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Kikuchi, Toru and Iwasa, Kazumichi  
Kobe University, Kobe University

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# Competing Industrial Standards and the Impact of Trade Liberalization

Toru Kikuchi\*and Kazumichi Iwasa †

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## Abstract

The main purpose of this study is to illustrate, with simple trade theory, the relationship between competing industrial standards and trade liberalization. We assume that there are two competing industrial standards in an international context, each of which consists of differentiated products. A product can be used only in combination with other products based on the same industrial standard. We examine the impact of trade liberalization (i.e., a decline in trade costs) on consumers' choice of a standard. It will be shown that the degree

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\*Graduate School of Economics, Kobe University, Japan, e-mail: kikuchi@econ.kobe-u.ac.jp

†Graduate School of Economics, Kobe University, Japan

of indirect network effects, captured with substitution between differentiated products, plays an important role as a determinant of the impact of trade liberalization.

# 1 Introduction

Two of the most important trends in the global economy in recent decades have been (1) the dramatic increase in the role of information-intensive products (e.g., various types of computer software products, consumer electronic products and IT-related services), and (2) the proliferation of trade liberalization through both economic integration and preferential trade agreements.

Trade liberalization and advances in digital technology have been associated with a growing connectivity among individuals and organizations and a consequent increase in the flow of information-intensive products across national boundaries. Stemming from these changes, competing proprietary, incompatible standards have arisen throughout the world.<sup>1</sup> In particular, competition between a “domestic” standard and a “non-domestic” standard is often observed. For example, Funk (1998) provides qualitative evidence that in the global competition among wireless telecommunications service providers, firms are likely to dominate domestically, thereby making the “home” standard dominant. That is, firms by and large have not succeeded in marketing “non-domestic” standards.<sup>2</sup> Also, it is widely recognized that

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<sup>1</sup>In this study, we will use the term ‘standard,’ not in the sense of government regulation but in the universal sense of the set of technical specifications that enable compatibility among products.

<sup>2</sup>Funk (1998) suggests that U.S. Motorola’s share of the world market dropped from 40 in 1994 percent to 32 percent in 1995, as the installed base on European GSM standard

products based on the same industrial standard exhibit an *indirect network effect*: the utility of consumers is increasing in the variety of complementary products based on a particular standard.<sup>3</sup> There seems to be a case for closer examination and more formal modeling of competing industrial standards and their impact on trade and national welfare.

In the literature on trade and competing industrial standards, the role of government standardization policy is often emphasized. In their influential contribution, Gandal and Shy (2001) analyzed governments' incentives to recognize foreign standards when there are potentially both network effects (i.e., consumption benefits) and conversion costs. Their focus was on how standardization policy affects both international trade flows and national welfare.

An important question about the relationship between competing industrial standards and trade liberalization remains unanswered: How does trade liberalization affect consumers' choice between incompatible standards? The grew: Motorola dominated in the U.S. while Nokia/Ericsson dominated in Europe. See, also, Lembke (2002).

<sup>3</sup>The seminal contributions on the indirect network effect are Chou and Shy (1990) and Church and Gandal (1992). See Gandal (2001, 2002) and Farrell and Klemperer (2007) for surveys of the relevant literature. In the international context, see Iwasa and Kikuchi (2008) and Kikuchi (2005, 2007) for analyses of trade liberalization in the presence of network effects.

main purpose of this study is to illustrate, with simple trade theory, this relationship. Following Matsuyama (1992), we assume that there are two incompatible standards, each of which consists of differentiated products. A product can be used only in combination with other products based on the same industrial standard. Matsuyama assumed a closed economy and paid scant attention to the role of trade liberalization. In contrast, in this study we focus on the case of competing industrial standards in an international context (i.e., a Home standard and a Foreign standard) and examine the impact of trade liberalization (i.e., a decline in trade costs) on consumers' choice of a standard. Also, following Chou and Shy (1996), we emphasize the role of consumers' heterogeneous tastes for standards. We analyze the effects of changing the distribution of consumer tastes on the impact of trade liberalization.

The structure of this paper is as follows. In the next section we present a basic model. The impact of trade liberalization is considered in Section 3, followed by concluding remarks presented in Section 4.

## **2 The Model**

Suppose that there are two countries, Home and Foreign. We concentrate on what happens in the Home market. Both Home firms and Foreign firms

compete in the Home market, which is defined as a line of unit length representing consumers' set of preferences. Home consumers are indexed by  $z$ ,  $z \in [0, 1]$ , and with no loss of generality, we normalize the total mass of Home consumers to equal 1. Each consumer is endowed with the amount  $E$  of income to be spent on differentiated products.

Assume that there are two competing industrial standards: *Home standard* and *Foreign standard*. A variety of differentiated products can be produced based on either standard: we simply assume that Home (resp. Foreign) firms produce products based on the Home (resp. Foreign) standard. The two standards are not compatible with each other, hence any product can be used only in combination with other products based on the same standard.<sup>4</sup>

A consumer is assumed to purchase products based on only one standard (Home or Foreign). We call these groups of differentiated products Home standard products and Foreign standard products. We assume that the utility of consumers is increasing in the variety of complementary products based on a particular standard. We define the utility of an individual type  $z$  by

$$\begin{aligned}
 U(z) &= (1 - z)C^* \text{ if he chooses Foreign standard products, and} \\
 U(z) &= zC \text{ if he chooses Home standard products,}
 \end{aligned}
 \tag{1}$$

where  $C$  ( $C^*$ ) is the quantity index of Home (Foreign) standard products.

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<sup>4</sup>See Matsuyama (1992) for this point.

These indices are defined as the Dixit-Stiglitz (1977) form

$$\begin{aligned} C &= \left[ \sum_{i=1}^n (c_i)^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}, \\ C^* &= \left[ \sum_{j=1}^{n^*} (c_j)^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}, \end{aligned} \quad (2)$$

where  $n$  ( $n^*$ ) is the number of Home (resp. Foreign) standard products and  $\sigma > 1$  is the elasticity of substitution between every pair of products *within the same standard*.

Following Chou and Shy (1996), we assume that the density function of consumers' types is given by,

$$f(z, \varepsilon) = \frac{1 + \varepsilon}{(1 + \varepsilon z)^2}, \quad \varepsilon > -1. \quad (3)$$

When  $\varepsilon = 0$  the density function becomes a uniform density representing the case in which consumers are evenly distributed on  $[0, 1]$ . Figure 1 shows that when  $\varepsilon$  increases, the distribution shifts towards the Foreign standard.

The importation of Foreign products is inhibited by frictional trade barriers, which are modeled as iceberg costs a la Samuelson: for 1 unit of Foreign product to reach Home,  $t \in (1, \infty)$  units must be shipped. Thus, the price of an imported product to Home consumers will be  $tp^*$ , where  $p^*$  is the producer's price for Foreign standard products. It is important to note that this trade cost includes all impediments to trade such as tariffs, but also communication difficulties, information barriers and cultural differences. Price indices

for each group of standard products, which indicate costs for obtaining one unit of quantity, are defined as follows:

$$P = \left[ \sum_{i=1}^n (p_i)^{1-\sigma} \right]^{1/(1-\sigma)} = n^{1/(1-\sigma)} p, \quad (4)$$

$$P^* = \left[ \sum_{j=1}^{n^*} (tp_j)^{1-\sigma} \right]^{1/(1-\sigma)} = (\tau n^*)^{1/(1-\sigma)} p^*, \quad (5)$$

where  $\tau \equiv t^{1-\sigma} \in (0, 1)$  is the measure of the freeness of trade, which increases as  $t$  falls and is equal to one when trade is costless ( $t = 1$ ). Note that  $\tau n^*$  represents an *effective* number of Foreign standard products: trade liberalization (i.e., a larger  $\tau$ ) can be interpreted as an increase in the number of varieties even if  $n^*$  remains unchanged.

Now, let us turn to the cost structure of differentiated products. Technology is assumed to be identical between countries and characterized by increasing returns to scale, since product creation typically involves fixed costs. We denote the constant marginal cost of production for every product by  $\beta$ , and the product development cost by  $\alpha$ . We assume that firms are monopolistic competitors. Given a Dixit-Stiglitz specification with constant demand elasticity  $\sigma$ , each firm chooses its constant markup prices as

$$p = p^* = \frac{\beta\sigma}{\sigma - 1}. \quad (6)$$

Let us denote the number of consumers who purchase Home (resp, Foreign) standard products as  $\rho$  (resp.  $\rho^*$ ). Note that  $\rho + \rho^* = 1$ . Then, assuming

that the entry and production decisions of the potential firms cannot individually affect the existing firms, the equilibrium number of products produced according to each standard becomes proportional to the total expenditure on products based on each standard:

$$n = \frac{(1 - \rho^*)E}{\alpha\sigma}, \quad (7)$$

$$n^* = \frac{\rho^*E}{\alpha\sigma}. \quad (8)$$

Combining (4), (5), (7), and (8), it can be easily shown that a consumer's welfare increases when more consumers purchase products with the same standard. As more consumers choose the same standard, more firms choose to produce based on that standard. This results in increased product diversification among products with that standard.

**Result 1:** *A consumer's welfare is an increasing function of the number of consumers who purchase products with the same standard.*

This results in the types of “indirect network effects” analyzed by both Chou and Shy (1990) and Church and Gandal (1992).

Now let us turn to the equilibrium number of consumers who purchase Home/Foreign standard products. Denote by  $\hat{z}$  the type of the marginal consumer who is between two standards. Using (1),  $\hat{z}$  is derived as

$$\hat{z} = \frac{1}{1 + (P^*/P)} = \frac{1}{1 + (n/\tau n^*)^{1/(\sigma-1)}}. \quad (9)$$

The equilibrium number of consumers who purchase Foreign standard products,  $\rho^*$ , can be obtained by integrating the density function (3) from 0 to  $\hat{z}$  as follows:

$$\begin{aligned}\rho^* &= \int_0^{\hat{z}} f(z, \varepsilon) dz = \frac{(1 + \varepsilon)\hat{z}}{1 + \varepsilon\hat{z}} \\ &= \frac{1}{1 + (1 + \varepsilon)^{-1}(\hat{z}^{-1} - 1)} \\ &= \frac{1}{1 + (1 + \varepsilon)^{-1}(n/\tau n^*)^{1/(\sigma-1)}}.\end{aligned}\quad (10)$$

Substituting in the equilibrium number of differentiated products, we can obtain the equilibrium proportion of consumers who purchase Home standard products:

$$\frac{\rho}{\rho^*} = \left(\frac{1 + \varepsilon}{t}\right)^{(\sigma-1)/(2-\sigma)}.\quad (11)$$

### 3 The Impact of Trade Liberalization

In this section we consider the impact of trade liberalization (i.e., a reduction in  $t$ ). From (11), we can obtain the equilibrium relationship for the number of consumers who purchase Foreign standard products:

$$\rho^* = \phi(\rho^*) \equiv \frac{(1 + \varepsilon)(\rho^*)^{1/(\sigma-1)}}{(1 + \varepsilon)(\rho^*)^{1/(\sigma-1)} + t(1 - \rho^*)^{1/(\sigma-1)}}.\quad (12)$$

Figures 2 and 3 help to illustrate the trading equilibrium. Increasing curves indicate  $\phi(\rho^*)$  functions, which show a possible number of consumers who

purchases Foreign standard products that is consistent with firms' entry/exit decisions. The trading equilibrium is obtained as the intersection between these curves and the 45 degree line. According to the shape of  $\phi(\rho^*)$  function, we can obtain the following:

$$\begin{aligned} \phi(0) &= 0 \quad \text{and} \quad \phi(1) = 1. \\ \phi'(\rho^*) &= \frac{(1 + \varepsilon)t}{\sigma - 1} \cdot \frac{[\rho^*(1 - \rho^*)]^{(2-\sigma)/(\sigma-1)}}{[(1 + \varepsilon)(\rho^*)^{1/(\sigma-1)} + t(1 - \rho^*)^{1/(\sigma-1)}]^2} > 0, \\ \lim_{\rho^* \rightarrow 0} \phi'(\rho^*) &= \begin{cases} 0 & \text{if } \sigma < 2, \\ \infty & \text{if } \sigma > 2, \end{cases} \\ \lim_{\rho^* \rightarrow 1} \phi'(\rho^*) &= \begin{cases} 0 & \text{if } \sigma < 2, \\ \infty & \text{if } \sigma > 2. \end{cases} \end{aligned}$$

These results indicate that, depending on the level of elasticity between varieties,  $\sigma$ , two cases emerge. We shall discuss each case in detail.

### 3.1 Case 1: $\sigma > 2$

When  $\sigma > 2$  holds, indirect network effects are relatively mild. Initial trading equilibrium is obtained as point  $I$  in Figure 2. Trade liberalization implies an increase in the *effective* number of Foreign varieties  $\tau n^*$ , which makes Foreign standard products more attractive: this change is shown as an upward shift of  $\phi$  curve. Since some consumers who had been purchasing Home standard products switch to Foreign standard products, more Foreign firms enter into

Home markets. The new equilibrium is obtained as point  $N$  on the 45 degree line.

**Proposition 1:** *Given that  $\sigma$  is greater than 2, trade liberalization will induce a relatively small proportion of consumers to purchase Home standard products.*

The point is that there is a *cumulative process* in which trade liberalization will enhance Home consumers' propensity to switch to the Foreign standard, and this switching will induce further product diversification among Foreign products. Still, since the indirect network effect is mild, some consumers who prefer Home standard products continue to choose those products.

This result is also quite important from the welfare perspective: since trade liberalization leads some Home consumers to 'switch' to the Foreign standard, the market size for Home standard products will shrink and consumers who continue to choose Home standard products are made worse off by trade liberalization.

**Proposition 2:** *Given that  $\sigma$  is greater than 2, consumers who continue to choose Home standard products will be made worse off by trade liberalization.*

### 3.2 Case 2: $2 > \sigma > 1$

When  $2 > \sigma > 1$  holds, consumers' valuation of product varieties (i.e., the degree of indirect network effects) is relatively high. In this case, initial trading equilibrium is obtained as point  $I$  in Figure 3. An increase in the *effective* number of Foreign varieties has more influence than in the previous case (i.e., an upward shift of the  $\phi$  curve). Then consumers' incentives to switch to Foreign standard products also become greater, which further induces Foreign firms' entry. Then, the demand for Home standard products vanishes. The new equilibrium is obtained as point  $N$  on the 45 degree line. From Figure 3, one can obtain the surprising feature of the impact of trade liberalization.

**Proposition 3:** *Given that  $\sigma$  is smaller than 2, trade liberalization will result in the situation where no consumer purchases Home standard products.*

A comparison between these two cases highlights the important role of indirect network effects. On one hand, if the indirect network effect is mild, trade liberalization makes the Foreign standard more attractive to some extent. Still, some consumers who prefer Home standard products continue to choose them. On the other hand, if the indirect network effects are sufficiently strong, trade liberalization will make Home standard products completely out of the Home market.

Before closing this section, it is worthwhile to note that Equation (11)

implies an interesting result of changes in the distribution of consumers' tastes:

**Proposition 4:** *A shift in consumers' tastes towards the Foreign standard will induce a relatively small share of consumers to purchase Home standard products.*

## 4 Concluding Remarks

Both trade liberalization and advances in digital technology have driven particularly intensified competition between incompatible industrial standards. In this study, we explained the mechanism of how trade liberalization influences consumers' choice of a standard. It should be emphasized that the degree of substitution between product varieties plays an important role in determining the impact of trade liberalization: if the degree of substitution is sufficiently small (i.e., the indirect network effect is relatively large), trade liberalization will make Home standard products completely out of the Home market.

The present analysis must be regarded as tentative. Hopefully, it provides a useful paradigm for considering how trade liberalization affects international competition among industrial standards.

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Figure 1. The graph of  $f(z, \varepsilon)$

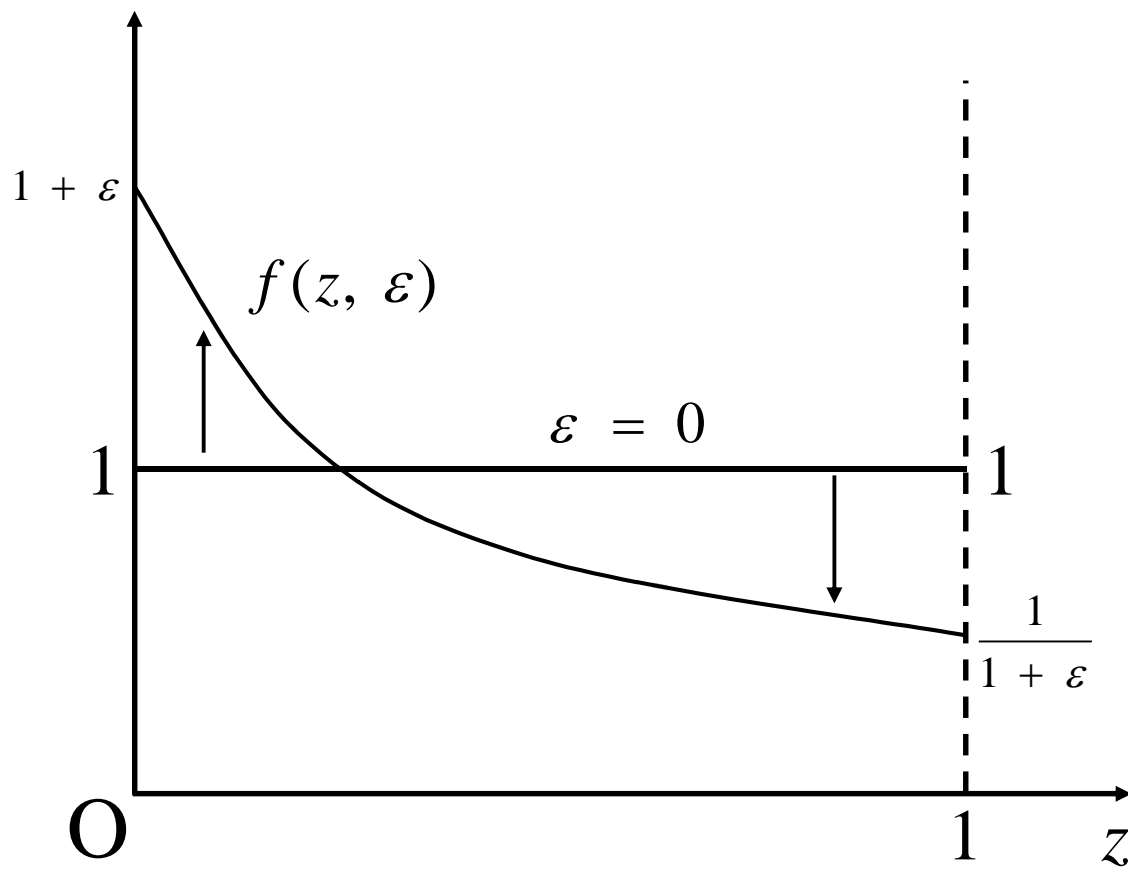


Figure 2. The graph of  $\phi(\rho^*)$  ( $\sigma > 2$ )

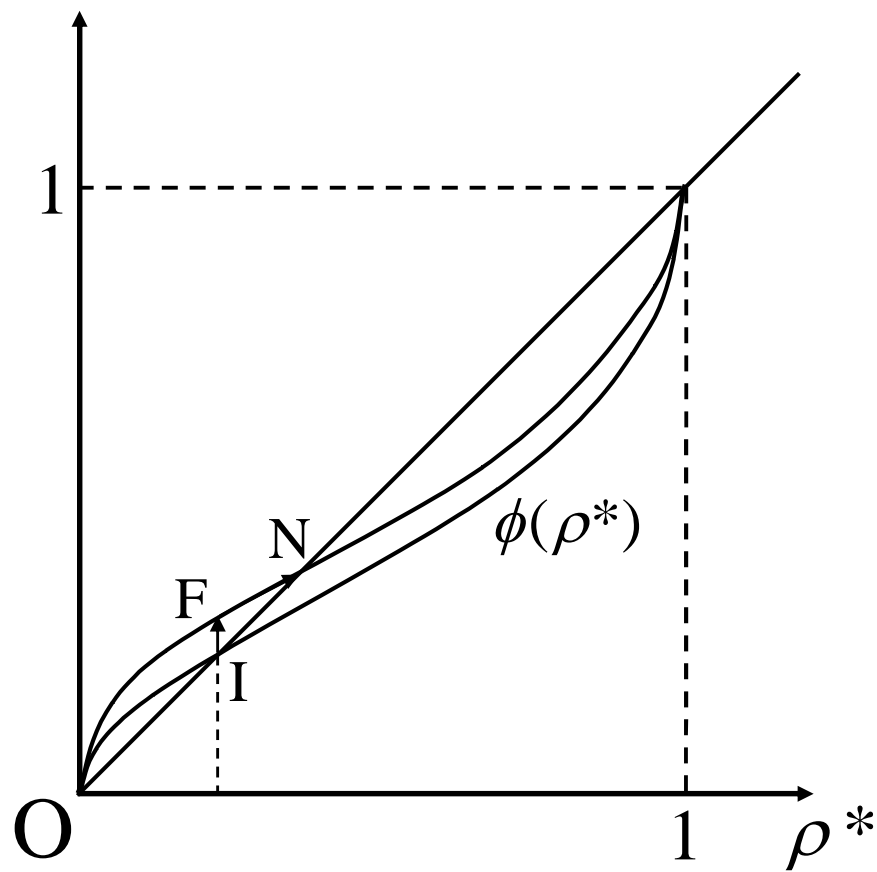


Figure 3. The graph of  $\phi(\rho^*)$  ( $\sigma < 2$ )

