditions are also necessary because if $q_0 > 0$, (14) implies $\partial II / \partial \alpha > 0$ for any $\alpha < \beta$, per case I above, and there exists an optimal solution $\alpha > \beta$, as demonstrated in Case II. Thus only the corner solution of $\alpha = \beta = 1$ would yield rational compatibility with the international product standard if there is positive installed base in the original domestic technology. Q.E.D.

This result indicates that a start-up firm with market power in a network good (i.e., a firm given an exclusive concession by the government, but for which $q_0 = 0$) will adopt the international standard, whatever it is, in order to take advantage of the broader international standard network. An established import-competing firm, however, will only conform to an international product standard that is itself perfectly compatible with the firm's original technology. This is due to the twin
considerations outlined earlier of maximizing network size by being compatible with both preexisting
technologies and positioning the new technology between the old domestic technology and the
international standard so as to secure a price advantage by reducing consumer switching costs.

We now consider the social welfare implications of the choice of \( \alpha \). The economic surplus
enjoyed by a consumer joining a network depends on the network size. By equations (5) and (7), a
consumer whose \( r > \phi \) derives a surplus of \( r + q + q^* - A \) from joining a network with sales of
\( Q = q + q^* \). Only those whose \( r \) is greater than the hedonic price, \( \phi = A - Q \), join a network. Integrating
over all consumers who enter the market yields aggregate consumers' surplus

\[
S = \int_{A-Q}^{A} (\tau + Q - A) d\tau = \frac{Q^2}{2}
\]

(16)

Let \( W \) denote the aggregate welfare in our fulfilled expectations Cournot equilibrium, i.e., the sum
of producer and consumer surplus. Letting \( F \) denote the sum of redesign and other fixed costs,

\[
W = (\Pi - F) + S
\]

(17)

Suppose initially that \( \alpha = \beta \). The producer's incentive to deviate from \( \beta \), evaluated around \( \alpha = \beta \) is

\[
\frac{\partial (\Pi - F)}{\partial \alpha} \bigg|_{\alpha = \beta} = \frac{\partial \Pi}{\partial \alpha} \bigg|_{\alpha = \beta} > 0
\]

(18)

as established earlier in case I of section II. Meanwhile, the change in consumers' surplus with respect
to \( \alpha \), evaluated in the neighborhood of \( \alpha = \beta \) is

\[
\frac{\partial S}{\partial \alpha} \bigg|_{\alpha = \beta} = \frac{\partial (Q^2 / 2)}{\partial \alpha} \bigg|_{\alpha = \beta} = Q \frac{\partial Q}{\partial \alpha} \bigg|_{\alpha = \beta}
\]

(19)

4 Since \( r - \phi > 0 \), substitute \( \phi \) from equation (7) to obtain this expression.

5 As long as \( F \) remains independent of the compatibility decision, \( \alpha \), it has no effect on the analysis.
Using (1) and (8), equation (19) can be rewritten in the following form

\[
\frac{\partial S}{\partial \alpha} \bigg|_{\alpha=\beta} = Q \left[ v'(N) \left|_{\alpha=\beta} \left( q_0 + f'(\alpha - \beta) \left( q^* + q_0^* \right) \right) - \text{SC}'(\alpha) \right|_{\alpha=\beta} \right] > 0 \tag{20}
\]

Consumer surplus is increasing in \( \alpha \) when evaluated in the neighborhood of \( \alpha=\beta \) because the network externality function, \( v(N) \) is monotonically increasing in \( N \) and switching costs are monotonically decreasing in \( \alpha \). This leads directly to a second proposition.

**Proposition 2:** Under the preceding assumptions, the social incentive to deviate from the international product standard is greater than the private incentive.

The proof of this proposition comes from combining (17), (18) and (20). Since the marginal change in welfare with respect to \( \alpha \) equals the sum of the marginal changes in consumer and producer surplus with respect to \( \alpha \), and since the former is positive by (20), it follows that

\[
\frac{\partial W}{\partial \alpha} \bigg|_{\alpha=\beta} > \frac{\partial \Pi}{\partial \alpha} \bigg|_{\alpha=\beta} \quad \text{Q.E.D.} \tag{21}
\]

Just as the domestic producer will generally choose not to introduce a new technology that is fully compatible with the international standard, unless \( \beta=1 \) or \( q_0=0 \), conformity with the international product standard, \( \beta \), would likewise yield suboptimal social welfare in the importing
country. A social welfare maximizing government recognizing this point might be predisposed to introduce technical barriers to trade in an effort to resolve the externality evident in (21).

Proposition 2 raises a serious challenge to the international standard-setting process. If an importing country government aims to maximize social welfare, it has no incentive to require domestic producers to conform (against their will, per Proposition 1) to the international standard. Indeed, the government has even greater incentives to deviate from the international standard than does the domestic firm. A government from a country that imports network products can 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 obstruct entry of the international standard for the sale of the consumer welfare. This obviously poses a serious challenge to the process of setting international product standards that will be honored globally.

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 firms and countries makes standards-setting a difficult process.

The simple model presented in this paper suggests the task may be harder than previously thought for an important class of goods, those characterized by network externalities, for which compatibility is central to market performance. 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 social welfare maximizing government of an importing country has no incentive to force its producer to comply with the international standard. Indeed, the firm’s profit maximizing choice to deviate from the international product standard generates additional domestic consumer surplus because it reduces consumers’ switching costs. 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 carefully. We employed 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 firms. 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 firms’ and governments’ incentives to adopt international product standards. This paper nevertheless offers an intriguing first look at the economics of international product standardization.
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