Standardization Policy and International Trade*
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Abstract

We analyze governments' incentives to recognize foreign standards when there are potentially both network effects and conversion costs. When government policy is limited to either recognizing all foreign standards or not recognizing any foreign standard, recognition is always the outcome.

We then consider a setting in which countries can form standardization unions. When conversion costs are relatively large, two countries can increase their welfare by forming a standardization union which does not recognize the standard of the third (nonmember) country. When network effects are significant, all countries mutually recognize all standards and have no incentives to form standardization unions.

Keywords: International Trade, Standardization Policy, Trade Policy, Network Effects

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1 Introduction

The trade policy literature has focused primarily on the strategic effects and welfare consequences of 'traditional' trade barriers such as tariffs, quotas, and VERs. The success of GATT in reducing these trade restrictions has been accompanied by an increase in less visible trade restrictions or nontariff barriers (NTBs) in which standardization policy is often used as a key instrument. The Uruguay Round of GATT left countries with the option of setting standards on safety and health grounds.[1] Our goal in this paper is to examine strategic aspects of governmental standardization policy and the welfare implications when products and standards are horizontally differentiated.

There are two phenomena associated with standardization:

- There are often"network effects." Direct network effects exist when the value of a product is increasing in the number of consumers that use compatible products. For example, the value of access to a telephone or e-mail network depends directly on the total number of consumers with similar access. Virtual network effects exist when the utility of consumers is increasing in the variety of complementary products available for a base product. Examples of virtual networks include consumer electronic durables such as video cassette recorders, compact disc players, and personal computers. In both cases (direct and virtual network effects), standardization provides consumption benefits by insuring that all consumers use compatible products.

  Network effects do not stop at international boundaries. In 1992, it was estimated that seventy-two percent of all new personal computers sold throughout the world were shipped with the MS-DOS operating system or a fully compatible operating system (such as PC-DOS); hence all of these computers could run applications software written for the MS-DOS operating system.[2]

- While network effects provide consumption benefits, requiring foreign firms to com-

ply with domestic standards may raise the costs of foreign producers.[3] Examples of strategic horizontal standards employed by "home" governments to raise the costs of foreign producers include the European experience with color television standards. As described by Crane (1979), European governments adopted different color television standards in order to protect the interests of domestic firms. In order to sell television sets in France, foreign manufacturers had to adapt (convert) the receivers to the SECAM standard.

Another case of "strategically raising the costs of foreign producers" involves the Israeli tea market. In 1984, the Standards Institution of Israel (SII) approved a standard that prohibited the use of (metal) staples in teabags. Nearly all tea producers in the world use staples to attach teabags to the string. The one significant exception is the Israeli tea producer Wittsotsky, which uses glue to attach the teabag to the string. For that reason the Israeli market was dominated by Wittsotsky until May 1996; at that time producers using staples were allowed to sell tea in Israel. Now, the supermarkets carry all brands of tea that are popular throughout the world.

In this paper we develop a framework to analyze governments' incentives to recognize foreign standards and to form standardization unions for the purpose of mutual standard recognition when there are potentially both network effects and conversion costs. We examine two cases: in the first case, we assume that the network effects are small relative to conversion costs. In this setting, when governments do not recognize foreign standards, foreign firms must incur a standard conversion cost in order to adhere to the local specification and be permitted to sell in the domestic country. In the second case, we assume the network effects are large relative to conversion costs.

In both cases, we first examine the (benchmark) setting in which government policy is limited to (i) either recognizing all foreign standards or (ii) not recognizing any foreign standards. We show that mutual recognition (which maximizes aggregate world welfare) is the

outcome in this case. We then enrich the model by allowing countries to join standardization unions. In a *Standardization Union*, member countries mutually recognize all standards of the goods produced in other member countries. If a standardization union is formed, the union sets a common standardization policy towards nonmember countries.

For the setting in which conversion costs dominate, we find that when the (standardization) conversion costs are relatively small, all countries mutually recognize all standards; they have no incentives to form standardization unions. When the conversion costs are relatively large, any two countries can increase their welfare by forming a standardization union which does not recognize the standard of the third (nonmember) country. Hence the possibility of forming standardization unions reduces aggregate world welfare.

In the setting in which network effects dominate, all countries always recognize all foreign standards and have no incentives to form standardization unions. The implication is that when network effects are large relative to conversion costs, standardization unions will be less likely to form.

1.1 Related Literature

The literature on standardization policy and international trade has primarily examined the effects of (i) imposing minimum quality (vertical) standards and (ii) compatibility standards. Recent contributions on the effect of imposing minimum quality standards include Barrett (1994), Boom (1995) and Lutz (1996). The latter two authors employ a model of vertical product differentiation to examine the effect of minimum quality standards. Barrett (1994) examines the incentives for governments to impose environmental protection standards on industries that compete in oligopolistic international markets. Casella (1996) reviews the literature on minimum quality (vertical) standards.

Kende (1991a) and Shy (1991) respectively consider the effect of compatible international standards on licensing and on the incentives for conducting R&D. Kende (1991b) shows that standardization increases a domestic firm's profits internationally because of the

increase in the product's gross utility. None of these papers examines governments' strategic standardization policies.

Jensen and Thursby (1996) examine strategic incentives for setting standards. In their paper, governments set standards in order to improve the chances of domestic firms in R&D competition. Our paper differs from theirs in that we focus on the effects of such policies on trade and examine how institutions such as standardization unions affect trade. An important difference is that we allow for positive consumption (network) effects as well as conversion costs.

Sykes (1995) verbally discusses (in a trade context) the "standardization" tradeoff that we examine between network effects and increased costs for foreign producers. Our papers are complements: given the (verbal) framework, Sykes cannot examine governments' strategic standardization policies.

Our setting significantly differs from tariffs when there are network effects; here, government policy directly affects the consumption value of the good as well as the price of the good, while in a tariff setting, government policy only affects the price of a good.[4] As we discussed above, network effects reduce the likelihood of standardization unions which divert trade and reduce world welfare.

1.2 A Road Map

Section 2 develops the basic three-country, three-firm, horizontal differentiation model and describes how governmental recognition policies affect firms and consumers. In Section 3 we restrict the model to the case where standard recognition does not have a direct effect on consumer welfare, i.e., there are no network effects. In this case, foreign firms must incur a conversion cost if their standard is not recognized. We first solve for equilibrium standardization policies under the assumption that countries act unilaterally. Section 3.2 formally defines Standardization Unions, and analyzes countries' incentives to participate in such organizations. Section 3.3 briefly investigates how different population sizes affect

countries' incentives to form standardization unions. Section 4 develops the polar model where standardization enhances consumer utility due to the positive network effects. In this case, we assume that conversion costs are negligible. Here, we repeat the analysis of section 3. Section 5 provides further discussion and conclusions.

2 A Three-Country Model

In this section, we develop a three-country, three-variety world economy model. We denote the three countries by α, β, and γ and the three varieties by 1, 2, and 3, where brand 1 is produced in country α, brand 2 in country β, and brand 3 by country γ. We index countries by $k = \alpha, \beta, \gamma$, and brands by $i, j, \ell \in \{1, 2, 3\}$. In the following subsections we describe the market in one *representative* country where all three firms are selling. We assume that the markets are segmented, so firms can charge different prices in different countries. The firms are assumed to be equally spaced on each country's circle (normalized to 3 units of distance), so the distance between any two firms equals exactly one unit of distance. (See Figure 1.)

2.1 Consumers

In each country k, $k = \alpha, \beta, \gamma$, there is a continuum of 3 consumers uniformly distributed on a circle. Thus, consumers are uniformly distributed with density 1.[5] The circle is illustrated in Figure 1.

INSERT FIGURE 1 ABOUT HERE

Each consumer has an inelastic (unitary) demand for the product. Let $s_1(x)$, $s_2(x)$, and $s_3(x)$ denote the shortest arc distance between an arbitrary consumer x and firms 1, 2, and 3, respectively, and let p_1, p_2, and p_3 be the price charged by each firm respectively.

Formally, the utility function of an arbitrary consumer x in country k, $k = \alpha, \beta, \gamma$ is given by[6]

$$U_x \equiv \begin{cases} V_1^k - p_1^k - [s_1(x)]^2 & \text{if he buys brand 1} \\ V_2^k - p_2^k - [s_2(x)]^2 & \text{if he buys brand 2} \\ V_3^k - p_3^k - [s_3(x)]^2 & \text{if he buys brand 3,} \end{cases} \quad (1)$$

where V_i^k is the utility from consuming brand i in country k; If there are no network effects, $V_i^k = V$ is the utility from each brand.

If there are network effects, the utility from brand i depends on how many other (foreign) brands are recognized in country k. If one foreign brand is recognized in country k, the utility from the consumption of one of these products (the domestic brand or the recognized foreign brand) is $V_i^k = V + d$, where d is the positive network effect. If both foreign brands are recognized in country k, the utility from the consumption of any one of the three products is $V_i^k = V + 2d$.

If there are network effects, recognition thus implies two-way compatibility. That is, if country k recognizes a brand, it insures that this brand is compatible with the home brand and vice-versa.[7] This increases the utility from both brands. Thus in the case of network effects, standard recognition policy confers a "positive" externality on the recognized brand(s).

$[s_i(x)]^2$ is the transportation cost associated with buying a brand which is located distance $s_i(x)$ from the consumer's 'ideal' brand.

2.2 Firms and Technology

We assume that production costs are identical for all brands and without loss of generality, we normalize these costs to zero. We assume that each country has an established standard and that the domestic product meets this standard. Thus, the firm located in country α produces brand 1 to operate on α's standard. Similarly, the firm located in country β produces good 2 to operate on β's standard, and so on.

If country β, for example, does not recognize any *foreign* standard, in the case of con-

version costs, foreign producers will have to incur conversion costs in order to adhere to the local standard and be permitted to sell their products in country β. We denote these unit conversation costs by c.[8] On the other hand, if the government of a particular country recognizes all standards, foreign producers need not incur the unit conversion cost in order to sell in the local market.

2.3 Timing of the game

The interaction takes place in stages. In the first stage, each government decides whether or not to recognize foreign standards. In the second stage, each firm sets profit maximizing prices in each country and consumers make purchases. We solve the game by backwards induction beginning with the second stage.

2.4 The second stage equilibrium

In this stage, government standardization policies are given. We assume that the conversion costs are not too large relative to transportation costs, that is $c < 5$. This ensures an equilibrium in which all three brands have positive market shares in each country in the benchmark case (in which countries are restricted to either recognizing all foreign standards or not recognizing any foreign standard);[9] hence we can solve for the equilibrium prices in a representative country.

Denote by x_i^k the market share of firm i, and by $x_{i,j}^k$ the location of a consumer who is indifferent between buying brands i and j, as measured from the location of firm i, in country k; see Figure 1. Each firm takes the prices of its rivals and government standardization policy as given and sets its price to maximize its profit in that country. The following three equations summarize equilibrium prices (p_i^k), market shares (x_i^k), and profits (π_i^k) of firm i in a representative country k in the second stage:

$$p_i^k = 1 + \frac{2V_i^k - V_j^k - V_\ell^k + 3c_i^k + c_j^k + c_\ell^k}{5}, \qquad i,j,\ell \in \{1,2,3\}, \;\; i \neq j \neq \ell \tag{2}$$

$$x_{i,j}^k = \frac{1}{2} + \frac{(V_i^k - V_j^k) - (c_i^k - c_j^k)}{5} \quad \text{and} \quad x_i^k = 1 + \frac{2V_i^k - V_j^k - V_\ell^k - 2c_i^k + c_j^k + c_\ell^k}{5} \tag{3}$$

$$\pi_i^k = \frac{(5 + 2V_i^k - V_j^k - V_\ell^k - 2c_i^k + c_j^k + c_\ell^k)^2}{25}, \quad i, j, \ell \in \{1, 2, 3\}, \quad i \neq j \neq \ell. \tag{4}$$

2.5 Illustration of the Two Cases

In this section, we illustrate the second stage equilibrium for our two cases: (i) the conversion cost case and (ii) the network effects case. In the conversion cost case, we assume (for simplicity) that there are no network effects ($d = 0$), so that $V_i = V$ for all brands. In the setting in which network effects dominate conversion costs, we assume (for simplicity) that there are no conversion costs ($c = 0$).

2.5.1 Conversion Cost Case[10]

In this case, the second stage equilibrium under recognition of all foreign standards is given by

$$p_i^k = 1, \quad x_i^k = 1 \quad \pi_i^k = 1, \tag{5}$$

while in the case in which foreign standards are not recognized in country k, the second stage equilibrium in country k (where i is the domestic firm) is

$$p_i^k = 1 + \frac{2c}{5}, \quad p_j^k = p_\ell^k = 1 + \frac{4c}{5}, \tag{6}$$

$$x_i^k = 1 + \frac{2c}{5}, \quad x_j^k = x_\ell^k = 1 - \frac{c}{5}, \tag{7}$$

$$\pi_i^k = \frac{(5 + 2c)^2}{25}, \quad \pi_j^k = \pi_\ell^k = \frac{(5 - c)^2}{25}. \tag{8}$$

2.5.2 Network Effects Case[11]

Recall that if country k does not recognize foreign brands, the "gross utility" of each brand sold in country k is $V^k = V$, while if all foreign brands are recognized, the gross utility from each brand is $V^k = V + 2d$. The symmetry means that in this case, the second stage equilibrium is the same regardless if all foreign standards are recognized or if all of the foreign standards are not recognized. The prices, market shares and profits are identical to the conversion cost case when all foreign standards are recognized. (See equation (5).)

This illustrates a key difference between the network effects and conversion cost cases. In the case of conversion costs, nonrecognition increases the market share and profits of the domestic firm and reduces the market share and profits of the foreign firms relative to the case in which foreign standards are recognized. In the network effects case, nonrecognition of foreign standards has no effect on prices, market shares, or profits.[12]

2.6 Welfare

In a given country, denote by E_i^k the total consumer expenditure on brand i, $i = 1, 2, 3$. $E_i^k = p_i^k x_i^k$, where p_i^k and x_i^k are from (2) and (3) respectively. Similarly, for each brand i, $i = 1, 2, 3$, the aggregate consumer transportation cost for brand i is given by

$$T_i^k = \left[\int_0^{x_{i,j}^k} y^2 dy + \int_0^{x_{i,\ell}^k} y^2 dy \right], \quad i, j, \ell \in \{1, 2, 3\}, \quad i \neq j \neq \ell. \tag{9}$$

Country k's aggregate consumer surplus is given by total gross utility less the sum of aggregate consumer expenditure on all brands and the aggregate economy's transportation cost. Formally, country k's **consumer surplus** is

$$CS^k \equiv V_1^k + V_2^k + V_3^k - (E_1^k + E_2^k + E_3^k + T_1^k + T_2^k + T_3^k), \quad k = \alpha, \beta, \gamma. \tag{10}$$

Let Π^i denote firm i's aggregate world-wide profit from selling the brand i in the three countries. That is, $\Pi_i = \pi_i^\alpha + \pi_i^\beta + \pi_i^\gamma$, where π_i^k is the profit earned by firm i from selling in country k as given in (4).

Hence, **total surplus** in country k, with domestic firm i is

$$TS^k \equiv CS^k + \Pi_k. \tag{11}$$

We assume that the objective of each government k is to maximize total surplus, that is the government of country k chooses its action to maximize (11).

3 Conversion Costs Case

3.1 Benchmark Equilibrium

In the benchmark case, each government k is restricted to choosing a strategy $a^k \in \{R, NR\}$, where R means recognizing *all* foreign standards, and NR means not recognizing any foreign standards. We define a world standardization outcome as the strategy triplet $(a^\alpha, a^\beta, a^\gamma)$. The second column of Table 1 provides the total surplus of country α under all possible standardization policies outcomes.[13]

$(a^\alpha, a^\beta, a^\gamma)$	α's Welfare$^{\text{Cost}}$ (TS^α)	α's Welfare$^{\text{Net}}(TS^\alpha)$
(R, R, R)	$3V - \frac{1}{4}$	$3(V+2d) - \frac{1}{4}$
(NR, R, R)	$3V + \frac{(24c^2 - 120c - 25)}{100}$	$3V - \frac{1}{4}$
(R, NR, NR)	$3V + \frac{(8c^2 - 80c - 25)}{100}$	$3(V+2d) - \frac{1}{4}$
(NR, NR, NR)	$3V + \frac{(32c^2 - 200c - 25)}{100}$	$3V - \frac{1}{4}$
(R, R, NR)	$3V + \frac{(4c^2 - 40c - 25)}{100}$	$3(V+2d) - \frac{1}{4}$
(NR, NR, R)	$3V + \frac{(28c^2 - 160c - 25)}{100}$	$3V - \frac{1}{4}$

Table 1: Country α's total surplus under all possible standardization policy outcomes.

We can state the following proposition:

Proposition 1 *When governments' strategies are restricted to either fully recognizing all foreign standards, or to not recognizing any foreign standard, then recognizing foreign standards (strategy R) is a dominant strategy for each government.*[14]

Proof. From second column of Table 1, $TS^{\alpha}(R, a^{\beta}, a^{\gamma}) > TS^{\alpha}(NR, a^{\beta}, a^{\gamma})$ for all given $a^{\beta}, a^{\gamma} \in \{R, NR\}$ if and only if $c < 5$, which holds by assumption. ■

3.1.1 Intuition for Benchmark Equilibrium

The intuition for Proposition 1 is as follows: Under the assumed constant returns to scale production technologies, the standardization policy of each government does not affect the profit of domestic firms from *foreign sales*. That is, nonrecognition only enhances the domestic sales of the domestic firm by raising the costs of foreign brands. Section 2.5 showed that this increases the equilibrium market share, price and profits of the domestic firm, relative to the case in which foreign standards are certified. This effect increases domestic welfare. However, there are two effects associated with nonrecognition that reduce domestic welfare:

- Relative to recognition, the domestic and foreign firms charge higher prices under nonrecognition. Hence total consumer expenditure is higher under nonrecognition.
- The economy's aggregate transportation costs increase relative to recognition; this is because the policy of nonrecognition leads to asymmetric equilibrium prices, which results in unequal market shares.

Proposition 1 shows that the two effects that reduce welfare dominate the profit effect, that is, total surplus is higher under recognition. Hence, the mutual recognition outcome $(a^{\alpha}, a^{\beta}, a^{\gamma}) = (R, R, R)$ constitutes an equilibrium in dominant strategies. Note that the mutual recognition outcome (R, R, R) Pareto dominates the nonrecognition outcome (*NR, NR, NR*) because nonrecognition imposes an unnecessary resource (conversion) cost on the world economy.

3.2 Common Markets and Standardization Policies

Here we show that under certain conditions, welfare maximizing countries can gain relative to the mutual recognition equilibrium (Proposition 1) by forming standardization unions that mutually recognize member countries' standards while not recognizing the standards of nonmember countries.

We denote by $a^k = R^{k',\neg k''}$ a strategy where the government of country k recognizes the standard of country k' but *does not* recognizes the standard of country k''. Similar to the concept of a *customs union*, we introduce the following terminology:

DEFINITION 1 *A* ***Standardization Union (SU)*** *exists if member countries mutually recognize all standards of the goods produced in other member countries and agree on a common policy towards the recognition or nonrecognition of the standards of nonmember countries. Formally, a* ***standardization union*** *is a set of countries, $SU \subseteq \{\alpha, \beta, \gamma\}$ such that for all $k, k' \in SU$ and $k'' \notin SU$,*

$$\textit{either } \left[a^k = R^{k',\neg k''} \textit{ and } a^{k'} = R^{k,\neg k''}\right], \quad \textit{or} \quad \left[a^k = R^{k',k''} \textit{ and } a^{k'} = R^{k,k''}\right].$$

Thus, if $SU = \{\alpha, \beta, \gamma\}$ for example, then all countries mutually recognize all countries' standards [i.e., (R, R, R) in Table 1]. If $SU = \{\alpha, \beta\}$ for example, then either they do not recognize country γ ($a^\alpha = R^{\beta,\neg\gamma}$, $a^\beta = R^{\alpha,\neg\gamma}$) or, they do recognize γ ($a^\alpha = R^{\beta,\gamma}$, $a^\beta = R^{\alpha,\gamma}$); where country γ forms a single-country union thereby either recognizing countries α and β or not. Finally, if each country does not join with any country to form a union, each country is considered a single-country union which either recognizes other countries or not. There are two cases to consider:

3.2.1 Standardization Policies Do not Lead to Foreclosure $c < 5/2$

Suppose that conversion costs are not too large, i.e., $c < 5/2$. In this case, the total surplus for country α when countries α and β form a SU and neither recognizes country γ is shown

in the second column of Table 2. The second column of Table 3 shows the surplus received by country γ under a standardization union. From the second column of Tables 2 and 3, we can state the following proposition regarding the formation of standardization unions.[15]

Proposition 2 *In the setting in which countries may form standardization unions, we obtain the following results:*

1. *When the conversion costs are small, so that $c < 5/4$, mutual standard recognition among all countries yields higher total surplus to each country than the surplus obtained by each country under a (two country) standardization union.*

2. *When the conversion costs are moderate, so that $5/4 \leq c \leq 5/2$, the total surplus to each country in a standardization union is greater than the surplus that the country would receive in the absence of a union. (Recall from Proposition 1 that in the absence of a union, all foreign standards are recognized.)*

3. *Whenever a standardization union is formed, the excluded country's total surplus is highest when it recognizes all standards.*

Proof. Clearly, by Proposition 1, we can restrict our welfare comparison to the mutual recognition outcome *(R, R, R)*. Tables 2 and 3 imply that

$$TS^{\alpha}(R^{\beta,\neg\gamma}, R^{\alpha,\neg\gamma}, R) > (\leq)\ \ TS^{\alpha}(R,R,R) \quad \text{if } \ c > (\leq)\frac{5}{4}.$$

The last part follows from the second column of Table 3. ■

3.2.2 Standardization Policies Leading to Foreclosure: $5/2 < c < 5$

We now turn to analyzing governments' policies when the conversion costs are relatively large. In Appendix B, we show that when conversion costs are large so that $5/2 < c < 5$, a standardization union would result in the foreclosure of the nonmember country. Using this result, we can state the following proposition, which is proved in Appendix C.

$(a^\alpha, a^\beta, a^\gamma)$	α's Welfare$^{\text{Cost}}$ (TS^α)	γ's Welfare$^{\text{Net}}$ (TS^α)
$(R^{\beta,\neg\gamma}, R^{\alpha,\neg\gamma}, NR)$	$3V + \frac{(16c^2 - 60c - 25)}{100}$	$3V + \frac{(16d^2 + 280d)}{100} - \frac{1}{4}$
$(R^{\beta,\neg\gamma}, R^{\alpha,\neg\gamma}, R)$	$3V + \frac{(16c^2 - 20c - 25)}{100}$	$3V + \frac{(16d^2 + 280d)}{100} - \frac{1}{4}$

Table 2: Total Surplus for SU member Country α.

$(a^\alpha, a^\beta, a^\gamma)$	γ's Welfare$^{\text{Cost}}$ (TS^α)	γ's Welfare$^{\text{Net}}$ (TS^γ)
$(R^{\beta,\neg\gamma}, R^{\alpha,\neg\gamma}, NR)$	$3V + \frac{(56c^2 - 280c - 25)}{100}$	$3V + \frac{(32d^2 - 160d)}{100} - \frac{1}{4}$
$(R^{\beta,\neg\gamma}, R^{\alpha,\neg\gamma}, R)$	$3V + \frac{(32c^2 - 160c - 25)}{100}$	$3(V + 2d) + \frac{(32d^2 - 160d)}{100} - \frac{1}{4}$

Table 3: Total surplus for the nonmember country γ.

Proposition 3 *When conversion costs are large so that* $5/2 < c < 5$, *total surplus to a union country under a (two country) standardization union is higher than the surplus it would obtain under mutual recognition.*

3.2.3 Intuition for Standardization Union Results

The intuition behind Propositions 2 and 3 is as follows. A standardization union is established for the purpose of increasing the market shares of member countries' firms (in member countries' markets) at the expense of the firm in the nonmember country. These propositions demonstrate that union formation (that excludes the third country) is preferred by member countries over the world mutual recognition outcome when the conversion costs are moderate or large. (Proposition 2 addresses the case when conversion costs are moderate so that a firm from a nonmember country will still have sales in "union" countries; Proposition 3 addresses the case when conversion costs are large, so that a firm from the nommember country will not have any sales in member countries.) Under these conditions, the increase in the profits of the domestic firm in the market of the *other member country* dominates the reduction in

domestic consumer surplus associated with nonrecognition of the standard of the nonmember firm. That is, under moderate or high conversion costs, a standardization union yields higher surplus for a member country than it would obtain under mutual recognition.

Although union formation between two countries increases the welfare of member countries at the expense of the firm of the third (excluded) country, the excluded country maximizes total surplus by recognizing all foreign brands.[16]

Recall that in the absence of a standardization union, all countries adhere to mutual recognition. Hence world welfare is reduced by the ability of countries to form standardization unions when conversion costs are moderate or large.

3.3 Country Size and Standardization Unions

In the previous sections we investigated the incentives for two countries to mutually recognize each other's standards. We showed that in the setting in which all countries are of the same size, any two countries will have an incentive to reach an agreement to mutually recognize standards (and exclude a third country) whenever the conversion costs are moderate or large. The obvious follow-up question is how country size affects the incentives of countries to form standardization unions.

Due to the symmetry of firms' location, consumers in country α are unaffected by whether the country forms a SU with country β or country γ. Hence, we merely need to check the profit of firm 1 under two alternative standardization unions.[17]

In this section, we assume that consumers are uniformly distributed with a density of n^k per country, $k = \alpha, \beta, \gamma$. When (i) country α signs a SU with country β, (ii) the standardization union does not recognize the standard of the nonmember country, and (iii) country γ fully recognizes all countries, equation (4) implies that the total profit of firm 1 from selling in countries α, β, and γ is given by

$$\pi_1^{\alpha+\beta,\neg\gamma} = \frac{n^\alpha (c+5)^2}{25} + \frac{n^\beta (c+5)^2}{25} + n^\gamma.$$

Similarly, when the union is between countries α and γ

$$\pi_1^{\alpha+\gamma,\neg\beta} = \frac{n^\alpha (c+5)^2}{25} + \frac{n^\gamma (c+5)^2}{25} + n^\beta.$$

Hence,

$$\pi_1^{\alpha+\beta,\neg\gamma} \geq \pi_1^{\alpha+\gamma,\neg\beta} \quad \text{if and only if} \quad n^\beta > n^\gamma.$$

The SU enhances the profit of the domestic firm in the foreign member country; this profit enhancement increases with the population size of the other member country. Therefore, the largest country gains more by forming a standardization union with the second largest country than it does by forming a standardization union with the smallest country. Similarly, the second largest country gains more by forming a standardization union with the largest country than it gains by forming a standardization union with the smallest country.

Thus the union with the two largest counties leads to the biggest increase in members' surplus relative to the case of no union formation. Perhaps it not surprising then that the U.S. and the European Union (two large blocks) recently reached a pact in which they will "accept each other's industrial and regulatory standards for sectors as varied as telecommunications equipment and pharmaceutical." It is estimated that the pact will save companies \$172 Million a year and significantly increase trade.[18]

4 Network Effects Case

In this case, we assume that there are relatively large network effects and that conversion costs are negligible, i.e., $c = 0$. If country k does not recognize foreign brands, the "gross utility" of each brand sold in country k is $V^k = V$. Recall that if a single foreign brand is recognized, the gross utility of the home and the recognized brand are $V + d$ for each brand, $d > 0$. In such a case, the gross utility from the nonrecognized brand is V. If all foreign brands are recognized, the gross utility from each brand is $V^k = V + 2d$.

4.1 Standardization policies without unions

From the analysis in section 2.5, $p_i^k = 1$ and $\pi_i^k = 1$; hence $\Pi_k = 3$. Total consumer expenditure in country k is $E^k = 3$. Total transportation expenditure in country k is $T^k = 6 \times \int_0^{1/2} y^2 dy = 1/4$. Altogether, total surplus of country k, $k \in \{\alpha, \beta, \gamma\}$ is

$$TS^k = 3V^k + \pi^k - E^k - T^k = 3V^k - \frac{1}{4}. \tag{12}$$

In similar fashion, we calculate the total surplus under all possible outcomes in the benchmark case. Total surplus for each case is displayed in the third column of Table 1.

In the case in which governments' strategies are restricted to either fully recognizing all foreign standards or not recognizing any foreign standard, we can state the following proposition, which follows immediately from Table 1.

Proposition 4 *When governments' strategies are restricted to either fully recognizing all foreign standards, or to not recognizing any foreign standard, recognizing foreign standards (strategy R) is a dominant strategy for each government.*

Section 2.5, showed that recognition of all foreign standards had no effect on prices, market shares or profits of the firms. Hence, the only difference between recognition and non-recognition of foreign standards is the effect on consumer surplus. When there are network effects, consumer welfare is increased by recognition, since recognition implies compatibility between brands. Hence, the result in proposition 4 follows immediately.

Note that the incentive for recognition in this case is even stronger than in the case in which there are conversion costs. In that case, nonrecognition led to benefits for domestic firms. In the case of network effects, this domestic firm effect is not present.

4.2 Standardization Policies When a Union Can Form

Now assume that it is possible to form a standardization union. We first calculate the total surplus of a country who is a member in the union between country α and β. In each member

country, a member country's brand is valued by $V + d$ whereas country γ's brand is valued by V only. Because of the linear network benefit function, the regions which define whether a standardization union forecloses the nonrecognized brand are identical to those identified in sections 3.2.1 and 3.2.2.

4.2.1 Standardization Policies do not Lead to Foreclosure: $d < 5/2$.

The total surplus of a country in the union is shown in the third column of Table 2, while, the total surplus of the outside country is shown in the third column of Table 3. Note that a union country receives the same total surplus regardless if the outside country recognizes foreign standards. This is because under two-way compatibility, the profits of the union firm in the excluded country are unaffected by the policy adopted in the third country. The following proposition follows immediately from the third columns of Tables 2 and 3.

Proposition 5 *When the network benefits are moderate so that $d < 5/2$, mutual standard recognition among all countries always yields higher total surplus to each country than the surplus obtained by each country under a (two country) standardization union.*

4.2.2 Standardization Policies Leading to Foreclosure: $5/2 < d < 5$.

Despite the fact that a standardization union would result in the foreclosure of the non-member country when the network effects are large, it is easy to show that mutual standard recognition among all countries yields higher total surplus to each country than the surplus obtained by a union country under a (two country) standardization union.

4.2.3 Intuition for nonformation of standardization unions in the presence of network effects.

In the case when conversion costs are moderate or large, Propositions 2 and 3 show that countries will form exclusionary standardization unions. In contrast, sections 4.2.1 and 4.2.2

show that when there are network effects and no conversion costs, mutual recognition always leads to higher domestic surplus than an exclusionary standardization union.

In both the network effect and conversion cost cases, a standardization union resulting in foreclosure increases the profits of the firms based in the member countries. However, the presence of network effects means that nonrecognition of the brand of the nonmember country results in a direct loss of consumption benefits as well as an increase in transportation costs. For this reason, there is no incentive to form exclusionary standardization unions when there are network effects.

5 Conclusion

Our analysis focused on government standardization policies in the presence of (i) conversion costs and (ii) network effects. In the case in which there are conversion costs but no network effects, it is profitable for two of the countries to form a union when the conversion costs are moderate or large. The formation of a standardization union will cause some consumers in member countries to switch from the third country's brand to a brand produced by a member country. Hence, if a union if formed, trade between member countries will increase, whereas trade between members and the nonmember will decrease. Thus, in Viner's terminology, the formation of a SU will cause *trade diversion*, and therefore will reduce aggregate world welfare, since with the absence of the SU, countries will choose to mutually recognize all standards.[19]

In the case in which there are positive network effects, and no conversion costs, standardization unions will not form in our framework. In the more realistic setting in which there are both conversion costs and network effects, the welfare costs/benefits of a standardization union will depend on the relative magnitudes of the two effects. Hence our results suggest that strong network effects will reduce the likelihood of standardization unions which divert trade and reduce world welfare.

Finally, we should point out that standardization unions are not necessarily welfare reducing. In an earlier version of this paper, we showed that when standardization conversion costs are extremely large, so that nonrecognition of foreign brands leads to the foreclosure of all foreign products, union formation will create trade (between the union countries). Thus in some instances, allowing for a discriminatory standardization policy (a standardization union) will be a step in the right direction.

Appendix

A Proof of equilibrium in section 2.4

Consider an arbitrary economy, k ($k = \alpha, \beta, \gamma$) with population size 3 located on an 3-unit-circumference circle, where each firm produces a single brand and located one unit of distance from each other. Figure 1 illustrates such an economy.

We now solve for the general model assuming that for any possible standardization policy enacted by all governments, in equilibrium, each firm has a strictly positive market share in all countries.

Given prices for the three brands, the consumer who is indifferent between purchasing brand 1 and brand 2 must satisfy

$$V^k - p_1^k - (x_{1,2}^k)^2 = V^k - p_2^k - (1 - x_{1,2}^k)^2$$

implying that

$$x_{1,2}^k = \frac{1}{2} + \frac{p_2^k - p_1^k}{2}. \tag{13}$$

Similarly,

$$x_{3,1}^k = \frac{1}{2} + \frac{p_1^k - p_3^k}{2}.$$

In each country k, firm 1 takes all prices charged by other firms as given and chooses p_1^k that solves

$$\max_{p_1^k} \pi_1^k = (p_1^k - c_1^k)\left(x_{1,2}^k + 1 - x_{3,1}^k\right) = (p_1^k - c_1^k)\left(1 + \frac{p_2^k + p_3^k - 2p_1^k}{2}\right)$$

yielding first order condition given by

$$p_1^k = \frac{1}{2} + \frac{p_2^k + p_3^k + 2c_1^k}{4} \tag{14}$$

We can now generalize (14) for any firm i:

$$p_i = \frac{1}{2} + \frac{p_j^k + p_\ell^k}{4}, \quad i, j, \ell \in \{1, 2, 3\},\ i \neq j \neq \ell. \tag{15}$$

Solving the three equations given in (15) yields

$$p_i^k = 1 + \frac{3c_i^k + c_j^k + c_\ell^k}{5}, \quad i, j, \ell \in \{1, 2, 3\},\ i \neq j \neq \ell. \tag{16}$$

Substituting the expressions for p_i^k and x_i^k into the expression for profits yields equilibrium profits

$$\pi_i^k = \frac{(5 - 2c_i^k + c_j^k + c_\ell^k)^2}{25}, \quad i, j, \ell \in \{1, 2, 3\},\ \ i \neq j \neq \ell. \tag{17}$$

■

B Proof of the foreclosure result in section 3.2.2

Assume that countries α and β form a SU. Let us concentrate on country α only. We now show that $p_1 = p_2 = 3/2$ and $p_3 = c$ constitute a unique Bertrand-Nash equilibrium where firm 3 is foreclosed.

To see why firm 3 does not sell even when it charges $p_3 = c$ note that the for a consumer whose ideal brand is 3, the utility from purchasing from firm 1 is $V - p_1 - 1$, while the utility from purchasing from firm 3 is $V - c$. When $p_1 = 3/2$, the former utility is higher whenever $c > 5/2$. Hence, even the consumer most oriented towards brand 3 would prefer buying brand 1 or 2 rather than brand 3.

We now show that the above prices constitute a unique Bertrand-Nash equilibrium when only firms 1 and 2 sell in this market. In view of Figure 1, firms 1 and 2 are separated by an

arc with length one and arc of length two. On the "shorter" arc, the market size of firm 1, given in (13), is

$$x_{1,2}^S = \frac{1 + p_2 - p_1}{2}.$$

Similarly, its market share on the "longer" arc is

$$x_{1,2}^L = \frac{2 + p_2 - p_1}{2}.$$

Thus firm 1 chooses p_1 to maximize $p_1(x_{1,2}^S + x_{1,2}^L)$. Performing a similar maximization for firm 2 yields the equilibrium prices $p_1 = p_2 = 3/2$. ■

C Proof of Proposition 3

Under the SU, the profit of firm 1 from selling in α and β is given by $\pi_1^\alpha + \pi_1^\beta = 2[3/2 \times 3/2] = 9/2$. By (4), in the nonunion country, $\pi_1^\gamma = 1$, since in the third country, all standards are recognized. Aggregate consumer expenditure is $E^\alpha = 3(3/2) = 9/2$. Under the standardization union, aggregate transportation costs in a union country are $T^\alpha = 3/4$.[20] Hence total surplus to country α under a standardization union is $3V + 1/4$; total surplus under recognition (the equilibrium when it is not possible to form a standardization union) is $3V - 1/4$. ■

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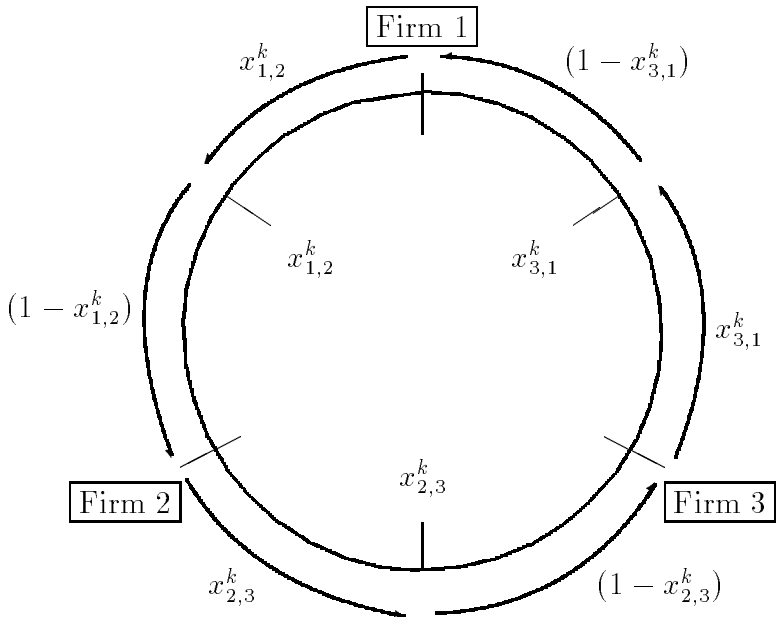

Figure 1: Salop's circular country

Notes

[1]See *Business America,* Vol 115: 22-23, January 1994.

[2]See Baseman, Warren-Boulton, and Woroch (1995) and the references cited within.

[3]As Jensen and Thursby (1996) note, the National Competitive Act of 1993 and Congressional studies emphasize the importance of strategically using standards to help U.S. firms which are in direct competition with foreign ones.

[4]Our setting is identical to one in which tariffs are applied only when there are no network effects. In the case of tariffs, the government also collects revenues, but this is a second-order consideration.

[5]In section 3.3, we relax the equal population assumption.

[6]We assume that V^k is large enough so that each consumer makes a purchase.

[7]For example, this might involve requiring a domestic software producer to allow a foreign firm to engage in beta testing to insure that its product is indeed compatible with the domestic brand.

[8]Our results would be qualitatively unchanged if the conversion costs are incurred as fixed rather than marginal costs. When the fixed conversion costs are small, free trade prevails and when the fixed conversion costs are large, there is no international trade.

[9]When conversion costs are very large, so that $c > 5$, in the benchmark case the equilibrium is foreclosure, i.e., a country does not recognize foreign standards. See the conclusion for further discussion.

[10]See section 3 for the full analysis of the conversion cost case.

[11]See section 4 for the full analysis of the network effects case.

[12]Of course, there is an effect on consumer welfare as we discuss in section 4.

[13]The third column of Table 1 refers to the network effects case in section 4.

[14]Obviously, political pressures of domestic firms may affect the objective function that the government maximizes. If a government puts sufficient weight on the profits of the domestic firm, it would be a dominant strategy for governments not to recognize foreign standards even in this case. Since we are interested in how standardization unions affect the benchmark case, it is not necessary to examine differential weights on profits and welfare.

[15]Note again that the third columns of Tables 2 and 3 refer to the network effects case.

[16]This conforms to the well known result in trade theory that small countries generally gain from not imposing any trade restrictions.

[17]We showed that the nonmember country will always recognize the standards of the member countries.

[18]Wall Street Journal Europe, May 29, 1997, p.2.

[19]Viner (1950) defines trade diversion as situation in which a country switches from low-cost foreign sources to high-cost foreign sources. His welfare loss is due to the deadweight loss from lower consumption. In our setting, all brands are produced with the same unit cost (zero); trade diversion occurs when nonrecognition leads consumers to "switch" to a recognized brand, thereby increasing the aggregate transportation (distaste) cost.

[20]Note that under foreclosure, the formula for transportation costs in (9) is no longer valid.