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by

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Agreements on product standards in a three-country model of international oligopoly

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Abstract

This study extends the comparative institutional analysis of agreements on product standards developed by Costinot (2008) to a three-country world, in which there are two member countries of an agreement on standards and a nonmember country. We examine the comparative performance of two principles: national treatment (NT) and mutual recognition (MR). Assuming an international oligopoly with the traded goods generating consumption externalities, we show that member countries prefer MR to NT for low externality levels and NT to MR for high externality levels. Further, nonmember countries never prefer MR to NT. We also discuss whether a bilateral agreement on standards can be a building or stumbling block to a multilateral agreement by all three countries.

Keywords: product standards, national treatment, mutual recognition, consumption externality, domestic policy

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1 Introduction

Tariffs have been considered the main barriers to trade for a long time. For example, before the establishment of the General Agreement on Tariffs and Trade (GATT) in 1948, the average world tariff was around 40% (Bown and Irwin, 2015). However, the average applied tariff has been reduced to a sufficiently low level, that is, below 2.7%,[1] through the efforts of the World Trade Organization (WTO) and GATT and by increasing regional trade agreements (RTAs) and preferential trade agreements (PTAs), as claimed by Pascal Lamy, the Director-General of the WTO (2005–2013).[2] Therefore, tariffs are no longer the main barriers to trade.

However, global integration is far from complete. The existence of various non-tariff barriers (NTBs) has become a new issue impeding global free trade. Among all NTBs, product standards are regulatory instruments widely used to protect safety and environmental quality, which might restrict imports or exports; some examples are vehicle emissions and safety standards, restrictions on pesticide residues in agricultural goods, regulations on food additives, and safety standards for electrical products. If countries implement different product standards between domestic and imported goods arbitrarily, this can lead to trade disputes and even protectionism. Empirical analyses have shown that differing product standards have significant negative effects on trade. For example, country-specific product standards reduce the average wages of exporting firms (Sánchez et al., 2008), decrease the exports of developing countries (Disdier et al., 2008), cause diseconomies of scale, and affect decisions to enter export markets (Chen et al., 2006). Wilson et al. (2002) provide evidence of heterogenous environmental regulations among countries having negatively affected trade.

Conversely, reasonable and coordinated product standards, such as harmonized standards, can promote trade flows, with many studies providing evidence of this effect. According to the literature, harmonized standards lower

[1] The data are from the World Bank and can be accessed at https://data.worldbank.org/indicator/TM.TAX.MRCH.WM.AR.ZS

[2] On July 16, 2012, Lamy made a speech titled "The universe of non-tariff measures has changed."

the information asymmetries between firms and allow for a more efficient organization of inter-firm trade (Grajek, 2004), reduce country-specific adaptation costs and contribute to global trade growth (Schmidt and Steingress, 2022), increase partner country export variety (Shepherd, 2007), and positively pull foreign direct investment and push trade in developing nations (Clougherty and Grajek, 2008). Chen and Mattoo (2008), Baller (2007), Mark and Bruno (2004), and Vancauteren and Weisbers (2011) show that, under mutual recognition (MR), regulation harmonization could lead to more trade among member countries (e.g., intra-European Union [EU] trade).

For international organizations, imposing harmonized standards will prevent conflicts among countries. However, it is not feasible to achieve harmonized standards considering the huge costs involved. As such, the WTO, EU, and RTAs have committed to two principles to solve the problem of countries' arbitrary use of product standards: national treatment (NT) and MR. The NT principle requires that the member countries of the agreement do not apply discriminatory treatment to imported and domestic products or services, at least after the foreign goods have entered the market. Some RTAs, such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), adopt the NT principle. The MR principle requires the member countries of an agreement to mutually approve the results of the regulatory conditions implemented by other members as equivalent to the results of those they have executed. The EU and the PTAs formed by it adopting the MR principle.

To explain these different approaches to standards agreements adopted by the WTO and EU, Costinot (2008) analyzes the comparative performance of the two principles and finds that NT should be preferred over MR when the amount of trade in goods characterized by high externality levels is large. Geng (2019) extends Costinot's (2008) analysis with heterogeneous preferences toward positive and negative externalities and shows that NT is relatively more welfare-enhancing than MR for countries with dissimilar preferences. These findings explain why the WTO, CPTPP, and EU choose different types of standards agreements. Note that these studies compare MR and NT only for bilateral agreements. However, multilateral agreements are now prevalent, and many bilateral agreements extend to multilateral ones. Accordingly, this study compares the performances of NT and MR principles in multilateral agreements and analyzes whether bilateral agreements lead to multilateral ones.

No studies have hitherto compared the performance of two regimes in multilateral trade agreements. However, this issue is not only of practical significance for the real economy but also has theoretical implications. Most past economic analyses have focused on the role of the NT principle in bilateral agreements. For example, Gulati and Roy (2008) and Geng (2022) analyze the optimal policy settings of tariff, non-tariff measures, and domestic instruments. Ferrara et al. (2019) compare the effects of discriminating and non-discriminating tariffs on the environment. Further, Battigalli and Maggi (2003) and Bagwell and Staiger (2001b) justify whether the rule of NT is equipped to handle disputes. Staiger and Sykes (2011) verify whether there are excessive non-discriminatory regulations under the WTO's legal framework. Meanwhile, Mei (2018) assesses which of the non-discriminatory and harmonization standards could lead to international efficiency. Bagwell and Staiger (2001a) discuss how NT cooperates with the most favored-nation-principle. Finally, Ederington (2001) analyzes how to deal with domestic regulatory policies when considering trade policies.

A few studies focus on NT and MR simultaneously. Costinot (2008) and Geng (2019) compare the performance of NT with that of MR. Further, Grossman et al. (2021) analyze how to coordinate countries' regulatory policies under NT and MR. While the above studies consider bilateral agreements, some studies use a three-country model to analyze the effects of endogenous product standards in multilateral agreements (Takarada et al., 2020; Kawabata and Takarada, 2021; Yanase and Kurata, 2022). However, they only focus on the NT principle. Therefore, the literature fails to identify the clear implications of product standards under multilateral agreements and the comparative performance of the NT and MR principles. This study thus aims to cover this gap in the literature.

Specifically, we extend Costinot's (2008) model with negative externalities to a three-country model. Our three-country framework discusses whether bilateral agreements can be a building or stumbling block to multilateral agreements under the respective regimes. We find that, if the level of externalities is in a specific range, multilateral agreements on standards can be achieved via bilateral agreements, irrespective of whether the agreement is based on NT or MR. However, this building block outcome is only a small subset of all possible

outcomes; otherwise, the bilateral agreements of member and nonmember countries will block a multilateral agreement on standards.

Following Ferrara et al.'s (2019) assumption, we assume that the member countries of a bilateral agreement on standards can choose discriminatory standards for the imported goods produced by a nonmember country. One may argue that WTO member countries are prohibited from using regulatory policies to discriminate against foreign producers. Therefore, the assumption that member countries can implement standard policies in a discriminatory manner is not realistic. However, based on the following considerations, the assumption of discriminatory regulations is reasonable. First, GATT Article XX presents potential exceptions, outlining cases in which members can breach the general WTO principles, particularly regarding health and the environment. Ferrara et al. (2019) adopt discriminatory regulations to examine the role of NT and consider prominent Article XX exceptions when goods are vertically differentiated and generate consumption externalities. Second, GATT Article XXIV allows the formation of a PTA, provided that the members of that agreement do not impose higher or more restrictive trade barriers on nonmembers. Therefore, as long as the heterogeneous standards among members and nonmembers of a PTA do not lead to higher or more restrictive trade barriers for nonmembers, this assumption does not violate the WTO rule.

International law scholars highlight the limitations of strictly extending the WTO rule to issues relating to NTBs. For example, Hoekman and Mavroidis (2015) explain why, in a world where tariffs become gradually obsolete and markets are being segmented through NTBs, it is unrealistic to expect deep integration to occur at the WTO level. Mavroidis (2015) also argues that non-discrimination is ill-equipped to deal effectively with regulatory barriers in a near-tariff-free world. Considering these arguments, we assume that GATT Article XXIV can be applied to the "deep" integration considered in this study.

The remainder of this paper is organized as follows. In Section 2, we set up our three-country model and derive the policy game equilibrium without any agreements on standards. Section 3 considers bilateral agreements and derives the policy game equilibria for the respective institutional arrangements—NT and MR. We also examine

the welfare effects of bilateral agreements on member and nonmember countries. In Section 4, we derive the outcomes when all three countries conclude multilateral agreements, while Section 5 discusses whether bilateral agreements can be extended to multilateral ones. Section 6 summarizes the study, and Section 7 concludes the paper.

2 The Model

We consider three countries, denoted by A, B, and C, each respectively having one firm denoted by a, b, and c that produces a homogeneous product. All countries share the same preferences and technologies. Following Costinot (2008), firms can produce two types of products: H (high pollution) type, which incurs zero-unit production cost but whose consumption generates $\theta > 0$ units of pollution, and L (low pollution) type, whose unit cost is $c > 0$ and whose consumption generates no pollution. We consider a mass of consumers, each buying at most one unit of a product, and they are indifferent between the two types of products. Pollution damage occurs at the location of consumption, and there is no spillover of pollution damage across countries.

Consumers are heterogeneous concerning their consumption benefits, and the utility of type $v \in [0,1]$ consumer living in country J is given by

$$u(v) = \begin{cases} v - p^J - \phi^J & \text{if } the\ consumer \text{ buys either version,} \\ -\phi^J & \text{if } the\ consumer \text{ buys nothing,} \end{cases} \quad (1)$$

$J = A, B, C$, where v is uniformly distributed with support $[0, 1]$; p is the price of the product; and ϕ^J is the pollution damage in country J. Denoting firm k's sales in country J by q_k^J $(k = a, b, c;\ J = A, B, C)$, the pollution damage in country J is represented by $\phi^J = \sum_{k=a,b,c} \theta_k^J q_k^J$, where $\theta_k^J \in \{0, \theta\}$. As consumers with $v \geq p$ will buy the product and pollution damage is a pure externality, consumers' utility maximization behavior derives the inverse demand as $P(Q^J) = 1 - Q^J, J = A, B, C$, where Q^J denotes consumption in country J and is equal to $\sum_{k=a,b,c} q_k^J$.

We assume that the markets are segmented and that the three firms compete in quantity in each country's market. Assuming no tariffs or transport costs, we define firm k's profit earned in country J's market ($k = a, b, c;\ J = A, B, C$) as

$$\pi_k^J = \left[P^J(Q^J) - c_k^J\right]q_k^J = \left(1 - Q^J - c_k^J\right)q_k^J, \tag{2}$$

where $c_k^J \in \{0, c\}$ denotes the unit production cost of the good produced by firm k and consumed in country J.

Country J's government can regulate its market by setting standards $\sigma_k^J \in \{H, L\}$ for each of firm k's products ($k = a, b, c$), and each firm can sell in country J's market if and only if its product version satisfies the minimum quality standard. That is, if $\sigma_k^J = H$, firm k can sell both the H and L types (i.e., there is no regulation), but it chooses to produce and sell H type because the unit cost is zero; by contrast, if $\sigma_k^J = L$, firm j must produce and sell the L type product.

The following two-stage game represents our model. In the first stage, the government of each country sets product standards for each good. In the second stage, given the standards of the respective products, firms engage in Cournot competition in each country's market. We solve the game by backward induction to derive the subgame perfect Nash equilibrium.

2.1 Cournot–Nash equilibrium

In stage 2, given the standards policy in the respective countries, the firms play the Cournot game in each country's market. In country J's market, firm k chooses q_k^J to maximize (2), taking $q_k^J,\ i \neq k$ as given. From the first-order conditions for profit maximization, the Cournot equilibrium outputs can be obtained as $q_k^J = (1 - 3c_k^J + \sum_{i \neq k} c_i^J)/4, k, i = a, b, c$. The equilibrium sales and price in country J are then derived as $Q^J = (3 - \sum_{k=a,b,c} c_k^J)/4$ and $P(Q^J) = (1 + \sum_{k=a,b,c} c_k^J)/4$, respectively.

Country J's welfare is given by the sum of consumer surplus (inclusive of pollution damages) and the domestic firm's profits (from domestic sales and exports). From (1), consumer surplus can be written as $CS^J = (Q^J)^2/2 - \phi^J$. As for the equilibrium profits, (2) can be rewritten as $\pi_k^J = (q_k^J)^2$ in the Cournot–Nash equilibrium. Therefore, substituting the equilibrium outputs and sales into the expressions for consumer surplus and firm profits, country J's welfare can be represented as

$$SW^J = CS^J + \sum_{K=A,B,C} \pi_J^K$$

$$= \frac{(3-\sum_{k=a,b,c} c_k^J)^2}{32} - \sum_{k\in a,b,c} \theta_k^J \frac{1-3c_k^J+\sum_{i\neq k} c_i^J}{4} + \sum_{K=A,B,C} \frac{(1-3c_J^K+\sum_{i\neq k} c_i^K)^2}{16}. \quad (3)$$

Throughout this paper, we assume that there are no political factors that affect governments' standards policies. As such, we assume each government's objective function is its national welfare, $SW^J, J = A, B, C$. We also propose the following assumption.[3]

Assumption 1 $c < 1/5$.

2.2 Noncooperative policy equilibrium without agreements

As a benchmark for the subsequent analysis, we start with the situation in which governments noncooperatively determine their standards without making any agreements among countries. In the absence of agreements on standards, in stage 1, country *J*'s government chooses the standards for the products consumed in that country, $(\sigma_a^J, \sigma_b^J, \sigma_c^J)$, to maximize country *J*'s social welfare, taking other countries' standards, $(\sigma_a^K, \sigma_b^K, \sigma_c^K)$, $K \neq J$, as given. There are three regimes for each government to choose from: (i) full regulation (FR), under which $\sigma_k^J =$

[3] It can be easily verified that, under Assumption 1, all firms choose positive export levels.

L for $k = a, b, c$; (ii) no regulation (NR), under which $\sigma_k^J = H$ for $k = a, b, c$; and (iii) discrimination (D), under which $\sigma_j^J = H$ and $\sigma_k^J = L$ for $k \neq j$.[4]

Although governments seek to maximize their respective welfare, (3) indicates that export profits depend only on other countries' standards. This means that governments choose standards to maximize their respective domestic component of social welfare, which is the sum of the consumer surplus and the domestic firm's profit from domestic sales:

$$CS^J + \pi_j^J = \frac{(3-\sum_{k=a,b,c} c_k^J)^2}{32} - \sum_{k\in a,b,c} \theta_k^J \frac{1-3c_k^J+\sum_{i\neq k} c_i^J}{4} + \frac{(1-3c_j^J+\sum_{i\neq j} c_i^J)^2}{16}. \quad (4)$$

By comparing domestic welfare under the respective strategies for standards policy, we obtain the following proposition.

Proposition 1 *In an unconstrained noncooperative standards game without any international agreements, the equilibrium standards regime implies:*

・NR for $0 \leq \theta < \underline{\theta}^U$;

・D for $\underline{\theta}^U \leq \theta > \overline{\theta}^U$; and

・FR for $\overline{\theta}^U \leq \theta$,

where $\underline{\theta}^U \equiv \frac{c(1-3c)}{4(1-c)}$ and $\overline{\theta}^U \equiv \frac{c(18+c)}{8(1+2c)}$.

Proof See the Appendix.

The intuition behind Proposition 1 is as follows. When choosing standards, each government faces the following trade-off: A more stringent standards policy results in decreased consumption and domestic profit, but pollution damage decreases in that country. If pollution damage θ is low, the former effect dominates; however,

[4]Strictly speaking, the discrimination regime D here should be termed as "negative discrimination". Because the government discriminates against foreign firms by setting more stringent standards. We may consider another type of discriminatory standard's regime, namely "positive discrimination," under which the government sets less stringent standards on foreign products than domestic ones; $\sigma_j^J = L$ and $\sigma_k^J = H$ for $k \neq j$. However, we can verify that, under Assumption 1, positive discrimination will never be an equilibrium outcome. Therefore, throughout this paper, we regard the negative discrimination case as the discrimination regime.

if θ is high, the latter effect dominates. If θ is moderate, the discrimination strategy can increase domestic profit while reducing pollution damage.

3 Bilateral Agreements on Standards Policy

Here, we consider a situation in which two of the three countries, namely countries A and B, conclude an agreement that requires a commitment to the rigid rule regarding their standards policy. We consider two rules for standard agreements: NT and MR. As previously mentioned, NT means that the same standards should be applied to both the domestic product and the product imported from the member country of the agreement. MR means that control over standards on the exported product is transferred from the importer to the exporter member country, meaning that the exporter country sets the standards, and the importer country has to accept them.

We consider a form of agreement with the least degree of integration, meaning that standards are still determined by each member country of the agreement noncooperatively, rather than member countries harmonizing their standards to maximize joint welfare.[5] That is, we assume that member countries A and B, when facing a constraint imposed by NT or MR, determine their respective standards to maximize their respective welfare. Country C, an outsider to the agreement, also determines its standards noncooperatively. As country C's optimal standards are independent of the other countries' standards, Proposition 1 holds for country C even in the presence of bilateral agreements.

3.1 Policy game under NT

As in the unconstrained noncooperative case, export profits only depend on the foreign standards under NT. Therefore, for countries A and B, the government's problem in stage 1 is to choose the standards policy that

[5] This is similar to a relationship between a free trade agreement (FTA) and a customs union (CU) in terms of the determination of tariffs; each member country of an FTA determines its external tariffs independently, whereas, under a CU, member countries jointly set common external tariffs.

maximizes the domestic welfare in (4), subject to the constraint that the same standards should be applied to the domestic product and the one imported from the member country; that is, the constraint is $\sigma_a^J = \sigma_b^J \in \{H, L\}, J = A, B$.

Again, there are three regimes for member countries' governments to choose from. As in the no-agreement case, these governments ($J = A, B$) have an option to choose: (i) full regulation, under which $\sigma_k^J = L$ for $k = a, b, c$ or (ii) no regulation, under which $\sigma_k^J = H$ for $k = a, b, c$. In addition, they may choose a standards policy that discriminates against nonmember country C, which we simply call (iii) discrimination, under which $\sigma_k^J = H$ for $k = a, b$ and $\sigma_c^J = L$, $J = A, B$.[6]

The following proposition characterizes the optimal standards policy.

Proposition 2 *Under a bilateral agreement on a standards policy with NT, member countries' equilibrium standards regime implies:*

・NR for $0 \leq \theta < \underline{\theta}$;

・D for $\underline{\theta} \leq \theta < \overline{\theta}^N$; and

・FR for $\overline{\theta}^N \leq \theta$,

where $\underline{\theta} \equiv \frac{c(2-3c)}{8(1-2c)}$ and $\overline{\theta}^N \equiv \frac{c(5-2c)}{4(1+c)}$.

Proof See the Appendix.

[6] As discussed in Section 1, we assume that GATT Article XXIV, which allows the formation of a preferential trade agreement, provided that the members of this agreement do not impose higher or more restrictive trade barriers on nonmembers, can be applied to the "deep" integration considered in this study. It can be verified that any shifts in standards policies in the course of a transition from the unconstrained noncooperative policy equilibrium to a bilateral agreement on standards do not make member countries' standards on imports from the nonmember country more stringent.

3.2 Policy game under MR

Under MR, each member country transfers the right to control imports to the other member (i.e., exporter) country. This means that country A's government determines, in addition to σ_a^A and σ_c^A, the standard on firm a's product exported to country B, that is, σ_a^B. Analogously, country B's government determines σ_b^A in addition to σ_b^B and σ_c^B. Moreover, each member country faces the constraint that the same policy should be applied to the domestically consumed product and the one produced by the same firm and exported to another member country; that is, $\sigma_j^A = \sigma_j^B$ must hold for $j = a, b$.

Unlike under the NT regime, each member country's standards policy affects the export profit earned in another member country, as well as consumer surplus and domestic profit. Therefore, the objective function of the government in each member country $J = A, B$ with domestic firm $j = a, b$ is given by

$$CS^J + \pi_j^A + \pi_j^B$$

$$= \frac{(3 - \sum_{k=a,b,c} c_k^J)^2}{32} - \sum_{k \in a,b,c} \theta_k^J \frac{1 - 3c_k^J + \sum_{i \neq k} c_i^J}{4} + \sum_{K=A,B} \frac{(1 - 3c_j^K + \sum_{i \neq k} c_i^K)^2}{16}. \quad (5)$$

The government's problem is to maximize (5) subject to $\sigma_j^A = \sigma_j^B$.

The government in each member country has the following strategies for standards: (i) full regulation, under which $\sigma_j^A = \sigma_j^B = \sigma_j^C = L$ for $(j, J) \in \{(a, A), (b, B)\}$; (ii) no regulation, under which $\sigma_j^A = \sigma_j^B = \sigma_j^C = H$ for $(j, J) \in \{(a, A), (b, B)\}$; and (iii) discrimination against country C, under which $\sigma_j^A = \sigma_j^B = H$ and $\sigma_C^J = L$ for $(j, J) \in \{(a, A), (b, B)\}$.

From (5), under MR, one member country's optimal standards depend on the other member country's standards. This means that, unlike the previous policy regimes, we first need to derive each member country's best response strategy and then obtain the Nash equilibrium of the standard game. As we will see below, both member

countries' standards are strategic complements in the MR game. This particular feature of MR leaves room (in our setting with discrete policy choices) for multiple Nash equilibria (see also the Appendix). Therefore, to compare the outcomes under MR with those under NT, we need to refine the equilibrium in the MR game. We follow Costinot (2008) to restrict our attention to the Pareto efficient or "most cooperative" equilibrium. That is, if one equilibrium is strictly preferred over any other by both countries, we assume that they can coordinate on this equilibrium. The most cooperative equilibrium in the MR game can be characterized by the following proposition.

Proposition 3 *Under a bilateral agreement on standards policy with MR, member countries' equilibrium standards regime in the most-cooperative equilibrium implies:*

・NR for $0 \leq \theta < \underline{\theta}$;

・D (against the nonmember) for $\underline{\theta} \leq \theta < \overline{\theta}^{M}$; and

・FR for $\overline{\theta}^{M} \leq \theta$,

where $\overline{\theta}^{M} \equiv \frac{(30+7c)c}{8(1+2c)}$.

Proof See the Appendix.

3.3 Comparison between NT and MR

Comparing the threshold values of θ, we can verify that $\underline{\theta}^{U} < \underline{\theta} < \overline{\theta}^{N} < \overline{\theta}^{U} < \overline{\theta}^{M}$. That is, compared to the case without agreements on standards, the threshold value of θ above which the member countries begin to shift from discrimination to full regulation is lower under NT and higher under MR (see Figure 1). This means that the

member countries tend to choose more stringent standards under NT. By contrast, they tend to choose less stringent standards under MR.[7]

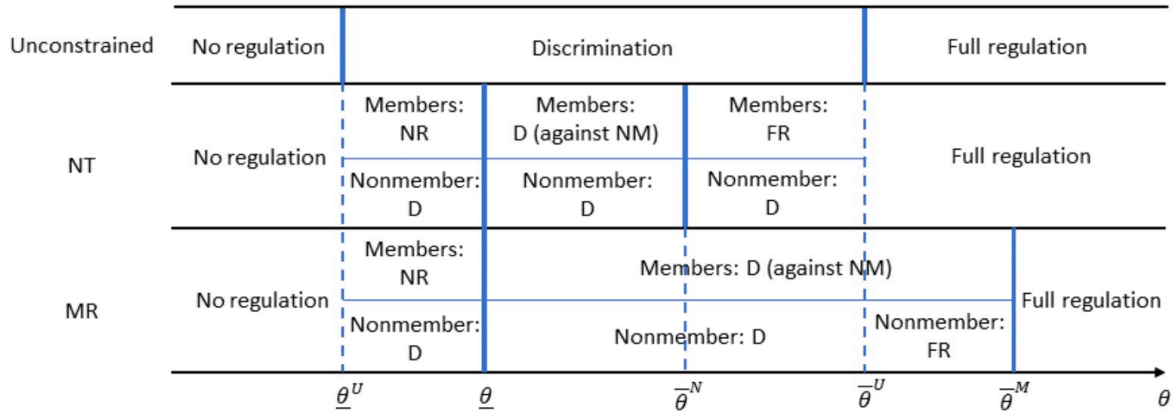


Figure 1 Summary of policy game outcomes

The intuition behind these differences in the stringency of member countries' standards between types of standards agreements can be interpreted as follows. In our three-country model, the unconstrained benchmark allows each country's government to discriminate against both of its exporters, but under NT, each member country can discriminate against only the exporter in the nonmember country. This reduces the domestic firm's cost advantage compared to its foreign rivals under NT. As the member countries' objective function is expressed by (4) both under the benchmark and NT cases, these countries evaluate the importance of pollution externalities to a greater extent under NT, leading to more stringent standards.

Under MR, each member country loses control over the standards of the imported product from another member country but instead gains control over the standards of the product exported to its partner's market. Therefore, the government in each member country considers the domestic firm's profit earned in its partner's

[7] In his two-country model, Costinot (2008) considers the result under NT as "green protectionism," while the result under MR is considered a "race to the bottom." In our three-country model, member countries' standards have similar properties.

market, as well as its domestic profit, and has an incentive to loosen the regulation on the domestic firm to promote exports to that market. In addition, member countries do not consider the externalities generated by the domestic firm in foreign countries. Therefore, under MR, the member countries choose less stringent standards than under the benchmark case.

From Figure 1, if the environmental externality is negligible (i.e., $\theta < \underline{\theta}^U$) or very severe (i.e., $\theta \geq \overline{\theta}^M$), both types of standards agreement achieve the same outcomes as the unconstrained noncooperative equilibrium. In addition, NT and MR induce member countries to choose different policies only if $\overline{\theta}^N \leq \theta < \overline{\theta}^M$. This indicates that the welfare effects of these agreements, which are discussed below, differ only if θ is in this range.

We now present the welfare effects of the standards agreements on the respective countries. We begin with the welfare effects on member countries. Let us denote member country J's welfare, which is the sum of consumer surplus CS^J and domestic firm j's total profits, $\pi_j = \sum_{K=A,B,C} \pi_j^K$, under the unconstraint noncooperative equilibrium, NT, and MR by SW_J^N and SW_J^M, respectively, for $(j,J) \in \{(a,A),(b,B)\}$. Then, the welfare gains (or losses) in each member country under the respective standards regimes (i.e., $SW_J^N - SW_J^U$ under the NT regime and $SW_J^M - SW_J^U$ under the MR regime) can be illustrated as in Figure 2.

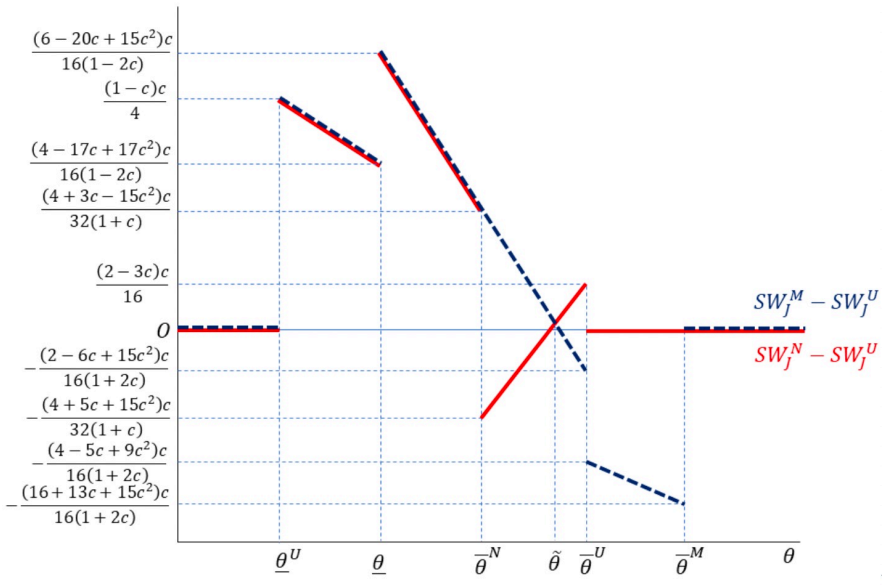


Figure 2 Welfare comparison of member countries

We obtain the following proposition from Figure 2.

Proposition 4 *For the member countries of the standards agreement, (i) NT and MR are indifferent when* $\theta < \overline{\theta}^N$ *and* $\overline{\theta}^M \leq \theta$*; (ii) MR is preferred over NT when* $\overline{\theta}^N \leq \theta < \overline{\theta}^M$*; and (iii) NT is preferred over MR when* $\overline{\theta} \leq \theta < \overline{\theta}^M$*, where* $\overline{\theta} \equiv \frac{(7-2c)c}{4(1+c)}$.

The intuition behind Proposition 4 can be interpreted as follows. As shown in Figure 1, for $\underline{\theta}^U < \theta < \underline{\theta}$, the member countries of a standards agreement choose discrimination in the absence of an agreement but choose not to regulate all products both under NT and MR. This policy change increases the domestic firm's profits but leads to higher pollution externalities. However, as the value of θ is small, the former positive effect outweighs the latter negative one. For $\underline{\theta} < \theta < \underline{\theta}^N$, the member countries discriminate against the exporter from the nonmember country both under NT and MR by regulating that firm. This leads to a cost advantage for the domestic firm and, thus, has a positive effect on member countries' welfare. If θ is between $\overline{\theta}^N$ and $\overline{\theta}^M$, NT and MR make member countries choose different standards policies; NT leads them to choose stricter standards, and MR leads them to choose looser standards. For $\overline{\theta}^N \leq \theta < \overline{\theta}^U$, member countries choose full regulation under NT while still discriminating against nonmembers under MR. Owing to the increase in firms' costs, NT results in lower consumption and profits for the domestic firm, making the member countries worse off compared to in the no-agreement case. Meanwhile, a full regulation policy removes environmental externalities and leads to a welfare gain under NT as θ increases. For $\overline{\theta}^U \leq \theta < \overline{\theta}^M$, all countries choose full regulation under both the NT and benchmark situations, meaning that the member countries achieve the same welfare level. By contrast, member countries continue to discriminate against nonmember countries under MR. The domestic firm in each member country has a cost advantage compared to the firm in the nonmember country, contributing to member countries' welfare gains under MR. Simultaneously, not regulating member countries' firms leads to more pollution and, thus,

welfare losses. Since the value of θ is sufficiently high in the current situation, the latter negative effect outweighs the former positive one, resulting in a net loss for member countries under MR.

We now consider the welfare effects of bilateral agreements on standards for the nonmember country of each type of agreement. Figure 3 illustrates the net gain in nonmember country C's welfare compared to that under the benchmark scenario of unconstrained noncooperative equilibrium (i.e., $SW_C^N - SW_C^U$ under NT and $SW_C^N - SW_C^U$ under MR). For $\underline{\theta}^U < \theta < \underline{\theta}$, the member countries lift the regulation on imported goods as they move from D to NR, while the nonmember country continues to implement D. Consequently, the nonmember country becomes better off compared to the benchmark case. However, for $\underline{\theta} < \theta < \underline{\theta}^N$, member countries move from NR to D, which discriminates against the nonmember. This policy change benefits firms in the member countries at the cost of firm c's export profits. Therefore, the nonmember country's welfare decreases drastically. For $\overline{\theta}^N \leq \theta < \overline{\theta}^U$, while the member countries continue to discriminate against imports from nonmember countries under MR, they shift from D to FR under NT. This means that, under NT, firm c regains the same competitiveness in the export markets as firms a and b, which is beneficial to the nonmember country. This advantage of the NT regime for the nonmember country disappears as all countries choose FR for $\theta \geq \overline{\theta}^U$. However, under MR, the nonmember country further becomes worse off because the threshold value of θ above which the member countries begin to shift from D to FR is higher under MR. That is, member countries continue to discriminate against the nonmember country, which chooses FR and, thus, its domestic firm loses competitiveness in the export markets.

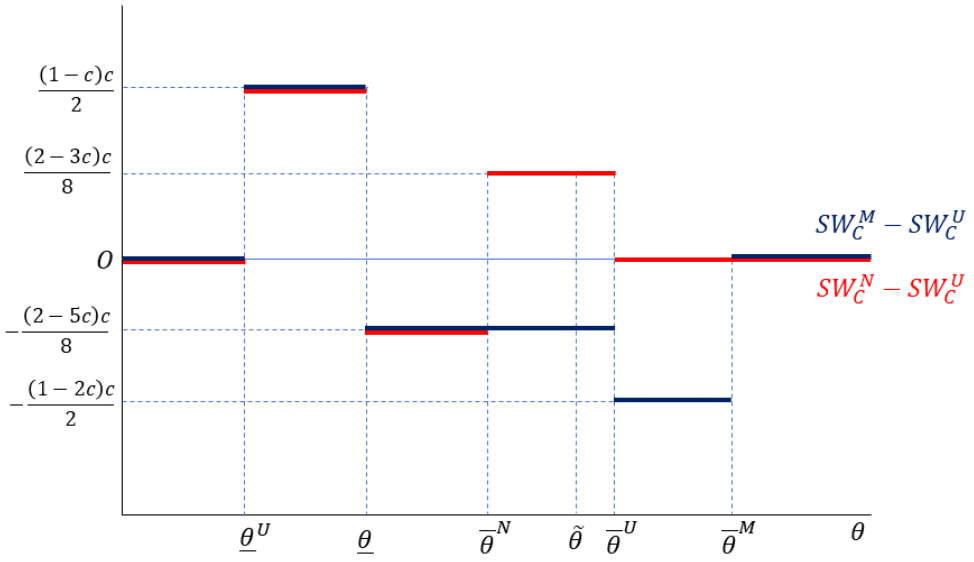


Figure 3 Welfare comparison of the nonmember country

From Figure 3, for the nonmember country, the bilateral agreement on standards based on MR cannot be preferred over the one based on NT, as demonstrated by the following proposition.

Proposition 5 *For a nonmember country outside the standards agreement, (i) NT and MR are indifferent when* $\theta < \overline{\theta}^N$ *and* $\overline{\theta}^M \leq \theta$ *and (ii) NT is preferred over MR when* $\overline{\theta}^N \leq \theta < \overline{\theta}^M$.

The nonmember country can never prefer MR to NT because the threshold level of θ at which the member countries start to implement full regulation is lower under NT and higher under MR. For the values of θ below that threshold, member countries choose to discriminate against the nonmember. In other words, compared to the no-agreement benchmark, NT makes member countries implement a less discriminatory standards policy, while MR leads to more discriminatory standards by members.

Combining Propositions 4 and 5, preferential agreement over standards policy can benefit all countries only when $\underline{\theta}^U < \theta < \underline{\theta}$ (under both NT and MR) and $\overline{\theta} \leq \theta < \overline{\theta}^U$ (under NT only). For other values of θ, the standards agreements make at least one country worse off.

4 Multilateral Agreements

We now discuss what outcomes can be obtained when the bilateral agreements on standards are expanded to multilateral ones. Assume that country C joins the agreement, which can be of either the NT or MR type and, thus, the standards and policies are harmonized globally.

Each type of multilateral agreement can be characterized as follows. Under NT, the government in each country controls the standards on the products sold in the domestic market, that is, $(\sigma_a^J, \sigma_b^J, \sigma_c^J)$, such that $\sigma_a^J = \sigma_b^J = \sigma_c^J$ for $J = A, B, C$. Under MR, each country's government controls the standards on the products produced by the domestic firm, that is, $(\sigma_j^A, \sigma_j^B, \sigma_j^C)$, such that $\sigma_j^A = \sigma_j^B = \sigma_j^C$ for $j = a, b, c$. Irrespective of the type of agreement, the governments treat all countries equally, meaning that discrimination cannot be a possible strategy. We assume that each government seeks to maximize its own welfare.[8]

4.1 Outcomes under NT

Under NT, as in the case of the bilateral agreement, the export profits that the domestic firm earns are beyond the control of the national government because they only depend on other countries' standards. Thus, the governments choose standards to maximize their respective domestic components of social welfare, as given by (4). In addition, as explained above, the governments cannot implement discriminatory standards; hence, their possible strategy is either (i) full regulation, under which $\sigma_k^J = L$, or (ii) no regulation, under which $\sigma_k^J = H$ for $k = a, b, c$ and $J = A, B, C$. The following proposition represents the solution to this policy game.

Proposition 6 *Under a multilateral agreement on standards based on NT, the equilibrium standards regime implies:*

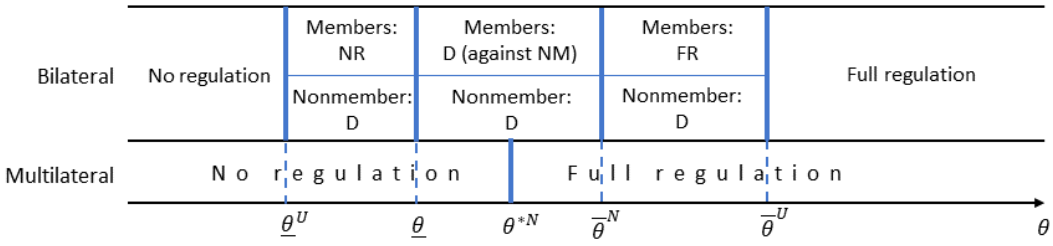
[8] It can be easily verified that if the governments were to cooperate on the standards policies to maximize their joint welfare, NT and MR achieve identical solutions for the globally optimal standards.

• NR for $0 \leq \theta < \theta^{*N}$, and

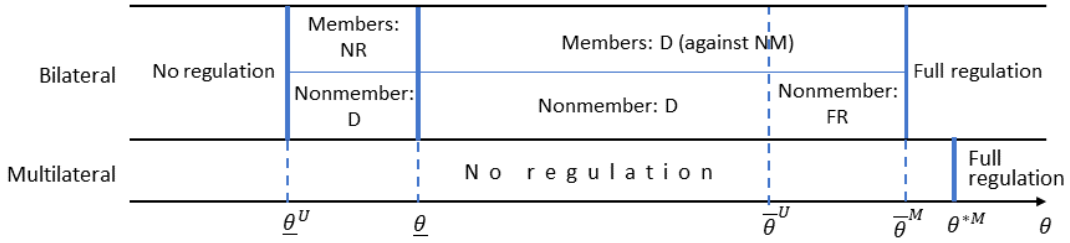
• FR for $\theta^{*N} \leq \theta$, *where* $\theta^{*N} \equiv \frac{11c(2-c)}{24}$.

Proof See the Appendix.

As demonstrated in the proof of Proposition 1, θ^{*N} is greater than $\underline{\theta}^{U}$ and smaller than $\overline{\theta}^{U}$. We can also verify that $\underline{\theta} < \theta^{*N} < \overline{\theta}^{N}$ for any $c < 1/5$ (see also Figure 4 (a)). That is, the threshold value of θ at which the governments start to implement full regulation is lower under the multilateral agreement than under the bilateral agreement. This means that a multilateral agreement based on NT induces the government to implement a more stringent standards policy. The intuition is as follows. Under the bilateral agreement on standards, member countries still had an option to discriminate against the exporter from the nonmember country. However, discriminatory standards are not available under the multilateral agreement. As the governments cannot raise the domestic firm's export profits through the standards policies under NT, the importance of pollution externalities increases under the multilateral agreement. They thus have an incentive to regulate products, even for lower externality values.



(a) Agreements based on NT



(b) Agreements based on MR

Figure 4 Summary of optimal standards under multilateral agreements

4.2 Outcomes under MR

In the case of a multilateral agreement with MR, each country's standards policy affects the export profits of other countries. This means that governments' objective function is social welfare SW^J given by (3), $J = A, B, C$. Their possible strategy is either (i) full regulation, $\sigma_j^K = L$ or (ii) no regulation (NR), under which $\sigma_j^K = H$ for $j = a, b, c$ and $K = A, B, C$. Since the objective function of country J's government, SW^J, depends on the other two countries' standards policies, the optimal standards for country J's government, $(\sigma_j^A, \sigma_j^B, \sigma_j^C)$, also depend on those countries' standards. Therefore, we first need to derive each member country's best response strategies and then obtain the Nash equilibrium of the standard game. Again, there can be multiple Nash equilibria, and we focus on the most cooperative equilibrium, which can be characterized by the following proposition.

Proposition 7 *Under a multilateral agreement on standards based on MR, the equilibrium standards regime in the most-cooperative equilibrium implies:*

• NR for $0 \leq \theta < \theta^{*M}$, and

• FR for $\theta^{*M} \leq 0$, where $\theta^{*M} \equiv \frac{c(42+13c)}{8(1+2c)}$.

Proof See the Appendix.

It can be verified that θ^{*M} is greater than $\overline{\theta}^{M}$; the threshold value of θ at which the governments start implementing full regulation is higher under the multilateral agreement than under the bilateral one. This means that a multilateral agreement based on MR induces the government to implement a less stringent standards policy. Intuitively, compared to the bilateral agreement under MR, the multilateral agreement further reduces governments' control over the standards on imported products but increases their control over the standards on the domestic firm's export products. By loosening the regulation on the domestic firm, each country can gain from the increased exports; the resulting externalities only affect foreign welfare and not domestic welfare. Thus, under the multilateral agreement on standards policy based on MR, the governments do not impose regulations unless the level of externalities is exceptionally high.

5 Can Bilateral Agreements be a Building Block to Multilateral Agreements?

We now compare each country's welfare under multilateral agreements with that under bilateral agreements. Based on the comparison, we discuss whether the respective types of multilateral agreements can be a building or stumbling block to multilateral agreements.

5.1 NT-based agreement

As the bilateral and multilateral agreements achieve the same outcomes for $\theta < \underline{\theta}^{U}$ (under which all countries choose NR) and $\overline{\theta}^{U} \leq \theta$ (under which all countries choose FR), we begin with a comparison of the welfare between the two types of agreements for the case when $\overline{\theta}^{U} \leq \theta < \underline{\theta}$. In this case, the member countries of the bilateral agreement choose NR and do so under the multilateral agreement as well, whereas the nonmember country chooses D under the bilateral agreement and NR under the multilateral agreement. As the nonmember country lifts its discriminatory measures after joining the multilateral agreement, the domestic firm's cost advantage reduces. By contrast, member countries' firms no longer suffer the cost disadvantage after the multilateral

agreement. Therefore, for $\overline{\theta}^{U} \leq \theta < \underline{\theta}$, switching from a bilateral to multilateral one makes the member countries better off and the nonmember worse off.

For $\underline{\theta} \leq \theta < \theta^{*N}$, the members of the bilateral agreement choose D against the nonmember, and the nonmember chooses D, while all countries choose NR under the multilateral agreement. The nonmember country's policy response to a change from a bilateral to a multilateral agreement is the same as the one when $\underline{\theta}^{U} \leq \theta < \underline{\theta}$. Therefore, this change harms the nonmember's welfare. However, the member countries also lift the discriminatory measure against the nonmember, eliminating the cost disadvantage of the nonmember country's firm and, thus, improving its welfare. This positive effect outweighs the former negative effect, and the nonmember country becomes better off. For member countries' firms, these two effects caused by the change from the bilateral to the multilateral agreement work in the opposite direction; the nonmember country's policy change from D to NR benefits member countries' firms, but member countries' policy change from D against the nonmember to NR harms these firms. In addition, as all firms produce polluting goods under the multilateral agreement, pollution damage increases. Consequently, the member countries become better off after the transition from the bilateral to the multilateral agreement if θ is smaller than a threshold level, denoted by $\theta' \in \left(\underline{\theta}, \theta^{*N}\right)$, but they become worse off if $\theta > \theta'$.

For $\theta^{*N} \leq \theta < \overline{\theta}^{N}$, the members of the bilateral agreement choose D against the nonmember, and the nonmember chooses D, while all countries choose FR under the multilateral agreement. Under the multilateral agreement, all firms now face stricter standards and, thus, their costs increase. In addition, since countries remove discriminatory measures under the multilateral agreement, the cost advantage of domestic firms disappears. Simultaneously, as an exporter, each firm's cost disadvantage also disappears. In this three-country model, firm a, for example, has already been as competitive as firm b in country B's market, and the change from the bilateral to the multilateral agreement only improves firm a's competitiveness in country C's market. Therefore, the member countries become worse off after the conclusion of the multilateral agreement. By contrast, for firm c, a transition

from the bilateral to the multilateral agreement helps it regain its competitiveness in the markets of both countries A and B. Since the governments implemented full regulation under the multilateral agreement, the countries now incur no environmental damages. As the level of θ is relatively high in this case, the nonmember country becomes better off.

Finally, for $\overline{\theta}^N \leq \theta < \overline{\theta}^U$, the members of the bilateral agreement choose FR and the nonmember chooses D, while all countries choose FR under the multilateral agreement. In this case, member countries' firms regain competitiveness in the nonmember country's market, while the nonmember country's firm loses its cost advantage in the domestic market. As such, the change from a bilateral to a multilateral agreement makes the member countries better off and the nonmember country worse off.

5.2 MR-based agreement

We now consider the case of the MR-based agreement. In light of (4), the same outcomes are obtained under the bilateral and multilateral agreements for $\theta < \underline{\theta}^U$ (under which all countries choose NR) and $\theta^{*M} \leq \theta$ (under which all countries choose FR). Consider case $\underline{\theta}^U < \theta < \underline{\theta}$, under which the member countries of the bilateral agreement choose NR and also do so under the multilateral agreement, whereas the nonmember country chooses D under the bilateral agreement but chooses NR under the multilateral agreement. This case has already been discussed for the NT-based agreement; that is, a transition from the bilateral to the multilateral agreement makes the member country better off but the nonmember country worse off.

For $\underline{\theta} \leq \theta < \overline{\theta}^U$, the members of the bilateral agreement choose D against the nonmember, and the nonmember chooses D, while all countries choose NR under the multilateral agreement. This case is also the same as that under the NT-based agreement for $\underline{\theta} \leq \theta < \theta^{*N}$. That is, as already discussed, there is a threshold value $\theta' \in \left(\underline{\theta}, \theta^{*N}\right)$ such that a change from a bilateral to a multilateral agreement makes the member countries better

off only if $\theta < \theta'$, while the nonmember country is unambiguously better off. For $\theta' \leq \theta < \overline{\theta}^{U}$, the members of the bilateral agreement become worse off after the conclusion of the multilateral agreement.

For $\overline{\theta}^{U} \leq \theta < \overline{\theta}$, the members of the bilateral agreement choose D against the nonmember, and the nonmember chooses FR, while all countries choose NR under the multilateral agreement. As member countries' firms have already been unregulated and lose their cost advantage over the nonmember country's firm after the conclusion of the multilateral agreement, these firms' profits decrease. By contrast, the nonmember country's firm regains its competitiveness in the export markets. However, this positive effect on the nonmember country's welfare is outweighed by the increase in pollution damage, as the value of θ is already high in this case. Thus, a transition from a bilateral to a multilateral agreement makes all countries worse off.

Finally, for $\overline{\theta} \leq \theta < \theta^{*M}$, all countries choose FR under the bilateral agreement, while all countries choose NR under the multilateral agreement. Firms do not need to comply with standards to enjoy higher profits after the conclusion of the multilateral agreement. Nonetheless, the value of θ is so high that the damage from negative externalities outweighs the positive effects on firm profits. As such, a change from a bilateral to a multilateral agreement makes all countries worse off.

6 Discussion

A multilateral agreement on standards via a bilateral one can be achieved only if it is not blocked by the member or nonmember countries of the bilateral agreement. Summarizing the above discussion for the respective types of standards agreements, this is possible only if $\underline{\theta} \leq \theta < \theta'$, where θ' is smaller than θ^{*N}. In this case, both the members and nonmembers of the bilateral agreements, irrespective of whether the agreements are based on NT or MR, become better off after concluding the multilateral agreement. Otherwise, a transition from a bilateral to a multilateral agreement on standards causes welfare losses to either the nonmember or member countries and, thus, the multilateral agreement will be blocked by these countries.

The member countries of a bilateral agreement are assumed to conclude the agreement. The discussion is meaningful only if the members have an incentive to conclude the bilateral agreement. However, as illustrated in Figure 2, the member countries gain from the conclusion of the bilateral agreement when $\theta \in (\underline{\theta}, \theta')$. That is, for $\underline{\theta} \leq \theta < \theta'$, a multilateral agreement on standards can be achieved via an agreement concluded by two of the three countries. Starting from a noncooperative equilibrium of standards policies, two of the three countries will conclude a bilateral agreement on standards and, then, the remaining country has an incentive to join the agreement, which also enhances member countries' welfare. Therefore, we obtain the following proposition.

Proposition 8 *A bilateral agreement on standards, irrespective of whether it is based on NT or MR, can be a building block to a multilateral agreement only if* $\theta \in (\underline{\theta}, \theta')$.

How can Proposition 8 be interpreted? Does it offer a positive message with regard to achieving the harmonization of standards at the global level? We are rather pessimistic about it for the following reasons. First, interval $(\underline{\theta}, \theta')$ in Proposition 8 is only a small subset of the possible values of θ. Second, for the externality parameter satisfying $\theta \in (\underline{\theta}, \theta')$, the respective countries choose discriminatory standards under bilateral agreements, and shift to less stringent standards policies after concluding the multilateral agreement. However, as previously discussed, implementing a discriminatory standards policy might go against the non-discrimination principle in the WTO law, even if preferential agreements are allowed. Moreover, the multilateral agreement results in a "race to the bottom," which the agreement does not aim for.

7 Conclusion

This study extended Costinot's (2008) comparative analysis of the agreements on product standards to a three-country model. By considering a bilateral agreement between a subset of the world economy, we discussed the comparative performance of the different regimes of standards agreements, namely NT and MR, for both the member and nonmember countries of the agreements.

We have shown that the equilibrium standards depend on the value of the externality parameter, θ. The patterns of the equilibrium standards in the unconstrained noncooperative standards game without any international agreements and in the bilateral agreement on standards under NT are the same, but the threshold values of θ differ: no regulation for small values of θ, discrimination for intermediate values of θ, and full regulation for large values of θ. Compared to the case without agreements on standards, we have shown that the threshold value of θ above which the member countries begin to shift from a discrimination strategy to full regulation is lower under NT and higher under MR; this means that member countries tend to choose more stringent standards under NT, whereas they tend to choose less stringent standards under MR. We also examined the welfare gains from bilateral agreements for both member and nonmember countries. For member countries, for small values of θ, MR is preferred over NT, while for large values of θ, NT is preferred over MR. We have also shown that a nonmember country can never prefer MR to NT.

We further considered multinational agreements on standards. For NT-based agreements, the threshold value of θ at which governments start to implement full regulation is lower under the multilateral agreement than under the bilateral agreement; this suggests that a multilateral agreement based on NT induces the government to implement a more stringent standards policy. By contrast, for MR-based agreements on standards, the threshold value of θ at which the governments start implementing full regulation is higher under the multilateral agreement than under the bilateral one. This means that a multilateral agreement based on MR induces the government to implement a less stringent standards policy. We have also shown that there exists a range of θ for which the multilateral agreement on standards can be achieved via agreements concluded by two of the three countries. Specifically, starting from a noncooperative equilibrium of standards policies, two of the three countries will conclude a bilateral agreement on standards and then, the remaining country has an incentive to join the agreement, which also enhances member countries' welfare. Otherwise, a multilateral agreement on standards will be blocked by the member countries or a nonmember country of the bilateral agreement.

Some noteworthy extensions of the analysis warrant further study. First, future studies should consider the case of asymmetric countries (i.e., developed countries and developing countries). In this study, we considered three symmetric countries join the trade agreements. In future studies, we will consider asymmetric countries to join the agreements. Second, this research considered the impact of non-tariff barriers. While under some trade agreements, the tariff is still in force. Thus, future study will consider import tariffs and export subsidies (two traditional trade instruments) together with product standards.

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Declarations

The authors declare no potential conflict of interest regarding the publication of this work.

The authors declare no use of generative AI and AI-assisted technologies in the writing process.

Appendix

A.1 Proof of Proposition 1

As export profits depend on other countries' standards, the government's objective in each country is to maximize the domestic component of national welfare, i.e., the sum of consumer surplus and domestic profit, represented by (4). If country J's government implements full regulation (FR), $c_k^J = c$ and $\theta_k^J = 0$ for k = a, b, c. Thus, (4) can be rewritten as

$$CS^J + \pi_j^J = \frac{11(1-c)^2}{32} \quad (A.1)$$

If the government chooses no regulation (NR), $c_k^J = 0$ and $\theta_k^J = \theta$ for k = a, b, c, and (4) becomes

$$CS^J + \pi_j^J = \frac{11}{32} - \frac{3\theta}{4} \quad (A.2)$$

If the government chooses Discrimination (D), it holds that $(c_k^J,\ \theta_k^J) = (0, \theta)$ and $(c_k^J,\ \theta_k^J) = (c, 0)$ for $j \neq k$. Then, (4) can be rewritten as

$$CS^J + \pi_j^J = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1+2c)^2}{16} \quad (A.3)$$

Comparing the welfare under different standards policies, we obtain the following threshold values for θ:

$$FR \succ NR \text{ iff } \theta > \frac{11}{24}c(2-c) \equiv \theta_1;$$

$$FR \succ D \text{ iff } \theta > \frac{c(18+c)}{8(1+2c)} \equiv \theta_2;$$

$$NR \succ D \text{ iff } \theta < \frac{c(1-3c)}{4(1-c)} \equiv \theta_3.$$

It can be easily verified that under Assumption 1 (i.e., c < 1/5), $\theta_3 < \theta_1 < \theta_2$ holds. Then, the optimal standards policy for country J under the unconstrained noncooperative policy game can be represented by Figure A.1.

From Figure A.1, country J's government finds it optimal to choose NR for $0 \leq \theta < \theta_3$, D for $\theta_3 \leq \theta < \theta_2$, and FR for $\theta_2 \leq \theta$. Considering that the three countries are symmetric, governments in all countries have the same choice for optimal standards. Redefining θ_3 and θ_2 by $\underline{\theta}^U$ and $\overline{\theta}^U$ respectively, we obtain the statement of Proposition 1.

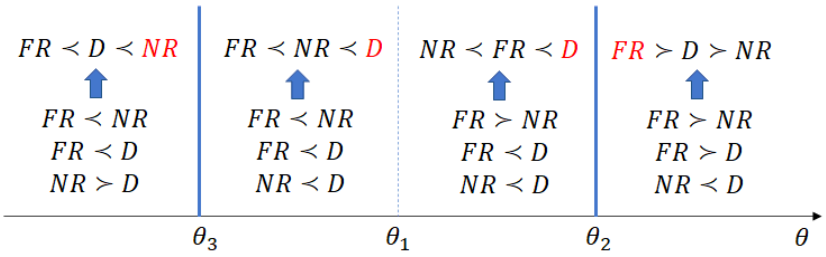

Figure A.1: Optimal standards in the unconstrained noncooperative equilibrium

A.2 Proof of Proposition 2

As in the unconstrained noncooperative case, export profits depend only on the foreign standards under NT; thus, the member countries choose standards to maximize domestic welfare. Let us focus on country A. If country A's government chooses FR, $c_j^A = 0$ and $\theta_j^A = \theta$ for j = a, b, c holds and, thus, its domestic welfare is the same as (A.1). If NR is chosen, $c_j^A = 0$ and $\theta_j^A = \theta$ for j = a, b, c hold, meaning that the domestic welfare is the same as (A.2). If country A's government discriminates against country C regarding the standards policy, $(c_a^A,\ \theta_a^A)$= $(c_b^A,\ \theta_b^A) = (0, \theta)$ and $(c_c^A,\ \theta_c^A) = (c, 0)$ hold, and (4) can be rewritten as

$$CS^A + \pi_a^A = \frac{(3-c)^2}{32} - 2\theta\frac{1+c}{4} + \frac{(1+c)^2}{16}. \tag{A.4}$$

Comparing the welfare under different standards policies, we obtain the threshold values for θ as follows. The comparison between FR and NR is the same as that in the unconstrained noncooperative case; that is, FR ≻ NR if and only if $\theta > \theta_1$, where θ_1 is defined in the proof of Proposition 1. From (A.1), (A.2), and (A.4), we obtain the other threshold values

$$FR \succ D \text{ iff } \theta > \frac{c(5-2c)}{4(1+c)} \equiv \theta_2^n;$$
$$NR \succ D \text{ iff } \theta < \frac{c(2-3c)}{8(1-2c)} \equiv \theta_3^n.$$

It can be verified that $\theta_3^n < \theta_1 < \theta_2^n$ holds if c<1/5.

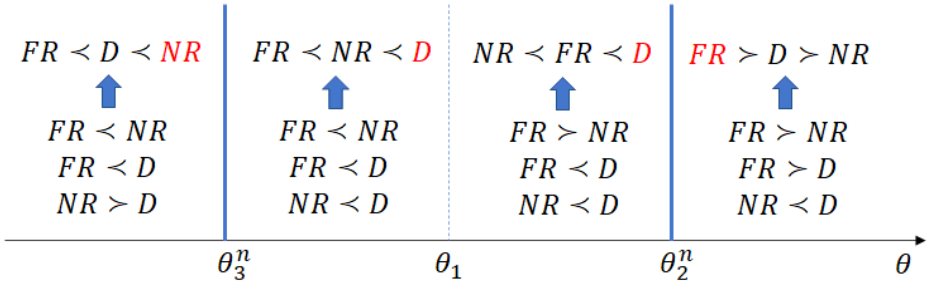

Figure A.2: Bilateral agreement on standards based on NT principle

From Figure A.2, country A's government finds it optimal to choose NR for $0 \leq \theta < \theta_3^n$, D for $\theta_3^n \leq \theta < \theta_2^n$, and FR for $\theta_2^n \leq \theta$. With symmetry, country B's government follows the same choice for optimal standards. Redefining θ_3^n and θ_2^n by $\underline{\theta}$ and $\overline{\theta}^N$, respectively, we obtain the statement of Proposition 2.

A.3 Proof of Proposition 3

We first prove the following lemma.

Lemma A.1 *Under a bilateral agreement of standards policy with MR, the member countries' equilibrium standards regime implies that:*

・No regulation for $0 \leq \theta < \underline{\theta}$;

・Discrimination (against the nonmember) for $\underline{\theta} \leq \theta < \overline{\theta}^M$ and

・Discrimination or Full regulation for $\overline{\theta}^M \leq \theta < \theta'$ and

・Full regulation for $\theta' \leq \theta$,

where $\overline{\theta}^M \equiv \frac{(30+7c)c}{8(1+2c)}$ and $\theta' = \frac{15(2-c)c}{8}$.

Proof Let us consider country A's government, whose objective function is given by (5). If the government chooses FR, $c_a^A = c_a^B = c_c^A = c$ and $\theta_a^A = \theta_c^A = \theta$ but θ_b^A depends on country B's strategy. Thus, (5) can be rewritten as

$$CS^A + \pi_a^A + \pi_a^B$$

$$= \frac{(3-2c-c_b^A)^2}{32} - \theta_b^A \frac{1+2c-3c_b^A}{4} + \frac{(1-2c+c_b^A)^2}{16} + \frac{(1-3c+c_b^B+c_c^B)^2}{16} \quad \text{(A.5)}$$

If NR is chosen, $c_a^A = c_a^B = c_c^A = 0$ and $\theta_a^A = \theta_c^A = \theta$, and (5) can be rewritten as

$$CS^A + \pi_a^A + \pi_a^B = \frac{(3-c_b^A)^2}{32} - 2\theta \frac{1+c_b^A}{4} - \theta_b^A \frac{1-3c_b^A}{4} + \frac{(1+c_b^A)^2}{16} + \frac{(1+c_b^B+c_c^B)^2}{16}. \quad \text{(A.6)}$$

If country A's government discriminates against country C regarding the standards policy, $(c_a^A,\ \theta_a^A) = (c_a^B,\ \theta_a^B) = (0, \theta)$ and $(c_c^A,\ \theta_c^A) = (c, 0)$ hold. Thus, (5) can be rewritten as

$$CS^A + \pi_a^A + \pi_a^B$$

$$= \frac{(3-c-c_b^A)^2}{32} - \theta \frac{1+c+c_b^A}{4} - \theta_b^A \frac{1+c-3c_b^A}{4} + \frac{(1+c+c_b^A)^2}{16} + \frac{(1+c_b^B+c_c^B)^2}{16} \quad \text{(A.7)}$$

Let us begin with country A's best response strategy when country B uses FR, which means $c_b^A = c_c^B = c$ and $\theta_b^A = 0$. Then, (A.5), (A.6), and (A.7) can further be rewritten as

$$\frac{13(1-c)^2}{32};$$

$$\frac{(3-c)^2}{32} - \theta \frac{1+c}{2} + \frac{(1+c)^2}{16} + \frac{(1+2c)^2}{16}, \text{ and}$$

$$\frac{(3-2c)^2}{32} - \theta \frac{1+2c}{4} + \frac{(1+2c)^2}{8},$$

respectively. Comparing the above expressions one after another, we obtain the threshold values of θ when FR is chosen in country B:

$$FR \succ NR \text{ iff } \theta > \frac{c(16-c)}{8(1+c)} \equiv \theta_1^{FR};$$

$$FR \succ D \text{ iff } \theta > \frac{c(30+7c)}{8(1+2c)} \equiv \theta_2^{FR};$$

$$NR \succ D \text{ iff } \theta < \frac{c(2-9c)}{8} \equiv \theta_3^{FR}.$$

It can be verified that $\theta_3^{FR} < \theta_1^{FR} < \theta_2^{FR}$ under the assumption $c < 1/5$. Then, we have a similar pattern to Figures A.1 and A.2 regarding the best response strategy of country A's government; that is, when country B's standards

policy is FR, country A find it optimal to choose NR for $0 \leq \theta < \theta_3^{FR}$, D for $\theta_3^{FR} \leq \theta < \theta_2^{FR}$, and FR for $\theta_2^{FR} \leq \theta$.

We next consider country A's best response strategy when country B uses NR, which means $c_b^A = c_b^B = c_c^B = 0$ and $\theta_b^A = \theta$. Eqs. (A.5), (A.6), and (A.7) can be rewritten as

$$\frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1-2c)^2}{16} + \frac{(1-3c)^2}{16}$$

$$\frac{13}{32} - \frac{3\theta}{4}, \text{ and}$$

$$\frac{(3-c)^2}{32} - \theta\frac{1+c}{4} + \frac{(1+c)^2}{16} + \frac{1}{16}$$

respectively. The threshold values can be calculated as follows:

$$FR \succ NR \text{ iff } \theta > \frac{c(16-15c)}{8(1-c)} \equiv \theta_1^{NR};$$

$$FR \succ D \text{ iff } \theta > \frac{3c(10-9c)}{8} \equiv \theta_2^{NR};$$

$$NR \succ D \text{ iff } \theta < \frac{c(2-3c)}{8(1-2c)} \equiv \theta_3^{NR}.$$

We have $\theta_3^{NR} < \theta_1^{NR} < \theta_2^{NR}$ under the assumption c < 1/5. Again, country A's best response strategies when NR is implemented in country B are NR for $0 \leq \theta < \theta_3^{FR}$, D for $\theta_3^{FR} \leq \theta < \theta_2^{FR}$, and FR for $\theta_2^{FR} \leq \theta$.

Finally, let us consider country A's best response strategy when country B uses D, which means $c_b^A = c_b^B = 0$, $c_c^B = c$ and $\theta_b^A = \theta$. Eqs. (A.5), (A.6), and (A.7) can be rewritten as

$$\frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1-2c)^2}{8}$$

$$\frac{13}{32} - \frac{3\theta}{4} + \frac{(1+c)^2}{16}, \text{ and}$$

$$\frac{(3-c)^2}{32} - \theta\frac{1+c}{2} + \frac{(1+c)^2}{8},$$

respectively. The threshold values can be calculated as follows:

$$FR \succ NR \text{ iff } \theta > \frac{c(16-9c)}{8(1-c)} \equiv \theta_1^D;$$

$$FR \succ D \text{ iff } \theta > \frac{15c(2-c)}{8} \equiv \theta_2^D;$$

$$NR \succ D \text{ iff } \theta < \frac{c(2-3c)}{8(1-2c)} \equiv \theta_3^D.$$

Note that $\theta_3^{NR} = \theta_3^D$. Because $\theta_3^D < \theta_1^D < \theta_2^D$ holds under Assumption 1, country A's best response strategies when country B uses D, are NR for $0 \leq \theta < \theta_3^D$, D for $\theta_3^D \leq \theta < \theta_2^D$, and FR for $\theta_2^D \leq \theta$.

Comparing the lower bounds of the threshold values under different strategies, we can verify that $\theta_3^{FR} - \theta_3^{NR} = \theta_3^{FR} - \theta_3^D < 0$. Comparing the upper bounds of the threshold values, we have $\theta_2^{FR} < \theta_2^{NR} < \theta_2^D$; moreover, we can verify that $\theta_3^{NR} = \theta_3^D < \theta_2^{FR}$. Thus, we can summarize country A's best response strategies by Figure A.3. By symmetry, country B's best response strategies are the same as Figure A.3, with A replaced by B.

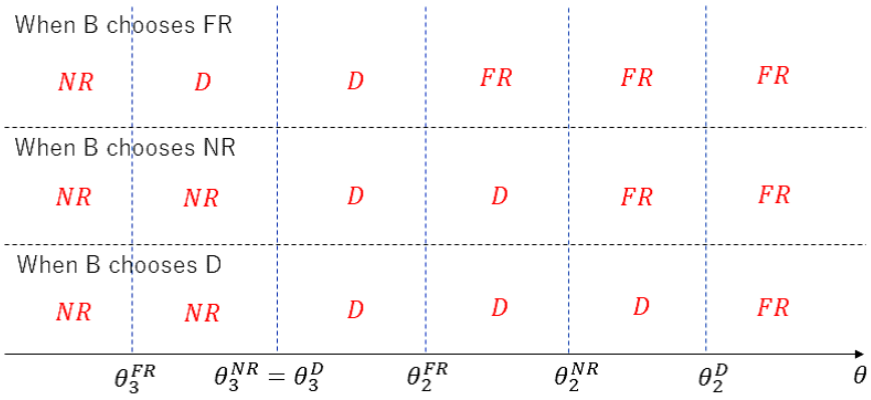

Figure A.3: Summary of member country A's best response strategies

From Figure A.3, it immediately follows that the Nash equilibrium standards for the member countries are uniquely determined for $0 \leq \theta < \theta_3^{NR} = \theta_3^D$, in which NR is the Nash equilibrium standards, for $\theta_3^{NR} = \theta_3^D \leq \theta < \theta_2^{FR}$, in which D is the Nash equilibrium standards, and for $\theta_2^D \leq \theta$, in which FR is the Nash equilibrium standards. For $\theta_3^{FR} \leq \theta < \theta_2^{NR}$, there are two Nash equilibria, D and FR. In view of Proposition 2, $\theta_3^{NR} = \theta_3^D$ is equal to $\underline{\theta}$. Then, by redefining θ_2^{FR} and θ_2^D by $\overline{\theta}^M$ and θ', respectively, we obtain the statement of the lemma

As there are multiple Nash equilibria when $\overline{\theta}^{M} \leq \theta < \theta'$, we make a refinement of equilibrium using the following lemma.

Lemma A.2 *In the most cooperative equilibrium under MR regime, the member countries will coordinate on FR when* $\theta \in [\overline{\theta}^{M}, \theta']$.

Proof We begin with the derivation of optimal standards when the member countries jointly determine their standards to maximize the sum of their welfare. As the export profits earned in country C depend only on country C's standards, the member countries A and B choose $(\sigma_a^A, \sigma_b^A, \sigma_c^A)$ and $(\sigma_a^B, \sigma_b^B, \sigma_c^B)$ to maximize the following objective function:

$$CS^A + \pi_a^A + \pi_a^B + CS^B + \pi_b^A + \pi_b^B$$

$$= \sum_{J=A,B} (CS^J + \pi_a^J + \pi_b^J)$$

$$= \sum_{J=A,B} \left[\frac{(3 - \sum_{k=a,b,c} c_k^J)^2}{32} - \sum_{k \in a,b,c} \theta_k^J \frac{1 - 3c_k^J + \sum_{i \neq k} c_i^J}{4} + \sum_{k=a,b} \frac{(1 - 3c_k^J + \sum_{i \neq k} c_i^J)^2}{16} \right]. \quad \text{(A.8)}$$

However, because the two member countries are symmetric, the joint-welfare maximization problem is equivalent to choosing country A's standards policy $(\sigma_a^A, \sigma_b^A, \sigma_c^A)$ that maximizes

$$CS^A + \pi_a^A + \pi_b^A$$

$$= \frac{(3 - \sum_{k=a,b,c} c_k^A)^2}{32} - \sum_{k=a,b,c} \theta_k^A \frac{1 - 3c_k^A + \sum_{i \neq k} c_i^A}{4} + \sum_{j=a,b} \frac{(1 - 3c_j^A + \sum_{i \neq k} c_i^A)^2}{16}. \quad \text{(A.9)}$$

We consider four strategies regarding country A's choice of standards: (i) full regulation (FR) in which $(\sigma_a^A, \sigma_b^A, \sigma_c^A)$ = (L, L, L), (ii) no regulation (NR) in which $(\sigma_a^A, \sigma_b^A, \sigma_c^A)$ = (H, H, H), (iii) discrimination (D) in which $(\sigma_a^A, \sigma_b^A, \sigma_c^A)$ = (H, L, L), and (iv) discrimination against country C (DC) in which $(\sigma_a^A, \sigma_b^A, \sigma_c^A)$ = (H, H, L). In the respective regimes, (A.9) can be rewritten as follows

$$FR: CS^A + \pi_a^A + \pi_a^B = \frac{13(1-c)^2}{32}; \quad \text{(A.10)}$$

$$FR: CS^A + \pi_a^A + \pi_a^B = \frac{13}{32} - \frac{3\theta}{4}; \quad \text{(A.11)}$$

$$D: CS^A + \pi_a^A + \pi_a^B = \frac{13-4c(3-5c)}{32} - \theta\frac{1+2c}{4}; \quad \text{(A.12)}$$

$$DC: CS^A + \pi_a^A + \pi_a^B = \frac{13+c(2+5c)}{32} - \theta\frac{1+c}{2}. \quad \text{(A.13)}$$

Note that by comparing (A.11) and (A.13), NR $\prec$ DC always holds. This means that NR cannot be an optimal policy, and thus it suffices to compare FR, D, and DC to obtain the following threshold values for θ:

$$FR \succ D \text{ iff } \theta > \frac{7c(2+c)}{8(1-c)} \equiv \theta_1^b;$$

$$FR \succ DC \text{ iff } \theta < \frac{c(7-2c)}{4(1+c)} \equiv \theta_2^b;$$

$$D \succ DC \text{ iff } \theta < \frac{c(14-15c)}{8} \equiv \theta_3^b.$$

Note also that NR $\prec$ DC always holds for any $\theta > 0$.

It can be verified that $\theta_3^b < \theta_1^b < \theta_2^b$. Then, the optimal standards policy for the member countries under bilateral cooperation can be represented by Figure A.4; that is, the member countries' governments find it optimal to choose DC for $0 \leq \theta < \theta_2^b$ and FR for $\theta_2^b \leq \theta$.

It can be verified that θ_2^b is smaller than $\bar{\theta}^M$. This means that for $\theta \in [\bar{\theta}^M, \theta']$, the member countries have an incentive to coordinate on FR even though there are multiple Nash equilibria in the policy game under MR.

Proof of Proposition 3 In light of Lemma A.2, Lemma A.1 is modified to Proposition 3.

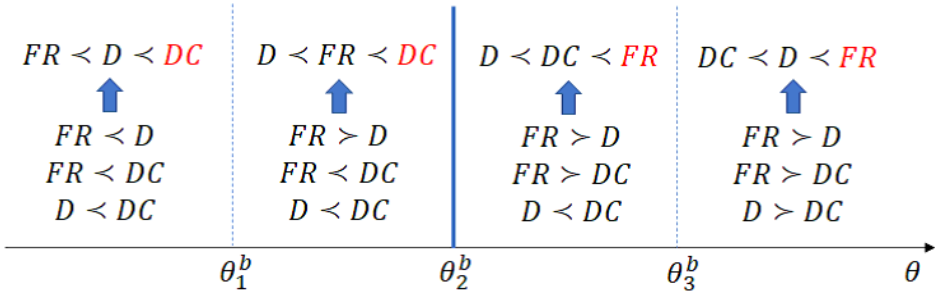

Figure A.4: Optimal standards under bilateral cooperation

A.4 Comparison of welfare between unconstrained noncooperative solution and bilateral agreements

From Propositions 1 to 3, we observe that the respective countries' equilibrium standards vary as the value of θ changes, as shown by Figure 1. Table 1 summarizes the equilibrium standards $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B; \sigma_a^C, \sigma_b^C, \sigma_c^C)$ under respective standards regimes, where H and L represent (H, H, H) and (L, L, L), respectively.

	Unconstrained	NT	MR
(1) $0 \le \theta < \underline{\theta}^U$	$(\boldsymbol{H}; \boldsymbol{H}; \boldsymbol{H})$	$(\boldsymbol{H}; \boldsymbol{H}; \boldsymbol{H})$	$(\boldsymbol{H}; \boldsymbol{H}; \boldsymbol{H})$
(2) $\underline{\theta}^U \le \theta < \underline{\theta}$	$(H, L, L; L, H, L; L, L, H)$	$(\boldsymbol{H}; \boldsymbol{H}; L, L, H)$	$(\boldsymbol{H}; \boldsymbol{H}; L, L, H)$
(3) $\underline{\theta} \le \theta < \bar{\theta}^N$	$(H, L, L; L, H, L; L, L, H)$	$(H, H, L; H, H, L; L, L, H)$	$(H, H, L; H, H, L; L, L, H)$
(4) $\bar{\theta}^N \le \theta < \bar{\theta}^U$	$(H, L, L; L, H, L; L, L, H)$	$(\boldsymbol{L}; \boldsymbol{L}; L, L, H)$	$(H, H, L; H, H, L; L, L, H)$
(5) $\bar{\theta}^U \le \theta < \bar{\theta}^M$	$(\boldsymbol{L}; \boldsymbol{L}; \boldsymbol{L})$	$(\boldsymbol{L}; \boldsymbol{L}; \boldsymbol{L})$	$(H, H, L; H, H, L; \boldsymbol{L})$
(6) $\bar{\theta}^M \le \theta$	$(\boldsymbol{L}; \boldsymbol{L}; \boldsymbol{L})$	$(\boldsymbol{L}; \boldsymbol{L}; \boldsymbol{L})$	$(\boldsymbol{L}; \boldsymbol{L}; \boldsymbol{L})$

Table 1: Summary of the equilibrium standards $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B; \sigma_a^C, \sigma_b^C, \sigma_c^C)$

Case 1 ($0 \le \boldsymbol{\theta} < \underline{\boldsymbol{\theta}}^{\boldsymbol{U}}$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B; \sigma_a^C, \sigma_b^C, \sigma_c^C)$=(H, H, H; H, H, H; H, H, H) under all regimes, meaning that $SW_J^U = SW_J^N = SW_J^M$ for J = A, B, C. In other words, $SW_J^N - SW_J^U = SW_J^M - SW_J^U = 0$ for both member and nonmember countries.

Case 2 ($\underline{\boldsymbol{\theta}}^{\boldsymbol{U}} \le \boldsymbol{\theta} < \underline{\boldsymbol{\theta}}$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B; \sigma_a^C, \sigma_b^C, \sigma_c^C)$ =(H, L, L; L, H, L; L, L, H) under unconstrained noncooperative equilibrium. Because $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B; c_a^C, c_b^C, c_c^C)$ = (0, c, c; c, 0, c; c, c, 0) and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B; \theta_a^C, \theta_b^C, \theta_c^C)$ =(θ, 0, 0; 0, θ, 0; 0, 0, θ),

$$SW_A^U = SW_B^N = SW_C^M = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1+2c)^2}{16} + \frac{(1-2c)^2}{8}$$

holds.

Under NT and MR, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B; \sigma_a^C, \sigma_b^C, \sigma_c^C)$ = (H, H, H; H, H, H; L, L, H) holds. Since $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B; c_a^C, c_b^C, c_c^C)$ =(0, 0, 0; 0, 0, 0; c, c, 0) and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B; \theta_a^C, \theta_b^C, \theta_c^C)$ =(θ, θ, θ; θ, θ, θ; 0, 0, θ), the respective countries' welfare can be represented as follows:

$$SW_J^N = SW_J^M = \frac{13}{32} - \frac{3\theta}{4} + \frac{1}{8} + \frac{(1-2c)^2}{16}, J = A, B,$$

$$SW_C^N = SW_C^M = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1+2c)^2}{16} + \frac{1}{8}.$$

Therefore, it follows that

$$SW_J^N - SW_J^U = SW_J^M - SW_J^U = \frac{c(3-5c)}{8} - \theta\frac{1-c}{2}, J = A, B$$

$$SW_C^N - SW_C^U = SW_C^M - SW_C^U = \frac{c(1-c)}{2} > 0.$$

Case 3 ($\underline{\theta} \le \theta < \bar{\theta}^N$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ = (H, L, L; L, H, L; L, L, H) under unconstrained noncooperative equilibrium. Therefore, each country's welfare is the same as in case 2:

$$SW_A^U = SW_B^N = SW_C^M = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1+2c)^2}{16} + \frac{(1-2c)^2}{8}$$

Under NT and MR, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C$ = (H, H, L; H, H, L; L, L, H) holds. This means that $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B; c_a^C, c_b^C, c_c^C)$= (0, 0, c; 0, 0, c; c, c, 0) and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B;\ \theta_a^C, \theta_b^C, \theta_c^C)$ = (θ, θ, 0; 0, θ, θ; 0, 0, θ) and, thus, the respective countries' welfare can be represented as follows:

$$SW_J^N = SW_J^M = \frac{(3-2c)^2}{32} - \theta\frac{1+c}{2} + \frac{(1+c)^2}{8} + \frac{(1-2c)^2}{16}, J = A, B,$$

$$SW_C^N = SW_C^M = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1-3c)^2}{8} + \frac{(1+2c)^2}{16}.$$

Therefore, it follows that

$$SW_J^N - SW_J^U = SW_J^M - SW_J^U = \frac{c(14-15c)}{32} - \frac{\theta}{4}, J = A, B$$

$$SW_C^N - SW_C^U = SW_C^M - SW_C^U = -\frac{c(2-5c)}{8} < 0.$$

Case 4 ($\overline{\theta}^N \le \theta < \overline{\theta}^U$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ =(H, L, L; L, H, L; L, L, H) under unconstrained noncooperative equilibrium. Therefore, each country's welfare is the same as in Case 2:

$$SW_A^U = SW_B^N = SW_C^M = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1+2c)^2}{16} + \frac{(1-2c)^2}{8}$$

Under NT, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ = (L, L, L; L, L, L; L, L, H) holds. Considering that $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B; c_a^C, c_b^C, c_c^C)$ = (c, c, c; c, c, c; c, c, 0) and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B;\ \theta_a^C, \theta_b^C, \theta_c^C)$ = (0, 0, 0; 0, 0, 0; 0, 0, θ), the respective countries' welfare can be represented as follows:

$$SW_A^N = SW_B^N = \frac{9(1-c)^2}{32} + \frac{(1-c)^2}{8} + \frac{(1-2c)^2}{16}, J = A, B,$$

$$SW_C^N = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1-c)^2}{8} + \frac{(1+2c)^2}{16}.$$

Under MR, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ = (H, H, L; H, H, L; L, L, H) holds. Then, the expressions for the respective countries' welfare are the same as those in Case 3:

$$SW_A^M = SW_B^M = \frac{(3-c)^2}{32} - \theta\frac{1+c}{2} + \frac{(1-c)^2}{8} + \frac{(1-2c)^2}{16}, J = A, B,$$

$$SW_C^M = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1-3c)^2}{8} + \frac{(1+2c)^2}{16}.$$

Therefore, we obtain the following results regarding the comparison of the respective countries' welfare under NT with that under the unconstrained noncooperative equilibrium:

$$SW_J^N - SW_J^U = \frac{-7c(2+c)}{32} + \theta\frac{1+2c}{4}, J = A, B$$

$$SW_C^N - SW_C^U = \frac{c(2-3c)}{8} > 0.$$

As for the comparison of the respective countries' welfare under MR with that under the unconstrained noncooperative equilibrium, we obtain the following results:

$$SW_J^M - SW_J^U = \frac{c(14-15c)}{32} - \frac{\theta}{4}, J = A, B$$

$$SW_C^M - SW_C^U = -\frac{c(2-5c)}{8} < 0.$$

Case 5 ($\overline{\boldsymbol{\theta}}^{\boldsymbol{U}} \leq \boldsymbol{\theta} < \overline{\boldsymbol{\theta}}^{\boldsymbol{M}}$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B ;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ =(L, L, L; L, L, L; L, L, L) under unconstrained noncooperative equilibrium and NT. Since $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B; c_a^C, c_b^C, c_c^C)$ = (c, c, c; c, c, c; c, c, c) and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B;\ \theta_a^C, \theta_b^C, \theta_c^C)$ = (0, 0, 0; 0, 0, 0; 0, 0, 0), it follows that

$$SW_J^U = SW_J^N = \frac{9(1-c)^2}{32} + \frac{3(1-c)^2}{16} = \frac{15(1-c)^2}{32}, J = A, B, C.$$

Therefore, we obtain the following result regarding the comparison of welfare:

$$SW_J^U = SW_J^N, J = A, B, C.$$

Under MR, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B ;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ = (H, H, L; H, H, L; L, L, L) holds. This means$(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B; c_a^C, c_b^C, c_c^C)$ = (0, 0, c; 0, 0, c; c, c, c) and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B;\ \theta_a^C, \theta_b^C, \theta_c^C)$ = (θ, θ, 0; θ, θ, 0; 0, 0, 0), the respective countries' welfare can be represented as follows:

$$SW_A^M = SW_B^M = \frac{(3-c)^2}{32} - \theta\frac{1+c}{2} + \frac{(1+c)^2}{8} + \frac{(1-c)^2}{16},$$

$$SW_C^M = \frac{9(1-c)^2}{32} + \frac{(1-3c)^2}{8} + \frac{(1-c)^2}{16}.$$

Therefore, it follows that

$$SW_J^M - SW_J^U = \frac{c(7-2c)}{8} - \theta\frac{1+c}{2}, J = A, B$$

$$SW_C^M - SW_C^U = -\frac{c(1-2c)}{2} < 0.$$

Case 6 ($\overline{\theta}^M \leq \theta$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$=(L, L, L; L, L, L; L, L, L) under all regimes, meaning that $SW_J^M = SW_J^N = SW_J^U$ for all J = A, B, C. In other words, $SW_J^M - SW_J^U = SW_J^N - SW_J^U = 0$ for both member and nonmember countries.

A.5 Proof of Proposition 6

As the objective function of each country's government is (4) and the government's choice is either FR or NR, we can refer to the discussion in the proof of Proposition 1; that is, FR is preferred to NR if and only if $\theta > \frac{11c(2-c)}{24}$, and vice versa. Letting $\theta^{*N} \equiv \frac{11c(2-c)}{24}$, we obtain the statement of the proposition.

A.6 Proof of Proposition 7

We first prove the following lemma.

Lemma A.3 *Under a multilateral agreement of standards policy with MR, each country's equilibrium standards are as follows:*

• No regulation for $0 \leq \theta < \theta_1^M$,

• No regulation or Full regulation for $\theta_1^M \leq \theta < \theta_2^M$ and

• Full regulation for $\theta_2^M \leq \theta$,

where $\theta_1^M \equiv (42 + 13c)\, c/8(1 + 2c)$ and $\theta_2^M \equiv (42 - 55c)\, c/8(1 - 2c)$.

Proof Let us consider country A's government, whose objective function is given by (3). To consider country A's best response strategy, we need to calculate country A's welfare when (i) both countries B and C choose FR, (ii) both countries B and C choose NR, and (iii) one country chooses FR and the other country chooses NR.

Starting from the case when both countries B and C choose FR (i.e., $c_b^J = c_c^J = c$ and $\theta_b^J = \theta_c^J = 0$ for J = A, B, C), country A's welfare can be calculated as

$$SW^A = \frac{15(1-c)^2}{32}$$

if country A chooses FR (i.e., c_a^J = c and θ_a^J = 0 for J = A, B, C), and

$$SW^A = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + 3\frac{(1+2c)^2}{16}$$

If it chooses NR (i.e., c_a^J = 0 and θ_a^J = θ for J = A, B, C). Comparing the levels of SW^A under different strategies, it follows that

$$\text{FR>NR iff} \quad \theta > \frac{c(42+13c)}{8(1+2c)} \equiv \theta_1^M.$$

We next consider the case when both countries B and C choose NR (i.e., $c_b^J = c_c^J = 0$ and $\theta_b^J = \theta_c^J = \theta$ for J = A, B, C) Then, country A's welfare can be calculated as

$$SW^A = \frac{3(1-3c)^2}{16} - \theta\frac{1+c}{2} + \frac{(3-c)^2}{32}$$

if country A chooses FR, and

$$SW^A = \frac{15}{32} - \frac{3}{4}\theta$$

if it chooses NR. Comparing the levels of SW^A, it follows that

$$\text{FR>NR iff} \quad \theta > \frac{c(42-55c)}{8(1-2c)} \equiv \theta_2^M.$$

Finally, let us consider the case when one country, say B, chooses FR while the other country, say C, chooses NR ((i.e., $c_b^J = c, c_c^J = 0,\ \theta_b^J = 0$ and $\theta_c^J = \theta$ for J = A, B, C). Then, country A's welfare can be calculated as

$$SW^A = \frac{3(1-3c)^2}{16} - \theta\frac{1+2c}{4} + \frac{(3-2c)^2}{32}$$

if country A chooses FR, and

$$SW^A = \frac{3(1+c)^2}{16} - \theta\frac{1+c}{2} + \frac{(3-c)^2}{32}$$

if it chooses NR. Comparing the levels of SW^A, it follows that

$$\text{FR}\succ\text{NR iff} \quad \theta > \frac{21c(2-c)}{8} \equiv \theta_3^M.$$

Comparing the threshold values of θ, we obtain $\theta_1^M < \theta_3^M < \theta_2^M$. Thus, we can summarize country A's best response strategies by Figure A.5. By symmetry, countries B and C follow a similar pattern of best response strategies.

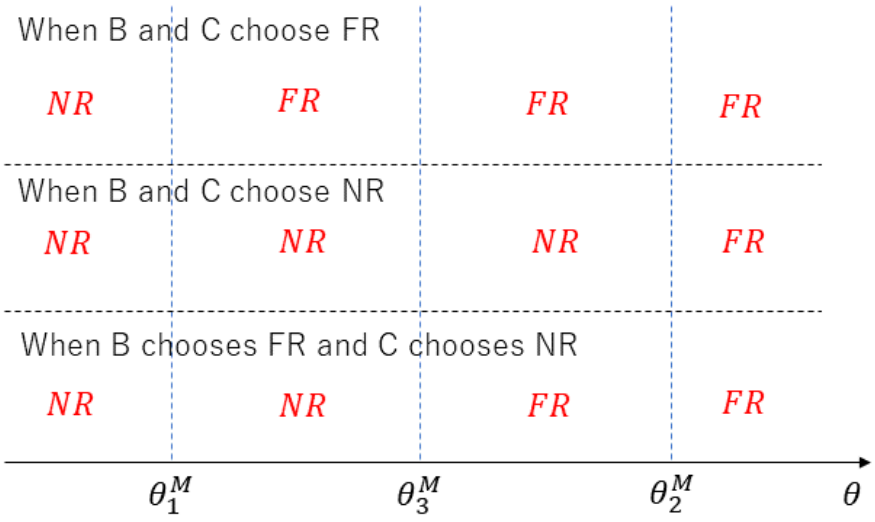

Figure A.5: Summary of country A's best response strategies

From Figure A.5, it immediately follows that the Nash equilibrium standards for each country are uniquely determined for $0 \leq \theta < \theta_1^M$, in which NR is the Nash equilibrium standards and for $\theta_2^M \leq \theta$, in which FR is the Nash equilibrium standards. For $\theta_1^M \leq \theta < \theta_2^M$, there are two Nash equilibria, NR and FR. Then, we obtain the statement of the lemma.

As there are multiple Nash equilibria when $\theta_1^M \leq \theta < \theta_2^M$, we make a refinement of equilibrium using the following lemma.

Lemma A.4 *In the most cooperative equilibrium under MR regime, the countries will coordinate on FR when* $\theta \in [\theta_1^M, \theta_2^M]$.

Proof We begin with the derivation of optimal standards when the countries jointly determine their standards to maximize the sum of their welfare, $\sum_{J=A,B,C} SW^J$. However, since all countries are symmetric, the joint-welfare maximization problem is equivalent to choosing country J's standards policy $(\sigma_a^J, \sigma_b^J, \sigma_c^J)$ that maximizes

$$CS^J + \sum_{k=a,b,c} \pi_k^J$$

$$= \frac{(3-\sum_{k=a,b,c} c_k^J)^2}{32} - \sum_{k\in a,b,c} \theta_k^J \frac{1-3c_k^J+\sum_{i\neq k} c_i^J}{4} + \sum_{k=a,b,c} \frac{(1-3c_k^J+\sum_{i\neq k} c_i^J)^2}{16}. \quad \text{(A.14)}$$

We consider the following strategies regarding country J's choice of standards: (i) full regulation (FR) in which σ_k^J = L for k = a, b, c, (ii) no regulation (NR) in which σ_k^J = H for k = a, b, c, and (iii) discrimination (D) in which σ_j^J = H and σ_k^J = L for k≠ j. In the respective regimes, (A.14) can be rewritten as follows:

$$\text{FR: } CS^J + \sum_{k=a,b,c} \pi_k^J = \frac{15(1-c)^2}{32}; \quad \text{(A.15)}$$

$$\text{NR: } CS^J + \sum_{k=a,b,c} \pi_k^J = \frac{15}{32} - \frac{3}{4}\theta; \quad \text{(A.16)}$$

$$\text{D: } CS^J + \sum_{k=a,b,c} \pi_k^J = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + 3\frac{(1+2c)^2}{16} \quad \text{(A.17)}$$

From (A.15), (A.16) and (A.17), we obtain the following threshold values for θ

$$FR \succ NR \text{ iff } \theta > \frac{5c(2-c)}{8} \equiv \theta_1^*;$$
$$FR \succ D \text{ iff } \theta < \frac{c(10+13c)}{8(1+2c)} \equiv \theta_2^*;$$
$$NR \succ D \text{ iff } \theta < \frac{c(5-7c)}{4(1-c)} \equiv \theta_3^*.$$

It can be easily verified that under Assumption 1, $\theta_2^* < \theta_1^* < \theta_3^*$ holds. Then, the optimal standards policy under international cooperation can be represented by Figure A.6; that is, NR is chosen for $0 \leq \theta < \theta_1^*$ and FR is chosen for $\theta_1^* \leq \theta$.

It can be verified that θ_1^* is smaller than θ_1^M. This means that for $\theta \in [\theta_1^M, \theta_2^M]$ the countries have an incentive to coordinate on FR even though there are multiple Nash equilibria in the policy game under MR.

Proof of Proposition 7

In light of Lemma A.4, Lemma A.3 is modified to the statement that the most cooperative equilibrium outcome is to choose NR for $0 \leq \theta < \theta_1^M$ and FR for $\theta_1^M \leq \theta$. By redefining θ_1^M by θ^{*M}, we obtain the statement of Proposition 7.

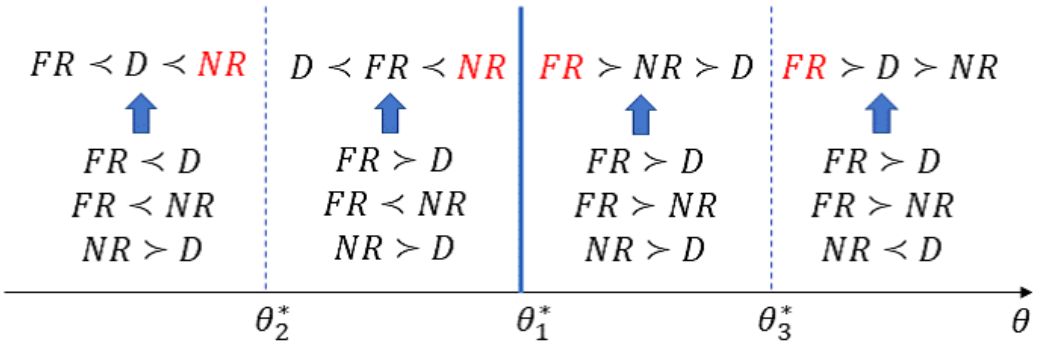

Figure A.6: Optimal standards in the cooperative solution

A.7 Comparison of welfare between bilateral and multilateral agreements

From Propositions 1, 2, 3, 6, and 7, we obtain the respective countries' equilibrium standards under bilateral and multilateral standards regimes depending on the value of θ, as shown in Figure 4. Tables 2 and 3 summarize the equilibrium standards $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ under NT and MR, respectively.

	Bilateral agreement	Multilateral agreement
(1N) $0 \le \theta < \underline{\theta}^U$	$(H,H,H;H,H,H;H,H,H)$	$(H,H,H;H,H,H;H,H,H)$
(2N) $\underline{\theta}^U \le \theta < \underline{\theta}$	$(H,H,H;H,H,H;L,L,H)$	$(H,H,H;H,H,H;H,H,H)$
(3N) $\underline{\theta} \le \theta < \theta^{*N}$	$(H,H,L;H,H,L;L,L,H)$	$(H,H,H;H,H,H;H,H,H)$
(4N) $\theta^{*N} \le \theta < \bar{\theta}^N$	$(H,H,L;H,H,L;L,L,H)$	$(L,L,L;L,L,L;L,L,L)$
(5N) $\bar{\theta}^N \le \theta < \bar{\theta}^U$	$(L,L,L;L,L,L;L,L,H)$	$(L,L,L;L,L,L;L,L,L)$
(6N) $\bar{\theta}^U \le \theta$	$(L,L,L;L,L,L;L,L,L)$	$(L,L,L;L,L,L;L,L,L)$

Table 2: Summary of the equilibrium standards $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ based on NT

	Bilateral agreement	Multilateral agreement
(1M) $0 \le \theta < \underline{\theta}^U$	$(H,H,H;H,H,H;H,H,H)$	$(H,H,H;H,H,H;H,H,H)$
(2M) $\underline{\theta}^U \le \theta < \underline{\theta}$	$(H,H,H;H,H,H;L,L,H)$	$(H,H,H;H,H,H;H,H,H)$
(3M) $\underline{\theta} \le \theta < \bar{\theta}^U$	$(H,H,L;H,H,L;L,L,H)$	$(H,H,H;H,H,H;H,H,H)$
(4M) $\bar{\theta}^U \le \theta < \bar{\theta}^M$	$(H,H,L;H,H,L;L,L,L)$	$(H,H,H;H,H,H;H,H,H)$
(5M) $\bar{\theta}^M \le \theta < \theta^{*M}$	$(L,L,L;L,L,L;L,L,L)$	$(H,H,H;H,H,H;H,H,H)$
(6M) $\theta^{*M} \le \theta$	$(L,L,L;L,L,L;L,L,L)$	$(L,L,L;L,L,L;L,L,L)$

Table 3: Summary of the equilibrium standards $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ based on MR

Let us begin with the comparison of each country's welfare under bilateral and multilateral agreements based on NT. We have already denoted country J's welfare under the bilateral agreement based on NT by SW_J^N, and let us denote its welfare under multilateral agreement by SW_J^{NM} J = A, B, C.

Case 1N ($0 \le \theta < \underline{\theta}^U$)

In this case, σ_k^J = H for k= a, b, c and J =A, B, C under all regimes, meaning that $SW_J^N = SW_J^{NM}$ for J = A, B, C. In other words, a shift from bilateral to the multilateral agreement has no effect on both member and nonmember countries' welfare.

Case 2N ($\underline{\boldsymbol{\theta}}^{\boldsymbol{U}} \leq \boldsymbol{\theta} < \underline{\boldsymbol{\theta}}$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ = (H, H, H; H, H, H; L, L, H) holds under the NT-based bilateral agreement. Since $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B\ ;\ c_a^C, c_b^C, c_c^C)$ = (0, 0, 0; 0, 0, 0; c, c, 0), and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B;\ \theta_a^C, \theta_b^C, \theta_c^C) =$ (θ, θ, θ; θ, θ, θ; 0, 0, θ) the respective countries' welfare can be represented as follows:

$$SW_J^N = \frac{13}{32} - \frac{3\theta}{4} + \frac{(1-2c)^2}{16}, J = A, B,$$

$$SW_C^N = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1+2c)^2}{16} + \frac{1}{8}.$$

Under the NT-based multilateral agreement, σ_k^J= H holds, which means c_k^J =0 and θ_k^J =θ for k = a, b, c and J = A, B, C. Each country's welfare is given by

$$SW_J^{NM} = \frac{15}{32} - \frac{3\theta}{4}, J = A, B, C$$

Therefore, we obtain the following results regarding the comparison of welfare:

$$SW_J^{NM} - SW_J^N = \frac{c(1-c)}{4} > 0, J = A, B$$

$$SW_C^{NM} - SW_C^N = \frac{-3c^2 + 4c\theta + c - 4\theta}{8}.$$

It can be verified that $SW_C^{NM} - SW_C^N$ is equal to 0 when $\theta = \underline{\theta}^U$ and monotonically decreasing in θ. Thus, $SW_C^{NM} - SW_C^N < 0$ for $\underline{\theta}^U \leq \theta < \underline{\theta}$.

Case 3N ($\underline{\boldsymbol{\theta}} \leq \boldsymbol{\theta} < \boldsymbol{\theta}^{*\boldsymbol{N}}$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ = (H, H, L; H, H, L; L, L, H) holds under the NT-based bilateral agreement. Because $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B\ ;\ c_a^C, c_b^C, c_c^C)$ = (0, 0, c; 0, 0, c; c, c, 0) and

$(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B;\ \theta_a^C, \theta_b^C, \theta_c^C)$= (θ, θ, 0; 0, θ, θ; 0, 0, θ), the respective countries' welfare can be represented as follows:

$$SW_J^N = \frac{(3-2c)^2}{32} - \theta\frac{1+c}{2} + \frac{(1+c)^2}{8} + \frac{(1-2c)^2}{16}, J = A, B,$$

$$SW_C^N = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1-3c)^2}{8} + \frac{(1+2c)^2}{16}.$$

As σ_k^J = H holds for k = a, b, c and J = A, B, C under the NT-based multilateral agreement, each country's welfare is given by SW_J^{NM} = $\frac{15}{32} - \frac{3\theta}{4}$, J = A, B, C. Therefore, it follows that

$$SW_J^{NM} - SW_J^N = \frac{c(6-13c) - 8\theta(1-2c)}{32}, J = A, B$$

$$SW_C^{NM} - SW_C^N = \frac{c(7-12c) - 4\theta(1-c)}{8}.$$

It can be verified that $SW_J^N - SW_J^{NM}$ is monotonically decreasing in θ, and $SW_J^N - SW_J^{NM}$ is positive if $\theta = \underline{\theta}$ but negative if $\theta = \theta^{*N}$, J = A, B. Thus, there exists a threshold value θ′ such that $SW_J^N - SW_J^{NM} = 0$. This threshold value is explicitly derived as θ′ = c (6 − 13c)/8(1 − 2c). As for the sign of $SW_C^N - SW_C^{NM}$ it can be verified that although the $SW_C^{NM} - SW_C^N$ is monotonically decreasing in θ, the sign of this expression is positive for all θ ∈ [$\underline{\theta}$, θ^{*N}].

Case 4N ($\boldsymbol{\theta^{*N} \le \theta < \overline{\theta}^N}$)

In this case, the expressions for the respective countries' welfare under the NT-based bilateral agreement are the same as those in Case 3N. However, under the multilateral agreement, σ_k^J = L holds, and thus c_k^J = c and θ_k^J = 0 for k = a, b, c and J = A, B, C. Each country's welfare is given by

$$SW_J^{NM} = \frac{15(1-c)^2}{32}, J = A, B, C.$$

Therefore, we obtain the following results regarding the comparison of welfare:

$$SW_J^{NM} - SW_J^N = \frac{8\theta(1+c) - (12-c)c}{16}, J = A, B$$

$$SW_C^{NM} - SW_C^N = \theta\frac{1+2c}{4} - \frac{c(2+33c)}{32}.$$

It can be verified that $SW_J^{NM} - SW_J^N$ is negative, J = A, B, while $SW_C^{NM} - SW_C^N$ is positive for all $\theta \in [\theta^{*N}, \overline{\theta}^N]$.

Case 5N ($\overline{\boldsymbol{\theta}}^{\boldsymbol{N}} \leq \boldsymbol{\theta} < \overline{\boldsymbol{\theta}}^{\boldsymbol{U}}$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$ = (L, L, L; L, L, L; L, L, H) holds under the NT-based bilateral agreement. This means that $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B; c_a^C, c_b^C, c_c^C)$ = (c, c, c; c, c, c; c, c, 0) and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B;\ \theta_a^C, \theta_b^C, \theta_c^C)$ = (0, 0, 0; 0, 0, 0; 0, 0, θ) and, thus, the respective countries' welfare can be represented as follows:

$$SW_J^N = \frac{13(1-c)^2}{32} + \frac{(1-2c)^2}{16}, J = A, B.$$

$$SW_C^N = \frac{(3-2c)^2}{32} - \theta\frac{1+2c}{4} + \frac{(1-c)^2}{8} + \frac{(1+2c)^2}{16}.$$

As σ_k^J = L holds for k = a, b, c and J = A, B, C under the NT-based multilateral agreement, each country's welfare is given by $SW_J^N = \frac{15(1-c)^2}{32}$, J = A, B, C. Therefore, it follows that

$$SW_J^{NM} - SW_J^N = \frac{(2-3c)c}{16} > 0, J = A, B$$

$$SW_C^{NM} - SW_C^N = \frac{8(1+2c)\theta - c(18+c)}{32}.$$

It can be verified that $SW_C^{NM} - SW_C^N$ is monotonically increasing in θ and equal to 0 if $\theta = \overline{\theta}^U$. Thus, the sign of $SW_C^{NM} - SW_C^N$ is negative for $\overline{\theta}^N \leq \theta < \overline{\theta}^U$.

Case 6N ($\overline{\boldsymbol{\theta}}^{\boldsymbol{U}} \leq \boldsymbol{\theta}$)

In this case, σ_k^J = L for k = a, b, c and J = A, B, C under all regimes, meaning that $SW_J^{NM} - SW_J^N$ for J= A, B, C.

We next consider the case of standards agreements based on MR. We have already denoted country J's welfare under the MR-based bilateral agreement by SW_J^M, and let us denote its welfare under multilateral agreement by SW_J^{MM}, J = A, B, C.

From Tables 2 and 3, we can easily verify that the outcomes under Cases (1M), (2M), (3M), and (6M) are the same as Cases (1N), (2N), (3N), and (6N), respectively. Therefore, we omit the analysis of welfare comparison for these cases.

Case 4M ($\overline{\boldsymbol{\theta}}^{\boldsymbol{U}} \leq \boldsymbol{\theta} < \overline{\boldsymbol{\theta}}^{\boldsymbol{M}}$)

In this case, $(\sigma_a^A, \sigma_b^A, \sigma_c^A; \sigma_a^B, \sigma_b^B, \sigma_c^B;\ \sigma_a^C, \sigma_b^C, \sigma_c^C)$=(H, H, L; H, H, L; L, L, L) holds under the MR-based bilateral agreement. This means that $(c_a^A, c_b^A, c_c^A; c_a^B, c_b^B, c_c^B; c_a^C, c_b^C, c_c^C)$ = (0, 0, c; 0, 0, c; c, c, c) and $(\theta_a^A, \theta_b^A, \theta_c^A; \theta_a^B, \theta_b^B, \theta_c^B;\ \theta_a^C, \theta_b^C, \theta_c^C)$ = (θ, θ, 0; θ, θ, 0; 0, 0, 0) and thus, it follows that

$$SW_J^M = \frac{(3-c)^2}{32} - \theta\frac{1+c}{2} + \frac{(1+c)^2}{8} + \frac{(1-c)^2}{16}, J = A, B.$$

$$SW_C^M = \frac{11(1-c)^2}{32} + \frac{(1-3c)^2}{8}.$$

Under the MR-based multilateral agreement, σ_k^J = H holds, which means c_k^J = 0 and θ_k^J = θ for k = a, b, c and J = A, B, C. Each country's welfare is thus given by SW_J^{MM} = $\frac{15}{32} - \frac{3\theta}{4}$, J = A, B, C. Therefore, we obtain the following results regarding the comparison of welfare:

$$SW_J^{MM} - SW_J^M = \frac{c(2-7c) - 8\theta(1-2c)}{32}, J = A, B$$

$$SW_C^{NM} - SW_C^N = \frac{(46-47c)c - 24\theta}{32}.$$

It can be verified that the signs of the above expressions are both negative for $\overline{\boldsymbol{\theta}}^{\boldsymbol{U}} \leq \boldsymbol{\theta} < \overline{\boldsymbol{\theta}}^{\boldsymbol{M}}$.

Case 5M ($\overline{\boldsymbol{\theta}}^{\boldsymbol{M}} \leq \boldsymbol{\theta} < \boldsymbol{\theta}^{*\boldsymbol{M}}$)

In this case, under the MR-based bilateral agreement, σ_k^J = L holds, which means c_k^J = c and θ_k^J = 0 for k = a, b, c and J = A, B, C, for k = a, b, c and J = A, B, C. Each country's welfare is

$$SW_J^M = \frac{15(1-c)^2}{32}, J = A, B, C$$

Under the MR-based multilateral agreement, σ_k^J = L holds, which means c_k^J = 0 and θ_k^J = θ for k = a, b, c and J = A, B, C. Each country's welfare is

$$SW_J^{MM} = \frac{3(5-8\theta)}{32}, J = A, B, C.$$

Thus, it follows that

$$SW_J^{MM} - SW_J^M = \frac{3[5(2-c)c-8\theta]}{32}.$$

It can be verified that the above equation is monotonically decreasing in θ and is negative if θ = $\overline{\theta}^M$. Thus, $SW_J^{MM} - SW_J^M < 0$ for $\overline{\theta}^M \leq \theta < \theta^{*M}$

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