Integration and International Standardization

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Abstract

The paper develops a two country overlapping generations model of product improvement innovation to analyze the evolution of incompatible standards among countries. The paper emphasizes the tradeoff between international standardization of products and product improvement innovation. We analyze the effects of governments mandating standards on product imporvement R&D, and the incentives of governments to subsidize R&D in order to advance the quality of its standard.

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1 Introduction

The present analysis distinguishes between national and international network effects. More precisely, some products, such as the telephone, fax machines, the telex, marine and aviation radio and navigation equipment, in which consumers in one country value the number of consumers using the same products in the foreign country in the same magnitude they value domestic usage. However, there are other products, that differ according to size measurements (a very simple example is the size of the thread of the screw) in which consumers attach very little value to the foreign network size compared with the domestic one. Some products, such as video players and recorder The present paper analyzes the effects of varying the degree of the international network externality on the level of product improvement R&D.

The paper is organized as follows. Section 2 develops the basic infinite horizon overlapping generations model of product improvement innovation in the presence of network externalities. Section **??** analyzes and evaluates two Section 6 concludes.

2 The Environment

model.s

Consider a two country, indexed by k, $k = \alpha, \beta$, discrete time overlapping generations economy, where in each period t, $t = 1, 2, ...$, the population of each economy consists of two individuals: the young of generation $\tau = t$ and the old of generation $\tau = t - 1$.

A consumer gains utility from the purchase of a durable product (can be interpreted as a television set, or any other products which can be improved over time and may operate on different standards). We assume that the consumer adopts the product when she is young for the two periods of her life and that the product cannot be resold.

2.1 A Consumer's Choice Problem

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We denote by V_t^k the *lifetime stand alone* value of the period t technology embodied in a product produced in country k to a consumer (of any nationality) who adopts the product in period t and consumes it in periods t and $t+1$. The country k consumer who is born in period t (generation $\tau = t$) faces given stand alone values for the products (V_t^α and V_t^β) and purchases the product only when she is young. The consumer who is young at t in country k chooses from a set of two actions: the consumer can purchase the product produced in its own country (*adopting* the local standard, action denoted by A), or the consumer can purchase the product produced by the other country (*deserting* the local standard, action denoted by D). We denote by c_τ^k the consumption action taken by a generation τ consumer in country k, where $c_\tau^k \in \{A, D\}$.

2.2 Preferences and Network Effects

We assume that in addition to the given stand alone value of the product, a consumer's preference for the product also increases with the number of consumers *consuming* the same product at the time of purchase (*network valuation* in what follows).[1] Let $n_t^k(l) \in \{0, 1, 2\}$

[1] With some complication, it is possible to model the consumers preferences as influenced by period t *and* period $t+1$ network sizes, see an earlier version, Shy (1991).

denote the county k period t number of users of a *particular* standard developed in country l, $(k, l = \alpha, \beta)$, where, $n_t^k \in \{0, 1, 2\}$. Also, let p_t^k denote the period t price of the product produced in country k.

Altogether, the *lifetime utility* of a of generation τ consumer is assumed to be a function of the (given) *lifetime* stand alone value placed on the product adopted in period τ and consumed in periods τ and $\tau + 1$, and a monotonic function $u(\cdot)$ of period τ network size. Hence, in view of the possible actions, country k, generation τ's utility level is given by

$$U^{\tau,k} = \begin{cases} V_\tau^k + u\left(n_\tau^k(k) + \rho n_\tau^{\tilde{k}}(k)\right) - p_\tau^k & \text{if } c_\tau^k = A \\ V_\tau^{\tilde{k}} + u\left(n_\tau^k(\tilde{k}) + \rho n_\tau^{\tilde{k}}(\tilde{k})\right) - p_\tau^{\tilde{k}} & \text{if } c_\tau^k = D \end{cases} \tag{1}$$

utfnft

The parameter ρ, $0 \leq \rho \leq 1$, shows that consumers may not place the same weight on the domestic and foreign network sizes. Thus, the parameter ρ 'discounts' the size of the foreign network relative to the domestic network in the consumer's preference. If $\rho = 0$, a generation's welfare is not affected by the number of foreign users who adopt the same standard. However, for some products such as the telephone, facsimile machines, avionics and radio equipment, and electronic mail standards setting $\rho = 1$ seems appropriate.

2.3 Product improvement and innovators

innovato

We assume that if a country k (young) innovator invests I units of resources in period t, she will be able to sell an improved product in period $t + 1$. Formally, the law of motion of the stand-alone valuation (quality) of the standard 'produced' in country k is given by

$$V_t^k = \begin{cases} V_{t-1}^k + \phi & \text{if innovation was undertaken at } t-1 \\ V_{t-1}^k & \text{otherwise} \end{cases} \tag{2}$$

value

In each period in each country, the producing firm is owned by the *old* in that country who collects the profit and then transfers the (unpatented) technology to the young who is born in the same country and will own the firm in the subsequent period. Thus, we assume that a new technology cannot be patentable for more than one period. The would-be firm owner young can innovate by spending $I > 0$ units of resources in order to improve the product as described in (2). We denote by $i_\tau^k(\cdot)$, $i_\tau^k \in \{0, I\}$, the investment/innovation decision of the young of generation τ in country k. Let π_t^k denote the revenue collected by period t firm owner in country k. The profit of a period t country k innovator (would-be period $t+1$ firm owner) is given by

$$\Pi_t^k = \pi_{t+1}^k - i_t^k = [n_{t+1}^k(k) + n_{t+1}^{\tilde{k}}(k)]p_{t+1}^k - i_t^k \tag{3}$$

profitft

2.4 Consumer's adoption equilibrium

adoption

With no loss of generality, let $V_t^\beta \geq V_t^\alpha$ (that is, country β has the (weakly) more advanced standard in period t. Define the quality difference by $\Delta V_t \equiv V_t^\beta - V_t^\alpha$. Also, note that if in period t a country k consumer deserts, she 'loses' a network value of $u(2)$ and gains a network value of $u(1 + \rho 2)$, (since adopting the local standard makes the number of local users to be 2, while desertion means that the 2 (young and old) foreign users are discounted by ρ.) Hence, we define the 'network' switching cost by $S \equiv S(\rho) \equiv u(2) - u(1+\rho 2)$, which is the utility loss from switching to the foreign network. Note that $S > 0$ (< 0) if $\rho < \frac{1}{2}$ $(> \frac{1}{2})$. That is, switching cost are present when the degree of international network externality is lower than $\frac{1}{2}$. Otherwise, switching costs are negative thereby providing a strong incentives for the desertion of one country.

In each period t, generation $\tau = t$ faces given product stand-alone valuation (V_t^α, V_t^β), the prices in each country (p_t^α, p_t^β) and the adoption decision of the consumer in the foreign country $(c_t^{\tilde{k}})$, and chooses c_t^k to maximize (1). Simple calculations from 1 yield that a unique consumers' adoption equilibrium is given by

$$< c_t^\alpha, c_t^\beta >= \begin{cases} < A, A > & \text{if } \Delta V_t - S \leq p_t^\beta - p_t^\alpha \leq \Delta V_t + S \\ < D, A > & \text{if } p_t^\beta - p_t^\alpha < \Delta V_t - S \\ < A, D > & \text{if } p_t^\beta - p_t^\alpha > \Delta V_t + S \end{cases} \tag{4}$$

conseql

2.5 Equilibrium prices

priceeql.s

The (old) firm owner in country k faces predetermined stand alone value for the products (V_t^α, V_t^β) and the price of the other country's product $(p_t^{\tilde{k}})$, and chooses p_t^k to maximize (3) subject to the consumers' decision rules (4). That is, we look for a Nash equilibrium prices p_t^α, p_t^β.

Proposition 1 *Given that* $\Delta V_t = V_t^\beta - V_t^\alpha \geq 0$*,*

1. *If the period t difference between the two stand-alone valuations of the two standards*

is small relative to the switching cost, ($\Delta V_t < 3S$), then the Nash equilibrium prices are given by

$$p_t^\alpha = 2S - \frac{2}{3}\Delta V_t \quad and \quad p_t^\beta = 2S + \frac{2}{3}\Delta V_t \tag{5}$$

In this case, there is no desertion in period t, and all consumers purchase the product operating on their country's standard. That is, $c_t^\alpha = c_t^\beta = A$.

2. *If the period t difference between the two stand-alone valuations of the two standards is large relative to the switching cost, ($\Delta V_t > 3S$), then the Nash equilibrium prices are given by*

$$p_t^\alpha = 0 \quad and \quad p_t^\beta = \Delta V_t - S \tag{6}$$

priceout

In this case, country α's consumer deserts. That is, $c_t^\alpha = D$ and $c_t^\beta = A$.

prodeql.p

Proof. See appendix A.

Proposition 1 shows that when the quality gap is small (or the switching cost is high), the price difference increases with the quality gap ΔV_t. In addition, both prices increase with a decrease in the degree of international network externality ρ (an increase in S). That is, a smaller ρ increases switching cost and makes desertion less beneficial so that firms can keep higher prices. When the quality gap is high, the firm in country β undercuts the other firm by a price equals to the quality gap minus the switching cost. In this case β's price increases with the size of the technology gap but decreases with the degree of international network externality ρ (since α's consumer bears the switching cost which is subsidized by β's price.)

In view of (6), we can state the following.

Corollary 1 *Given $V_t^\beta > V_t^\alpha$, if the degree of international network externality is high ($\rho > \frac{1}{2}$, implying negative switching costs), then one country deserts and the world operates on a uniform standard from period t and on.* desert.c

2.6 Innovation equilibrium in the short-run

innovsr.s

In this subsection, we look for the equilibrium innovation levels of generation 1 in each country. Generation $\tau = 1$ (young) innovator in country k, takes country $\tilde{k}$ generation $\tau = 1$ innovator's investment action $i_1^{\tilde{k}}$ as given and chooses her investment action i_1^k to maximize its profit subject to the decision *rules* of the *future generations of consumers* in *both* countries.

Table 1 shows the period 1 payoffs for every investment outcome of the game. In view of (**??**), the outcomes depend on the 'magnitude of the product improvement innovation. The upper part corresponds to the case where the innovation is *major*, and the lower part corresponds to the case where the innovation is *minor*.

	Innovation is Major $\phi > 3S$			
$i_t^\alpha \setminus i_t^\beta$	0		I	
0	$2S$	$2S$	0	$\phi - S - I$
I	$\phi - S - I$	0	$2S - I$	$2S - I$
	Innovation is Minor $\phi < 3S$			
$i_t^\alpha \setminus i_t^\beta$	0		I	
0	$2S$	$2S$	$2S - \frac{2}{3}\phi$	$2S + \frac{2}{3}\phi - I$
I	$2S + \frac{2}{3}\phi - I$	$2S - \frac{2}{3}\phi$	$2S - I$	$2S - I$

Table 1: *Generation* 1 *profit levels,*$< \Pi_1^\alpha, \Pi_1^\beta >$

Now the period 1 equilibrium innovation levels depend on the cost of innovation, I.

If the product improvement innovation is major, $\phi > 3S$, then there are three cases: (1) $< i_1^\alpha = I, i_1^\beta = I >$ when innovation cost is low ($I < 2S$), (2) $< i_1^\alpha = 0, i_1^\beta = I >$ or $< i_1^\alpha = I, i_1^\beta = I >$ when the innovation cost is intermediate ($2S < I < \phi - S$), and (3) $< i_1^\alpha = 0, i_1^\beta = 0 >$ when the innovation cost is high ($I > \phi - S - I$).

If the product improvement innovation is minor, $\phi < 3S$, then there are two cases: (1) $< i_1^\alpha = I, i_1^\beta = I >$ when the innovation cost is low ($I < \frac{2}{3}\phi$), and (2) $< i_1^\alpha = 0, i_1^\beta = 0 >$ when the innovation cost is high ($I < \frac{2}{3}\phi$).

The two cases illustrate that when the innovation cost is low (in either definitions) the two innovators are involved in a Prisoners' Dilemma equilibrium where both innovate but due to competition, are unable to extract a higher surplus from the consumers.

The only case where the period 1 innovation equilibrium is not symmetric is when the innovation is major and the innovation cost is at the intermediate level. In this case, a zero profit is greater than the profit under the Prisoners' Dilemma type of equilibrium.

2.7 Innovation equilibrium in the long-run

The analysis of the previous section relies on the assumption that although the two countries are endowed with different standards, the two standards have the same stand-alone valuation in the initial period (period 1). Thus, since all but one equilibrium are symmetric, the equilibria of the previous subsection would yield that $V_2^{\alpha} = V_2^{\beta}$, the conditions yielding the period 1 symmetric equilibrium would also yield the same symmetric equilibrium in every generations of innovators.

We summarize the section with the following proposition.

Proposition 2 *Suppose that the two countries are operating on different standards of equal stand-alone values in period 1. Then,*

1. *when the consumers place a high value on the international network* ($\rho > \frac{1}{2}$)*, a consumer in one country deserts, and the world operates on a single standard. In this case, if* $I < 2\phi$*, innovation occurs each period, and the profits are collected by the host country.*

2. *when consumers place a low value on the international network* $\rho < \frac{1}{2}$*, then*

   (a) when the innovation is major ,$\phi > 3S$*, and the innovation cost takes an intermediate value,* $2S < I < \phi - S$*, one country deserts in period 1, and if* $I < 2\phi$*, innovation is undertaken each period by the host country*

   (b) otherwise, no desertion occurs and both countries operate on different standards. In addition, if innovation occurs, it occurs in both countries in each period.

eql.p

3 Policy

policy.s

In this section we analyze the behavior of governments in each country. In an overlapping generations model there are many ways to define governments' objectives, since policies may lead to Pareto non-comparable allocations. Therefore, we will analyze two types of governments. The first type is concerned with the short-run which is defined as the welfare participating agents in period 1. Incorporating this kind of governments into a welfare analysis is important since, especially in the context of standard setting, short-run politics plays a big role in decision making. In the ensuing subsection, we analyze governments acting as long-run social planners.

We restrict the governments to two actions.

Standard Protection (SP): The government of a country prohibits its residents from purchasing the product operating on the foreign standard. That is, desertion is prohibited.

R&D Subsidy (RS): In each period t, the government of a country taxes the young at t by I in order to finance innovation at t.

Note that the second policy basically means that the government 'forces' each generation to innovate.

4 Short-run governments

A short-run government in country k is defined as one that maximizes in period 1 the sum of the welfare of existing generations, the revenue collected by the old of generation 0, and the profit earn by generation 1. $U^{0,k} + U^{1,k} + \pi_1^k + \Pi_1^k$. Since $U^{0,k}$ is predetermined, each government maximizes $U^{1,k} + \pi_1^k + \Pi_1^k$.

5 Governments as social planners

Here we assume that each government is concerned with the welfare and profit levels of all generations. Thus,

6 Conclusion

This paper addresses questions regarding the consequences for countries remaining on separate or similar standards. The literature on compatibility has focused on the (static) tradeoff between (the utility from) variety and standardization (compatibility). This paper recognizes another tradeoff that is dynamic by nature: the tradeoff between dynamic speed of R&D and standardization. The implication for the international economy is straight forward: There are some benefits of having countries using different standards or incompatible products, since incompatibility may increase the incentives for product improvement innovations. Obviously this dynamic tradeoff applies not only to the international economy but also to smaller economies.

Appendix

A. Proof of Proposition 1

Let p_t^α, p_t^β denote the equilibrium prices, and let $\hat{p}_t^\alpha, \hat{p}_t^\beta$ denote out of equilibrium prices. Assuming $\Delta V_t \leq 3S$ implies that the equilibrium prices satisfy $\Delta V_t - S \leq p_t^\beta - p_t^\alpha = \frac{4}{3}\Delta V_t \leq \Delta V_t + S$. Hence, (4) implies that $c_t^\alpha = c_t^\beta = A$. Now, if β undercuts α (so that $c_t^\alpha = D$), it has to reduce the price to $\hat{p}_t^\beta \leq p_t^\alpha + \Delta V_t - S = \frac{1}{3}\Delta V_t + S$. In this case, $\hat{\pi}_t^\beta \leq 2(\frac{1}{3}\Delta V_t + S)$, which is less than or equal the equilibrium profit $Pi_t^\beta = 2S + \frac{2}{3}\Delta V_t$. Notice that any higher p_t^α would make β's undercutting profitable. Similarly, if α undercuts β, then it has to set $\hat{p}_t^\alpha \leq p_t^\beta - \Delta V_t - S$. In this case, $\hat{\pi}_t^\alpha \leq 2(S - \frac{1}{3}\Delta V_t)$ which is less than or equal the equilibrium profit $\hat{\pi}_t^\alpha = 2S - \frac{2}{3}\Delta V_t$. Altogether, neither firm finds in beneficial to undercut its rival foreign firm.

When $\Delta V_t > 3S$, $p_t^\beta - p_t^\alpha = \Delta V_t - S$. Any at higher p_t^β, α's consumer would not desert. Thus, the only possible deviation is to raise p_t^β to a maximal level subject to not having β's consumer deserting to α. In this case $\hat{p}_t^\beta = 0 + \Delta V_t + S = \hat{\pi}_t^\beta$, which is less than the equlibrium profit level $\pi_t^\beta = 2(\Delta V_t - S)$. *Q.E.D.*

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