Journal of Korea Trade Vol. 25, No. 3, May 2021, 1-20
https://doi.org/10.35611/jkt.2021.25.3.1
ISSN 1229-828X

Standards Harmonization and Asymmetric Compliance Technology*

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JKT 25(3)

Received 26 May 2020
Revised 27 January 2021
Accepted 8 February 2021

Abstract

Purpose – The purpose of this paper is to examine the welfare effects of standards harmonization between technologically asymmetric countries, and to determine optimal harmonization strategies for a country with mid-level technological advancement.

Design/methodology – Following Salop's circular city model (Salop, 1979), this study constructs a simple, horizontally-differentiated oligopoly model in which three firms and three countries exist. Each country adopts different compatibility standards and each firm incurs conversion costs for foreign market access due to differences in standards. The conversion costs are related to technology; standards harmonization removes these costs between participating countries. The paper considers three cases: i) no harmonization; ii) harmonization with the more technologically-advanced country and iii) harmonization with the less technologically-advanced country.

Findings – The paper first considers a scenario in which all three firms occupy some share of the market in each country. It shows that standards harmonization with both the technologically more- or less-advanced country always increases consumer surplus and social welfare. In addition, the producer surplus will increase if the harmonization partner has a higher technology level, whereas it may decrease if the partner has a lower technology level. It also shows that if most domestic export goods are in sectors with conversion costs above a certain level, harmonizing standards with a technologically more-advanced country should be prioritized. Such strategies, moreover, should be emphasized when there exists a large technology gap among countries. Lastly, the paper considers another scenario, in which harmonization leads to the foreclosure of the non-member firm from the member countries' markets. It shows that harmonization improves the social welfare of a mid-level technology country regardless of its partner's technology. It also shows that the country should prioritize harmonization with the technologically less-advanced country.

Originality/value – Though some of the existing studies consider the welfare effects of harmonization, their main assumption is that firms have the same conversion technology. Since complying with standards often requires substantial technological advancement and technical expertise, harmonization of compatibility standards between countries with gaps in technological ability carries different implications. This paper investigates the welfare effects of this harmonization and determines an optimal harmonization strategy while considering technological asymmetry among countries in standards compliance.

Keywords: Compliance Cost, Harmonization, Non-tariff Measures, Standards, Technology Asymmetry

JEL Classifications: F12, F13, F15, L5

* The author is extremely grateful to anonymous referees for insightful and detailed comments that have substantially improved the paper. He is also grateful to Yeolyong Sung and the participants of the 2016 Korea International Economic Association Annual Meeting for helpful comments. This work extends Ryu Han-Eol et al. (2015, pp. 101-117).

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1. Introduction

Since the fostering of trade liberalization in the 1990s, conventional trade barriers such as tariffs have been dropping steadily worldwide. Under the WTO regime, member countries are unable to impose higher tariff rates than the bound rates, and effective tariff rates have been decreasing consistently as a result. In addition, the spread of multilateral and bilateral trade agreements has accelerated this phenomenon. It follows that many governments are resorting to unconventional non-tariff measures (NTMs), such as technical measures and standards, in the pursuit of strategic trade initiatives. The variety and volume of NTMs have thus increased.

Among NTMs, standards are intended primarily to improve the compatibility and quality of products and protect consumers, but may in fact serve as de-facto trade barriers that prevent foreign corporations from entering the domestic market, thereby protecting domestic businesses whether the government in question intends to or not.[1] By setting standards that reflect esoteric domestic production processes or by requiring duplicative domestic tests and certifications, governments may effectively discriminate against foreign producers.

The U.S. Federal Motor Vehicle Safety Standards and Regulations (FMVSS) are a typical set of standards functioning as trade barriers. In most countries, vehicles are produced according to international safety standards set by the United Nations Economic Commission for Europe (UNECE), which are accepted in nearly every country in the world — except the U.S. and Canada. Foreign automakers that manufacture vehicles meeting UNECE and wish to export them to the U.S. and Canada must satisfy the additional FMVSS regulations. This means making additional modifications to models already in compliance with UNECE standards. This creates additional costs for the foreign firms, who already face stiff competition from American firms in the U.S. market.[2] Moreover, standards as trade barriers are an even greater concern for less-developed countries. Complying with standards often requires substantial technological advancement and expertise. Since less-developed economies lag behind developed economies in technology and technical skills, producers in less-developed countries may have a comparative disadvantage over those in developed countries in dealing with standards as trade barriers (Baldwin, 2000; Essaji, 2008; Maskus and Wilson, 2001).[3]

With the issues described above in mind, the WTO Agreement on Technical Barriers to Trade (the TBT Agreement) was struck to ensure that standards do not create unnecessary obstacles to international trade. However, due to the nature of multilateral agreement, it is not easy to satisfy all the member countries' needs and to regulate the use of standards as barriers. Meanwhile, small numbers of countries can form standards unions or include TBT chapters in free trade agreements that outline specific trade obligations and measures

[1] According to the Annex 1.2 of the WTO Agreement on Technical Barriers to Trade, standards refer to a "document approved by a recognized body that provides for common and repeated use, rules, guidelines or characteristics for products or related processes and production methods, with which compliance is not mandatory."

[2] Compliance with a standard is a matter of choice and not mandatory. However, if the regulatory authorities use standards as a basis for legislation, then the standards turns into technical regulation with which all economic agents are obliged to comply. In such cases, standards can serve as effective obstacles to trade.

[3] Some empirical studies showed that TBTs set by developed countries have negative effects on developing countries' exports while having positive effects on those of developed countries. See, for instance, Chen, Otsuki and Wilson (2006), Disdier, Fontagné and Mimouni (2008), and Essaji (2008).

reflecting the characteristics of each member country. In these ways, member countries can harmonize their standards and minimize the barriers between them.

Given the above, this paper analyzes the welfare effects of harmonizing compatibility standards when there exist technological asymmetries among countries in complying with standards and describes the optimal harmonization strategy.

There is a wide literature on standards issues in international trade. One strand of the literature focuses on the effects of imposing Minimum Quality Standards (MQS). This research usually assumes that firms produce vertically-differentiated products and face quality-dependent costs in examining the effects of MQS. For example, Boom (1995) examined a two-country model with a vertically differentiated duopoly in which additional costs are incurred when exporting. She considered two cases of setting MQS: one in which two countries adopt identical standards and another in which they adopt different standards. She showed that the two markets are connected by the quality choice of the duopoly firms. Lutz (2000) also considered a vertical differentiated duopoly model where the duopoly firms face quality-dependent costs and compete in two segmented markets. He showed that MQS can be utilized to increase welfare whether set uniformly or according to the mutual recognition principle. He also showed that if firms have identical costs, then mutual recognition is the optimal policy but if they have different costs then full harmonization is optimal. Pezzino (2012) studied the effects of MQS when three identical firms compete in a vertically-differentiated market. He showed that the introduction of MQS results in an increase of the average quality of the product. In addition, he showed if all three firms are domestic, then domestic welfare decreases. Whereas, if foreign firms operate in the domestic market then welfare may increase. Lutz and Pezzino (2012) examined the effect of MQS in a two-country model of vertical product differentiation while considering three alternative standard-setting arrangements: full harmonization, national treatment and mutual recognition. They showed that mutual recognition appeared to be a welfare-improving regulatory alternative under a given set of conditions; hence mutual recognition is the only possible equilibrium since it is the default procedure if countries fail to reach unanimous agreement. Petropoulou (2013) examined national incentives in setting MQS using a two-firm, two-country reciprocal trade model with vertically-differentiated products. She showed that cross-country externalities caused by trade links between countries result in inefficient national MQS. Trade flows are lower under Nash equilibrium MQS than under globally-optimal standards.[4]

Another branch of the literature examined the effects of setting compatibility standards. It often postulates that firms produce horizontally-differentiated products and that compatibility standards work as barriers to trade, since they discriminate against foreign producers by forcing them to incur conversion costs or testing and certification costs to comply with domestic standards. For instance, Baldwin (2000) provides a comprehensive overview of regulatory protectionism issues. In addition, he employs a simple three country model to examine how two types of standards harmonization — preferential and neutral harmonization — affect the trade of participating and excluded countries. He shows that preferential harmonization induces consumers in participating countries to switch their consumption from the products of excluded countries to that of participating countries since it sets a common standard that results in higher conversion costs for firms in excluded countries. He also shows that neutral harmonization has no asymmetric effects on participating and excluded countries, since it adopts common standards that would lower conversion costs for all firms. Gandal and Shy (2001), in a three-country model, attempts to

[4] For studies involving other aspects of MQS, see Berti and Falvey (2018) and Geng (2019).

study government incentives for harmonizing standards with other countries when there are either conversion costs or network effects. They show that if conversion costs are relatively large, preferential harmonization between two countries can increase the welfare of both. In addition, if network effects are significant, all three countries would have set unilateral standards and have no incentive to set preferential harmonization. Chen, Otsuki and Wilson (2006) examined the effects of foreign standards on firm export performance. In their model, multiple firms and countries exist and a firm requires individual fixed and variable costs when complying with each country's standards. The requirement of meeting different compliance costs in each market endogenizes a firm's export decisions and the total number of markets to enter. They showed that the differences in standards across countries cause diseconomies of scale for firms and affects decisions about whether to enter export markets.[5]

Among the above-cited studies, Baldwin (2000) and Gandal and Shy (2001) examined the effects of harmonizing compatibility standards. However, the implications carried by the harmonization of compatibility standards when there exists technological asymmetry between countries in standards compliance — the central focus of the present paper — is beyond the scope of those papers.

Since technology asymmetry adds complexity to the analysis, this paper will analyze the issue by building a simple three-country, three-firm model in which each country has adopted differing compatibility standards. Foreign firms are required to comply with domestic standards and have to bear conversion costs in order to comply with domestic standards and access the domestic market. The paper considers preferential harmonization; thus, if two countries harmonize their compatibility standards, conversion costs are eliminated between those participating countries only, whereas the excluded country would still incur them. To be more realistic, the paper assumes that technology asymmetry among countries in the conversion process exists. Hence, a firm in a technologically more advanced economy bears lower conversion costs. The paper examines the welfare effects of harmonization under two cases. In the first case, a country possessing mid-level conversion technologies harmonizes its compatibility standards with a technologically more-advanced country. In the second, a country possessing mid-level conversation technologies harmonizes standards with a less-advanced country.

The paper first considers a scenario in which all firms occupy some share of the market in each country. It shows that harmonization always increases consumer surplus and the social welfare of a country possessing mid-level conversion technology, regardless of the partner's technology level. In addition, harmonizing standards with technologically more-advanced countries improves the producer surplus, while doing so with a less-advanced one may either enlarge or shrink the producer surplus. The paper then considers optimal harmonization policy for a country with middling levels of technology. It shows that harmonization with the technologically superior country should be prioritized in sectors with conversion costs above a certain level. Whereas, harmonizing standards with a technologically inferior country should be prioritized in sectors with conversion costs below a certain level. Moreover, these strategies should be emphasized when asymmetries among the countries are severe.

The paper considers another scenario in which harmonization leads to the foreclosure of the non-member firm from the member countries' markets. It shows that harmonization improves the social welfare of a mid-level technology country regardless of its partner's technology. It also shows that the country should prioritize harmonization with the technologically less-advanced country.

The remainder of this paper is organized as follows. Section 2 introduces the model and

[5] Granslandt and Markusen (2001) suggest approaches to modeling standards and technical regulations.

Section 3 characterizes equilibrium before harmonization in a benchmarking discussion. Section 4 examines the welfare effects of harmonizing compatibility standards between technologically asymmetric countries. The government's optimal harmonization strategy is analyzed in Section 5. Section 6 investigates harmonization policies leading to the foreclosure of a non-member country. Section 7 concludes.

2. The Model

Consider a three-country, three-firm world economy model. Three countries are denoted by L, M, and H and each country is represented by the firms l, m, and h, respectively. Each firm produces a single horizontally differentiated product and sells it to all three countries. Assume that all three firms always have some share of the market in each country and cannot be expelled. Assume also that the markets are segmented; that is, firms are able to set different prices in different countries. Following Salop's circular city model (Salop, 1979), which is a variant of the Hotelling's linear city model (Hotelling, 1929), assume that each country has a circle of perimeter 3 and the representative firm in each country is positioned with equal space on that circle. Thus, the distance between any two firms is equal to one.

Each country has a continuum of 3 consumers which are uniformly distributed and located with a unit density around the circle's perimeter. Each consumer has an inelastic demand for each firm's product. Assume that the consumers who consume their ideal product obtain utility V.[6] Let p_i^n be the price of firm i's product in country n. Let also $d_i(x)$ be the shortest arc distance between firm i's product and an arbitrary consumer's ideal product, x. Consumption of firm i's product, which is located at a distance of $d_i(x)$ from a consumer's ideal product incurs transportation costs of $[d_i(x)]^2 = x^2$. Therefore, the utility function of an arbitrary consumer whose ideal product is located in x in the country n's circle and who consumes firm i's product can be expressed as follows:

$$U_x = V - p_i^n - [d_i(x)]^2, \quad \text{where } n = L, M, H \text{ and } i = l, m, h.$$

This paper assumes that the production costs for all firms are the same and without loss of generality, is set to zero. Each of the three countries has adopted different compatibility standards, and all products sold on the domestic market should meet this standard. In addition, foreign firms have to incur marginal standard conversion costs to satisfy local standards and be allowed to sell their products on the domestic market. Thus, for example, firm m should produce products according to country M's standards. If a foreign firm h or l exports its product to country M, it needs to pay standard conversion costs to comply with M's standards. On the contrary, if a country participates in harmonization with another country, then it will recognize participating country's standards and the member country need not incur the conversion costs when selling to its harmonization partner.[7]

The paper also assumes that there are differences in conversion technology among the three

[6] For example, though there are some technical differences between the UNECE and FMVSS auto safety standards, the objectives and outcomes of both regulations are similar. Thus, the welfare benefit to consumers of products made to comply with either set of standards is likely similar.

[7] For instance, according to Annex 2B of the Korea-EU free trade agreement, Korea and EU commit to use international standards as a ground for electromagnetic compatibility and electrical safety. Hence, standards cannot be barriers to trade between them. However, a non-member country who does not adopt those standards still incurs standards conversion costs when exporting electronic goods to Korea or the EU. Korea and the EU can be countries M and H, and the non-member country can be country L in the current model.

nations, with H being the technologically most-advanced and L being the least-advanced. This technology gap is reflected in the marginal conversion costs, which can be expressed as $c_h^n < c_m^n < c_l^n$. To simplify the discussion, the paper assumes that $c_h^n = c - \gamma$, $c_m^n = c$ and $c_l^n = c + \gamma$ where $n = L, M, H$, and c and γ represent the average conversion cost in the industry and gaps in compliance technology, respectively.[8,9] Such cost setting makes it possible to identify sectoral policy implications while also taking into account technological gaps between the countries. Compliance costs vary across industries.[10] Thus, the welfare effects of harmonization may differ depending on the compliance costs faced by an industry thus so may the optimal harmonization policy. There is therefore a need to consider sectoral differences in compliance costs. Considering this, this paper sets various levels of c as unique sectors and γ as technology differences between the countries in that sector.[11]

Since the technologically less-advanced country would have difficulties in developing adequate standards and in reaching harmonization with the more-advanced one, the paper focuses on harmonization with a country with mid-level technology.

The structure of the game is as follows. In the first stage, the government of the country possessing mid-level technology determines whether or not to harmonize its standards with another country. In the second stage, each representative firm sets optimal prices to maximize profit. The game is solved through backward induction.

3. Before Harmonization

I first check market equilibrium before harmonization as a benchmark case. Let firm i's market share in country n be x_i^n. Let also a consumer in country n who is indifferent between buying firm i's product and firm j's product be $x_{i,j}^n$. That consumer should satisfy the following equation:

$$V - p_i^n - \left(x_{i,j}^n\right)^2 = V - p_j^n - \left(1 - x_{i,j}^n\right)^2,$$

which can be solved for $x_{i,j}^n = \frac{1}{2} + \frac{p_j^n - p_i^n}{2}$. If all three firms occupy certain shares of each country's market, the inverse demand function that each firm faces in country n's market is

$$x_{i,j}^n + 1 - x_{k,i}^n = 1 + \frac{p_j^n + p_k^n - 2p_i^n}{2}, \qquad \text{where } i, j, k \in \{l, m, h\},\ i \neq j \neq k.$$

Then, the profit function of firm i in country n is defined as follows:

$$\pi_i^n = (p_i^n - c_i^n)\left(x_{i,j}^n + 1 - x_{k,i}^n\right) = (p_i^n - c_i^n)\left(1 + \frac{p_j^n + p_k^n - 2p_i^n}{2}\right). \tag{1}$$

[8] Considering conversion costs as the constant marginal costs is one of the standard model specifications in studying standards harmonization. For example, see Baldwin (2000) and Gandal and Shy (2001).

[9] This paper assumes that the difference in conversion costs between M and H and the costs between M and L are always the same, but in the real-world, they are mostly different. This is a clear limitation of the model. To reflect this reality, one may think of modeling the difference in conversion costs between M and H as γ_{MH} and the costs between M and L as γ_{ML}. However, since consideration of this aspect significantly adds the complexity of analysis and produces less intuitive results, this paper utilizes the simple technology gap structure described above.

[10] Maskus, Otsuki and Wilson (2005) and Moenius (2004) showed that the costs of complying with standards and technical regulations could be different across industries.

[11] Some literature considering technology asymmetry between countries has used this type of cost structure. See, for example, Kim Young-Han (2005).

Firm i chooses p_i^n to maximize its own profits while taking the prices of all other firms as given. Since the representative firms of each country produce their products following local standards, there are no conversion costs for them when they sell in the domestic market. That is, c_l^L, c_m^M, c_h^H are zero. Thus, the second stage equilibrium in country n before harmonization is:

$$\begin{aligned} p_i^n &= 1 + \frac{c_j^n + c_k^n}{5}, p_j^n = 1 + \frac{3c_j^n + c_k^n}{5}, p_k^n = 1 + \frac{3c_k^n + c_j^n}{5} \\ x_i^n &= 1 + \frac{c_j^n + c_k^n}{5}, x_j^n = 1 - \frac{2c_j^n - c_k^n}{5}, x_k^n = 1 - \frac{2c_k^n - c_j^n}{5}, \\ \pi_i^n &= \frac{\left(5 + c_j^n + c_k^n\right)^2}{25}, \pi_j^n = \frac{\left(5 - 2c_j^n + c_k^n\right)^2}{25}, \pi_k^n = \frac{\left(5 - 2c_k^n + c_j^n\right)^2}{25}, \end{aligned} \tag{2}$$

where $i, j, k \in \{l, m, h\},\ i \neq j \neq k$.
Therefore, the equilibrium profits of the three representative firms are expressed as follows:[12]

$$\pi_l = \pi_l^L + \pi_l^M + \pi_l^H = (75 + 6c^2 + 6c\gamma + 14\gamma^2 - 60\gamma)/25,$$

$$\pi_m = \pi_m^L + \pi_m^M + \pi_m^H = (75 + 6c^2 + 2\gamma^2)/25,$$

$$\pi_h = \pi_h^L + \pi_h^M + \pi_h^H = (75 + 6c^2 - 6c\gamma + 14\gamma^2 + 60\gamma)/25.$$

In country n, consumer surplus is determined by total gross utility minus the sum of aggregated consumer expenditure and transportation costs. Since the consumers are distributed evenly around the circle and obtain V utility irrespective of which firm's goods they consume, total gross utility will be $3V$. Aggregate consumer expenditure of firm i's product in country n is denoted by $e_i^n = p_i^n x_i^n$, where p_i^n and x_i^n are from (2). Similarly, the total transportation costs for firm i are denoted by:

$$t_i^n = \left[\int_0^{x_{i,j}^n} z^2\, dz + \int_0^{x_{i,k}^n} z^2\, dz\right], \qquad \text{where } i, j, k \in \{l, m, h\},\ i \neq j \neq k.$$

Aggregate consumer expenditures and transportation costs in country n will therefore be $e^n = e_l^n + e_m^n + e_h^n$ and $t^n = t_l^n + t_m^n + t_h^n$, respectively. Accordingly, country n's consumer surplus and social welfare are:

$$CS^n = 3V - (e^n + t^n), W^n \equiv CS^n + \pi_n. \tag{3}$$

Therefore, the social welfare of each country can be summarized as follows:

$$W^L = (300V + 32c^2 - 200c + 16c\gamma + 64\gamma^2 - 140\gamma - 25)/100,$$

$$W^M = (300V + 32c^2 - 200c + 32\gamma^2 - 25)/100,$$

$$W^H = (300V + 32c^2 - 200c - 16c\gamma + 64\gamma^2 + 140\gamma - 25)/100.$$

[12] Since the paper assumes that all three firms supply a positive amount of their product in all three markets in this section, each firm should have non-negative demand and prices in each market. Thus, before harmonization, $c < 5 - 3\gamma$ should be satisfied.

4. Standards Harmonization

In this section, this paper considers the welfare impacts of harmonizing compatibility standards between two countries. When two countries recognize each other's standards, they mutually benefit as conversion costs formally incurred by those countries' firms are eliminated. But the one country of the three not included in the harmonization agreement receives no benefit; thus the welfare effects of the harmonization of standards between two countries will be different for the countries party to the agreement and the country excluded from it. In addition, if asymmetries in conversion costs exist between nations due to technology differences, such harmonization may lead to the technologically more-advanced country losing its superiority or the less-advanced country overcoming its inferiority.

This paper concentrates on a country possessing mid-level technology, M, and posits two cases. The first case considers harmonizing compatibility standards between countries M and H and the second considers harmonization between countries M and L.

4.1. Harmonizing Standards with the Technologically More-advanced Country

Suppose that M harmonizes its compatibility standards with the technologically more-advanced H, leaving out less-advanced L. Once harmonization takes effect, M and H would recognize other member country's standards, thereby eliminating conversion costs incurred in trade between them. Thus, in addition to c_l^L, c_m^M, c_h^H, the conversion costs $c_m^M, c_h^M, c_m^H, c_h^H$ are zero.

Similar to the benchmark discussion in the preceding section, the equilibrium price, outputs, and profits of firm i selling its products in country n can be obtained. For example, the equilibrium price, outputs, and profits of m in each country are as follows:

$$p_m^H = p_m^M = 1 + \frac{c+\gamma}{5}, p_m^L = 1 + \frac{3c+(c-\gamma)}{5}$$

$$x_m^H = x_m^M = 1 + \frac{c+\gamma}{5}, x_m^L = 1 - \frac{2c-(c-\gamma)}{5},$$

$$\pi_m^H = \pi_m^M = \frac{[5+(c+\gamma)]^2}{25}, \pi_m^L = \frac{[5-2c+(c-\gamma)]^2}{25}.$$

Social welfare also can be obtained in a similar way in (3).

Note here that since all three firms always occupy some share of the market in each country, the parameters should meet non-negative demand and price conditions. These conditions are $c < 5 - 3\gamma$ before harmonization, $c < 5/2 - \gamma$ if M and H harmonize, and $c < 5 - 2\gamma$ and $c < 5/2 + \gamma$ if M and L harmonize. In addition, since this paper will compare the welfare effects of harmonization among the three cases, each case needs to satisfy all the above conditions for the purpose of comparison. Therefore, the parameters should meet $\gamma < c$ and $c < 5/2 - \gamma$, which satisfies non-negative demand and prices for the three firms in each market in all three cases.

The effects of harmonization between M and H on the welfare of M are summarized in Table 1.

Table 1. The Effects of the Harmonization between M and H on the Welfare of M[13]

	Before harmonization	After harmonization	The welfare effects of standards harmonization
Consumer surplus of *M*	$(300V - 200c + 24\gamma^2 + 8c^2 - 325)/100$	$(300V - 100c - 100\gamma + 16c\gamma + 8\gamma^2 + 8c^2 - 325)/100$	$\Delta CS^M = (25 + 4\gamma)(c - \gamma)/25 > 0$ $\frac{\partial \Delta CS^M}{\partial \gamma} = -(25 - 4c + 8\gamma)/25 < 0$ $\frac{\partial \Delta CS^M}{\partial c} = (25 + 4\gamma)/25 > 0$
Producer surplus of *M*	Total PS: $(75 + 6c^2 + 2\gamma^2)/25$	Total PS: $(75 + 10c + 10\gamma + 6c\gamma + 3\gamma^2 + 3c^2)/25$	$\Delta PS_m = (-3c^2 + 10c + 6c\gamma + \gamma^2 + 10\gamma)/25 > 0$ $\frac{\partial \Delta PS_m}{\partial \gamma} = 2(5 + 3c + \gamma)/25 > 0$ $\frac{\partial \Delta PS_m}{\partial c} = 2[5 - 3(c - \gamma)]/25 \gtreqless 0$
	PS in home market: $(5 + 2c)^2/25$	PS in home market: $(5 + \gamma + c)^2/25$	$\Delta PS_m^M = -(c - \gamma)(10 + 3c + \gamma)/25 < 0$ $\frac{\partial \Delta PS_m^M}{\partial \gamma} = 2(5 + c + \gamma)/25 > 0$ $\frac{\partial \Delta PS_m^M}{\partial c} = 2(-3c + \gamma - 5)/25 < 0$
	PS in the member market, H: $[5 - (c - \gamma)]^2/25$	PS in the member market, H: $[5 + (c + \gamma)]^2/25$	$\Delta PS_m^H = 4c(\gamma + 5)/25 > 0$ $\frac{\partial \Delta PS_m^H}{\partial \gamma} = 4c/25 > 0$ $\frac{\partial \Delta PS_m^H}{\partial c} = 4(\gamma + 5)/25 > 0$
	PS in the non-member market, L: $[5 - (c + \gamma)]^2/25$	PS in the non-member market, L: $[5 - (c + \gamma)]^2/25$	0
The social welfare of *M*	$(300V - 200c + 32\gamma^2 + 32c^2 - 25)/100$	$(60V - 12c - 12\gamma + 8c\gamma + 4\gamma^2 + 4c^2 - 5)/20$	$\Delta W^M = (-3c^2 + 35c + 10c\gamma - 3\gamma^2 - 15\gamma)/25 > 0$ $\frac{\partial \Delta W^M}{\partial \gamma} = -(15 - 10c + 6\gamma)/25 \gtreqless 0$ $\frac{\partial \Delta W^M}{\partial c} = (35 - 6c + 10\gamma)/25 > 0$

As shown, harmonization between M and H always improves the consumer surplus of M. The conversion costs between the two are eliminated as a result of the standards harmonization and this, in turn, allows both m and h to reduce export costs to H and M, respectively. The level of competition among the three firms in M's market will intensify, and consumers in M would have a chance to buy products at a lower price. Thus, the consumer surplus increases after harmonization ($\Delta CS^M > 0$). In addition, the producer surplus of M also increases. The relative competitiveness of m in H's market is improved after harmonization, whereas in M's market it deteriorates. So, the profits m obtains from H's market increases, but those from M's market decrease. Since M possesses less-advanced conversion technology than H, m's reduction in conversion costs due to the harmonized standards is larger than that of h. Therefore the increase in m's profits in H's market would be larger than the decrease in M's market and harmonizing standards between M and H

[13] Use has been made of the non-negative demand and price conditions in determining the signs of the welfare effects of harmonization between M and H.

would raise the producer surplus of M ($\Delta PS_m > 0$).[14] In total, harmonization between M and H improves the social welfare of M, which is the sum of the consumer and producer surplus ($\Delta W^M > 0$).[15]

An expansion of the technology gap γ lowers the conversion costs of h, while it raises those of l. In other words, as the technology gap widens, so too does the competitive edge of h over l in terms of exports. Following that, the improvements in h's competitiveness in M's market under harmonization is small given the large technology gap, and so an increase in γ restricts the increase of the consumer surplus through harmonization ($\partial \Delta CS^M/\partial\gamma < 0$) and also places a lower bound on the decline in m's profits in M's market ($\partial \Delta PS_m^M/\partial\gamma > 0$). In addition, since an increase in γ lowers the relative competitiveness of l's exports, it amplifies the magnitude of the increase in m's profits under harmonization in H's market ($\partial \Delta PS_m^H/\partial\gamma > 0$). Therefore, the larger the technology gap, the greater the magnitude of improvements in M's producer surplus through harmonization ($\partial \Delta PS_m/\partial\gamma > 0$). Since the effect of an increase in γ on changes in consumer and producer surpluses through harmonization have opposite signs, the overall change in M's social welfare depends on the relative size of the change in the consumer and producer surplus ($\partial \Delta W^M/\partial\gamma \gtreqless 0$).

If the average conversion cost of the industry (as denoted by c) is high, then the elimination of conversion costs via harmonization for m and h are also high. Hence, the larger the value of c, the stronger the competitiveness of h in M's market and m in H's under harmonization. Therefore, an increase in c boosts the magnitude of the increase in consumer surplus ($\partial \Delta CS^M/\partial c > 0$), the extent of the decline in m's profits in its home market ($\partial \Delta PS_m^M/\partial c < 0$), and the magnitude of the increase in m's profits in H's market ($\partial \Delta PS_m^H/\partial c > 0$). In sum, the effects of an increase in c on m's profits can be positive or negative ($\partial \Delta PS_m/\partial c \gtreqless 0$), but it can be shown that the aggregated effects of an increase in c on M's social welfare is always positive. Thus, an increase in c always augments the magnitude of the increase in M's social welfare ($\partial \Delta W^M/\partial c > 0$).

Since L is excluded from harmonization in the scenario described above, m and h still incur conversion costs when exporting to L. Hence, there is no change in the consumer surplus of L. The competitiveness of m and h over l is improved in M and H's markets as harmonization eliminated the conversion costs between the two. So l's profits in both M's market and H's market fall, while its profits in its home market remain unchanged. Harmonization thus lowers the producer surplus of L. Any change in L's social welfare caused by the harmonization comes solely from the change in producer surplus, since the harmonization between M and H has no effect on L's consumer surplus. Therefore, the welfare effects of harmonizing compatibility standards between M and H on L are always negative.[16, 17]

Proposition 1. Consider the three-country, three-firm model described above. Suppose a country possessing mid-level conversion technology harmonizes its compatibility standards with a technologically more-advanced country. Then this harmonization has the following

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[14] The harmonization between M and H will not cause any change in m's profit obtaining from excluded L market, since both m and h keep requiring the conversion costs when exporting to L.

[15] It can be shown that the welfare effects of harmonization on country H is $\Delta W^H = (-3c^2 + 35c + 8c\gamma - 8\gamma^2 - 20\gamma)/25 > 0$. Thus, partner country H also has an incentive to join the harmonization agreement.

[16] $\Delta CS^L = 0$, $\Delta PS_l^M = (c - \gamma)(3c + 5\gamma - 10)/25 < 0$, $\Delta PS_l^H = c(3c + 4\gamma - 10)/25 < 0$, and $\Delta PS_l = \Delta W^L = (-20c + 10\gamma + 6c\gamma - 5\gamma^2 + 6c^2)/25 < 0$.

[17] Chen and Mattoo (2008) examined the effects of regional agreements on the trade of member and non-member countries. They showed that harmonization of standards increases trade between participating countries but reduces the exports of excluded countries.

effects on the welfare of the mid-level country:

(i) Harmonization always increases the consumer and producer surpluses, and thus social welfare.
(ii) If the technology difference between nations is large, then the magnitude of the increase in the consumer surplus through harmonization is small, while that of the producer surplus is large. Changes in social welfare can be large or small.
(iii) If the average conversion costs in the industry are high, then the degree of improvement in the consumer surplus is high, while that of the producer surplus can be high or low. Improvements in social welfare are always high.
(iv) The social welfare of the non-member country i.e. technologically less-advanced country, regresses following harmonization.

4.2. Harmonizing Standards with the Technologically Less-advanced Country

Suppose that M harmonizes its compatibility standards with a technologically less-advanced country L. It follows that the conversion costs c_l^L, c_m^L, c_l^M, c_m^M become zero as M and L adopt common standards or recognize one another's standards.

The effects of harmonization between country M and L on the welfare of participating country M are summarized in Table 2.

Similar to the case of harmonizing standards between M and H, the harmonization between M and L always increases the consumer surplus of M. Since the conversion costs are eliminated between M and L, the competition among the three representative firms intensifies in M's market. The consumers of M benefit from the chance to consume products at a lower price. Thus, the consumer surplus of M improves after harmonization ($\Delta CS^M > 0$). The producer surplus of M can increase or decrease after harmonization with L. Harmonization allows both m and l to reduce export costs.[18] Thus, m's profits in its home market decrease but increase in L's market. Since H, which has more advanced technology, is excluded in this agreement (unlike the case of harmonization between M and H) the technology gap and the average conversion costs of the industry determine whether the producer surplus of M increases or decreases ($\Delta PS_m \gtreqless 0$). As is shown in Table 2, harmonization between M and L always improves the total social welfare of M ($\Delta W^M > 0$).[19]

If the technology gap γ increases, the conversion costs for h decrease but those of l increase. It follows that the improvements in the competitiveness of l in M's market through harmonization are significant given the large technology gap. Therefore, contrary to the case of harmonizing with H, an increase of γ amplifies the magnitude of improvements in the consumer surplus ($\partial \Delta CS^M/\partial\gamma > 0$) and also places increased downward pressure on declines in m's profit in M's market ($\partial \Delta PS_m^M/\partial\gamma < 0$). Since the relative competitiveness of h increases in L's market as γ increases, an increase of γ restricts the magnitude of any increases in m's profit in L's market ($\partial \Delta PS_m^L/\partial\gamma < 0$). Thus, the larger the technology gap, the smaller (larger) the magnitude of the increase (decrease) in M's producer surplus ($\partial \Delta PS_m/\partial\gamma < 0$). As has been shown, since the effects of an increase in γ on consumer and producer surplus through harmonization have opposite signs, the relative size of the change in the consumer and producer surpluses determines the change in M's social welfare ($\partial \Delta W^M/\partial\gamma \gtreqless 0$).

[18] Harmonizing standards between M and L has no effect on m's profit obtaining from excluded H market.

[19] It can be shown that the welfare effects of harmonization for country L is $\Delta\, \mathrm{W^L} = (-3c^2 + 35c - 8c\gamma - 8\gamma^2 + 20\gamma)/25 > 0$. Thus, harmonization is possibly reached between country M and L.

Table 2. The Effects of Harmonization between M and L on the Welfare of M[20]

	Before harmonization	After harmonization	The welfare effects of standards harmonization
Consumer surplus of M	$(300V - 200c + 24\gamma^2 + 8c^2 - 325)/100$	$(300V - 100c + 100\gamma - 16c\gamma + 8\gamma^2 + 8c^2 - 325)/100$	$\Delta CS^M = (25 - 4\gamma)(c + \gamma)/25 > 0$ $\frac{\partial \Delta CS^M}{\partial \gamma} = [25 - 4(c + 2\gamma)]/25 > 0$ $\frac{\partial \Delta CS^M}{\partial c} = (25 - 4\gamma)/25 > 0$
Producer surplus of M	Total PS: $(75 + 2\gamma^2 + 6c^2)/25$	Total PS: $(75 + 10c - 10\gamma - 6c\gamma + 3\gamma^2 + 3c^2)/25$	$\Delta PS_m = -(3c^2 - 10c + 6c\gamma + 10\gamma - \gamma^2)/25 \gtreqless 0$ $\frac{\partial \Delta PS_m}{\partial \gamma} = -2(5 + 3c - \gamma)/25 < 0$ $\frac{\partial \Delta PS_m}{\partial c} = 2[5 - 3(c + \gamma)]/25 \gtreqless 0$
	PS in home market: $(5 + 2c)^2/25$	PS in home market: $[5 + (c - \gamma)]^2/25$	$\Delta PS_m^M = -(10 + 3c - \gamma)(c + \gamma)/25 < 0$ $\frac{\partial \Delta PS_m^M}{\partial \gamma} = -2[5 + (c - \gamma)]/25 < 0$ $\frac{\partial \Delta PS_m^M}{\partial c} = -2(5 + 3c + \gamma)/25 < 0$
	PS in the non-member market, H: $[5 - (c - \gamma)]^2/25$	PS in the non-member market, H: $[5 - (c - \gamma)]^2/25$	0
	PS in the member market, L: $[5 - (c + \gamma)]^2/25$	PS in the member market, L: $[5 + (c - \gamma)]^2/25$	$\Delta PS_m^L = 4c(5 - \gamma)/25 > 0$ $\frac{\partial \Delta PS_m^L}{\partial \gamma} = -4c/25 < 0$ $\frac{\partial \Delta PS_m^L}{\partial c} = 4(5 - \gamma)/25 > 0$
The social welfare of M	$(300V - 200c + 32\gamma^2 + 32c^2 - 25)/100$	$(60V - 12c + 12\gamma - 8c\gamma + 4\gamma^2 + 4c^2 - 5)/20$	$\Delta W^M = -(3c^2 - 35c + 10c\gamma - 15\gamma + 3\gamma^2)/25 > 0$ $\frac{\partial \Delta W^M}{\partial \gamma} = [15 - 2(5c + 3\gamma)]/25 \gtreqless 0$ $\frac{\partial \Delta W^M}{\partial c} = [35 - 2(3c + 5\gamma)]/25 > 0$

An increase in c eliminates relatively more conversion costs for l in M's market through harmonization than it does for m in L's market. It follows that an increase in c augments increases in consumer surplus ($\partial \Delta CS^M/\partial c > 0$), depresses m's profits in M's market ($\partial \Delta PS_m^M/\partial c < 0$), and increases m's profits in L's market ($\partial \Delta PS_m^L/\partial c > 0$). Thus, depending on the relative size of the effects on m's profit in both its home market and in L's market, the degree of change in M's producer surplus can grow or fall with increases in c ($\partial \Delta PS_m/\partial c \gtreqless 0$). In total, the effect of an increase in c always raises the magnitude of the increase in social welfare ($\partial \Delta W^M/\partial c > 0$).

The welfare effects of the harmonization between M and L on excluded country H is always negative, similar to how L experienced only negative effects on its social welfare in the previous case where M and H harmonized standards.

[20] Non-negative demand and price conditions have been used in determining the signs of the welfare effects of harmonization between M and L.

Proposition 2. Consider the three-country, three-firm model described above. Suppose a country possessing mid-level conversion technology harmonizes its compatibility standards with a technologically less-advanced country. This harmonization has the following effects on the welfare of mid-technology country:

(i) The consumer surplus grows while producer surplus can either expand or contract. Social welfare always improves through harmonization.
(ii) If the technology difference between nations is large, then the magnitude of the increase in consumer surplus through harmonization is correspondingly large. The magnitude of change in the producer surplus and that of social welfare can be large or small.
(iii) If the average conversion costs in an industry are large, then improvements to the consumer surplus are significant. Levels of change in the producer surplus can be high or low; changes to social welfare are large.
(iv) The social welfare of the non-member country — that is, the technologically more-advanced country — always regresses after harmonization.

5. The Optimal Harmonization Strategy

The results of the analysis in Section 3 show that it is possible for M to improve overall social welfare by harmonizing compatibility standards with the technologically more-advanced country H or with the less-advanced country L. A country in M's position may have to prioritize between H and L to maximize its welfare gains from harmonization. This section will compare the welfare effects of the two choices from M's perspective: standards harmonization with H or with L, and determine M's optimal harmonization strategy.

Table 3 shows the supply costs for l, m, h in each market before and after harmonization.

Table 3. The Supply Costs for Each Country's Representative Firms in Each Market

	Before harmonization	After harmonization	
M market	$c+\gamma, 0, c-\gamma$	Between M and H	$c+\gamma, 0, 0$
		Between M and L	$0, 0, c-\gamma$
H market	$c+\gamma$, c, 0	Between M and H	$c+\gamma, 0, 0$
L market	$0, c, c-\gamma$	Between M and L	$0, 0, c-\gamma$,

Let the changes of country M's social welfare resulting from harmonization between M and H be ΔW_{MH}^{M} and those between M and L be ΔW_{ML}^{M}. From Tables 1 and 2, the following results can be obtained:

$$\begin{aligned} \Delta CS^{M}(HAR_{MH}) - \Delta CS^{M}(HAR_{ML}) &= 2\gamma(4c-25)/25 < 0, \\ \Delta PS^{M}(HAR_{MH}) - \Delta PS^{M}(HAR_{ML}) &= 4\gamma(3c+5)/25 > 0, \\ \Delta W^{M}(HAR_{MH}) - \Delta W^{M}(HAR_{ML}) &= 2\gamma(2c-3)/5 \gtreqless 0.^{21} \end{aligned} \tag{4}$$

Since the conversion cost for l is $c+\gamma$ whereas for h it is $c-\gamma$, the export competitiveness of h is higher than that of l before harmonization. Under such conditions described in Table

[21] From the non-negative demand and price conditions, $2\gamma(4c-25)/25 < 0$.

3, if M harmonizes with H, then the supply costs for l, m, and h in M's market become $c+\gamma$, 0, and 0, respectively. Whereas, if M harmonizes with L, supply costs in M's market become 0, 0, and $c-\gamma$, respectively. Thus, M's market becomes less competitive when harmonizing with H than when harmonizing with L. It follows that M's consumer surplus will exhibit little improvement, whereas m's profits obtained in its home market shrink less when harmonizing with H than when harmonizing with L. In addition, the supply costs for l, m, and h in H's market before harmonization are $c+\gamma$, c, and 0, respectively and 0, c, $c-\gamma$ in L's market, respectively. Harmonization between M and H will eliminate m's conversion costs for supplying H's market, and harmonization between M and L will remove its conversion costs for supplying L's market. Though the eliminated conversion costs in both policies are the same, the level of competition in H's market when harmonizing with H is lower than that in L's market when harmonizing with L. Thus, the increases in m's profits obtained in H's market following harmonization with H are larger than those obtained from L's market when harmonizing with L.[22] Therefore, harmonization with H improves M's consumer surplus to a smaller degree than does harmonization with L, but its producer surplus expands to a greater extent.

An increase of γ widens the gap in conversion costs between the three firms. Hence, it magnifies the difference in welfare effects resulting from harmonization with H and harmonization with L, described in equation (4). An increase in c raises the conversion costs of all three firms and attenuates the effects of a technology gap. Hence, it constricts the difference between the two policies' harmonization effects on consumer surplus, while it expands the difference in m's producer surplus in M's home market. In addition, an increase of c eliminates relatively more conversion costs for m after harmonization in a partner country's market, while the level of competition in H's market following harmonization is lower than the level of competition in L's market. Thus, it makes more marked the difference in the effects of harmonization on m's producer surplus in the partner country's market between the two policies. Thus, an increase of c lowers the gaps between the consumer surpluses among the two harmonization regimes while raising the gaps between the producer surpluses.

The relative size of the harmonization effects on the consumer and the producer surpluses determines whether M prioritizes harmonizing its standards with H or with L. As showed in equation (4), the relative size depends on the average conversion costs of the three firms, rather than on the technology differences among the three countries. If $c > 3/2$, then the effect of harmonization on the consumer surplus is smaller than its effect on the producer surplus. M should thus prioritize harmonizing standards with H. Whereas if $c < 3/2$, then the breadth of the effect is opposite, and M should prioritize harmonization with L. Furthermore, as γ increases, considering this prioritization becomes more important. These results can also be seen in Fig. 1.

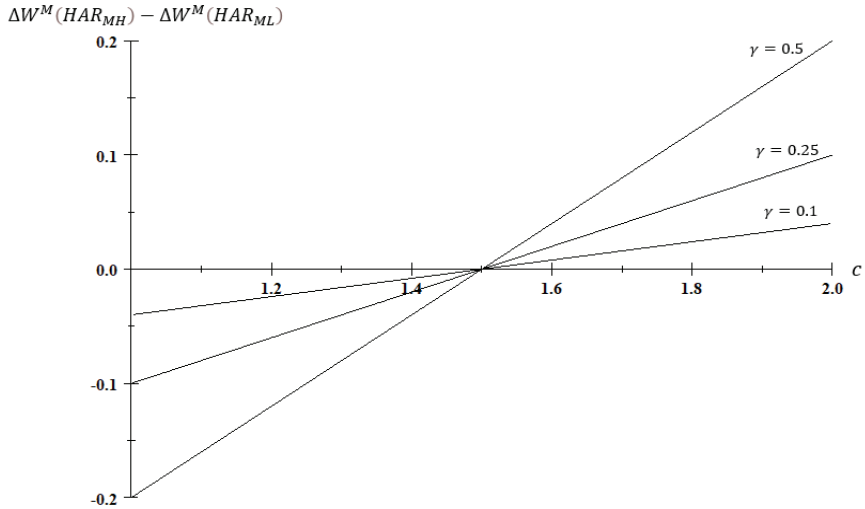
Proposition 3. Consider the three-country, three-firm model described above. Suppose compliance costs are relatively small so that all three firms have some share of the market in each country.

(i) If the average conversion costs in an industry are above a certain level, then a country possessing a mid-level conversion technology should prioritize harmonizing standards with the technologically more-advanced country, whereas if the average conversion costs are below a certain level, then the country should prioritize standards harmonization with the less-advanced country.

[22] $\Delta PS_m^H(HAR_{MH}) - \Delta PS_m^L(HAR_{ML}) = 8c\gamma/25 > 0$ and $\Delta PS_m^M(HAR_{MH}) - \Delta PS_m^M(HAR_{ML}) = 4\gamma(c+5)/25 > 0$.

(ii) The wider the technology gaps between countries, the more important prioritization between policies becomes.

Fig. 1. The Optimal Prioritization Strategy of Country M under $\gamma < c < 5/2 - \gamma$



6. Standards Harmonization Leading to Foreclosure

The results obtained in the previous sections are based upon the assumption that compliance costs are relatively small, so that all three representative firms have a positive share of each country's market. This section considers a case in which compliance costs are relatively high and firms can be expelled from the markets of each country. It can be shown that if $5/2 + \gamma < c < 5 - 3\gamma$, then the equilibrium prices are determined at $p_h^H = p_m^H = p_h^M = p_m^M = 3/2$ and $p_l^H = p_l^M = c + \gamma$, and harmonization would lead to the foreclosure of the non-member country from the member countries' markets. Suppose that countries M and H harmonize their compatibility standards. In the member countries' markets — for example in H's market — a consumer whose ideal product is produced by firm l obtains $V - p_h^H - 1$ utility from purchasing firm h(m)'s product, whereas that consumer obtains $V - p_l^H$ from purchasing firm l's product. When $p_h^H = 3/2$ and $p_l^H = c + \gamma$, the utility of the former is higher than the latter if $5/2 - \gamma < c$. Therefore, even the consumer who prefers firm l's product would buy firm h(m)'s good instead. In addition, it can be confirmed that these prices are unique under Bertrand equilibrium. Since firm l is eliminated in the member countries' markets, firms h and m are divided by an arc of length one and an arc of length two. On the arc of length one, the demand for firm h, as shown in Section 3, is $x_{h,m}^1 = (1 + p_m - p_h)/2$. In the same sense, the demand for firm h on the arc of length two is $x_{h,m}^2 = (2 + p_m - p_h)/2$. Following that, the inverse demand that firms h and m face in country H are

$$x_h^H = (2p_2 - 2p_1 + 3)/2 \; and \; x_m^H = (2p_1 - 2p_2 + 3)/2.$$

Therefore, firms h and m maximize their respective profits and equilibrium prices of $p_h^H = p_m^H = 3/2$ can be obtained. Since M's market has the same structure, unique Bertrand

equilibrium $p_h^M = p_m^M = 3/2$ and $p_l^M = c + \gamma$ can also be obtained.

Similarly, when countries M and L harmonize their standards, equilibrium prices are $p_m^M = p_l^M = p_m^L = p_l^L = 3/2$ and $p_H^M = p_H^L = c - \gamma$ if $5/2 + \gamma < c$, and the harmonization results in the foreclosure of the non-member country, H. Therefore, considering the condition $c < 5 - 3\gamma$ stating that all three firms have non-negative demand and prices before harmonization, in addition to the above two foreclosure conditions, if $5/2 + \gamma < c < 5 - 3\gamma$, harmonization would lead to the foreclosure of the non-member country's firm.

Under above foreclosure conditions, if M harmonizes with H, then the sum of the profits of firm m obtained from member countries is

$$\pi_m^H + \pi_m^M = \frac{9}{4} + \frac{9}{4} = \frac{9}{2}.$$

Since conversion costs are still needed to penetrate the non-member country's market, $\pi_m^L = [5 - (c + \gamma)]^2/25$ as shown in Table 1. The aggregate consumer expenditure and transportation costs in country M are $e^M = 3(3/2) = 9/2$ and $t^M = 3/4$, respectively. Following that, when M and H harmonize under the foreclosure conditions, the social welfare of country M is $W^M = (300V - 40c - 40\gamma + 8c\gamma + 4\gamma^2 + 4c^2 + 25)/100$. Thus, the effects of harmonization between M and H on the welfare of M are

$$\Delta W^M(HAR_{MH}) = \frac{1}{50}(80c - 14c^2 + 4c\gamma - 14\gamma^2 - 20\gamma + 25),$$

which is always positive under the condition of $5/2 + \gamma < c < 5 - 3\gamma$. Since conversion costs are removed between member countries when harmonizing standards between M and H, firm l becomes much less efficient than firms m and h in the member countries' markets compared to before harmonization and this in turn pushes firm l out of the member countries' markets. Thus, country M makes use of harmonization to improve its social welfare at the expense of the welfare of the non-member country, L.

In a similar way, the change in M's welfare when M and L harmonize under foreclosure conditions can be obtained as follow:

$$\Delta W^M(HAR_{ML}) = \frac{1}{50}(80c - 14c^2 - 4c\gamma - 14\gamma^2 + 20\gamma + 25).$$

In this case, firm h is foreclosed in the member countries' markets and the welfare of M improves at the expense of the welfare of H.

Both results show that $\Delta W^M(HAR_{MH})$ and $\Delta W^M(HAR_{ML})$ are always positive if $5/2 + \gamma < c < 5 - 3\gamma$ and $0 < \gamma < 1$.[23] Thus, in the foreclosure case, harmonization always improves M's social welfare regardless of its partner's technology, similar to the results in the non-foreclosure case.

To examine M's priorities in choosing a harmonization partner, the following can be obtained:

$$\Delta CS^M(HAR_{MH}) - \Delta CS^M(HAR_{ML}) = 0$$
$$\Delta PS^M(HAR_{MH}) - \Delta PS^M(HAR_{ML}) = -\frac{4}{25}\gamma(5 - c) < 0$$

[23] It can also be shown that the welfare effects of harmonization on the member countries $\Delta W^H(HAR_{MH}) > 0$ and $\Delta W^L(HAR_{ML}) > 0$ are positive. Thus, H or L will not deviate from harmonization equilibrium.

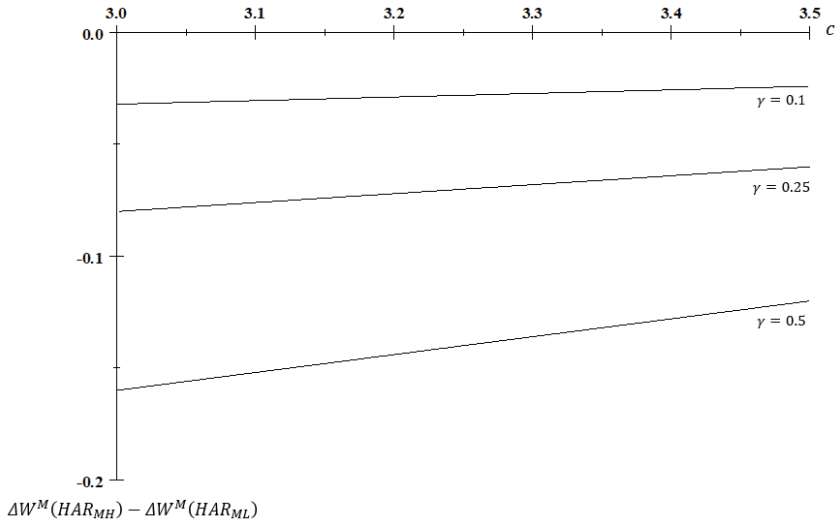
$$\Delta W^M(HAR_{MH}) - \Delta W^M(HAR_{ML}) = -\frac{4}{25}\gamma(5-c) < 0$$

On the one hand, as is shown in Table 3, before harmonization, the conversion costs for l, m, and h in M's market are $c+\gamma$, 0, and $c-\gamma$, respectively. Given that, if M harmonizes with H, then firm l is foreclosed and the conversion costs for m and h become zero in M's market. If M harmonizes with L, then firm h is eliminated and the conversion costs for m and l are also zero in M's market. Therefore, the magnitude of the change in M's consumer surplus and the profits of m in country M through harmonization are the same whether M harmonizes with H or L.[24]

On the other hand, the conversion costs for l, m, and h in H before harmonization are $c+\gamma$, c, 0, respectively and 0, c, $c-\gamma$ in L, respectively. So, the level of competition in H's market is lower than that in L's market before harmonization. Under such conditions, harmonization between M and H would eliminate firm l in H's market and reduce m's conversion costs to zero. Whereas, harmonization between M and L would eliminate firm h in L's market and reduce m's conversion costs to zero. Thus, the competition level in H's market after harmonization between M and H is the same as that in L's market after harmonization between M and L. Therefore, the magnitude of the change in m's profits in the member countries' markets is higher when harmonizing with L than when harmonizing with H.[25]

Thus, when comparing these two strategies, the magnitude of change in consumer surplus is the same but the magnitude of the producer surplus is higher when harmonizing with L. M should therefore prioritize harmonizing standards with L if compliance costs are relatively high and harmonization forecloses the non-member country's firm. In addition, prioritizing the selection of a harmonization partner becomes important as γ increases. Fig. 2 illustrates these results.

Fig. 2. The Optimal Prioritization Strategy of Country M under $5/2+\gamma < c < 5-3\gamma$



[24] $\Delta CS^M(HAR_{MH}) - \Delta CS^M(HAR_{ML}) = 0, \Delta PS_m^M(HAR_{MH}) - \Delta PS_m^M(HAR_{ML}) = 0.$
[25] $\Delta PS_m^H(HAR_{MH}) - \Delta PS_m^L(HAR_{ML}) = -4\gamma(5-c)/25 < 0.$

Proposition 4. Consider the three-country, three-firm model described above. Suppose compliance costs are relatively large so that harmonization would lead to the foreclosure of the non-member country.

(i) Harmonization always improves the social welfare of a country possessing mid-level conversion technology regardless of its partner's technology.

(ii) A country possessing a mid-level conversion technology should prioritize harmonizing standards with the technologically less-advanced country. In addition, the wider the technology gaps between countries, the more important prioritization between policies becomes.

Note that when compliance costs are extremely high, so that no firms can export to the other countries' markets, harmonization will create trade between member countries.[26] Thus, as mentioned in Gandal and Shy (2001), pursuing discriminatory harmonization policy can be beneficial in some cases.

7. Concluding Remarks

This paper has examined the economic impacts of harmonization between technologically asymmetric countries and optimal harmonization policies. It builds a three-firm, three-country model in which each country adopts different standards. The difference in standards requires foreign firms to comply with domestic standards; in doing so they incur conversion costs for market access. However, if a country harmonizes its compatibility standards with another country, then these conversion costs are eliminated between the two countries. To be more realistic, this paper assumes that the conversion process involves technology. Thus, if a firm is technologically more efficient, it is assumed to have lower conversion costs.

The paper first considers a scenario in which compliance costs are relatively small so that all three firms have some share of the market in each country. It showed that harmonizing compatibility standards always increases the consumer surplus and the social welfare of a country possessing mid-level conversion technology regardless of its partner's technology level. In addition, harmonization with a technologically advanced country will improve the mid-level country's producer surplus, whereas harmonization with a less-advanced country may improve or lower the mid-level country's producer surplus.

The paper also showed that technology gaps and the average cost of compliance in an industry affect the magnitude of the changes in social welfare caused by harmonization in the country possessing mid-level conversion technology. As the technology gap among nations increases, the magnitude of the increase in consumer surplus through harmonization decreases (increases) whereas the magnitude of change in the producer surplus increases (increases or decreases) if the mid-level country harmonizes with a technologically more-advanced (less-advanced) country. In addition, depending on whether the mid-level country harmonizes with a technologically more-advanced country or less-advanced one, as the average conversion costs in an industry increase, the level of increases in the consumer surplus brought about harmonization increases, but the producer surplus can either increase or decrease.

This paper further examined the optimal harmonization strategy of a mid-level technology country. It showed that the country should prioritize harmonization with the technologically more-advanced country rather than harmonization with the less-advanced country if the average conversion costs in the industry in question are above a certain size. But it should

[26] If $5 + 3\gamma < c$, then foreign firms cannot enter into the domestic markets in any of the three countries.

prioritize harmonization with a less-advanced country if the average conversion costs in the industry in question are below a certain size. In addition, prioritizing between these two policies becomes increasingly important the wider the technology gap.

Finally, the paper also considers another scenario in which compliance costs are relatively large, so that harmonization would lead to the foreclosure of the non-member firm from the member countries' markets. It shows that harmonization improves the social welfare of a mid-level technology country regardless of its partner's technology. It also shows that the country should prioritize harmonization with the technologically less-advanced country.

The results in this paper carry significant policy implications to a county with mid-level technology such as South Korea in the North-East Asian region. Japan has leading technologies in many sectors, followed by South Korea and China. The analytical model of this paper suggests that while standards may serve as trade barriers, South Korea can unambiguously improve its welfare by harmonizing standards with another country, for example, technologically more-advanced Japan or less-advanced China. In a sector with relatively small compliance costs — that is, one in which harmonization between two countries is not likely to lead to the elimination of non-member firms from the members' markets — South Korea should prioritize harmonization with either Japan or China, depending on the size of that industry's compliance costs. However, in a sector with relatively large compliance costs — that is, one in which harmonization will lead to the elimination of non-member firms from the members' markets — South Korea should prioritize China as its harmonization partner. In addition, such prioritization strategies should be emphasized when there exists large technology gaps between the North-East Asian neighbors in the sector in question.

Although the paper succeeds in obtaining several clear outcomes based on the one of the standard model specifications in studying harmonization, the results may vary under different model assumptions regarding the structure of the market, the way in which firms bear compliance costs, or the consumer's utility function. Nevertheless, the results based on the current model suggest that a country with an intermediate technology needs to actively harmonize its compatibility standards with other countries and to decide on harmonization partners strategically.

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