International Agreements on Product Standards under Consumption Externalities: National Treatment versus Mutual Recognition*

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Abstract

This paper provides a comparative analysis of product standards agreements between heterogeneous countries. A simple model of vertical standards is developed where countries have heterogeneous preferences for a negative or positive consumption externality. I compare two major types of standards agreements, those based on national treatment (NT) and mutual recognition (MR). Unlike NT, MR can induce a mismatch of standards between countries, a problem that tends to get worse as country preferences diverge. Due to this mismatch problem, NT tends to become relatively more welfare-enhancing than MR for countries with more dissimilar preferences. These findings explain why the WTO, the TPP and the EU choose different types of standards agreements. The paper also sheds new light on the desirability of international harmonization of product standards.

Keywords: Product standards, Consumption externality, Country heterogeneity, Trade agreements, National treatment, Mutual recognition. *JEL Classifications*: F13, F18, O24.

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1 Introduction

Over the past six decades or so, significant tariff reductions worldwide have brought increased attention to various types of non-tariff barriers to international trade.[1] Particularly, much attention has been centered around product standards, which arise from products having to meet specific requirements in order to be authorized for sale in a given country. There are two important international institutional arrangements on product standards. One is national treatment (NT) which is adopted in the product standards agreements administered by the WTO and the TPP.[2] The other, called mutual recognition (MR), is most well-known for being enforced within the EU but also underlies many other bilateral agreements on product standards.[3]

In a nutshell, NT mandates that product standards imposed on foreign firms should be no stricter than those on domestic firms – i.e. NT is essentially a non-discrimination requirement. On the other hand, MR requires that a country's standards on foreign firms be the same as what those firms have to comply with in their home countries. By design NT and MR are not compatible with each other: a country under NT has full control over the standards applied in its market, while under MR standards on foreign firms are determined by their own countries. This salient distinction sparks several important questions: Why have the WTO, the TPP and the EU chosen different principles in their product standards agreements? Are these choices well-founded from a welfare perspective? More broadly, what are the determinants of the relative efficacy of alternative policy regimes on product standards?

Costinot (2008) attempts to approach these questions by developing a model of standards on products that can generate a negative consumption externality. He shows that the degree of the externality plays a key role in the welfare implications of NT and MR. In particular,

[1] As Baldwin (1970) vividly notes: "The lowering of tariffs has, in effect, been like draining a swamp. The lower water level has revealed all the snags and stumps of nontariff barriers that still have to be cleared away." For a most recent comprehensive discussion of non-tariff barriers, see Ederington and Ruta (2016).

[2] It is worth noting that the U.S. has pulled out of the TPP under the new Presidential administration, so the future of the trade agreement is uncertain at best.

[3] See the Council Resolution 85/C 136/01 by the EU on the new approach to technical harmonization and standardization. The document is available online at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31985Y0604(01). Other examples of MR-based standards agreements include those between the EU and countries such as Canada and Japan.

global welfare is higher under NT for large consumption externality but is higher under MR when such externality is small. The paper concludes that the WTO favors NT since its member countries tend to trade goods with high consumption externalities, whereas the EU members mostly trade goods with low externalities and thus prefer MR. While this is an important insight, there is limited empirical evidence about the levels of externalities embedded in the goods traded within these trade blocs. More importantly, Costinot (2008) considers identical countries, which does not reflect the substantial heterogeneity among the member states of the WTO. In fact, it has become less plausible to view the EU as being homogeneous. For example, the EU recently admitted Romania and Croatia which are noticeably less developed from the existing member states.

The goal of this paper is to approach the set of questions proposed above through the lens of country preference heterogeneity. To this end, I consider a model of product standards on goods that can cause either a negative or positive consumption externality. An example of negative consumption externality is pollution generated by the use of cars. On the other hand, consumption of pharmaceuticals treating contagious diseases generates a positive externality by making people around the patient less likely to be infected. The premise of my analysis is that countries may have heterogeneous preferences for such consumption externalities. This assumption is relevant empirically. For instance, in the case of negative consumption externality, the famous environmental Kuznets curve suggests that poor countries tend to attach less importance to the negative impacts of pollution relative to rich countries.[4] When the level of externality reflects product quality, the country heterogeneity I examine also reflects non-homothetic preferences such that consumers in countries with high per capita income prefer better quality products, a pattern that has received substantial empirical support from recent trade literature.[5]

Importantly, I show that as country preference heterogeneity increases, NT tends to perform *relatively* better than MR from the welfare point of view. The key intuition behind

[4] Although per capita income plays a key role in the environmental Kuznets curve, explicitly modeling it is beyond the scope of this paper. Instead, the country preference heterogeneity I model should be seen as a reduced-form representation of a consequence of varying per capita income levels across countries.

[5] See, for example, Hallak (2006), Feenstra and Romalis (2014) and Caron et al. (2015). Specifically, these and other empirical studies have identified per-capita income as an important factor determining the quality of goods a country imports and exports.

this finding is that MR mandates countries to accept each other's standards and therefore can give rise to a *mismatch of standards* between countries. Moreover, this mismatch problem tends to become worse as country preferences diverge. This finding suggests that the WTO and the TPP that feature a high degree of country heterogeneity should view NT as relatively more attractive than MR, whereas the EU with more homogeneous members should find greater appeal in MR. This prediction accords well with the observed choices made by these trade blocs between NT and MR, which also justifies their choices as being consistent with welfare considerations.[6] In this sense, my analysis provides a novel and empirically relevant explanation for why trade blocs with different levels of heterogeneity may favor different types of standards agreements. In a broader sense, this paper highlights the important role of country heterogeneity in the design of international trade agreements.

The paper also yields several other novel insights. First, it provides a demand-side explanation for why countries choose different levels of product standards. It is well-known that the EU enforces the strictest safety and environmental standards in the world, whereas such standards in least developed countries barely exist. My analysis suggests that country preference heterogeneity can be an important contributing factor to such variations in the stringency of national standards. Second, the paper offers a nuanced view on international harmonization of product standards, which is a pillar of the WTO's Agreement on Technical Barriers to Trade. The key message is that whether such harmonization is desirable depends on the interplay between the levels of country heterogeneity and consumption externality. Specifically, I show that for goods with sufficiently high or low levels of consumption externality, *harmonizing standards even across heterogeneous countries* is necessary for global optimality. Nevertheless, as country heterogeneity increases harmonization will be optimal for a diminishing range of externality, indicating that countries with more different preferences would find less (but still some) common ground in their choices of national standards. Furthermore, harmonization over all levels of externality is necessarily sub-optimal, because for moderate externalities differential standards that respect heterogeneous country prefer-

[6] Interestingly, my analysis also cautions against the prospect of the EU maintaining MR in the realm of product standards if it continues to admit less developed countries. The reason is simply that with higher country heterogeneity within the EU, the potential welfare cost of enforcing MR relative to NT can become increasingly large.

ences would be efficiency-enhancing.

Finally, I demonstrate that the central finding in Costinot (2008) can be altered under heterogeneous countries. As above-mentioned, Costinot (2008) establishes that NT (MR) induces higher global welfare for relatively high (low) consumption externality. I show that in a heterogeneous world the *reverse* of the pattern as in Costinot (2008) can arise: NT (MR) can dominate for relatively low (high) levels of externality. The intuition is that as externality reduces, countries with different preferences for the externality would lower their standards sequentially, so that the underuse (overuse) of the low standard under NT (MR) occurs *twice,* once for each country respectively. This may duplicate the region over which NT and MR dominates each other. It follows that MR could dominate NT for higher levels of externality. An important policy implication is that the degree of country heterogeneity should be taken into account if the implementation of NT and MR can be contingent on the magnitude of consumption externality.

To develop the above results, I consider two scenarios depending on the presence of strategic incentives. In the first scenario countries coordinate their product standards to maximize joint welfare, while in the second they non-cooperatively choose their standards to maximize each's own welfare. In both scenarios countries are subject to the constraint of either NT or MR. Studying the first scenario of constrained policy coordination is important for two reasons. First, by shutting down the effects of strategic interactions, I am able to identify the mismatch of product standards between countries that arises from the implementation of MR. Second, it allows me to establish the socially efficient outcome constrained by NT or MR, which is the benchmark for identifying the efficiency loss caused by strategic interactions between countries. To see this, note that the effects of strategic interactions can be pinned down by comparing the non-cooperative Nash equilibrium with the coordination outcome. Since the former is constrained by NT or MR, it is necessary to compare it with the efficient outcome that is also constrained by these two principles. That said, I also consider coordination under no constraints to study the implications of enforcing NT and MR.

To my best knowledge, this is the first study that emphasizes the linkages between country heterogeneity and the welfare performance of alternative institutional arrangements on product standards. The paper that is most related to my work is Costinot (2008) who com-

pares NT and MR given country symmetry. Edwards (2012) studies how country's strategic incentives for setting product standards may differ under NT and MR, although the paper also considers symmetric countries. Markusen (2017) examines how asymmetric country preferences may affect government's incentives for setting environmental standards. Similar to the current study, the paper analyzes both cooperative and non-cooperative policies, but the focus is not the institutional arrangements on environmental policy such as NT and MR.[7]

This paper also relates to the theoretical studies that examine the welfare implications of a particular type of product standards agreement. Battigalli and Maggi (2003) provide an incomplete contract explanation about why NT has been taken as a rigid rule in the WTO. More recently, Staiger and Sykes (2011) apply the terms-of-trade framework to analyze the effect of NT on the regulation of product standards. The paper shows that the terms-of-trade effect gives rise to incentives for large countries to impose discriminatory standards that are overly stringent on foreign firms. Moreover, prohibiting such discrimination through NT may still lead to inefficiently stringent standards under certain circumstances. Toulemonde (2013) provides a welfare analysis of MR under differential learning ability of consumers about foreign norms. The analysis identifies winners and losers (i.e. firms versus consumers) from the adoption of an MR agreement. The current paper differs from these studies by emphasizing how the welfare implications of different types of product standards agreements can hinge crucially on country preference heterogeneity.[8]

There also exists an established literature that examines the strategic incentives of countries in choosing the national product standards. For quality standards, Barrett (1994) analyzes and emphasizes the strategic use of environmental standards between countries whose firms compete on the world market. Boom (1995) examines the effect of asymmetric standards on market outcomes in a vertical differentiation model. Fischer and Serra (2000) study the incentives for a country to impose minimum standards when its own firm faces foreign competition in the home market. For compatibility standards, Gandal and Shy (2001) examine a country's decision to recognize foreign standards and characterize condi-

[7] There is also a small literature that examines NT in policy contexts other than product standards. Horn (2006) and Sara and Saggi (2008) study the welfare implications of NT. Geng and Saggi (2015) evaluate the case for implementing NT in the international protection of intellectual property.

[8] Other related studies include Bagwell and Staiger (2001) and Suwa-Eisenmann and Verdier (2002). For a comprehensive treatment of the effect of technical barriers to trade liberalization, see Baldwin (2000).

tions under which countries are willing to form a standards union. Klimenko (2009) models strategic interactions of national product standards in the context of technical compatibility. While my analysis also captures strategic incentives, it differs from the above studies by placing a clear-cut focus on both country heterogeneity and the institutional aspect of product standards.

The rest of the paper proceeds as follows. Section 2 describes the model. In Section 3, I compare NT and MR assuming countries can coordinate their policies on product standards, while in Section 4 I investigate how the comparative results may be altered when countries strategically choose their standards. Section 5 provides further discussions and Section 6 concludes. I collect all the proofs in the appendix.

2 Model

Consider a world of two countries: country A and B. Each country has one firm that sells a homogeneous good with two possible versions: H and L. Consumption of each unit of version L generates a *negative* externality of a magnitude $\theta > 0$, while such externality for version H is zero.[9] The unit costs of producing version H and L are denoted with $c > 0$ and zero respectively, so that production of version H is more costly.[10] One example of such negative consumption externality is pollution where H (L) can be considered as the clean (dirty) version of a good. For ease of exposition I will refer to the negative externality as pollution when necessary. Section 5 discusses how the analysis also applies to the case of positive consumption externality. Firms are assumed to share identical technologies and compete à la Cournot in both countries.[11]

A representative consumer in either country can buy at most one unit of the good.

[9] Normalizing θ to zero for version H is without loss of generality. The analysis will go through as long as version H generates a smaller negative externality than version L. The same is true for the treatment of the differential production costs of the two versions of the good.

[10] Following Costinot (2008) I assume the regularity condition that $c < 1/4$.

[11] Following previous studies I assume that markets are segmented, so that firms can charge prices independently across countries. This is helpful to isolating the effect of country heterogeneity by controlling for the potential impact of market structure. A notable observation is that the EU actually involves a more integrated market than the WTO. Exploring how differences in market structure may affect the performance of product standards agreement is an interesting topic for future research.

Consumer's utility in country i is given as:

$$U_i = \begin{cases} u - p_i - s_i\varphi_i & \text{if she buys either version} \\ -s_i\varphi_i & \text{if she buys nothing,} \end{cases} \qquad i = A, B \tag{1}$$

where u represents consumer's willingness to pay for the good, p_i is the market price, φ_i denotes the magnitude of pollution incurred by the country, and $s_i \in [0, 1]$ is a key parameter that represents the degree of heterogeneity in country preferences for pollution, and more generally consumption externality. In particular, φ_i is defined as:

$$\varphi_i = \theta_i q_{ii} + \theta_j q_{ji}, \quad i, j = A, B \tag{2}$$

where q_{ii} and q_{ji} represent quantities of the good sold by the domestic and the foreign firm, θ_i and θ_j can equal θ or zero depending on the version being sold. Thus, the amount of pollution generated in a country depends on the quantity as well as the version of the good being consumed in its market. Note that even if a consumer does not buy the good, she is still affected by the pollution caused by the consumption of the dirty version by other buyers.[12] As with previous literature I assume u is uniformly distributed over $[0, 1]$. The market price can then be written as:

$$p_i = 1 - (q_{ii} + q_{ji}). \tag{3}$$

Consumers in the two countries have heterogeneous preferences for pollution. Without loss of generality, it is assumed that:

$$s_A < s_B. \tag{4}$$

Condition (4) says that country A's consumer utility is *less* affected by pollution than that of country B. Thus one may consider country A as a developing economy that is more willing to sacrifice environmental conditions in exchange for industrialization, which in turn

[12]It is worth noting that the formulation of φ implies that the consumption externality is local in the sense that it only affects domestic consumers. Local externality is a useful benchmark that occurs widely in reality. For example, the environmental impacts of many goods such as automobile, pesticide and product package tend to be local. That said, we will discuss the case of global externality in Section 5.2.

may arise from its comparative advantage in pollution-intensive productions. Without loss of generality, I normalize s_B to 1 and denote s_A with s, so that a smaller s representing more heterogeneous country preferences.

Let σ denote a product standard stipulating the version of the good that can be legally sold. In particular σ can be H or L. I refer to $\sigma = H$ as a high or strict standard under which only the clean version can be produced and sold, and $\sigma = L$ as a low or lenient standard which permits the sales of the dirty version. Each country sets a standard on the domestic and the foreign firm respectively: let σ_{ij} be country i's standard on the firm from country j where $i, j = A, B$.[13] Countries are subject to the rule of NT or MR when setting their product standards.[14] Under NT countries have to treat every firm the same way so that $\sigma_{ii} = \sigma_{ij}$. On the other hand, given MR a country's standard on the foreign firm is aligned with what the firm follows in its home country so that $\sigma_{ij} = \sigma_{jj}$. As a useful observation, note that a product standard under NT applies to both firms selling in a given country, whereas it applies to a given firm selling in both countries under MR.

It is worth noting that under either policy regime, each country only needs to determine the standard for its own firm: σ_{ii}. Under NT this standard will automatically extend to the foreign firm, while under MR the host country's standard for the foreign firm is determined by its home country. To economize notations I simply denote country i's standard under both policy regimes as σ_i, and use (σ_i, σ_j) to represent a generic policy combination for the two countries. As a useful illustration, let $(\{\sigma_{AA}, \sigma_{AB}\}, \{\sigma_{BB}, \sigma_{BA}\})$ be a full-fledged policy combination with $\{\sigma_{AA}, \sigma_{AB}\}$ and $\{\sigma_{BB}, \sigma_{BA}\}$ denoting the standards in country A and B respectively. Then we have the following correspondences:

(i) $(H, H) = (\{H,\ H\}, \{H, H\})$ under both NT and MR,

(ii) $(L, L) = (\{L, L\}, \{L, L\})$ under both NT and MR,

(iii) $(H, L) = (\{H,\ H\}, \{L, L\})$ under NT and $(\{H,\ L\}, \{L, H\})$ under MR,

[13] In principle countries may allow firms to produce more than one version, but in that case firms would simply produce version L as the production cost is lower. Therefore, without loss of generality we simply assume the choice of standard to be a singleton.

[14] Focusing on NT and MR reflects the fact that the WTO member states, which account for around 85% of world countries and more than 95% of global trade, follow either NT or MR when setting their product standards. It is interesting to examine the case where countries choose their standards under no institutional constraint. While I consider this possibility under policy coordination between countries, the case of Nash equilibrium is rather complicated and is beyond the scope of this paper.

(iv) $(L, H) = (\{L,\ L\}, \{H, H\})$ under NT and $(\{L,\ H\}, \{H, L\})$ under MR.

Next, define country i's national welfare under policy regime r as:

$$w_i^r(\sigma_i, \sigma_j; \theta) = cs_i^r(\sigma_i, \sigma_j; \theta) + \pi_{ii}^r(\sigma_i, \sigma_j; \theta) \\ +\pi_{ij}^r(\sigma_i, \sigma_j; \theta), \quad i = A, B, \tag{5}$$

where $r = NT$ or MR, $cs_i(\cdot)$ is consumer surplus, $\pi_{ii}(\cdot)$ and $\pi_{ij}(\cdot)$ represent firm's domestic and foreign profits. Joint welfare equals the sum of each country's welfare:

$$ww^r(\sigma_i, \sigma_j; \theta) = w_i^r(\sigma_i, \sigma_j; \theta) + w_j^r(\sigma_i, \sigma_j; \theta). \tag{6}$$

I consider two scenarios depending on the presence of policy coordination between countries. In the first scenario, countries coordinate their product standards to maximize their joint welfare while being subject to NT or MR; in the second countries non-cooperatively choose their product standards to maximize each's own welfare. The interactions between countries and firms proceed as follows:

Stage 1: countries simultaneously choose their product standards, either cooperatively or non-cooperatively, subject to the NT or the MR constraint.

Stage 2: firms compete à la Cournot in both countries following the standards set in the first stage.

3 Coordination over product standards

3.1 Efficient product standards under NT and MR

I use backward induction to solve this game. I first analyze coordination over product standards between countries that follow NT or MR. The purpose of this analysis is two-fold. First, by eliminating strategic incentives I can focus on the welfare impacts of imposing NT and MR. This allows me to unveil a possible mismatch of product standards between countries that is induced by MR. This mismatch problem is the key reason why NT performs

relatively better than MR for countries with more divergent preferences. The second goal of this section is to establish the constrained efficient outcomes that will serve as the benchmark for studying the welfare implications of strategic interactions in the non-cooperative case. Since the Nash equilibrium to be studied is subject to NT or MR, it is necessary to compare it with the coordination outcome that is also constrained by NT or MR.[15]

Assume first that both countries follow NT which mandates equal treatment of firms regardless of country origin. Then countries maximize joint welfare as:

$$\max_{\sigma_i,\sigma_j\in\{H,L\}} ww^{NT}(\sigma_i,\sigma_j;\theta) \quad \text{s.t. } \sigma_i=\sigma_{ii}=\sigma_{ij} \quad i,j=A,B \tag{7}$$

Since each country can choose high (H) or low (L) standard, there are four possible policy combinations under NT: (H,H), (L,L), (H,L) and (L,H). As will be seen, the constrained efficient policy combination that maximizes joint welfare depends crucially on the magnitude of pollution θ.

As a useful starting point, it can be shown that:

$$ww^{NT}(L,H;\theta) > ww^{NT}(H,L;\theta) \text{ for all } \theta. \tag{8}$$

Importantly, Eq. (8) says that (H,L) is dominated by (L,H) for all levels of θ and therefore is never chosen. The intuition for this result is straightforward: given country A is more tolerant of pollution, it should not implement a stricter standard than country B from the efficiency point of view.[16] Now given sufficiently large θ, it is optimal to impose the strict standard in both countries to avoid high pollution. As θ declines it is jointly optimal to have country A first loosen its standard, simply because its consumer welfare is less affected by pollution. It can be shown that there exists a unique threshold θ_{cu}^{NT} such that:

$$ww^{NT}(L,H;\theta) > ww^{NT}(H,H;\theta) \text{ if and only if } \theta < \theta_{cu}^{NT}. \tag{9}$$

[15] Of course, it is obvious that when countries engage in policy coordination, the joint welfare they can achieve under *no* institutional constraint must be weakly higher than that under NT or MR. The goal of my analysis is therefore not to emphasize this straightforward point.

[16] While I have suppressed the details, raising the standards in either country increases local prices and reduces the intensive margin of trade. This is consistent with the empirical findings in Fontagné et al. (2015).

That is, for θ below θ_{cu}^{NT} country A should switch to the low standard while country A maintains the high standard. As θ further decreases it is optimal to also have country A lower its standard. One can find the unique threshold θ_{cl}^{NT} below which this is the case:

$$ww^{NT}(L, L; \theta) > ww^{NT}(L, H; \theta) \text{ if and only if } \theta < \theta_{cl}^{NT}. \tag{10}$$

Moreover, it can be verified that:

$$\theta_{cl}^{NT} < \theta_{cu}^{NT} \text{ if and only if } s < 1, \tag{11}$$

which implies that (L, H) must be the unique efficient policy combination for $\theta_{cl}^{NT} < \theta < \theta_{cu}^{NT}$.

Furthermore, to see how preference heterogeneity affects the efficient standards under NT, one may readily derive the following condition:

$$\frac{\partial(\theta_{cu}^{NT} - \theta_{cl}^{NT})}{\partial s} < 0.$$

Recall that $(\theta_{cl}^{NT}, \theta_{cu}^{NT})$ is the region over which (L, H) is efficient. Therefore, as preference asymmetry between countries increases (i.e. s falls), (L, H) will remain efficient over a larger range of pollution. I summarize the above findings in the following proposition:

Proposition 1. *Suppose countries coordinate their product standards under NT. Then efficient product standards are as follows:*

(i) when pollution is high, i.e. $\theta > \theta_{cu}^{NT}$, both countries choose the strict standard (H, H);

(ii) when pollution is low, i.e. $\theta < \theta_{cl}^{NT}$, both countries choose the lenient standard: (L, L);

(iii) when pollution is moderate, i.e. $\theta_{cl}^{NT} < \theta < \theta_{cu}^{NT}$, country *$A$ chooses the lenient standard while* country *B enforces the strict standard: (L, H);*

(iv) as preference heterogeneity increases between countries, there will be a greater range of pollution $[\theta_{cl}^{NT}, \theta_{cu}^{NT}]$ over which (L, H) is efficient.

Now let us establish the efficient standards under MR. Particularly, countries maximize

joint welfare subject to the MR constraint:

$$\max_{\sigma_i,\sigma_j\in\{H,L\}} ww^{MR}(\sigma_i,\sigma_j;\theta) \quad \text{s.t. } \sigma_i=\sigma_{ii}=\sigma_{ji} \quad i,j=A,B. \tag{12}$$

Essentially, the MR constraint ensures that each firm is subject to the same standard everywhere. As a result, there are four policy combinations that can arise under MR: (H,H), (L,L), (H,L) and (L,H). Note that despite the same notations, the latter two policy combinations represent policy profiles $(\{H,\ L\},\{L,H\})$ and $(\{L,\ H\},\{H,L\})$ which are different from those under NT, i.e. $(\{H,\ H\},\{L,L\})$ and $(\{L,\ L\},\{H,H\})$.

To begin with, it can be shown that the following condition holds:

$$ww^{MR}(L,H;\theta)=ww^{MR}(H,L;\theta) \text{ for all } \theta, \tag{13}$$

that is, when standards are asymmetric across countries under MR, world welfare remains unchanged regardless of the country that implements the high (or the low) standard. The reason is that in either case each country always has both versions sold, and since firms have identical cost functions it does not matter which of them produces version H (or L). Market prices and outputs remain the same in both cases, which leads to the same aggregate profits (i.e. the sum of firm's global profit) and consumer surplus. Without loss of generality, I just assume countries choose (L,H) over (H,L) since it is natural for country A to implement the low standard.

Next, one can show that it is efficient for both countries to enforce the strict standard if pollution is high. In particular, it can be established that there exists a threshold θ_{cu}^{MR} such that:

$$ww^{MR}(L,H;\theta)>ww^{MR}(H,H;\theta) \text{ if and only if } \theta<\theta_{cu}^{MR}. \tag{14}$$

Hence, both countries should choose the high standard for $\theta>\theta_{cu}^{MR}$ and country A should switch to the low standard for $\theta<\theta_{cu}^{MR}$. Similarly, one can find a second threshold θ_{cl}^{MR} such that:

$$ww^{MR}(L,L;\theta)>ww^{MR}(L,H;\theta) \text{ if and only if } \theta<\theta_{cl}^{MR}, \tag{15}$$

i.e. it is efficient for both countries to set the low standard when the level of pollution falls

below θ_{cl}^{MR}. Importantly, we have:

$$\theta_{cu}^{MR} < \theta_{cl}^{MR}. \tag{16}$$

The implications of Eq. (16) are illustrated in Figure 1. As can be seen from the figure, when $\theta_{cu}^{MR} < \theta < \theta_{cl}^{MR}$ we have (L, H) dominated by either (H, H) or (L, L). Moreover, when $\theta < \theta_{cu}^{MR}$ and $\theta > \theta_{cl}^{MR}$, Eqs. (14) and (15) together indicate that (L, H) remains dominated by either (L, L) or (H, H). It follows that (L, H) is never optimal under MR for all values of θ. This implies that only (H, H) and (L, L) can possibly be jointly optimal.

[Figure 1 here]

Now comparing (H, H) and (L, L), one can establish a new threshold θ_{cm} such that:

$$ww^{MR}(H, H; \theta) > ww^{MR}(L, L; \theta) \text{ if and only if } \theta > \theta_{cm}. \tag{17}$$

Moreover, it can be readily checked that:

$$\theta_{cu}^{MR} < \theta_{cm} < \theta_{cl}^{MR}. \tag{18}$$

Eqs. (17) and (18) together imply that countries always choose identical standards under MR to maximize joint welfare. In particular, they both enforce the high standard when pollution is higher than θ_{cm} and vice versa. The following proposition summarizes the above findings:

Proposition 2. *Under MR, efficient standards are symmetric regardless of country preference heterogeneity. Specifically,*

(i) when pollution is high, i.e. $\theta > \theta_{cm}$, both countries choose the strict standard (H, H);

(ii) when pollution is low, i.e. $\theta < \theta_{cm}$, both countries choose the lenient standard (L, L).

Importantly, Proposition 2 shows that under coordination countries would never choose asymmetric standards (L, H) when MR is implemented. The key intuition is the following. With country preference heterogeneity, (L, H) under MR induces a mismatch of product standards between countries. In particular, when it is efficient to enforce a lenient standard

only in country A, MR requires country B to also apply the same standard to country A's firm. This can reduce country B's welfare since its consumers are more averse to pollution. On the other hand, country A also needs to recognize and apply the high standard to country B's firm, which again is welfare-reducing since consumers in country A can tolerate higher pollution. Hence the mismatch of standards induced by MR is *mutual*. As a result, countries will avoid this mismatch problem by simply choosing symmetric standards for all levels of pollution. It is also important to note that the mismatch of standards does not occur under NT. The reason rests crucially in that each country under NT has full control over the standards enforced in its market.

3.2 Comparing NT and MR

It has been shown that the mismatch of standards between countries can occur under MR but not NT. It is then natural to ask when the mismatch problem would affect the efficiency implications of MR relative to NT. This question can be answered by comparing the coordination outcomes under NT and MR. Figure 2 illustrates the comparison. When pollution is high or low (i.e. $\theta > \theta_{cu}^{NT}$ or $\theta < \theta_{cl}^{NT}$), both policy regimes induce the same coordination outcome: (H, H) or (L, L). This implies that the mismatch problem under MR does not take its toll. Intuitively, when the externality is either significant or minor, both countries would like to avoid or exploit it regardless of policy regime. As a result efficient product standards under NT and MR coincide.

[Figure 2 here]

However, when there is moderate pollution (i.e. $\theta_{cl}^{NT} < \theta < \theta_{cu}^{NT}$), the two policy regimes yield different coordination outcomes: under NT countries enforce (L, H) while under MR either (H, H) or (L, L) is chosen. This implies that joint welfare is lower under MR since (H, H) and (L, L) are options available under NT but not chosen. It follows that the mismatch problem under MR gives rise to an efficiency loss relative to NT for intermediate levels of pollution. Intuitively, when the externality is moderate it is efficient to allocate product standards differentially across countries depending on their preferences. However this is not feasible under MR because countries have to recognize each other's standard even

if the standard is incompatible with their domestic needs. This forces countries to stick with symmetric standards (H, H) or (L, L). But this outcome will be less efficient than (L, H) under NT, which respects country preference heterogeneity and does not give rise to the mismatch problem.

We have shown that the range of pollution where NT yields higher joint welfare than MR expands as s falls, i.e. $\frac{d(\theta_{cu}^{NT}-\theta_{cl}^{NT})}{ds} < 0$ for $0 \leq s \leq 1$. Thus the mismatch of standards under MR tends to get worse as country preference heterogeneity rises. As will be seen, in the non-cooperative case this turns out to be the key driving force for NT to fare relatively better than MR between more heterogeneous countries. Proposition 3 summarizes the above findings:

Proposition 3. *Suppose countries coordinate their product standards to maximize joint welfare. Then:*

(i) the mismatch of standards induced by MR reduces efficiency relative to NT for intermediate levels of pollution: $\theta_{cl}^{NT} < \theta < \theta_{cu}^{NT}$. Otherwise both policy regimes yield identical joint welfare.

(ii) the range of pollution $[\theta_{cl}^{NT}, \theta_{cu}^{NT}]$ expands as s decreases, i.e. the mismatch problem under MR becomes more efficiency-reducing relative to NT with higher preference heterogeneity between countries.[17]

It can be seen that country preference heterogeneity is essential for the mismatch problem under MR to arise. If countries are symmetric (i.e. $s = 1$) then we have $\theta_{cu}^{NT} = \theta_{cl}^{NT} = \theta_{cm}$. That is, efficient standards under NT become symmetric for all θ and coincide with those under MR. It follows that NT and MR simply have identical efficiency implications. Intuitively, when countries are symmetric they would prefer the same standards so that mismatch of standards can never arise.

[17]Note that the reasoning is robust to how preference difference across countries is modeled. Suppose instead $s_A = 1$ and s_B rises above 1. Then it is straightforward to check that NT will dominate MR over a new range $[\widetilde{\theta}_l^{NT}, \widetilde{\theta}_u^{NT}]$. As s_B increases it can be shown that $\widetilde{\theta}_l^{NT}$ falls while $\widetilde{\theta}_u^{NT}$ remains unchanged. As a result, $[\widetilde{\theta}_l^{NT}, \widetilde{\theta}_u^{NT}]$ continues to expand so that NT would still dominate MR for a larger range of the pollution. This further implies that my results would remain valid if both s_A and s_B can vary. The intuition is that the performance of NT relative to MR depends on the degree of asymmetry in country preferences rather than the levels of these preferences.

Lemma 1. *Suppose countries are identical, i.e.* $s = 1$. *Then coordination under NT and MR yield the same efficient product standards and welfare, so that MR does not give rise to a mismatch of standards.*

Finally, it is useful to examine the socially efficient outcome that is attained under no institutional constraints. By comparing this unconstrained efficient outcome with the optimal standards under NT and MR, I can identify the potential impacts of imposing the constraint of NT or MR. The reasoning for the unconstrained case is similar as above: starting with (H, H) for high pollution, it is efficient to switch to the lenient standard first in country A and then in country B as pollution declines. Moreover, I show in the appendix that it is efficient for either country to switch to the lenient standard on *both* firms simultaneously. In other words, unconstrained efficient outcome entails non-discriminatory product standards that follow NT. This result is stated in the following proposition.

Proposition 4. *Under no institutional constraints, coordination induces product standards in each country that conform to NT.*

Importantly, Proposition 4 implies that the efficient standards under NT are in fact second-best in the sense that they are also efficient under no constraints. Moreover, this is true regardless of country heterogeneity. An important implication is that the NT constraint itself does not work against efficiency, and it is not even necessary to mandate NT under coordination as the principle aligns with the incentives countries have to maximize their joint welfare.

4 Non-cooperative product standards

4.1 Nash equilibrium

In this section, I derive non-cooperative Nash equilibrium where countries simultaneously and independently set their product standards to maximize each's own welfare. Let us first consider the equilibrium outcome under NT. To start with, it is worth noting that policy decisions under NT are *independent* across countries, that is, one country's optimal

policy does not rely on the policy decision of the other country.[18] This is because the non-discrimination constraint imposed by NT eliminates the profit-shifting incentives as in Brander and Spencer (1985): countries are not able to shift profits to the domestic firm via setting a higher standard on the foreign firm since doing so will violate NT. On the other hand, profit-shifting incentives are present under MR so that policy decisions are *interdependent* between countries. These features will be manifested in the following analysis.

It turns out that Nash equilibrium outcome also depends on the level of pollution θ. First, for large θ uniformly strict standard must be the unique Nash equilibrium. To see this, note that it is country A that always has a stronger incentive to loosen the standard as pollution reduces. Particularly, one can show there exists a unique threshold θ_u^{NT} above which country A adopts the high standard:

$$w_A^{NT}(L, H; \theta) < w_A^{NT}(H, H; \theta) \text{ if and only if } \theta > \theta_u^{NT}. \tag{19}$$

Moreover, country B would maintain the high standard whenever country A does so because it is less tolerant of the pollution. Therefore no country has an incentive to deviate to a lenient standard for $\theta > \theta_u^{NT}$, which verifies that (H, H) is the unique Nash equilibrium.

Next one can show that uniformly low standard is the unique Nash equilibrium if pollution is sufficiently low. Note that starting from (L, L) it is country B that is more willing to raise the standard as θ rises. This implies that there exists θ_l^{NT} such that country B would switch to the high standard when $\theta > \theta_l^{NT}$:

$$w_B^{NT}(L, H; \theta) > w_B^{NT}(L, L; \theta) \text{ if and only if } \theta > \theta_l^{NT}. \tag{20}$$

On the other hand, country B would adopt the lenient standard as long as $\theta < \theta_l^{NT}$. But whenever this is the case country A would also implement the lenient standard since it is less susceptible to pollution. Thus (L, L) must be the unique Nash equilibrium for $\theta < \theta_l^{NT}$.

[18] An implication is that maximizing national welfare is equivalent to maximizing the sum of consumer surplus and firm's domestic profit, since firm's foreign profit will be determined by the other country's standards.

Moreover, it can be shown that:

$$\theta_l^{NT} < \theta_u^{NT} \text{ if and only if } s < 1, \tag{21}$$

and one needs to solve for the equilibrium for $\theta_l^{NT} < \theta < \theta_u^{NT}$. But over this range neither (H, H) nor (L, L) can dominate (L, H). This leaves (H, L) and (L, H) as the only possible Nash equilibria. One can further rule out (H, L) as country A does not have incentives to implement a higher standard than country B. It follows that (L, H) must be the unique Nash equilibrium over $\theta_l^{NT} < \theta < \theta_u^{NT}$.

It is also straightforward to show the effect of country preference heterogeneity on the Nash equilibrium under NT:

$$\frac{\partial(\theta_u^{NT} - \theta_l^{NT})}{\partial s} < 0.$$

The above inequality says that as preference difference between countries increases (L, H) arises as the equilibrium outcome for a larger range of pollution. We can summarize the above results in the next proposition:

Proposition 5. *Nash equilibrium product standards under NT are as follows:*

(i) when pollution is high, i.e. $\theta > \theta_u^{NT}$*, both countries choose the strict standard:* (H, H)*;*

(ii) when pollution is low, i.e. $\theta < \theta_l^{NT}$*, both countries choose the lenient standard:* (L, L);

(iii) when pollution is moderate, i.e. $\theta_l^{NT} < \theta < \theta_u^{NT}$*, country A chooses the lenient standard while country B imposes the strict standard:* (L, H)*;*

(iv) as country preference heterogeneity increases, i.e. s falls, asymmetric equilibrium (L, H) *arises for a larger range of pollution.*

Several comments are worth making about Proposition 5. First, the proposition sheds useful light on international harmonization of product standards which has been widely discussed by policy makers but has received limited formal analysis. Importantly, part (i) and (ii) of the proposition indicate that harmonization can be achieved even between countries of heterogeneous preferences. Moreover, such harmonization is most likely to happen to those goods with extreme consumption externalities. This is an important message: it suggests

that there can always exist some common ground between two countries in harmonizing their standards so as to address extremely large or small externalities. That said, part (iv) suggests that such common ground may shrink as country preference heterogeneity rises. Another important implication of the proposition is that harmonization can occur even when countries do *not* engage in policy coordination. This is a notable result since for goods with extreme externalities there is often a greater need for countries to coordinate their produce standards. Proposition 5 indicates that when it is more valuable to pursue policy harmonization, countries may voluntarily do so even without coordination. Interestingly, this result resonates with that in Loeper (2011) who shows in a different context that local jurisdictions would unilaterally enforce harmonization when coordination externalities are large enough.

Proposition 5 is also empirically relevant. To my best knowledge, it is the first formal demand-side explanation for why some standards substantially vary across countries, while others are more uniform on a global scale. For example, in the case of moderate pollution, the EU is known to implement stringent emission standards on motor vehicles, while such standards are noticeably lower in developing countries such as China and India. In contrast, goods with significant negative consumption externalities such as bovine spongiform encephalopathy contaminated beef are banned in almost all countries. Moreover, part (iv) of the proposition suggests that asymmetric standards should be more common between more heterogeneous countries. For example, it is plausible that preference heterogeneity is higher between South Korea and Kenya than between South Korea and China. In the meantime, standards for goods such as water and agricultural products are high in both South Korea and China but are lacking in Kenya.

Let us now compare the Nash equilibrium with the coordination outcome under NT. It can be shown that:

$$\theta_l^{NT} < \theta_{cl}^{NT} \text{ and } \theta_u^{NT} < \theta_{cu}^{NT}. \tag{22}$$

Eq. (22) is important as it says that under NT, the thresholds of θ below which countries switch to the low standard are *lower* in Nash equilibrium than under coordination. This implies that under NT, strategic incentives make countries less willing to impose the low

standard as compared to the social optimum. The reason is that lowering the standard under NT generates a positive externality for the foreign country: since NT requires all firms to be treated equally, relaxing the standard for the domestic firm means the same lower standard has to apply to the foreign firm as well. This would increase the profit of the foreign firm by reducing its production cost.[19] Therefore, when acting non-cooperatively countries tend to *overuse* the high standard under NT. This finding is established in Costinot (2008) under identical countries; here I show that it continues to hold between countries with different preferences for consumption externality.

Eq. (22) also implies that Nash equilibrium is socially efficient for sufficiently high and low levels of externality (e.g. $\theta > \theta_{cu}^{NT}$ and $\theta < \theta_{l}^{NT}$). This is an especially interesting observation given that setting product standards unilaterally by one country creates a profit externality on its trading partners. The intuition behind is that when the externality is very high or very low, the incentives to avoid or exploit the externality dominate the strategic incentives so that individual and social interests are perfectly aligned.

Now consider Nash equilibrium under MR. By examining country A's incentives, one can solve for the unique threshold θ_u^{MR} above which both countries would choose the strict standard. Specifically, θ_u^{MR} must satisfy:

$$w_A^{MR}(H, H; \theta) > w_A^{MR}(L, H; \theta) \text{ if and only if } \theta > \theta_u^{MR}. \tag{23}$$

One can similarly show that there exists a threshold θ_l^M below which country B would switch to the lenient standard:

$$w_B^{MR}(L, L; \theta) > w_B^{MR}(L, H; \theta) \text{ if and only if } \theta < \theta_l^{MR}. \tag{24}$$

It follows that both countries would choose the lenient standard as θ falls below θ_l^{MR}. Furthermore, the following useful result can be established:

$$\theta_u^{MR} > \theta_l^{MR} \text{ if and only if } s < s_a^{MR}, \tag{25}$$

[19] To see this, note that country B's firm makes a profit of $(1-c)^2/9$ in country A under the high standard, whereas its profit rises to $1/9$ when country A switches to the low standard.

where $s_a^{MR} \in (0,1)$ is a threshold for s that depends on the production cost of the H version c. Eq. (25) indicates that θ_u^{MR} can be larger or smaller than θ_l^{MR} depending on country preference heterogeneity s. In particular, when preferences are alike across countries (e.g. $s_a^{MR} < s \leq 1$), we have $\theta_u^{MR} < \theta_l^{MR}$ which implies both (H,H) and (L,L) emerge as Nash equilibria over $\theta_u^{MR} < \theta < \theta_l^{MR}$. Costinot (2008) finds that multiple equilibria exist under MR given symmetric countries, i.e., $s = 1$. Here I show that multiple equilibria would arise provided country preferences are sufficiently similar.

Multiple equilibria arise under MR since the policy regime induces strategic dependence across countries: it can be shown that the choices of product standards are *complementary* between countries. To see this, let θ_{Al}^{MR} and θ_{Ah}^{MR} be the thresholds below which country A lowers the standard given the country B chooses the low and the high standard respectively. Then the following holds:

$$\theta_{Al}^{MR} > \theta_{Ah}^{MR},$$

which implies that country A is more likely to choose the low standard when country B implements the low standard. Similarly, it can be shown that country B is more likely to choose the high standard if country A does so. Strategic complementarity occurs under MR due to the existence of profit-shifting incentives. For example, when country B lowers the standard on its own firm, country A has the obligation to apply the same low standard to country B's firm. This gives country B's firm a cost advantage in both countries and raises its global profit at the expense of the firm from country A. To offset such a negative impact, country A is more willing to also lower the standard on its own firm.

As a novel finding, when countries have sufficiently different preferences (e.g. $s < s_a^{MR}$) unique equilibrium can be attained under MR. To see this, note that when $s < s_a^{MR}$ we have $\theta_l^{MR} < \theta_u^{MR}$. For $\theta_l^{MR} < \theta < \theta_u^{MR}$, both (H,H) and (L,L) can no longer sustain as an equilibrium because either country would have an incentive to unilaterally switch its standard. Moreover, one can also rule out (H,L) as a viable equilibrium for all θ as country A is more tolerant of pollution. It follows that (L,H) is the unique equilibrium over $\theta_l^{MR} < \theta < \theta_u^{MR}$. Intuitively, this occurs because strategic complementarity reduces as countries have more divergent preferences. For instance, when countries are sufficiently

different, the level of pollution below which country A switches to a low standard would be too high for country B to make a similar policy change.

To identify the effects of strategic interactions under MR one can compare the Nash equilibrium with the coordination outcome. The following can be shown to hold:

$$\theta_{cl}^{MR} < \theta_{l}^{MR} \text{ and } \theta_{cu}^{MR} < \theta_{u}^{MR}. \tag{26}$$

Eq. (26) says that under MR the thresholds of θ below which countries switch to the low standard are *higher* in Nash equilibrium than in coordination. It follows that strategic incentives under MR make countries more willing to impose the low standard as compared to the social optimality. This is because lowering the standard on the domestic firm generates a negative profit externality on its foreign competitor: MR ensures that the domestic firm enjoys a lower production cost than the foreign firm in both countries and this lowers the profit for the foreign firm. As a result, when countries act non-cooperatively under MR they tend to *underuse* the high standard.

Finally, given $\theta_{l}^{MR} < \theta_{u}^{MR}$ it is easy to check that:

$$\frac{\partial(\theta_{u}^{MR} - \theta_{l}^{MR})}{\partial s} < 0.$$

Hence as countries preference heterogeneity increases (L, H) would become a more prevalent equilibrium under MR. We summarize the above findings in the following proposition:

Proposition 6. *Nash equilibrium standards under MR are as follows:*

(i) when countries are of similar preferences, i.e. $s > s_a^{MR}$, both countries choose either (H, H) or (L, L).

(ii) when countries have sufficiently different preferences, i.e. $s < s_a^{MR}$,

(ii-a) for high pollution, i.e. $\theta > \theta_u^{MR}$, both countries choose the strict standard: (H, H);

(ii-b) for low pollution, i.e. $\theta < \theta_l^{MR}$, both countries choose the lenient standard: (L, L);

(ii-c) for moderate pollution, i.e. $\theta_l^{MR} < \theta < \theta_u^{MR}$, country A chooses the lenient standard while country B imposes the strict standard: (L, H);

(ii-d) as country preference heterogeneity increases, asymmetric equilibrium (L, H) arises for a larger range of pollution.

Before comparing the welfare outcomes under NT and MR, it is worth noting a useful property of the threshold s_a^{MR}. The property is needed for proving Proposition 7 below.

Lemma 2. *The threshold s_a^{MR} is decreasing in c. In particular, $s_a^{MR}(c = 0) = 1$.*

Lemma 2 says that the cost differential between the two versions of the good can affect the profit-shifting incentives under MR. A lower c represents a smaller cost differential between the clean and the dirty version, which weakens the profit-shifting incentives since the gains from loosening the standard decline. This reduces the degree of strategic complementarity and makes multiple equilibria less likely to occur. For the remainder of the analysis I focus on the range of s such that $s \in [0, s_a^{MR}(c = 1/4)] = [0, 0.73]$ which induces unique equilibrium under MR.

4.2 Welfare analysis

I now compare the welfare implications of the Nash equilibria under NT and MR. As will be shown, in the presence of strategic incentives NT does not always yield weakly higher joint welfare than MR and can indeed be dominated by MR for certain levels of pollution. Therefore, to evaluate the *overall* effectiveness of NT relative to MR one needs to take account of all possible levels of pollution. Below I propose a simple measure for this purpose.

Definition 1. *Let the effectiveness of NT relative to MR be defined as:*

$$r = \frac{m(D)}{m(E)}, \tag{27}$$

where $D = \{\theta | \theta$ for which NT yields strictly higher joint welfare$\}$, $E = \{\theta | \theta$ for which MR yields strictly higher joint welfare$\}$ and $m(\cdot)$ denotes the length of the range of θ.[20]

[20] As the proof of Proposition 7 shows, both D and E must be compact sets so that $m(D)$ and $m(E)$ are finite.

Thus the measure r reflects the *relative* range of pollution θ over which joint welfare is higher under NT than under MR. A greater value of r indicates that NT yields higher joint welfare for a larger proportion of θ over which the two policy regimes yield different coordination outcomes.[21] A practical interpretation is that as r increases, NT performs strictly better than MR for a larger share of the available goods and therefore should be considered relatively more effective.[22]

A presupposition for the definition of r is that different levels of pollution carry the same weight in evaluating the effectiveness of NT relative to MR. It is reasonable to expect higher levels of pollution to be given greater weights as they typically have larger impacts on social welfare. For tractability I have abstracted from this consideration. Nevertheless, as will be seen, NT tends to dominate MR for *large* values of pollution, and such dominance is strengthened as preference asymmetry increases between countries. Thus, if NT performs relatively better between more heterogeneous countries, a result that I will establish below, then our findings would in fact be reinforced if also accounting for the significance of pollution.

The following proposition summarizes the main findings about the welfare performance of NT relative to MR in Nash equilibrium:

Proposition 7: *When countries non-cooperatively set their product standards under NT and MR, the followings hold:*

(i) NT and MR yield the same joint welfare for high and low levels of pollution, i.e. $\theta > \theta_u^{MR}$ and $\theta < \theta_l^{NT}$.

(ii) for intermediate levels of pollution $\theta_l^{NT} < \theta < \theta_u^{MR}$, *the welfare comparison of NT and MR depends on preference heterogeneity* s.

(ii-a) for small s (i.e. $s < \frac{3}{5}$), *NT yields higher world welfare for relatively high levels of the externality, while MR dominates for relatively low levels of the externality.*

(ii-b) for large s (i.e. $\frac{3}{5} < s < 0.73$), *the pattern in (ii-a) holds for two consecutive intervals of* θ.

(iii) the effectiveness of NT relative to MR increases as country preference heterogeneity

[21] Therefore we exclude the range of θ where NT and MR are equivalent from the calculation of r.

[22] By definition r is based on the relative difference between $m(D)$ and $m(E)$. One could instead use the *absolute* difference such as $m(D) - m(E)$. Nevertheless, the measure r is more "conservative" because a rise in r implies $m(D) - m(E)$ must increase but the converse may not be true.

rises.

Part (i) of Proposition 7 says that for extreme levels of pollution NT and MR yield identical joint welfare even in the presence of strategic interactions. This again highlights the key role of the magnitude of consumption externality in that unusual externalities can make NT or MR completely irrelevant to country's choices of standards. Part (ii) of the proposition conveys two important messages. First, part *(ii-a)* indicates that while NT always weakly dominates MR under coordination, this is not the case with strategic interactions: NT may yield lower welfare than MR over certain ranges of the externality. As discussed before, this occurs because strategic incentives create an efficiency loss under NT by making countries overuse the high standard, which explains why NT tends to be dominated by MR for large values of the externality. On the other hand, MR is dominated by NT when the externality is small since countries overuse the lenient standard under MR. Costinot (2008) establishes this result under identical countries, while part $(ii\text{-}a)$ shows that the pattern continues to hold provided countries are sufficiently different in their preferences for consumption externality.

Second, part $(ii\text{-}b)$ of the proposition indicates that for relatively low heterogeneity in country preferences, the pattern found in Costinot (2008) may occur over multiple regions of θ. That is, with heterogeneous countries the pattern in Costinot (2008) can be a *local* rather than a *global* feature. The intuition behind the result is the following. When countries are identical as in Costinot (2008) they always choose identical standards. In particular, they switch to the low standard simultaneously as θ falls, making the underuse (overuse) of the low standard under NT (MR) arise once only. This leads to the unique region of θ where NT and MR dominates each other. However, when countries are heterogeneous they would lower standards sequentially as θ declines. This implies that the underuse (overuse) of the low standard would arise twice, once for each country respectively. This would create two regions of θ where the pattern as in Costinot (2008) holds. Why does this feature disappear when country heterogeneity becomes sufficiently high? To see the answer recall that MR also induces a mismatch of standards between countries, and this gives rise to a large welfare loss under MR relative to NT for high preference heterogeneity between countries. As a result MR dominates NT only when the externality is small enough. Importantly, part $(ii\text{-}b)$ of the

proposition implies that one needs to take account of the degree of country heterogeneity when applying NT and MR based on the level of externality.

Part (*iii*) of the proposition indicates that NT would be considered as relatively more appealing than MR between more heterogeneous countries. As with the case of coordination, the key driving force for this result is the possible mismatch of standards induced by MR. However, unlike coordination the mismatch problem in the non-cooperative case can actually take place when (L, H) arises as the Nash equilibrium (e.g. part (*ii-d*) of Proposition 6). Intuitively, when coordination is absent each country does not take into account the externality of its product standards on the foreign country. Moreover, as country preference heterogeneity increases the range $\theta_l^{MR} < \theta < \theta_u^{MR}$ where (L, H) is the equilibrium outcome enlarges, implying that the mismatch of standards becomes more prevalent. This lowers the possibility of MR dominating NT and makes the latter relatively more effective.

Last but not least, combining the findings above, we see that the WTO and the TPP would be more likely to favor NT over MR as opposed to the EU regardless of policy coordination between member states. My analysis thus provides a robust insight about why trade blocs with different levels of country heterogeneity may make different choices between NT and MR as the foundations of their product standards agreement.[23]

5 Further discussion

5.1 Goods with positive consumption externality

It is important to note that the above analysis also holds under positive consumption externality. One example of goods with positive consumption externality is pharmaceutical products: medications such as vaccines not only protect the person who is inoculated but also lower the probability of people nearby being infected by certain diseases. In practice, pharmaceutical products are also subject to extensive technical standards and therefore can

[23]It is worth noting that our comparison is based on the assumption that the WTO and the EU have the same number of countries. Given that the WTO involves more countries, it should be subject to a larger effect of strategic interaction. But such effects will apply to both NT and MR and will work to cancel out one another when r is calculated. Also note that this is not a concern under coordination because strategic interaction is completely ruled out.

be appropriately studied in our framework.

Consumer utility under positive consumption externality can be written as follows:

$$U_i' = \begin{cases} u - p_i + s_i\varphi_i & \text{if she buys either version} \\ s_i\varphi_i & \text{if she buys nothing,} \end{cases} \qquad i = S, N \tag{28}$$

The key is to note that U_i' is obtained through a *renormalization* of the negative externality in U_i from Eq. (1). To capture country preference heterogeneity one can assume that $s_A < s_B$, that is, country B values positive consumption externality more. It can be shown that the foregoing analysis remains intact under this alternative specification. The welfare implications of NT and MR also remain unchanged. This can be seen by noting that: first, the mismatch problem induced by MR still exists under positive consumption externality. Hence the key mechanism that gives NT an edge over MR continues to be at work. Second, the nature of the profit externality due to strategic interactions does not alter, and this leads to analogous conclusions about equilibrium outcomes and welfare in the non-cooperative scenario.

5.2 Global externality

Consumption externality can also transmit beyond national borders and become global. In this section I investigate the welfare implications of NT and MR under coordination with global consumption externality. Recall that the mismatch of standards induced by MR is the key driving force that gives NT an edge with local externality. Therefore the goal of this section is to examine whether this essential mechanism is altered in the presence of global externality. To this end, I assume that the pollution incurred by a country is caused by both domestic and foreign consumptions, so that consumer utility in country i is modified as follows:

$$U_i = \begin{cases} u - p_i - s_i(\varphi_i + \delta\varphi_j) & \text{if she buys either version} \\ -s_i(\varphi_i + \delta\varphi_j) & \text{if she buys nothing,} \end{cases} \tag{29}$$

where δ measures the impact of the pollution on domestic consumers arising from foreign consumption. I assume that $\delta < 1$, i.e. pollution from the foreign country has a smaller

effect on domestic consumer utility as compared to local pollution. This is reasonable as pollution typically dies down with distance. Given the specification in (29), one can apply similar reasoning as before to solve for various thresholds of θ and characterize the optimal standards under the two types of policy regimes. In particular, starting with uniformly strict standards across countries, one can find $\theta_u^{NT\prime}$ under NT such that country A switches to the lenient standard for $\theta < \theta_u^{NT\prime}$, and $\theta_l^{NT\prime}$ such that country B also does so for $\theta < \theta_l^{NT\prime}$. Moreover, it can be shown that:

$$\theta_u^{NT\prime} > \theta_l^{NT\prime} \text{ if and only if } \delta < 1. \tag{30}$$

Hence for $\theta_l^{NT\prime} < \theta < \theta_u^{NT\prime}$ the differential standards (L, H) are optimal under NT. Along similar lines, we can find $\theta_u^{MR\prime}$ and $\theta_l^{MR\prime}$ under MR such that (H, H) dominates (L, H) for $\theta > \theta_u^{M\prime}$ and (L, L) dominates (L, H) for $\theta < \theta_l^{MR\prime}$. Moreover, it can be checked that:

$$\theta_l^{MR\prime} > \theta_u^{MR\prime}. \tag{31}$$

As with the case of local externality, condition (31) says that the differential standards (L, H) are never optimal under MR. This leaves (H, H) and (L, L) as the only possible candidate policy options. One can further show that there exists θ'_{cm} such that (H, H) and (L, L) are optimal for $\theta > \theta'_{cm}$ and $\theta < \theta'_{cm}$ respectively. Therefore, global consumption externality does not qualitatively change the pattern of constrained efficient standards. It follows that the key driving force remains unchanged given global externality: the mismatch of standards continues to exist under MR and the incentive for avoiding this problem leads countries to use symmetric standards. Moreover, it is easy to check that for fixed δ, the range of θ in which NT strictly dominates MR (i.e. $(\theta_u^{NT\prime} - \theta_l^{NT\prime})$) expands as s falls, indicating that the mismatch becomes more prevalent as preference heterogeneity rises between countries.

6 Conclusion

In this paper, I show that country heterogeneity has important implications for the desirability of alternative types of product standards agreements. I focus on a highly empirically

relevant dimension of country difference which is associated with consumer preferences for consumption externality. In particular, such consumption externalities can be either negative or positive. In this sense, the paper is more general than just studying environmental standards where the consumption externality is negative and is interpreted as pollution. Also, the simple approach of modeling heterogeneous country preferences for consumption externality should be useful for other studies of product standards where country asymmetry is of interest.

The paper is the first to formally demonstrate that MR can induce a mismatch of standards that is welfare-reducing. Due to this mismatch problem, NT becomes relatively more preferable to MR from a welfare point of view as countries exhibit more divergent preferences. These findings provide a novel account for the observed choices of standards agreement made by various trade blocs such as the WTO, the TPP and the EU. Moreover, the analysis sheds new light on the desirability of international harmonization of product standards which is a pillar of the WTO's product standards agreement. Finally, I show that when countries are asymmetric, the welfare implications of NT and MR in relation to the levels of externality can be different from that under identical countries.

While the paper generates interesting new insights, it abstracts from several important considerations. For example, I only consider vertical standards and do not examine the case of horizontal (compatibility) standards. The reason is that it is less intuitive to interpret heterogeneity in country preferences under compatibility standards where consumption externality is typically modeled as a network benefit. Second, to keep the reasoning sharp I assume away conversion cost, the saving of which is a major advantage of MR. Nevertheless, this does not qualitatively change the effects of country preference heterogeneity as long as the conversion cost does not increase rapidly with country preference heterogeneity. Finally, I have focused exclusively on product standards in the paper. It would be interesting to incorporate tariff and intellectual property protection and study the welfare implications of alternative standards agreements when countries can use more than one policy instrument.

7 Appendix

Expressions for the thresholds of θ and s.

Thresholds for θ				
NT	$\theta_u^{NT} = \frac{c(2-c)}{2s}$	$\theta_l^{NT} = \frac{c(2-c)}{2}$	$\theta_{cu}^{NT} = \frac{2c(2-c)}{3s}$	$\theta_{cl}^{NT} = \frac{2c(2-c)}{3}$
MR	$\theta_u^{MR} = \frac{c(20-3c)}{6s(1+c)}$	$\theta_l^{MR} = \frac{c(20-17c)}{6(1-c)}$	$\theta_{cu}^{MR} = \frac{c(8+3c)}{3(1+s)(1+c)}$	$\theta_{cl}^{MR} = \frac{c(8-11c)}{3(1+s)(1-c)}$
Others	$\theta_{cm} = \frac{4c(2-c)}{3(1+s)}$		$\theta_{cn} = \frac{7c^2}{3(1-s+c+sc)}$	
Thresholds for s	$s_a^M = \frac{20-23c+3c^2}{20+3c-17c^2}$		$s_b^M = \frac{3(2-c)(1-c)}{20-17c}$	

Proof of Proposition 4.

The key of the proof is to show that it is never socially optimal to discriminate between firms. To this end, we will need to write the full-fledged policy profile for each country. First, I prove that it is not optimal to apply discriminatory standards in country A. Let us define θ_{c1}^D such that:

$$ww(\{L,H\},\{H,H\};\theta) > ww(\{H,H\},\{H,H\};\theta) \text{ if and only if } \theta < \theta_{c1}^D, \tag{A1}$$

where $\theta_{c1}^D = \frac{c(8+3c)}{6s(1+c)}$. Similarly, we can find θ_{c2}^D such that:

$$ww(\{L,L\},\{H,H\};\theta) > ww(\{L,H\},\{H,H\};\theta) \text{ if and only if } \theta < \theta_{c2}^D, \tag{A2}$$

with $\theta_{c2}^D = \frac{c(8-11c)}{6s(1-c)}$. It can be shown that:

$$\theta_{c1}^D - \theta_{c2}^D < 0. \tag{A3}$$

Therefore, for all θ such that it is optimal to choose the discriminatory policy profile $(\{L,H\},\{H,H\})$ over $(\{H,H\},\{H,H\})$, the NT profile $(\{L,L\},\{H,H\})$ would actually yield high world welfare than $(\{L,H\},\{H,H\})$. Hence social optimality requires country A to never discriminate against the foreign firm.

Now examine the case for country B. We can analogously find θ_{c3}^D that makes the following condition hold:

$$ww(\{L,L\},\{L,H\};\theta) > ww(\{L,L\},\{L,L\};\theta) \text{ if and only if } \theta > \theta_{c3}^D, \tag{A4}$$

where $\theta_{c3}^D = \frac{c(8-11c)}{6(1-c)}$. Also we may calculate θ_{c4}^D such that:

$$ww(\{L,L\},\{H,H\};\theta) > ww(\{L,L\},\{L,H\};\theta) \text{ if and only if } \theta > \theta_{c4}^D, \tag{A5}$$

where $\theta_{c4}^D = \frac{c(8+3c)}{6(1+c)}$. It is straightforward to check that:

$$\theta_{c3}^D - \theta_{c4}^D > 0. \tag{A6}$$

Hence whenever the discriminatory policy profile $(\{L,L\},\{L,H\})$ dominates $(\{L,L\},\{L,L\})$, it must also be dominated by the NT profile $(\{L,L\},\{H,H\})$. This implies that discrimination from country B is not socially optimal either. This completes the proof.

Proof of Proposition 7.

Proof. The proof uses the four thresholds derived in the preceding analysis: θ_u^N, θ_l^N under NT and θ_u^M, θ_l^M under MR. First, it is easy to check that $\theta_u^N < \theta_u^M$, i.e. country A is more likely to choose the low standard under MR than under NT because (i) part of the pollution is borne by country B; (ii) profit is shifted to the domestic firm. Similarly, we have $\theta_l^N < \theta_l^M$ which implies country B is also more willing to lower the standard under MR for the same reason. Next, it can be show that there exists a unique threshold s_b^M such that $\theta_u^N > \theta_l^M$ if and only if $s < s_b^M$. Moreover it is straightforward to check that:

$$s_b^M - s_a^M < 0.$$

Therefore we have two subcases to examine: $s \leq s_b^M$ and $s_b^M < s \leq s_a^M$.

Case 1.1. $s < s_b^M$.

Given $s < s_b^M$ the ordering of the thresholds is $\theta_l^N < \theta_l^M < \theta_u^N < \theta_u^M$. The equilibrium policies under the two types of agreements are depicted in Figure 3.

[Figure 3 here]

First note that for $\theta < \theta_l^N$ and $\theta > \theta_u^M$, NT and MR lead to the same policy profiles, i.e. (L,L) and (H,H) and are equally efficient. For $\theta_l^N < \theta < \theta_l^M$, NT induces (L,H) while the equilibrium under MR is (L,L). Recall that (L,H) dominates (L,L) if $\theta > \theta_{cl}^N$. Moreover, it can be shown that $\theta_l^N < \theta_{cl}^N < \theta_l^M$, implying that MR prevails over $\theta_l^N < \theta < \theta_{cl}^N$ while NT is favored over $\theta_{cl}^N < \theta < \theta_l^M$. Next consider $\theta_l^M < \theta < \theta_u^N$ where the equilibrium under MR changes to (L,H). We can then find θ_{cn} such that:

$$ww^N(L,H;\theta) > ww^M(L,H;\theta) \text{ if and only if } \theta > \theta_{cn}. \tag{A7}$$

Hence (L,H) under NT dominates (L,H) under MR if $\theta > \theta_{cn}$.[24] Then we need to compare θ_{cn} and θ_l^M. Some simple algebra shows that:

$$\theta_{cn} < \theta_l^M, \tag{A8}$$

which implies that welfare is always higher under NT for $\theta_l^M < \theta < \theta_u^N$. Finally consider the range $\theta_u^N < \theta < \theta_u^M$, where the externality is relatively high so that the equilibrium under

[24] The reason underlying the tradeoff between (L,H) under the two agreements is the following. The outcome (L,H) under NT can be more efficient because the lenient standard is exclusively applied in country A. On the other hand, (L,H) under MR can dominate as it induces more intense competition in both countries. When θ is small the gain from enhanced competition dominates so that (L,H) under MR yields higher world welfare. On the other hand, welfare is higher for (L,H) under NT when θ is large because it prevents the lenient standard from being used in country B.

NT is uniform high standards. I have shown that (H,H) is preferred to (L,H) if $\theta > \theta_{cu}^M$. Moreover, it is easy to check that $\theta_{cu}^M < \theta_u^N$ if and only if $s < s_c^M$ where s_c^M is some threshold for s. But this must be the case because it can be verified that $s_c^M > s_b^M$, so whenever $s < s_b^M$ we must have $s < s_c^M$. Hence for all $\theta_u^N < \theta < \theta_u^M$ NT would yield higher welfare than MR.

Thus we have shown that over $s < s_b^M$, NT is more efficient for large values of the externality ($\theta_{cl}^N < \theta < \theta_u^M$) but is dominated by MR when the externality is small ($\theta_l^N < \theta < \theta_{cl}^N$). To compare the two agreements as asymmetry varies, note that by definition 1 we may write r in this case as:

$$r_2 = \frac{\theta_u^M - \theta_{cl}^N}{\theta_{cl}^N - \theta_l^N}.$$

Direct calculation shows that:

$$\frac{\partial r_2}{\partial s} < 0. \tag{A9}$$

Equation (A9) implies that as countries become more asymmetric (i.e. s lowers), NT would become more desirable by yielding strictly higher world welfare for a larger proportion of the externality. Next I examine the case when $s_b^M < s \leq s_a^M (c = 1/4)$.

Case 1.2. $s_b^M < s \leq s_a^M$.

In this case we have $\theta_l^N < \theta_u^N < \theta_l^M < \theta_u^M$. Again, for $\theta > \theta_u^M$ and $\theta < \theta_l^N$ NT and MR induce identical equilibrium outcome and are indistinguishable from the efficiency point of view. Now consider $\theta_l^N < \theta < \theta_u^N$. We already know from Case 1.1 that MR dominates NT over $\theta_l^N < \theta < \theta_{cl}^N$. Also it can be shown that $\theta_{cl}^N < \theta_u^N$ if and only if $s < \frac{3}{4}$. This must be the case given we are considering $s \leq s_a^M (c = 1/4) \approx 0.73$. Hence for $\theta_{cl}^N < \theta < \theta_u^N$ welfare is higher under NT. Next for $\theta_u^N < \theta < \theta_l^M$, we need to compare (H,H) under NT with (L,L) under MR. Recall $ww(H,H;\theta) > ww(L,L;\theta)$ if $\theta > \theta_{cm}$. Note that we must have $\theta_{cm} < \theta_l^M$ because of (18) and (26). Moreover, comparing θ_{cm} with θ_u^N we know:

$$\theta_{cm} < \theta_u^N \text{ if and only if } s < \frac{3}{5}. \tag{A10}$$

It can be checked that $s_b^M < \frac{3}{5}$. Hence if $s_b^M < s \leq \frac{3}{5}$ then NT dominates over $\theta_u^N < \theta < \theta_l^M$; if instead $\frac{3}{5} < s < s_a^M$, then MR performs better over $\theta_u^N < \theta < \theta_{cm}$ while NT dominates over $\theta_{cm} < \theta < \theta_l^M$. Figure 4 and 5 illustrate these two cases.

[Figure 4 and 5 here]

Finally consider $\theta_l^M < \theta < \theta_u^M$, in which we compare (H,H) under NT with (L,H) under MR. We already know $ww^M(H,H;\theta) > ww^M(L,H;\theta)$ if $\theta > \theta_{cu}^M$. Moreover, we can check that $\theta_{cu}^M < \theta_l^M$. Hence NT dominates MR for all $\theta_l^M < \theta < \theta_u^M$.

Depending on s, we can calculate r in the following ways:

$$r_3 = \frac{\theta_u^M - \theta_{cl}^N}{\theta_{cl}^N - \theta_l^N} \text{ if } s_b^M < s \leq \frac{3}{5}, \tag{A11}$$

$$r_4 = \frac{\theta_u^M - \theta_{cm} + \theta_u^N - \theta_{cl}^N}{\theta_{cm} - \theta_u^N + \theta_{cl}^N - \theta_l^N} \text{ if } \frac{3}{5} < s \leq s_a^M. \tag{A12}$$

As by definition $r_3 = r_2$, we know immediately:

$$\frac{\partial r_3}{\partial s} < 0.$$

Moreover, some algebra indicates that:

$$\frac{\partial r_4}{\partial s} < 0.$$

Thus for all $s_b^M < s \leq s_a^M$, NT becomes relatively more effective as countries possess more heterogeneous preferences.

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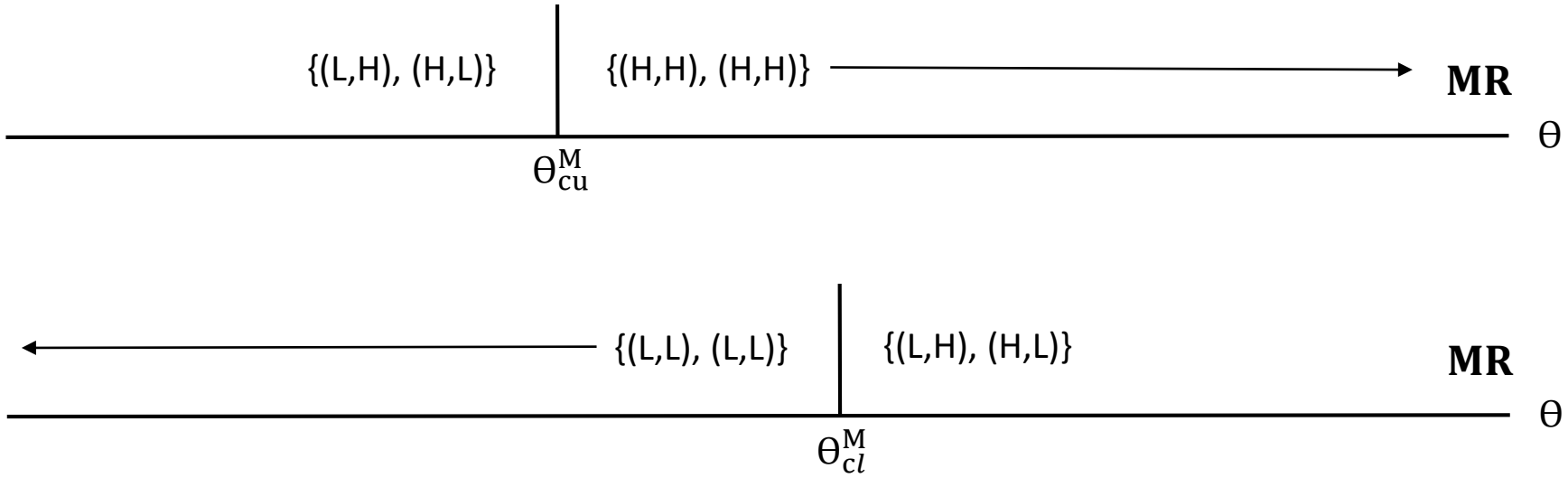

Figure 1: Optimal product standards under MR with policy coordination

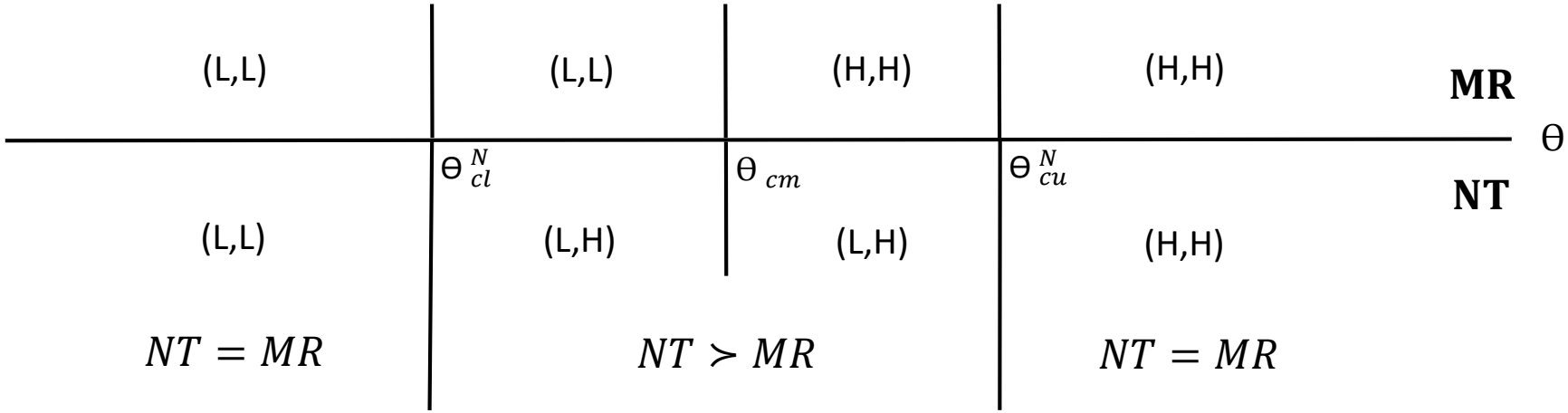

Figure 2: Optimal product standards and world welfare with policy coordination

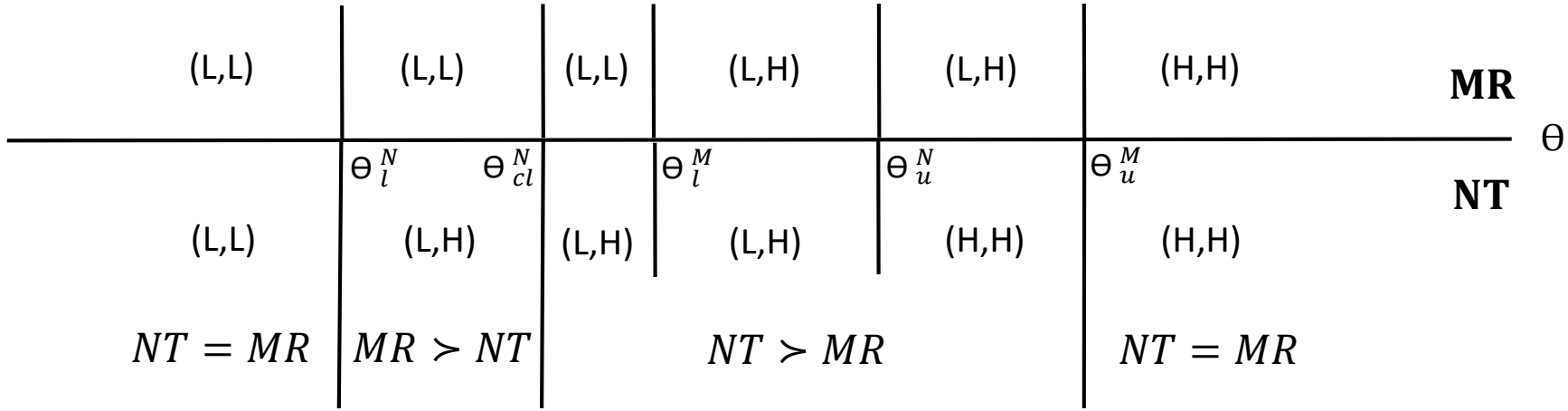

Figure 3: Product standards and world welfare in Nash equilibrium (Case 1.1)

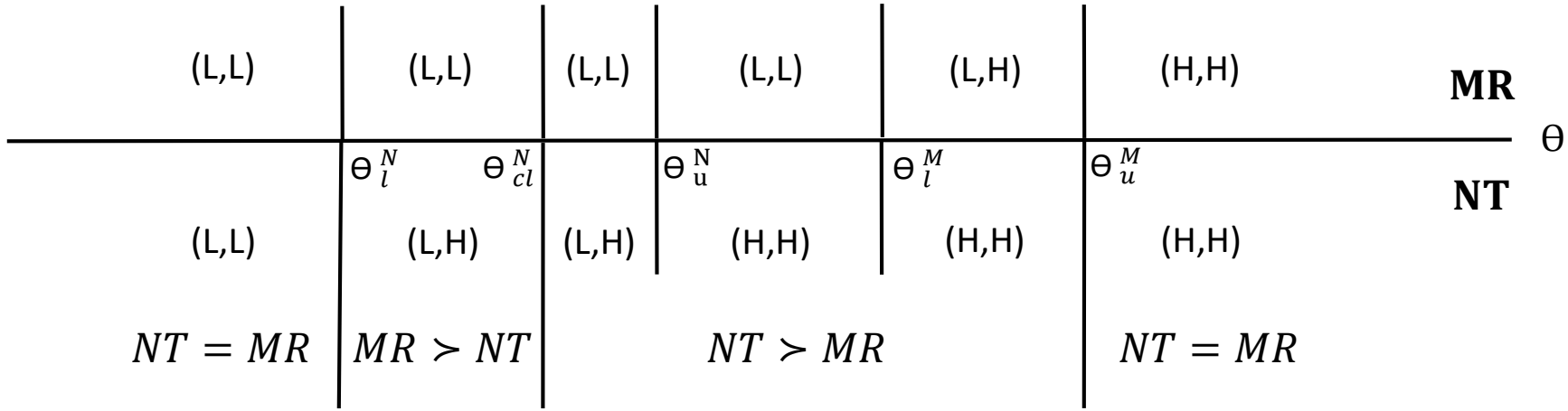

Figure 4: Product standards and world welfare in Nash equilibrium
(Case 1.2 with s_b^M<s< $\frac{3}{5}$)

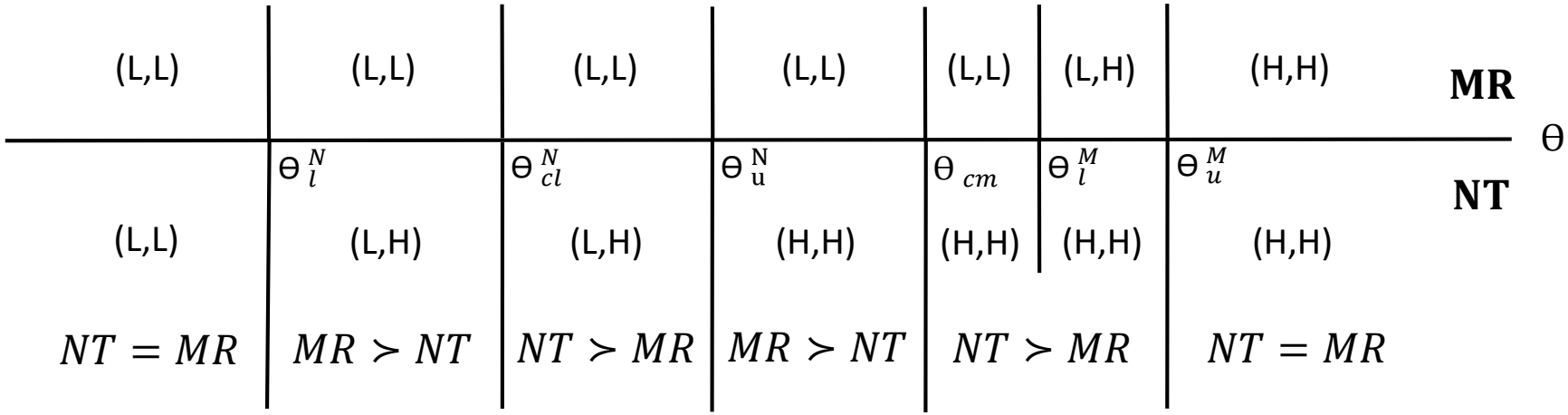

Figure 5: Product standards and world welfare in Nash equilibrium

(Case 1.2 with $\frac{3}{5}$<s<0.73)