Software Provision and the Impact of Market Integration

Iwasa, Kazumichi and Kikuchi, Toru

Kobe University, Kobe University

2008

Software Provisio and
the Impact of Market Integration: A Note

Kazumichi Iwasa*and Toru Kikuchi[†][‡]

March 3, 2008

Abstract

Both deeper market integration and advances in digital technology have driven particularly large decreases in the costs of intermarket software provision. In this note, we first explain the mechanism of how trade costs influence the software provision decisions of software firms. Then, we investigate the transformation of production/trade patterns given gradually decreasing trade costs for software products. It is shown that, if two incompatible types of hardware exist, deeper

---

*Graduate School of Economics, Kobe University, Japan

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

[‡] We are grateful to Jota Ishikawa, Eiji Ogawa, Takatoshi Tabuchi, Makoto Tawada, Shigemi Yabuuchi, Dao-Zhi Zeng and Laixun Zhao for their helpful comments.

market integration may *reduce* the variety of hardware technologies. It is also shown that, if the variety of hardware technologies is reduced by deeper integration, some consumers are made worse off. In other words, deeper market integration, which forms the basis for easier access to software products, may work as a catalyst for Pareto inferior outcomes.

Key Words: software provision; indirect network effects; hardware/software systems; market integration; Pareto inferior outcome

JEL Classification: D43, F12, R12

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 and IT-related services) in economic activity, and (2) the decline in intermarket transaction costs such as transport and communications costs. Both deepening market integration and advances in digital technology have driven particularly large decreases in the costs of intermarket software provision. Lower costs have been associated with a growing connectivity of individuals and organizations achieved through improved communications networks (e.g., the Internet and the satellite communications networks) and a consequent increase in the flow of information-intensive software provision across markets.[1]

Since these changes due to deeper market integration often provide an opportunity to acquire a variety of products not available from domestic producers, welfare gains via increased product diversification are emphasized in the trade/regional economy literature.[2] As yet, however, little attention has been paid to the impact of market integration on software provision in the presence of *indirect network effects.*

---

[1] Addressing this point, Illing and Peitz (2006) presented stylized facts on software industries.

[2] See, for example, Fujita et al. (1999) and Behrens et al. (2007).

Indirect network effects exist when the utility of consumers is increasing in the variety of complementary "software" products available for a "hardware" device. Examples of such devices include personal computers, video cassette recorders, and consumer electronics products. It is important to note that not only electronic products but also IT-related services exhibit strong indirect network effects. Internet auction sites such as eBay provide a good example: the more users sell through eBay ("hardware" in our terminology), the greater the variety of items ("software" in our terminology) that can be found, and the greater the value of buying through eBay. These examples suggest that the concept of indirect network effects has wide applicability in the modern economy.

Despite the fact that many industries have indirect network effects that are supported by deeper market integration, the literature on indirect network effects is almost exclusively focused on a single market.[3] Because the role of indirect network effects is amplified in the globalized world, it seems important to explore the impact of market integration in the presence of

---

[3] The seminal contributions on the role of a "hardware/software" system are Chou and Shy (1990) and Church and Gandal (1992). See Economides (1996), Gandal (2002), Farrell and Klemperer (2007) for surveys of the relevant literature. In the international context, Gandal and Shy (2001) analyze governments' incentives to recognize foreign standards when there are network effects. See, also, Kikuchi (2003, 2007) for an analysis of trade liberalization in the presence of network effects.

products with indirect network effects.

As our primary contribution, we extend Church and Gandal (1992)'s single market model with two incompatible types of hardware to an international (or regional) trade environment with two markets:[4] we emphasize the role of *intermarket trade costs* which includes not only shipping costs but also difficulty of communication, information barriers, etc., and show how deeper market integration (i.e., a reduction in trade costs) affects the software provision decision of software firms.[5] It is shown that, given that two incompatible types of hardware exist, deeper market integration may *reduce* the variety of hardware technologies. It is also shown that, if the variety of hardware technologies is reduced by deeper integration, some consumers are made worse off. In other words, deeper market integration, which forms the basis for easier access to software products (i.e., intensified indirect network effects), may work as a catalyst for Pareto inferior outcomes.

The rest of this note is organized as follows. Section 2 describes the basic

---

[4] Based on Hotelling's spatial approach, Schmitt (1993, 1995) investigates the product choices made by firms in a two-market environment. Also, in order to analyze the possibility of coalition formation among suppliers of retail services, Henkel et al. (2000) adapt the work of Church and Gandal (1992) to a spatial economy setting.

[5] Recent empirical studies suggest that trade costs are still high, even aside from trade-policy barriers and even between apparently highly integrated economies. See Anderson and van Wincoop (2004) for surveys of the relevant literature.

model. Section 3 analyzes trading equilibrium and Section 4 considers the impact of deeper market integration (i.e., a reduction in trade costs). Section 5 contains concluding remarks.

2 The Model

In this section, we describe the basic setup of the model: both technology and consumers' preferences are specified. Then, in the next section, the trading equilibrium with positive transport costs is explained in detail.

Suppose that there are two countries (or regions), Home and Foreign, and that they are identical in regard to tastes, size, and technology.[6] In each country there are three types of goods: hardware, a large variety of software products, and the outside good. We assume that there are two hardware technologies in both countries: *Hardware 0* and *Hardware 1.* We also assume that the hardware technologies are *incompatible*: software written for one hardware device will not work with the other available hardware. Without the provision of compatible software, no consumers will purchase a hardware device.

A market in each country is defined as a line of unit length representing both consumers' set of preferences and the firms' attribute space for hardware products. The characterization of the two hardware technologies is

---

[6] In this way, we rule out Ricardian comparative advantage.

exogenous: each is located at the end point of the unit line: let Hardware 0's technology be at the left end point and Hardware 1's technology at the right end point. We denote the marginal cost of each hardware production by c. We further assume that the hardware technologies are non-proprietary and that they will be offered at marginal cost.

Following Church and Gandal (1992), consumer preferences over the combination of hardware and software are modeled as a Dixit-Stiglitz (1977) CES utility function. We assume that the distribution of the tastes of Home (Foreign) consumers is uniform along a line of unit length $s \in [0,1]$. In each country, the consumers' density is uniform and equal to 1.

The preferences of a consumer of type s for system h $(h = 0, 1)$ are:

$$U(s,h) = \left[\sum_{i}^{n^h} (x_i^h)^\theta + \sum_{i*}^{n_*^h} (x_{i*}^h)^\theta \right]^{(1/\theta)} + \phi - k|s-h|, \quad (1/2) < \theta < 1, \quad (1)$$

where n^h (n_*^h) is the number of Home (resp. Foreign) software products written for Hardware h, x_i^h (resp. x_{i*}^h) is the level of consumption of software product i (resp. $i*$) written for Hardware h, $\sigma \equiv 1/(1-\theta) > 2$ is the elasticity of substitution between every pair of software products, and we assume that $\phi > k$. k is a measure of the degree of product differentiation between the hardware technologies: the greater k, the greater the degree of differentiation.

Intermarket trade in software products is inhibited by frictional trade barriers, which are modeled as iceberg costs à la Samuelson: for one unit of the software product to reach the other country (or region), $t \in (1, \infty)$ units must be shipped.[7] Thus, the price of an imported software product to Home consumers will be tp_*^h, where p_*^h is the producer's price for software products manufactured in Foreign. Intermarket trade cost includes all impediments to trade, such as shipping costs per se, but also different product standards, difficulty of communication, information barriers and cultural differences.

The representative consumer in Home who purchases Hardware h will maximize (**??**) subject to the following budget constraint:

$$\sum_i^{n^h} p_i^h x_i^h + \sum_{i*}^{n_*^h} t p_{i*}^h x_{i*}^h = e - c, \tag{2}$$

where p_i^h (resp. p_{i*}^h) is the price of Home (resp. Foreign) software variety i (resp. $i*$) for Hardware h, e is the total expenditure allocated to hardware and software, and c is the price (i.e., cost) of a unit of Hardware h.

The solution to this problem consists of the following demand functions:

$$x_i^h = (e-c)(P^h)^{\sigma-1}/(p_i^h)^{\sigma}, \tag{3}$$

$$x_{i*}^h = (e-c)(P^h)^{\sigma-1}/(tp_{i*}^h)^{\sigma}, \tag{4}$$

where

$$P^h = \left[\sum_j^{n^h} (p_j^h)^{1-\sigma} + \sum_{j*}^{n_*^h} (tp_{j*}^h)^{1-\sigma} \right]^{1/(1-\sigma)}. \tag{5}$$

---

[7] See Ottaviano and Thisse (2004, p.2581).

Similarly, we obtain the demand functions of each consumer in Foreign who purchases Hardware h as follows.

$$y_i^h = (e-c)(P_*^h)^{\sigma-1}/(tp_i^h)^{\sigma}, \tag{6}$$

$$y_{i*}^h = (e-c)(P_*^h)^{\sigma-1}/(p_{i*}^h)^{\sigma}, \tag{7}$$

where

$$P_*^h = \left[\sum_j^{n^h} (tp_j^h)^{1-\sigma} + \sum_{j*}^{n_*^h} (p_{j*}^h)^{1-\sigma}\right]^{1/(1-\sigma)} . \tag{8}$$

If the prices of software product are identical among countries (i.e., $p_i^h = p_{i*}^h = p^h$), the CES price indices (**??**) and (**??**) simplify to

$$P^h = p^h(n^h + \tau n_*^h)^{1/(1-\sigma)} \quad \text{and} \quad P_*^h = p^h(\tau n^h + n_*^h)^{1/(1-\sigma)}, \tag{9}$$

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 τ can be interpreted as a 'weight' on imported software products: the price index is decreasing in τ.

Then, the indirect utility of a type-s consumer in Home who purchases a system h is

$$V(s,h) = \frac{(n^h + \tau n_*^h)^{1/(\sigma-1)}(e-c)}{p^h} + \phi - k|s-h|. \tag{10}$$

On the other hand, the indirect utility of a type-s consumer in Foreign who purchases a system h is given by

$$V_*(s,h) = \frac{(\tau n^h + n_*^h)^{1/(\sigma-1)}(e-c)}{p^h} + \phi - k|s-h|. \tag{11}$$

The indirect utility functions are concave in $(n^h + \tau n_*^h)$ or $(\tau n^h + n_*^h)$: the marginal benefit of additional software variety is decreasing.

Now, let us turn to the cost structure of software provision. The technology for the production of software is characterized by increasing returns to scale, since software creation typically involves fixed costs. We denote the constant marginal cost of software production for every product by b, and the software development cost by f.

We assume that software firms are monopolistic competitors. With the total number of products available to consumers being very large, each producer chooses its constant markup prices as:[8]

$$p = p_* = b\sigma/(\sigma - 1). \tag{12}$$

3 Trading Equilibrium

In this section, we specify a simple game in which the strategy of each software firm is a decision to provide software for either hardware, 0 or 1. The timing of the game is as follows:[9] In the first stage software firms enter the industry. There is free entry into the software industry and software firms have rational expectations. Let us denote the free-entry numbers of software firms in Home and Foreign by N and N_*, respectively, that is, $N = n^0 + n^1$

---

[8] Hereafter, we drop the superscript h.

[9] This is taken from Church and Gandal's (1992) single market model.

and $N_* = n_*^0 + n_*^1$. Although there may be more than one equilibrium software configuration, we show that the sum of N and N_* is unique,[10] which we denote by $2N_F$. Also, in order to emphasize the role of trade costs, we restrict our attention to the case of *symmetric equilibrium* where $n^h = n_*^h$ and $N = N_* = N_F$ hold. In other words, we concentrate on the case where each country's equilibrium configuration is *identical*. From the consumers' viewpoint, this implies that the *effective* number of software varieties for Hardware h is $(1+\tau)n^h$ [see equations (**??**) and (**??**)].

In the second stage, software firms simultaneously choose which platform to provide software for. In the final stage, each consumer purchases either a Hardware 0 or a Hardware 1 system and some of the compatible software. We solve this problem backward.

3.1 Final Stage

Since we assume the marginal costs (prices) of hardware and software are equal for both systems, consumers determine which hardware to purchase considering only their tastes and the amount of software available for each system. From (**??**), a Home consumer located at s purchases Hardware 0 if

---

[10] See Subsection 3.3.

the following inequality holds:

$$\begin{aligned} & \frac{(n^0+\tau n_*^0)^{1/(\sigma-1)}(e-c)}{p}+\phi-ks \\ > \quad & \frac{[N_F-n^0+\tau(N_F-n_*^0)]^{1/(\sigma-1)}(e-c)}{p}+\phi-k(1-s), \end{aligned} \tag{13}$$

where use has been made of the equation $n^0+n^1=n_*^0+n_*^1=N_F$. Therefore, the location of the marginal consumer who purchases Hardware 0 is given by a function of (n^0, n_*^0), that is,

$$\begin{aligned} & s(n^0,n_*^0) \\ = & \frac{\{(n^0+\tau n_*^0)^{1/(\sigma-1)}-[(1+\tau)N_F-(n^0+\tau n_*^0)]^{1/(\sigma-1)}\}(e-c)(\sigma-1)}{2kb\sigma}+\frac{1}{2}. \end{aligned} \tag{14}$$

And it can be easily shown that the first derivatives of $s(n^0, n_*^0)$ with respect to n^0 and n_*^0 are positive. This means that the share of Hardware 0 is increasing in the amount of software available for it.

Similarly, the location of the marginal consumer in Foreign who purchases Hardware 0 is given by

$$\begin{aligned} & s_*(n^0,n_*^0) \\ = & \frac{\{(\tau n^0+n_*^0)^{1/(\sigma-1)}-[(1+\tau)N_F-(\tau n^0+n_*^0)]^{1/(\sigma-1)}\}(e-c)(\sigma-1)}{2kb\sigma}+\frac{1}{2}. \end{aligned} \tag{15}$$

Clearly, in the case of $n^0=n_*^0$, the location of the marginal consumer in each country is identical and given by a function of n^0, that is,

$$\begin{aligned} S(n^0) &\equiv s(n^0, n^0) \\ &= T(\tau)\frac{[(n^0)^{1/(\sigma-1)} - (N_F - n^0)^{1/(\sigma-1)}](e-c)(\sigma-1)}{2kb\sigma} + \frac{1}{2}, \end{aligned} \tag{16}$$

where

$$T(\tau) \equiv (1+\tau)^{1/(\sigma-1)}. \tag{17}$$

Then, the first derivative of $S(n^0)$ is given by

$$S'(n^0) \equiv \frac{dS(n^0)}{dn^0} = \frac{T(\tau)[(n^0)^{(2-\sigma)/(\sigma-1)} + (N_F - n^0)^{(2-\sigma)/(\sigma-1)}](e-c)}{2kb\sigma} > 0. \tag{18}$$

It can also be shown that

$$S(0) \geq 0 \text{ and } S(N_F) \leq 1 \quad \Longleftrightarrow \quad [(1+\tau)N_F]^{1/(\sigma-1)} \leq kb\sigma/[(e-c)(\sigma-1)] \tag{19}$$

and

$$S'(N_F/2) \geq 1/N_F \quad \Longleftrightarrow \quad [(1+\tau)N_F]^{1/(\sigma-1)} \geq 2^{1/(\sigma-1)}kb\sigma/2(e-c). \tag{20}$$

Based on the above, the function $S(n^0)$ can be depicted as curves in Figure 1,[11] where curves A, B, and C correspond to the graph of $S(n^0)$ under each of the following three cases: in case A, $t \geq \bar{t} \equiv [N_F/(\underline{N} - N_F)]^{1/(\sigma-1)}$, where

---

[11] The second derivative of $S(n^0)$ is negative (positive) if n^0 is smaller (greater) than

$\underline{N} \equiv \{kb\sigma/[(e-c)(\sigma-1)]\}^{\sigma-1}$; in case B, $\bar{t} > t > \underline{t} \equiv [N_F/(\bar{N}-N_F)]^{1/(\sigma-1)}$, where $\bar{N} \equiv 2[kb\sigma/2(e-c)]^{\sigma-1}$; and in case C, $t \leq \underline{t}$.[12] Note that

$$\bar{t} \in (1,\infty) \qquad \Longleftrightarrow \qquad \underline{N}/2 < N_F < \underline{N},$$

$$\underline{t} \in (1,\infty) \qquad \Longleftrightarrow \qquad \bar{N}/2 < N_F < \bar{N}.$$

Since $\underline{N}$ is smaller than $\bar{N}$, we can conclude that

$$1 < \underline{t} < \bar{t} < \infty \qquad \Longleftrightarrow \qquad \bar{N}/2 < N_F < \underline{N},$$

where $\bar{N}/2 < \underline{N}$ holds if $\sigma \in (2,3)$. The three curves are drawn for high, intermediate, and low levels of intermarket trade costs, respectively.

Note that in cases B and C, $S(n^0)$ can reach 0 or 1, even if there are still two types of software. Since the market is of unit length, there exists a critical number of software firms for each type of hardware such that if the number of software firms for one technology exceeds the critical number, then all consumers purchase the dominant hardware. On the other hand, in case A, there are two types of consumers unless one type of hardware is standardized; no software for the other hardware exists.[13]

$N_F/2$, since

$$\frac{d^2S(n^0)}{d(n^0)^2} = -\frac{T(\tau)[(n^0)^{(3-2\sigma)/(\sigma-1)} - (N_F-n^0)^{(3-2\sigma)/(\sigma-1)}](\sigma-2)(e-c)}{2kb\sigma(\sigma-1)},$$

where $\sigma > 2$ from the assumption $\theta > 1/2$.

[12] The importance of discriminating between case B and C will appear in the following.

[13] Since we assume that hardware only facilitates the consumption of software and pro-

3.2 Second Stage

In the second stage, software firms simultaneously select the network which they will supply software to. Given the marginal consumer in Home and Foreign, s and s_*, respectively, and the number of competing software firms in each country, (n^0, n^0_*) or (n^1, n^1_*), the profit of a Home firm writing software for Hardware 0 is

$$\begin{aligned} \pi^0 &= s(p-b)x^0 + s_*(tpy^0 - bty^0) - f \\ &= \frac{e-c}{\sigma}\left(\frac{s}{n^0+\tau n^0_*} + \tau\frac{s_*}{\tau n^0 + n^0_*}\right) - f, \end{aligned} \tag{21}$$

where $x^0 = (e-c)/[(n^0+\tau n^0_*)p]$ and $y^0 = (e-c)/[t^\sigma(\tau n^0 + n^0_*)p]$. Note that, due to the presence of intermarket trade costs, profits from exporting, $s_*/(\tau n^0 + n^0_*)$, is discounted by a weight τ. The profit of a Home firm for Hardware 1 is

$$\begin{aligned} \pi^1 &= (1-s)(p-b)x^1 + (1-s_*)(tpy^1 - bty^1) - f \\ &= \frac{e-c}{\sigma}\left(\frac{1-s}{n^1+\tau n^1_*} + \tau\frac{1-s_*}{\tau n^1 + n^1_*}\right) - f, \end{aligned} \tag{22}$$

where $x^1 = (e-c)/[(n^1+\tau n^1_*)p]$ and $y^1 = (e-c)/[t^\sigma(\tau n^1 + n^1_*)p]$.

Similarly, we can show that the profits of each Foreign firm writing software for Hardware 0 and Hardware 1, which we denote by π^0_* and π^1_*, respec-

---

vides no stand-alone benefits, in case A, the marginal consumer in each country changes discontinuously to 0 or 1 when n^0 and n^0_* are equal to 0 or N_F.

tively, are given by

$$\pi^0_* = \frac{e-c}{\sigma}\left(\tau\frac{s}{n^0+\tau n^0_*}+\frac{s_*}{\tau n^0+n^0_*}\right)-f, \tag{23}$$

$$\pi^1_* = \frac{e-c}{\sigma}\left(\tau\frac{1-s}{n^1+\tau n^1_*}+\frac{1-s_*}{\tau n^1+n^1_*}\right)-f. \tag{24}$$

From these equations, it is easily derived that if $n^0 = n^0_*$ and $s = s_*$, then $\pi^h = \pi^h_*$ $(h = 0, 1)$ and

$$\pi^0 \ \begin{matrix} > \\ = \\ < \end{matrix}\ \pi^1 \quad \Longleftrightarrow \quad s \ \begin{matrix} > \\ = \\ < \end{matrix}\ \frac{n^0}{N_F}. \tag{25}$$

Based on the latter inequality, each firm considers whether $S(n^0)$ is greater than n^0/N_F or not, and then chooses the network which they will supply software to.

3.3 First Stage

Since we focus attention on the case of *symmetric equilibrium* where $n^h = n^h_*$, we consider only two cases: case (i) n^h and n^h_* $(h = 0, 1)$ are positive; case (ii) $n^0 = N$ and $n^0_* = N_*$ or $n^1 = N$ and $n^1_* = N_*$.

At any equilibrium where two networks coexist both in Home and Foreign, $\pi^0 = \pi^1$ and $\pi^0_* = \pi^1_*$ must be satisfied. Therefore, in case (i), we can show from (**??**)-(**??**) that

$$s = \frac{n^0+\tau n^0_*}{N+\tau N_*} \quad \text{and} \quad s_* = \frac{\tau n^0+n^0_*}{\tau N+N_*}, \tag{26}$$

and then

$$\pi^0 = \pi^1 = \frac{e-c}{\sigma}\left(\frac{1}{N+\tau N_*} + \frac{\tau}{\tau N + N_*}\right) - f \tag{27}$$

and

$$\pi^0_* = \pi^1_* = \frac{e-c}{\sigma}\left(\frac{\tau}{N+\tau N_*} + \frac{1}{\tau N + N_*}\right) - f. \tag{28}$$

On the other hand, in case (ii), all software firms provide software for one network at equilibrium. Therefore, $(s, s_*, n^0, n^0_*) = (1, 1, N, N_*)$ or $(s, s_*, n^1, n^1_*) = (0, 0, N, N_*)$ holds. Then, from (**??**)-(**??**), we obtain

$$\pi^0 \quad \text{or} \quad \pi^1 = \frac{e-c}{\sigma}\left(\frac{1}{N+\tau N_*} + \frac{\tau}{\tau N + N_*}\right) - f \tag{29}$$

and

$$\pi^0_* \quad \text{or} \quad \pi^1_* = \frac{e-c}{\sigma}\left(\frac{\tau}{N+\tau N_*} + \frac{1}{\tau N + N_*}\right) - f. \tag{30}$$

Thus, in each country, the profit of each firm is independent of equilibrium software configurations. Since the free-entry prevails both in Home and Foreign, we can conclude that

$$N = N_* = \frac{e-c}{f\sigma}, \tag{31}$$

that is, the free-entry number of firms in each country is uniquely given as[14]

$$N_F \equiv \frac{(e-c)}{f\sigma}. \tag{32}$$

---

[14] In any other cases, for example, $n^0 = N$ and $n^1_* = N_*$, we can show that free entry in each country implies $N + N_* = 2N_F$.

Based on the foregoing argument, we can conclude that $\pi^0 = \pi^1 = 0$ holds for any pair (s, n^0) on the dotted line in Figure 1, $\pi^0 = 0$ at $(1, N_F)$, and $\pi^1 = 0$ at $(0, 0)$, while π^0 (π^1) is positive (negative) at any pair above the line and *vice versa.*

3.4 Nash Equilibrium Configurations

First, from (**??**), the first derivative of π^0 with respect to n^0 is given by

$$\frac{\partial \pi^0}{\partial n^0} = \frac{e-c}{\sigma}\left[\frac{1}{n^0+\tau n_*^0}\left(\frac{\partial s}{\partial n^0} - \frac{s}{n^0+\tau n_*^0}\right) + \frac{\tau}{\tau n^0 + n_*^0}\left(\frac{\partial s_*}{\partial n^0} - \frac{\tau s_*}{\tau n^0 + n_*^0}\right)\right].$$

Evaluating this derivative at $n^0 = n_*^0$ and $s = s_* = n^0/N_F$ yields

$$\begin{aligned}&\left.\frac{\partial \pi^0}{\partial n^0}\right|_{\substack{n^0=n_*^0\\ s=s_*=n^0/N_F}}\\ =&\frac{e-c}{\sigma(1+\tau)^2 n^0}\left[(1+\tau)\left.\frac{\partial s}{\partial n^0}\right|_{n^0=n_*^0} - \frac{1}{N_F} + \tau^2\left(\frac{1+\tau}{\tau}\cdot\left.\frac{\partial s_*}{\partial n^0}\right|_{n^0=n_*^0} - \frac{1}{N_F}\right)\right].\end{aligned}$$

Utilizing (**??**), (**??**), and (**??**), we obtain

$$(1+\tau)\left.\frac{\partial s}{\partial n^0}\right|_{n^0=n_*^0} = \frac{1+\tau}{\tau}\cdot\left.\frac{\partial s_*}{\partial n^0}\right|_{n^0=n_*^0} = S'(n^0).$$

Therefore,

$$\left.\frac{\partial \pi^0}{\partial n^0}\right|_{\substack{n^0=n_*^0\\ s=s_*=n^0/N_F}} = \frac{(e-c)(1+\tau^2)}{\sigma(1+\tau)^2 n^0}\left[S'(n^0) - \frac{1}{N_F}\right]. \tag{33}$$

Thus, we can conclude that

$$\frac{\partial \pi^0}{\partial n^0} \gtrless 0 \quad \Longleftrightarrow \quad S'(n^0) \gtrless \frac{1}{N_F} \tag{34}$$

holds for any pair (s, n^0) where the curve $s = S(n^0)$ and the dotted line $s = n^0/N_F$ intersects in Figure 1. Similarly, we can show that

$$\frac{\partial \pi^1}{\partial n^1} \begin{array}{c} > \\ = \\ < \end{array} 0 \quad \Longleftrightarrow \quad S'(n^0) \begin{array}{c} > \\ = \\ < \end{array} \frac{1}{N_F} \tag{35}$$

holds for that pair.

Based on the foregoing argument, we obtain the Nash equilibrium configurations as follows: In order for a configuration to be a Nash equilibrium, it must be impossible for a software firm to switch networks and increase its profit.

In case A, the graph of $S(n^0)$ is drawn as curve A in Figure 1. Thus, there are three equilibrium candidates; $(n^0 = n^1 = N_F/2)$, $(n^0 = N_F, n^1 = 0)$, and $(n^0 = 0, n^1 = N_F)$. Since

$$S(n^0) \begin{cases} > n^0/N_F & \text{if} \quad 0 < n^0 < N_F/2, \\ < n^0/N_F & \text{if} \quad N_F/2 < n^0 < N_F, \end{cases} \quad \text{and} \quad S'\left(\frac{N_F}{2}\right) < \frac{1}{N_F}, \tag{36}$$

we can conclude that only symmetric equilibrium $(n^0 = n^1 = n^0_* = n^1_* = N_F/2)$ is stable in a Nash equilibrium sense.

On the other hand, in case C, the graph is drawn as curve C and

$$S(n^0) \begin{cases} < n^0/N_F & \text{if} \quad n^0 < N_F/2, \\ > n^0/N_F & \text{if} \quad n^0 > N_F/2, \end{cases} \quad \text{and} \quad S'\left(\frac{N_F}{2}\right) \geq \frac{1}{N_F}. \tag{37}$$

Therefore, only two equilibria, $(n^0 = n^0_* = N_F, n^1 = n^1_* = 0)$ and $(n^0 = n^0_* =$

$0, n^1 = n^1_* = N_F)$, are stable.[15][16]

Finally, in case B, the graph of $S(n^0)$ is drawn as curve B and it is apparent from the discussion above that all three of the equilibria, $(n^0 = n^1 = n^0_* = n^1_* = N_F/2)$, $(n^0 = n^0_* = N_F, n^1 = n^1_* = 0)$, and $(n^0 = n^0_* = 0, n^1 = n^1_* = N_F)$, are stable. So, we have the following lemma:

Lemma: Depending on the parameter values, the following three cases emerge:

Case A: If $t \geq \bar{t}$*, a unique symmetric equilibrium exists,* $(n^0 = n^1 = n^0_* = n^1_* = N_F/2)$.

Case B: If $\bar{t} > t > \underline{t}$*, three equilibria,* $(n^0 = n^1 = n^0_* = n^1_* = N_F/2), (n^0 = n^0_* = N_F, n^1 = n^1_* = 0)$*, and* $(n^0 = n^0_* = 0, n^1 = n^1_* = N_F)$*, exist.*

Case C: If $t \leq \underline{t}$*, only two equilibria,* $(n^0 = n^0_* = N_F, n^1 = n^1_* = 0)$ *and* $(n^0 = n^0_* = 0, n^1 = n^1_* = N_F)$*, exist.*

There is one important thing to note about the effect of deeper market integration: the gradient of $S(n^0)$ in the neighborhood of the symmetric equilibrium is increased, and this change tends to make the symmetric equilibrium less stable. Figure 1 suggests that deeper market integration, by

---

[15] It can be easily shown that the symmetric equilibrium candidate is not a Nash equilibrium even if $S'(N_F/2)$ is equal to $1/N_F$ which corresponds to the case of $t = \underline{t}$.

[16] In the interval of n^0 where $S(n^0)$ is greater than 1 (smaller than 0), the actual marginal consumer in each country is equal to 1 (0) and is still above (below) the line $s = n^0/N_F$.

intensifying indirect network effects, increases the extent to which a given number of software varieties is consistent with hardware/software standardization.

4 The Impact of Market Integration

Now let us turn to the impact of deeper market integration (i.e., a gradual decrease in trade costs for software products).[17] A reduction in intermarket trade costs (i.e., a larger τ) implies one basic change: the effective number of software varieties, $(1+\tau)n^h$, becomes larger. This implies that an integrated market can make access to software products easier.[18] Since consumers prefer to consume a wide variety of software products, deeper market integration might result in gains from easier access to software products. However, we have to check *the changes in the variety of hardware.*

Figure 2 traces out equilibrium values of n^h as functions of the level of intermarket trade costs. At high values of t, the symmetric equilibrium is unique and both systems exist. As t drops below level $\bar{t}$, hardware (and software) standardization (i.e., only one type of hardware remains) becomes sustainable. For trade costs below $\underline{t}$, the symmetric equilibrium is unstable.

---

[17] The case of a move from a closed economy to full trade liberalization is discussed in Iwasa and Kikuchi (2008).

[18] Note that the total number of software varieties remained unchanged as $2N_F$.

Let us suppose a secular fall in intermarket trade costs. From an initial position in which two technologies coexist, hardware standardization spontaneously arises through a process of intensified indirect network effects. In what follows, to highlight the interaction between deeper market integration and software provision, let us examine the following two representative cases.

4.1 The Case of Hardware Differentiation

In what follows, t (resp. t') indicates trade costs before (resp. after) integration. Let us assume that the following condition is satisfied:

$$t > t' \geq \bar{t}. \tag{38}$$

Note that this condition holds when the degree of hardware differentiation (k) is relatively large (or the degree to which indirect network effects exist is relatively low). In this case, two types of hardware remain during the process of market integration. Thus, no consumer changes his or her hardware and market integration induces an effectively large number of software varieties for each type of hardware. From (**??**) and (**??**), this clearly increases every consumer's utility.

Proposition 1: *Given that condition* (**??**) *holds, both types of hardware remain in equilibrium and both countries gain from deeper market integration.*

4.2 The Case of Hardware Standardization

Next, let us assume that the following condition is satisfied:

$$t > \underline{t} \geq t'. \tag{39}$$

In this case, while both types of hardware may exist before integration, only one type of hardware remains after integration. In other words, intensified indirect network effects result in a *reduced* number of hardware varieties (2 rather than 1).

This can be interpreted as follows. An increased number of effective software varieties intensifies indirect network effects, which induces consumers to choose hardware that has had the largest amount of software written for it. Due to these changes, software firms change their software provision decision: all software firms choose to write software for a single type of hardware. Then, the demand for other types of hardware vanishes.

For simplicity, let us suppose that only Hardware 1 remains after market integration. In this case, there are some consumers who have to switch from Hardware 0 to Hardware 1 if the symmetric equilibrium was realized before integration. While there are gains from the increased diversity of software available, there are losses from switching to the other network.

Let us consider the marginal case where a sufficiently small decrease in trade costs occurs around $\underline{t}$. The change in the indirect utility of a type-s

consumer who switches to the other network is:[19]

$$\Delta V(s) = \frac{[2^{1/(\sigma-1)} - 1][(1+\underline{t}^{1-\sigma})N_F]^{1/(\sigma-1)}(e-c)(\sigma-1)}{2^{1/(\sigma-1)}b\sigma} - k(1-2s). \quad (40)$$

Note that the first term on the RHS represents the gains from software diversification while the second term on the RHS represents costs from increased disutility. Let us define a type-$\tilde{s}$ consumer who is indifferent to switching hardware as follows:

$$\begin{aligned}\tilde{s} &= \frac{1}{2} - \frac{[2^{1/(\sigma-1)} - 1][(1+\underline{t}^{1-\sigma})N_F]^{1/(\sigma-1)}(e-c)(\sigma-1)}{2^{\sigma/(\sigma-1)}kb\sigma} \\ &= \frac{1}{2} - \frac{[2^{1/(\sigma-1)} - 1]\bar{N}^{1/(\sigma-1)}(e-c)(\sigma-1)}{2^{\sigma/(\sigma-1)}kb\sigma} \\ &= \frac{1}{2} - \frac{[2^{1/(\sigma-1)} - 1](\sigma-1)}{4}, \qquad (41)\end{aligned}$$

where use has been made of the definitions $\underline{t} = [N_F/(\bar{N} - N_F)]^{1/(\sigma-1)}$ and $\bar{N} = 2[kb\sigma/2(e-c)]^{\sigma-1}$. Note that (**??**) is positive for $^{\forall}\sigma > 2$ and goes to $1/2 - (\ln 2)/4$ as $\sigma \to \infty$.[20] Now we can state the possibility of losses from market integration.

---

[19] Note that, in the case of hardware standardization, the number of software varieties for Hardware 1 increases from $2n_1$ to $4n_1$ (or from N_F to $2N_F$).

[20] (**??**) can be rewritten as $[1 - \psi(\sigma)](\sigma+1)/4$, where $\psi(\sigma) \equiv 2^{1/(\sigma-1)}(\sigma-1)/(\sigma+1)$. Then, $\psi(2) = 2/3$ and

$$\psi'(\sigma) = \frac{2^{1/(\sigma-1)}(2-\ln 2)}{(\sigma-1)(\sigma+1)^2}\left(\sigma - \frac{2+\ln 2}{2-\ln 2}\right).$$

Clearly, the derivative is positive (negative) if σ is greater (smaller) than $(2+\ln 2)/(2-\ln 2)$. It is also clear that $\lim_{\sigma\to\infty}\psi(\sigma) = 1$. Based on the above, we can conclude that $\tilde{s}$ is positive for $^{\forall}\sigma > 2$.

Proposition 2: *If a sufficiently small decrease in trade costs occurs around* $\underline{t}$ *and Hardware* 1 *(resp.* 0*) dominates the integrated market, both countries' consumers who are located at* $s \in [0, \tilde{s}]$ *(resp.* $t \in [1 - \tilde{s}, 1]$*) are made worse off by deeper market integration.*

This implies that trade liberalization leads some consumers to "switch" to an other-dominated brand, thereby increasing disutility. Note that this case is in distinct contrast to the cases of universal gains from trade, which are emphasized in the literature. We would like to stress that deeper market integration, which forms the basis for easier access to software products (i.e., intensified indirect network effects), may work as a catalyst for Pareto inferior outcomes.

5 Concluding Remarks

Both deeper market integration and advances in digital technology have driven particularly large decreases in the costs of intermarket software provision. In this note, we first explained the mechanism of how trade costs influence the software provision decision of software firms. Then, we investigated the transformation of production/trade patterns given gradually decreasing trade costs for software products. It is shown that, if two incompatible types of hardware exist, deeper market integration may *reduce* the variety of hardware technologies. It is also shown that, if the variety of hardware technologies is reduced by deeper integration, some consumers are made worse off (Proposition 2). In other words, deeper market integration, which forms the basis for easier access to software products, may work as a catalyst for Pareto inferior outcomes.

The present analysis must be regarded as tentative. Hopefully, it provides a useful paradigm for considering how deeper market integration affects both the structure of software provision and intermarket trade patterns.

References

[1] Anderson, J. E., and E. van Wincoop (2004) “Trade Costs,” *Journal of Economic Literature,* Vol. 42, pp. 691–751.

[2] Behrens, K., Gaigne, C., Ottaviano, G.I.P., and J.-F. Thisse (2007) “Countries, Regions and Trade: On the Welfare Impacts of Economic Integration,” *European Economic Review,* Vol. 51, pp. 1277–1301.

[3] Chou, C., and O. Shy (1990) “Network Effects without Network Externalities,” *International Journal of Industrial Organization,* Vol. 8, pp. 259–270.

[4] Church, N., and N. Gandal (1992) “Network Effects, Software Provision and Standardization,” *Journal of Industrial Economics,* Vol. 40, pp. 85–104.

[5] Dixit, A. K., and J. Stiglitz (1977) “Monopolistic Competition and Optimum Product Diversity,” *American Economic Review,* Vol. 67, pp. 297–308.

[6] Economides, N. (1996) “The Economics of Networks,” *International Journal of Industrial Organization,* Vol. 14, pp. 673–699.

[7] Farrell, J., and P. Klemperer (2007) “Coordination and Lock-In: Competition with Switching Costs and Network Effects,” in Armstrang, M.,

and R.-H. Porter (eds.) *Handbook of Industrial Organization,* Vol. 3, Elsevier, Amsterdam, pp. 1967–2072.

[8] Fujita, M., P. Krugman and A. J. Venables (1999) *The Spatial Economy: Cities, Regions and International Trade,* Cambridge, Mass.: MIT Press.

[9] Gandal, N. (2002) "Compatibility, Standardization, and Network Effects: Some Policy Implications," *Oxford Review of Economic Policy,* Vol. 18, pp. 80–91.

[10] Gandal, N., and O. Shy (2001) "Standardization Policy and International Trade," *Journal of International Economics,* Vol. 53, pp. 363–383.

[11] Henkel, J., K. Stahl and U. Walz (2000) "Coalition Building in a Spatial Economy," *Journal of Urban Economics,* Vol. 47, pp. 136-163.

[12] Illing, G., and M. Petitz (eds.) (2006) *Industrial Organization and the Digital Economy,* Cambridge, Mass.: MIT Press.

[13] Iwasa, K., and T. Kikuchi (2008) "Indirect Network Effects and the Impact of Trade Liberalization: A Note," Working Paper 07-15, Graduate School of Economics, Kobe University

[14] Kikuchi, T. (2003) "Interconnectivity of Communications Networks and International Trade," *Canadian Journal of Economics,* Vol. 36, pp. 155–167.

[15] Kikuchi, T. (2007) “Network Externalities and Comparative Advantage,” *Bulletin of Economic Research,* Vol. 59, pp. 327–337.

[16] Ottaviano, G., and J.-F. Thisse (2004) “Aggromeration and Economic Geography,” in Henderson, J. V., and J.-F. Thisse (eds.) *Handbook of Regional and Urban Economics,* Vol. 4, Elsevier, Amsterdam, pp. 2563–2608.

[17] Schmitt, N. (1993) “Equilibria and Entry in Two Interdependent Spatial Markets,” *Regional Science and Urban Economics,* Vol. 23, pp. 1–27.

[18] Schmitt, N. (1995) “Product Imitation, Product Differentiation, and International Trade,” *International Economic Review,* Vol. 36, pp. 583–608.