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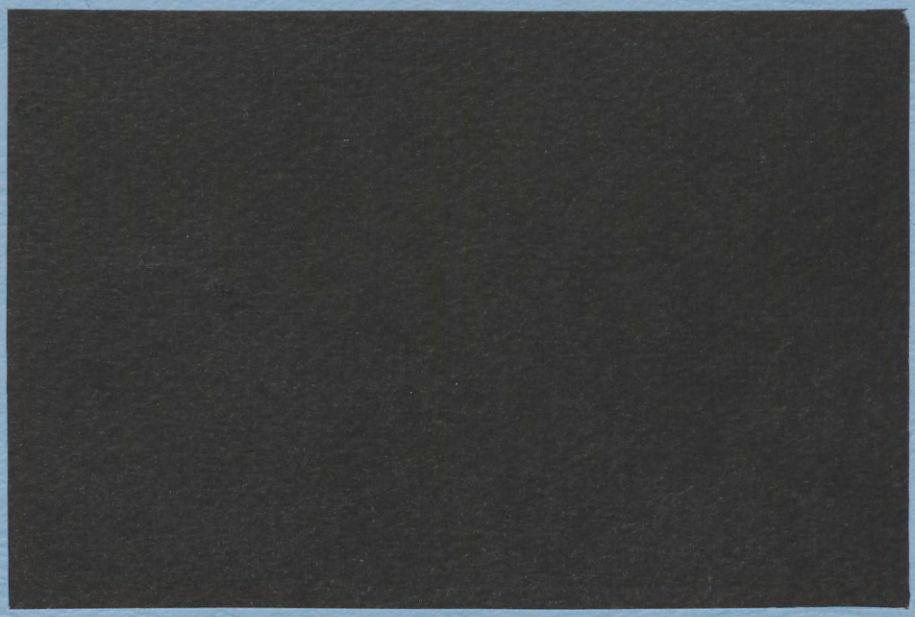
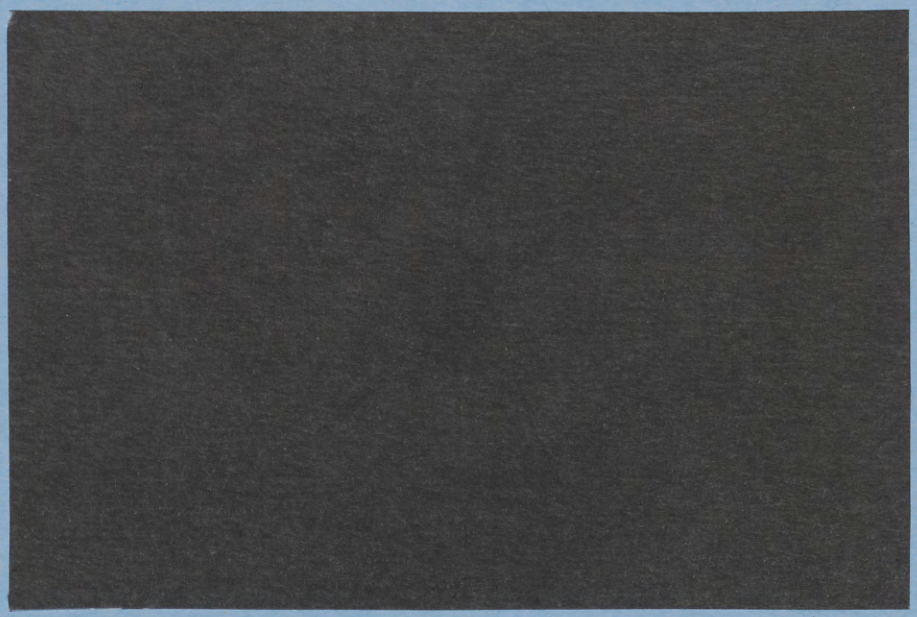


Tel Aviv University

The Eitan Berglas School of Economics

מכון סאקלר לכלכלה

הפקולטה למדעי החברה אוניברסיטת תל-אביב



The Sackler Institute for Economic Studies

Founded by Raymond R. Sackler, M,D, and Mortimer D. Sackler, M.D.

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STANDARDIZATION POLICY AND INTERNATIONAL TRADE

by

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ABSTRACT

In this paper we examine the incentives for governments to recognize the standards of foreign products. In the case of non-recognition, a foreign firm must incur an additional cost to sell in the local market. In the benchmark case, we assume that governmental policy is limited to either (1) recognizing all foreign standards or (2) not recognizing any standards. We then enrich the model and investigate whether countries can gain by forming blocks (standardization unions) which entail mutual standard recognition among member countries.

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.[1] The success of GATT in reducing these trade restrictions has been accompanied by an increase in less visible trade restrictions or non-tariff 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.[2]

In a recent document, the European Commission, asserted that because the U.S. typically does not recognize foreign standards, EC companies wishing to sell in the U.S. often have to unnecessarily incur extra costs in order to meet the U.S. standards.[3] Additionally, foreign manufacturers wishing to sell in the U.S. also must meet standard requirements of state and local governments; these typically exceed the U.S. Federal requirements. For example, in the case of telecommunications equipment in the U.S., the formal requirements (as set out by the U.S. Federal Communications Commission) are limited to "no harm to the network." Two major U.S. Cities (Chicago and Los Angeles) require that equipment be produced according Underwriter Laboratories (UL) Standards and that UL test and certify the equipment. Such practices are also common in other countries.[4]

Our goal in this paper is to examine strategic aspects of governmental standardization policy and the welfare implications when standards are horizontally differentiated. We develop a three-country, three-variety world economy model and analyze governments' incentives to recognize foreign standards and to form standardization unions for the purpose of mutual standard recognition. We assume that when governments do not recognize foreign

[1] See Corden (1984) for a summary of this research.

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

[3] A U.S. Congressional Research Service (1989) document notes that of the approximately 89,000 standards recognized in the U.S., only 17 were adopted directly from the international standard organizations.

[4] In the case of Israel, all telecommunications equipment must be tested and certified by the Ministry of Communications.

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.[5] On the other hand, if the local government recognizes all standards, foreign producers need not incur the conversion cost in order to sell in the local market.

In the basic (benchmark) case, we assume that government policy is limited to (1) either recognizing all foreign standards or (2) not recognizing any foreign standards. We then enrich the model by allowing firms 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. We obtain the following results:

- When the standardization conversion costs are relatively small, mutual recognition is the unique equilibrium, that is, no standardization union is formed; this outcome maximizes world welfare.

- When the standardization conversion costs fall in a moderate range, mutual recognition is the unique equilibrium in the benchmark case when standardization unions are prohibited. When standardization unions are allowed to form, two countries will form a standardization union and not recognize the standard of the third (non-member) country. Here, relative to the benchmark case, the formation of a standardization union reduces aggregate world welfare.

- When the standardization conversion costs are very large, nonrecognition is the unique equilibrium in the benchmark case. Here, nonrecognition leads to foreclosure; there is no international trade. When standardization unions are allowed to form, two countries form a standardization union and do not recognize the standard of the third (non-member) country. In this case, union formation creates trade and is welfare improving.

[5]The model also applies to certification and testing costs; Recall the discussion of telecommunications equipment imported into the U.S..

The literature on standardization policy and international trade has primarily examined the effects of imposing minimum quality standards. More recent contributions include Lutz (1993) and Boom (1995). Both authors employ a model of vertically differentiated product differentiation to examine the effect of minimum quality standards. In a related setting, Barrett (1994) examines the incentives for governments to impose environmental protection standards on industries that compete in oligopolistic international markets. Casella (1994) provides a review of the literature on standards and trades. In her survey, standards are also vertically differentiated. In our setting, standards are horizontally rather than vertically differentiated.

1.1 Organization of the Paper

Since our analysis investigates the incentives for mutual standard recognition, in the remainder of this section we briefly discuss international standards organizations and the European Community's (EC's) mutual standardization policy. Section 2 develops the basic three-country, three-firm product, horizontal differentiation model and describes how governmental certification policies affect firms and consumers. Section 3 solves for equilibrium standardization policies under the assumption that countries act unilaterally. Section 4 formally defines Standardization Unions, and analyzes countries' incentives to participate in such organizations. In sections 3 and 4, we assume that the conversion costs are small enough so that in equilibrium, all three brands are sold in each country regardless of the standardization policies enacted by the governments. Section 5 analyzes the case where the standard-conversion costs are relatively high; in such a case, not recognizing foreign standards leads to the exclusion of foreign firms from domestic markets. Section 6 briefly investigates how different population sizes affect countries' incentives to form standardization unions. Section 7 provides brief conclusions.

1.2 International standardization

At the international level, membership in international standards organizations such as the International Organization for Standards (ISO) and the International Electrotechnical Commission (IEC) is open to all countries of the world. Their main task is to elaborate and publish standards and to harmonize standards of members. However, ISO/IEC members are not obliged to implement international standards as national standards. Every member can freely decide whether it wishes to recognize the international standard directly, i.e., to accept it as a national standard, or to develop its own national standard. In our setting, each country independently chooses whether to recognize foreign standards.

1.3 Harmonization of technical standards within the EC

The 1957 Treaty of Rome was intended to create a single market across the European countries. Article 30 prohibited not only quantitative restrictions on imports but also *all* measures having an *equivalent* effects. Although a customs union was established very quickly and significant progress made with respect to the free movement of goods, physical and technical barriers continued to exist which prevented the creation of a genuine single market. Indeed, Article 36 of the Treaty permits prohibition or restrictions on the movement of goods based on health and safety concerns.

Up until 1985, the Community (using the so called 'old approach') removed technical barriers by harmonizing technical product specifications.[6] This approach became more difficult to employ since it fixed technical specifications without taking account of the diversity of production methods and consumers' preferences for variety.

In 1985, the Commission adopted a *new approach* to technical harmonization and standards.[7] Under the new policy the manufacturer may freely choose how to meet the essential requirements (EC directives). To assist in the process, the Commission issued mandates to European

[6] "A New Community Standards Policy," *Commission of the European Communities,* 4, January 1993.
[7] Council Resolution of 7 May 1985, *Official Journal of the European Communities,* No. C 136/1.

Standardization bodies (CEN, CENELEC, and ETSI) to develop voluntary standards which meet the essential requirements. In this paper, we examine the incentives for countries to agree to "mutual recognition" of standards. Our standardization unions play a role similar to that of the European Standardization bodies.

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 $i, j, l \in \{1, 2, 3\}$. In the following subsections we describe the market in one *representative* country where all three firms are selling.

2.1 Consumers

In each country k, $k = \alpha, \beta, \gamma$, there is a continuum of $3n^k$, $n^k > 0$, consumers uniformly distributed on a circle; we normalize the circumference to three (3) units of distance. Thus, consumers are uniformly distributed with density n^k. The circle is illustrated in Figure 1.

Each consumer has an inelastic (unitary) demand for the product. Let $d_1(x)$, $d_2(x)$, and $d_3(x)$ 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 is given by[8]

$$U_x \equiv \begin{cases} V - p_1 - \tau d_1(x) & \text{if he buys brand 1} \\ V - p_2 - \tau d_2(x) & \text{if he buys brand 2} \\ V - p_3 - \tau d_3(x) & \text{if he buys brand 3,} \end{cases} \tag{1}$$

where V is the utility common to all varieties, and τ measures the per unit transportation cost associated with buying a brand which is located distance $d_i(x)$ from the consumer's

[8]The inelastic unitary demand implies that V is large enough so that each consumer makes a purchase. In the welfare calculations we leave V out, since it would be the same for each regime.

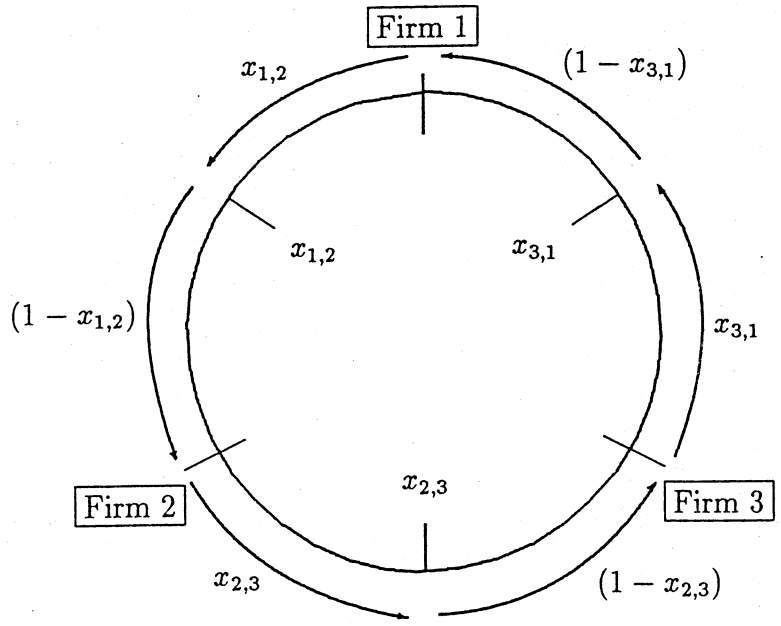

Figure 1: Salop's circular country

'ideal' brand.

2.2 Firms and technology

In each country there is a single firm producing a single brand. Brand 1 is produced in country α, brand 2 in country β, and brand 3 in country γ. The firms are assumed to be equally spaced on each country's circle, so the distance between any two firms equals exactly one unit of distance. (See Figure 1.)

We assume that production costs are identical for all brands and without loss of generality, we normalize these costs to zero. The specifications (standards) of each product are different, that is, all products have different standards that may or may not be recognized by other countries.

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, decides to recognize the standard employed by the domestic producer only, foreign producers will have to incur standard conversion costs in order to adhere to the local standard and be permitted to sell their products in country β. On the other hand, if the government of a particular country recognizes all standards, foreign producers need not incur the conversion cost in order to sell in the local market.

We denote the unit conversion cost for brand i by c_i, $i = 1, 2, 3$, where

$$c_i \equiv \begin{cases} c & \text{if standard } i \text{ is not recognized in country } k, \ (c > 0) \\ 0 & \text{if standard } i \text{ is recognized in country } k. \end{cases} \tag{2}$$

In the basic model, we assume that the conversion costs are not too large relative to transportation costs. This ensures an equilibrium where all three brands are sold in each country exists for all possible standard recognition policies enacted by governments: Formally,

ASSUMPTION 1 $c \leq 15\tau/7$.

In section 5, we examine the case in which the standardization (conversion) costs are high; in such a case, nonrecognition excludes foreign brands from the domestic market.

Finally, we assume that national markets are fully segmented so that no arbitrage takes place. This assumption implies that firms can set different prices in different countries.

2.3 Timing of the game

The interaction takes place in stages. In the first stage, each country decides whether or not to recognize all 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. The assumption that $c \leq 15\tau/7$ implies that all firms will have positive market shares in each country in equilibrium; hence we can solve for the equilibrium prices in a representative country. Denote by x_i the market share of firm i, and by $x_{i,j}$ the location of a consumer who is indifferent between buying brands i and j, as measured from the location of firm i, 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 proposition is proved in Appendix A:

Lemma 1 *Equilibrium prices (p_i), market shares (x_i), and profits (π_i) of firm i in a representative country k are:*

$$p_i = \tau + \frac{3c_i + c_j + c_l}{5}, \quad i,j,l \in \{1,2,3\}, \ i \neq j \neq l \tag{3}$$

$$x_{i,j} = \frac{1}{2} + \frac{c_j - c_i}{5\tau} \quad \textit{and} \quad x_i = 1 + \frac{-2c_i + c_j + c_l}{5\tau} \tag{4}$$

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

2.5 Welfare

In a given country, denote by E_i the total consumer expenditure on brand i, $i = 1,2,3$. Then, by (3) and (4) we have that

$$E_i \equiv n^k p_i x_i = n^k \left[\tau + \frac{c_j + c_l + 3c_i}{5}\right]\left[1 + \frac{c_j + c_l - 2c_i}{5\tau}\right] \ i,j,l \in \{1,2,3\}, \ i \neq j \neq l. \tag{6}$$

Similarly, for each brand i, $i = 1,2,3$, the aggregate consumer transportation cost for brand i is given by

$$T_i = n^k \frac{\tau}{2}\left[\frac{1}{2} + \frac{c_j - c_i}{5\tau}\right]^2 + n^k \frac{\tau}{2}\left[\frac{1}{2} + \frac{c_l - c_i}{5\tau}\right]^2, \quad i,j,l \in \{1,2,3\}, \quad i \neq j \neq l.^9 \tag{7}$$

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** (up to a constant) is

$$CS^k \equiv -(E_1^k + E_2^k + E_3^k + T_1^k + T_2^k + T_3^k), \quad k = \alpha, \beta, \gamma, \tag{8}$$

where E_i^k is defined in (6) and T_i^k in (7).

Let Π_i denote firm i's aggregate world-wide profit from selling 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 (5).

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

$$TS^k \equiv CS^k + \Pi_i. \tag{9}$$

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 (9).

3 Equilibrium Standardization Policies: Benchmark Case

In the benchmark case, each government k is restricted to choosing an action $a^k \in \{R, NR\}$, where R means recognizing *all* foreign standards, and NR means not recognizing foreign

[9] To derive this expression, note from figure 1 that to the left of firm 1 the average distance traveled to firm 1 is $x_{1,2}/2$, whereas the average distance traveled by the consumers located to the right of firm 1 is $(1 - x_{3,1})/2$. Hence, using (4), the aggregate transportation cost for brand 1 is given by

$$T_1 \equiv n^k \left[\frac{\tau(x_{1,2})^2}{2} + \frac{\tau(1 - x_{3,1})^2}{2}\right] = n^k \frac{\tau}{2}\left[\frac{1}{2} + \frac{c_2 - c_1}{5\tau}\right]^2 + n^k \frac{\tau}{2}\left[\frac{1}{2} + \frac{c_3 - c_1}{5\tau}\right]^2.$$

standards.[10] We define a world standardization outcome as the strategy triplet $(a^\alpha, a^\beta, a^\gamma)$. In sections 3–5, we assume that the population in each country is identical, i.e., $n^k = n$ for $k = \alpha, \beta, \gamma$. In section 6, we relax the equal population assumption.

Table 1 provides the total surplus of country α under all possible standardization policies outcomes.[11]

$(a^\alpha, a^\beta, a^\gamma)$	α's Welfare (TS^α)
(R, R, R)	$\frac{-3n}{4}$
(NR, R, R)	$\frac{3n(8c^2 - 40c\tau - 25\tau^2)}{100\tau}$
(R, NR, NR)	$\frac{n(8c^2 - 80c\tau - 75\tau^2)}{100\tau}$
(NR, NR, NR)	$\frac{n(32c^2 - 200c\tau - 75\tau^2)}{100\tau}$
(R, R, NR)	$\frac{n(4c^2 - 40c\tau - 75\tau^2)}{100\tau}$
(NR, NR, R)	$\frac{n(28c^2 - 160c\tau - 75\tau^2)}{100\tau}$

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

We can state the following proposition:

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

Proof. From 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 $c < 5\tau$, which is true by Assumption 1. ■

[10] Section 4 allows each country the option of recognizing one foreign standard, but not recognizing another foreign standard by forming standardization unions.

[11] Recall that we do not include the gross utility $(3nV)$ that is common to all standardization regimes.

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 profit of domestic firms from foreign sales. That is, nonrecognition only enhances the profit of the domestic firm by raising the costs of foreign brands. Lemma 1 shows that this increases the equilibrium market share, price and profits of the domestic firm, relative to the case in which are standards are certified. However, from Lemma 1, there are two effects associated with nonrecognition that reduce 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 the recognition; this is because the policy of nonrecognition leads to asymmetric equilibrium prices, which results in unequal market shares.

Proposition 1 shows that these latter two effects dominate, 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 actions. Note that the mutual recognition outcome (R, R, R) Pareto dominates the nonrecognition outcome (*NR, NR, NR*). However, such an equilibrium is not always observed. Indeed, in section 5, we'll see that when the conversion costs are relatively large, the equilibrium outcome is nonrecognition.[12]

4 Common Markets and Standardization Policies

In this section, 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 stan-

[12]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.

dards of nonmember countries. 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. A standardization union sets a common standardization policy towards nonmember countries.*

Thus, in this section we enlarge the strategy set of each government to include the possibility of recognizing the standard of one foreign country but not recognizing the standard of another foreign country. We denote by $a^k = R^{k',\neg k''}$ an action where the government of country k recognizes the standard of country k' but *does not* recognizes the standard of country k''. Thus, the strategy set of each country k is now enlarged to the set

$$\{R, NR, R^{k',\neg k''}, R^{k'',\neg k'}\}, \quad k \neq k' \neq k'' \text{ and } k, k', k'' = \alpha, \beta, \gamma. \tag{10}$$

In the first stage, any two countries can agree to "mutual recognition" of standards; in such a case, the standards of the respective domestic firms are recognized in both countries. The formation of a standardization union also means that the two countries then set a *common* standardization policy with respect to the nonmember country. Without loss of generality, we assume that if a mutual recognition policy is agreed upon, it is between countries α and β. The second stage is unchanged; firms set prices in each market and consumers make purchases. We again solve the game by backwards induction.

The total surplus for country α when countries α and β form a SU and neither recognizes country γ is shown in Table 2. The table also shows the surplus received by country γ.

From table 2, we can state the following proposition regarding the formation of standardization unions.

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

$(a^\alpha, a^\beta, a^\gamma)$	α's Welfare (TS^α)	γ's Welfare (TS^γ)
$(R^{\beta,\neg\gamma}, R^{\alpha,\neg\gamma}, NR)$	$\frac{n(4c^2 - 12c\tau - 15\tau^2)}{20\tau}$	$\frac{n(56c^2 - 280c\tau - 75\tau^2)}{100\tau}$
$(R^{\beta,\neg\gamma}, R^{\alpha,\neg\gamma}, R)$	$\frac{n(16c^2 - 20c\tau - 75\tau^2)}{100\tau}$	$\frac{n(32c^2 - 160c\tau - 75\tau^2)}{100\tau}$

Table 2: Total surplus for SU member Country α, and nonmember country γ.

1. *When the conversion costs are small, so that $c < 5\tau/4$, mutual standard recognition among all countries is the unique (subgame perfect) equilibrium outcome; no standardization union forms.*

2. *When the conversion costs are relatively large, so that $5\tau/4 \leq c \leq 15\tau/7$, the unique subgame perfect equilibrium outcome is for two countries form a standardization union.*

3. *Regardless whether a standardization union is formed, the excluded country's best response action is to recognize all standards.*

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

$$TS^\alpha(R^{\beta,\neg\gamma}, R^{\alpha,\neg\gamma}, R) > TS^\alpha(R, R, R) \quad \text{if} \quad 5\tau/4 \leq c \leq 15\tau/7.$$

The last part follows from the third column in Table 2. ∎

The intuition behind Proposition 2 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 non-member country. Proposition 2 demonstrates that union formation (that excludes the third country) is preferred by member countries over the world mutual recognition outcome when the conversion costs are relatively large. Under these conditions, the increase in the profits of the domestic firm in the market

of the *other member country* dominates the reduction in consumer surplus domestically associated with nonrecognition of the standard of the nonmember firm. 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.

In the case in which the conversion costs are very small, full recognition of standards is the unique equilibrium, regardless of whether Standardization Unions can form. When the conversion costs are larger, the unique equilibrium is for two countries to form a Standardization Union and to not to recognize the standard of the nonmember country. In such a case, allowing the formation of a SU *reduces* world welfare since in the absence of SU, all countries adhere to mutual recognition. In the following section, we consider the setting in which the conversion costs are very large.

5 Standardization Policies Leading to Foreclosure

Proposition 1 demonstrated that when the conversion costs are not too large, recognizing foreign standards is a dominant action for each country. We now turn to analyzing governments' policies when the conversion costs are very large. Formally, in this section we change Assumption 1 and assume that[13]

ASSUMPTION 2 $c > \frac{5\tau}{2}$.

When a country does not recognize foreign standards we can state the following:

[13]Comparing Assumption 1 to Assumption 2, we do not analyze the parameter range $15\tau/7 < c < 5\tau/2$. Appendix C proves that a pure strategy Bertrand-Nash equilibrium in prices does not exist for this parameter range when two countries form an SU. This is an unimportant technicality which is due solely to the fact that there are linear transportation costs in our model. With quadratic transportation costs, there would be no such region. Since the intuition from this model is easier to grasp using linear transportation costs, we elected not to employ the model with quadratic transportation costs. Nothing qualitative changes in such a case.

Lemma 2 *Suppose that country α does not recognize foreign standards. Under Assumption 2, the unique equilibrium prices in country α are $p_1^* = c - \tau$, and $p_2^* = p_3^* = c$. In this equilibrium, firm 1 sells to the entire market in country α and earns a profit of $\pi_1 = 3n(c-\tau)$.*

Proof. In the proof of Lemma 1, we showed that the profit of firm 1 when it forecloses foreign firms by setting $p_1^* = c - \tau$ exceeds the profits it earns in an interior equilibrium when $c > 2.16\tau$ which holds by Assumption 2. ∎

Hence, for large values of c, the local firm sets its price so that it subsidizes the transportation cost, τ, of the consumer whose ideal brand is a foreign brand (located where a foreign brand is located) and adds to the price the standardization cost "c" that must be incurred by the foreign firms.[14] Using Lemma 2, we now state the following proposition, which is proved in Appendix B.

Proposition 3 *Under Assumption 2:*

1. *Suppose that it is not possible to form a Standardization Union. Then, nonrecognition of foreign standards constitutes a dominant action for each country, and there will be no international trade.*

2. *Suppose that it is possible to form a Standardization Union. The equilibrium of the extended game is for two countries to form a Standardization Union and jointly not recognize the third (nonmember) country. In this equilibrium, there is no trade between member and nonmember countries.*

In this case, the formation of a Standardization Union increases world trade; if such institutions were prohibited, no international trade would occur. This contrasts with the case in which the conversion costs fall in the moderate range. In such a case, the possibility of forming a standardization union leads to a reduction of trade.

[14] Once the domestic firm becomes more attractive to this consumer, all consumers located between the two foreign firms also purchase from the domestic firm. This is why the foreclosure equilibrium exists.

6 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 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 moderately large. The obvious follow-up question is how country size affects the incentives of countries to form standardization unions.

We formally examine this issue under the assumption that conversion costs are either small or moderate, i.e., $c < 15\tau/7$.[15] 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 the two possible standardization unions.

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 (5) implies that the total profit of firm 1 from selling in countries α, β, and γ is given by

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

When (i) country α signs a SU with country γ, (ii) the standardization union does not recognize the standard of the nonmember country, and (iii) country β fully recognizes all countries, equation (5) implies that the total profit of firm 1 from selling in countries α, β, and γ is given by

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

Hence,

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

[15] It is easy to verify that the results (as summarized in Proposition 4) also hold for the case when conversion costs are large.

Therefore,

Proposition 4 *Under the assumption that side-payments are not allowed within the standardization union, if a standardization union forms, it will be formed between the two largest countries.*

Proposition 4 follows from the fact that 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.

7 Conclusion

Our analysis focused on government standardization policies. Table 3 summarizes our results:

c (standard conversion cost):	I. $c < \frac{5\tau}{4}$	II. $\frac{5\tau}{4} \leq c \leq \frac{15\tau}{7}$	III. $\frac{5\tau}{2} \leq c \leq 5\tau$
		UNIONS ARE PROHIBITED	
Dominant Action	R	R	NR
Foreclosure of Foreign Products	no	no	yes
World Optimal Outcome Achieved	yes	yes	no
		UNIONS ARE ALLOWED	
Standardization Union	no	yes	yes
Foreclosure of Nonmember Products	no	no	yes
World Welfare Relative to Benchmark	same	decrease	increase

Table 3: Policy choices and their effects

When standardization conversion or certification costs are small, mutual recognition is an equilibrium in dominant actions, regardless of whether standardization unions can form. This outcome maximizes world welfare, so, there is no market failure in this case.

When the standardization conversion or certification costs are moderate, two countries form a Standardization Union and do not recognize the standard of the third country. Relative to the equilibrium when unions are prohibited (and hence all standards are mutually

recognized), 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, 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.[16]

When the standardization conversion or certification costs are very large, the outcome is nonrecognition when unions are not permitted to form. This leads to a foreclosure of all foreign brands: there is no international trade. However, when unions are allowed to form, the outcome is for two countries to form an SU and not to recognize the third country. Using Viner's terminology, union formation will *create* trade and therefore is (world) welfare improving.

We developed the institutional structure which we call Standardization Union as an analog the Customs Union concept. We close by briefly examining an additional institutional structure (which is an analog of Free Trade Area): an **Open Standards Area (OSA)**. Similar to a standardization union, in an OSA, all member countries mutually recognize all standards of the goods produced in other member countries; unlike an SU, in an OSA, each member country is free to set its own standardization policy with respect to nonmember countries. In such an institutional setting, there is now an additional stage to the game that we described in the body of the paper. In the first stage, any two countries can agree to "mutual recognition" of standards. In the second stage, each "member" country (independently) decides whether to recognize the standard of the nonmember. It is easy to show that in our setting, each member country would recognize all standards, rather than

[16] 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.

just the standard of the member country. The intuition is that the standardization union is attractive because of the large profit of the domestic firm in the market of the other member country. Once a standardization union has been formed, each member government can increase domestic consumers' surplus by recognizing the standard of the excluded country. Of course, both member countries have incentives to behave in this fashion. Thus, the possibility of forming an OSA always leads to an increase in world welfare relative to the standardization union.[17]

Appendix

A Deriving a circular country model with asymmetric cost structure (Lemma 1)

Consider an economy with population size $3n^k$ 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. Given prices for the three brands, the consumer who is indifferent between purchasing brand 1 and brand 2 must satisfy

$$-p_1 - \tau x_{1,2} = -p_2 - \tau(1 - x_{1,2})$$

implying that

$$x_{1,2} = \frac{1}{2} + \frac{p_2 - p_1}{2\tau}. \tag{11}$$

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

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

yielding first order condition given by

$$0 = \frac{\partial \pi_1^k}{\partial p_1} = n^k \left(1 + \frac{2c_1 + p_2 + p_3 - 4p_1}{2\tau}\right). \tag{12}$$

[17] Of course, the member countries are better off under a standardization union.

We can now generalize (12) for any firm i:

$$p_i = \frac{\tau}{2} + \frac{p_j + p_l}{4} + \frac{c_i}{2} \quad i,j,l \in \{1,2,3\},\ i \neq j \neq l. \tag{13}$$

Solving the three equations given in (13) yields

$$p_i = \tau + \frac{3c_i + c_j + c_l}{5}, \quad i,j,l \in \{1,2,3\},\ i \neq j \neq l. \tag{14}$$

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

$$\pi_i^k = n^k \frac{(5\tau - c_i + c_j + c_l)^2}{25\tau}, \quad i,j,l \in \{1,2,3\},\ i \neq j \neq l.$$

We now must verify that this is indeed an equilibrium, i.e., that the domestic firm does not wish to foreclose foreign firms in the case of nonrecognition. When, country α does not recognize foreign standards, the domestic firm (firm 1) can foreclose the foreign firms by charging $p_1^* = c - \tau$. In this case, firm 1 sells to the entire market in country α and earns a (deviation) profit of $\pi_1 = 3n(c - \tau)$. Deviation profits are less than equilibrium profits if and only if

$$\pi_1 = 3n(c - \tau) < \frac{n(5\tau + 2c)^2}{25\tau},$$

which is true if and only if $c < \frac{5(11-\sqrt{57})\tau}{8} \approx 2.16\tau$, which holds by assumption.

B Proof of Proposition 3

We first prove the part one of the proposition. $\pi_1 = 3n(c - \tau) = E^\alpha$ which is aggregate consumer expenditure in country α. Since all of α's consumers buy from firm 1, the average distance traveled by consumers is 3/4 units of distance. Hence, aggregate transportation costs are $T^\alpha = 3n \times 3\tau/4 = 9n\tau/4$.[18] Altogether, under nonrecognition, the sum of consumer surplus and profit of the domestic firm locally is

$$CS^\alpha + \pi_1^\alpha = -T^\alpha = -\frac{9n\tau}{4}. \tag{15}$$

[18]Note that under foreclosure, the formula for transportation costs in (7) is no longer valid.

Under the full recognition policy, the average distance traveled by consumers is 1/4 unit of distance. Hence aggregate transportation costs are $T^{\alpha} = 3n\tau/4$. Under full recognition, the sum of domestic consumer surplus and profit of the domestic firm locally is

$$CS^{\alpha} + \pi_1^{\alpha} = -\frac{11n\tau}{4}. \tag{16}$$

Comparing (15) with (16), nonrecognition is a dominant strategy.

To prove the second part assume that countries α and β form a SU. Let us concentrate on country α only. We now show that $p_1 = p_2 = 3\tau/2$ 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 Assumption 2 implies that $3\tau/2 + \tau < c$. 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 (4), is

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

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

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

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 $p_1 = p_2 = 3\tau/2$.

Finally, we are left to show that countries α and β are better off under the SU compared with no union. Under the SU, the profit of firm 1 from selling in α and β is given by $\pi_1 = 2[3n/2 \times 3\tau/2] = 9n\tau/2$. Aggregate consumer expenditure is $E^{\alpha} = 3n(3\tau/2) = 9n\tau/2$. Under the standardization union, the average distance traveled by consumers is 5/12 unit of distance. Hence aggregate transportation costs are $T^{\alpha} = 5n\tau/4$. Hence, under this union,

consumer surplus in country α plus the profits of the domestic firm in country α from sales in countries a and β are

$$CS^{\alpha} + \pi_1^{\alpha} + \pi_1^{\beta} = -\frac{5n\tau}{4} > -\frac{9n\tau}{4}, \tag{17}$$

which is the sum of consumer surplus and the profits of the domestic firm in country α from sales in countries a and β without the union from (15).[19] ■

C Nonexistence of an equilibrium under SU for $15\tau/7 < c < 5\tau/2$

We look at countries α and β under a union. We first show that an interior equilibrium does not exist; we then show that a foreclosure equilibrium does not exist.

By a way of contradiction, suppose that an interior equilibrium exist; we'll focus on country α only. Then, by (3),

$$p_1 = p_2 = \tau + \frac{c}{5}. \tag{18}$$

Next, under no foreclosure, (5) implies that

$$\pi_1 = \frac{n(5\tau + c)^2}{25\tau}. \tag{19}$$

Now, let firm 1 deviate from the equilibrium price given in (18) and set $p_1' = c - \tau$ to undercut firm 3 (not recognized by the union). Then, by (4), on the short arc between firms 1 and 2 we have that

$$x_{1,2}^S = \frac{1}{2} + \frac{\tau + \frac{c}{5} - (c - \tau)}{2\tau}.$$

On the longer interval, the indifferent consumer satisfies

$$p_1 + \tau x_{1,2}^L = p_2 + \tau(2 - x_{1,2}^L)$$

yielding

$$x_{1,2}' = \frac{2(5\tau - c)}{5\tau}.$$

[19] Recall that without the SU, the domestic firm of country a has no sales in country β.

summing up

$$x_1 = x_{1,2}^S + x_{1,2}^L = \frac{35\tau - 8c}{10\tau}. \tag{20}$$

Since, under foreclosure ($p_1' = c - \tau$),

$$\pi_1' = (c-\tau)x_1 = \frac{n(c-\tau)(35\tau - 8c)}{10\tau}. \tag{21}$$

Now, foreclosing is profitable for firm 1 if

$$\pi_1' - \pi = \frac{n(5\tau + c)^2}{25\tau} - \frac{n(c-\tau)(35\tau - 8c)}{10\tau} > 0$$

or,

$$\frac{3n(-75\tau^2 + 65c\tau - 14c^2)}{50\tau} > 0.$$

There are two roots:

$$c = \frac{15\tau}{7} \quad \text{and} \quad c = \frac{5\tau}{2}.$$

Then, firm 1 benefits from foreclosure if

$$\frac{15\tau}{7} < c < \frac{5\tau}{2}.$$

Hence an interior equilibrium does not exist in this range of the parameter space.

Finally, assume now that an equilibrium exists in which country γ has no sales in countries α and β. From the proof in proposition 3 in Appendix B, the only possible (symmetric) equilibrium is characterized by $p_1 = p_2 = 3\tau/2$, and $p_3 = c$. For this to be a foreclosure equilibrium, firm 3 must not have any sales at these prices, that is, it must be the case that $3\tau/2 < c - \tau$ which implies that $c > 5\tau/2$. However $c < 5\tau/2$. Hence, a contradiction. ■

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