Tariffs, Product Standards, and National Treatment at the WTO

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Abstract

This paper develops an oligopolistic model with consumption externalities to study (i) the policy interaction between tariffs and product standards; (ii) how such interaction may affect the welfare justification of national treatment (NT) in product standards. Absent NT, tariff reductions can lead to more discriminatory standards against foreign firms. Imposing NT eliminates discrimination but can induce higher tariffs which tend to undermine efficiency. As a result, the welfare justification of NT is stronger when tariffs are constrained. These findings suggest that the WTO's success in tariff liberalization can strengthen the case for its NT-based approach to product standards.

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1 Introduction

Over the past several decades, the World Trade Organization (WTO) and numerous free trade agreements (FTAs) have succeeded in significantly lowering global tariff barriers. Meanwhile, these agreements often leave much room for the use of behind-the-border measures, raising the concern that countries may manipulate their internal measures to offset the impact of tariff reductions (Copeland and Taylor, 2004; Ederington and Ruta, 2016). This concern is especially salient in the case of product standards. For instance, a number of empirical studies find that countries can subject foreign firms to stricter regulatory standards as their tariff barriers decline (e.g. Orefice, 2017; Herghelegiu, 2018; Beverelli et al., 2019; Niu et al., 2020).[1] While the documented policy substitution may serve legitimate purposes such as protecting public safety, it can also be protectionist. As a result, tariff liberalization can make product standards unjustifiably discriminatory against foreign firms.[2]

To combat unjustifiably discriminatory product standards, the WTO and various FTAs adopt national treatment (NT) as one of their core institutional arrangements.[3] In short, NT is a non-discrimination rule requiring that countries treat foreigners no worse than their own nationals.[4] The welfare impact of NT in product standards has been

[1] Earlier papers obtaining similar findings include Ray (1981), Gawande (1999), Eliste and Fredriksson (2002), Ederington and Minier (2003) and Kee et al. (2009). Some empirical studies also examine how product standards may affect trade flows. See for example Chen and Mattoo (2008) and Fontagné et al. (2015).

[2] Tariff liberalization is also associated with certain trade disputes over potentially discriminatory product standards. For instance, China raised a concern to the WTO in 2003 about the European Union (EU) restricting its import of Chinese natural honey, which was found to contain a toxic antibiotic called chloramphenicol. This dispute occurred just one year before Poland and Slovenia's accession to the EU which would reduce their tariffs on Chinese honey from 89% and 45% to 17.3% (Orefice, 2017). Such anecdotal observations might not imply causality, but they can echo the concern that tariff liberalization could engender greater discrimination in product standards.

[3] For instance, NT is the core principle of all the trade agreements administered by the WTO, including the Agreement on the Application of Sanitary and Phytosanitary Measures and the Agreement on Technical Barriers to Trade, both of which cover product standards. NT was also adopted by major FTAs such as the Southern Common Market, the Central American/Dominican Republic FTA and the recently signed United States–Mexico–Canada Agreement.

[4] As one practical example, Article 2.1 of the Agreement on Technical Barriers to Trade under the WTO states that "in respect of their technical regulations, products imported from the territory of any Member be accorded treatment no less favourable than that accorded to like products of national origin and to like products originating in any other country."

examined by previous studies which mostly assume standards as the only instrument available to governments. However, countries in practice often have access to a variety of policy measures, so that following NT in standards can affect their incentives for setting other measures such as tariffs provided the use of those measures is unconstrained.[5] This is a relevant scenario given the interdependence between product standards and tariffs as documented by empirical research. Hence, evaluating the welfare impact of NT in product standards entails taking into account the adjustment of related policy instruments.

This paper aims to address two main interrelated questions implied by the foregoing discussion. One is the positive question concerning the policy interaction between a country's import tariffs and product standards. Despite extensive empirical research on this topic, related conceptual work remains scarce. Specifically, existing models of product standards predominantly assume zero or exogenous tariffs, and thus do not study the interdependence between the two policy instruments. The other is the normative question about how the interaction between tariffs and standards may shape the implications of NT in product standards. In particular, we study how tariff liberalization (i.e. constraining tariffs) may affect the welfare justification of NT. This question is important because both tariff liberalization and NT are institutional pillars of the WTO, but the welfare linkage between them remains understudied.

To address these questions, we introduce endogenous tariffs into an open-economy oligopolistic model of quality standards as in Costinot (2008). Firms from different countries sell a homogeneous good across markets. The good comes with two versions: a low quality version whose consumption generates a negative externality and a high quality version with zero externality but requiring a compliance cost to produce. Countries set product standards which stipulate the version of the good each firm can sell.[6] Examples

[5] Despite significant reductions in global trade policy barriers, countries today still preserve a certain degree of freedom in their use of border measures such as import tariffs. For example, the WTO members commit to certain tariff bounds rather than exact tariff levels: for some countries such bounds can be as high as 40%.

[6] The discrete formulation of product version and standards is not essential and can be extended to be continuous. As will be shown, countries in our model switch from the low to the high standard as the externality becomes sufficiently large. If continuity is assumed, optimal standards would become a continuously increasing function of the level of the externality provided regularity assumptions are

of such type of standards include sanitary and phytosanitary measures as well as emission standards on vehicles. We first analyze the case where only one policy measure (i.e. standards or tariffs) is endogenous and examine how its level may vary with exogenous changes in the other measure. This enables us to characterize the two-way policy interaction between tariffs and standards. We then allow countries to endogenously set both policy measures in order to examine how the welfare performance of NT may be affected if its implementation can cause tariffs to adjust. In particular, the welfare performance of NT is defined as world welfare under NT relative to that under the unconstrained product standard regime (UC) where NT is absent.

While our model yields a rich set of results, there are three main findings to highlight. First, we show that there can exist mutual policy substitution between a country's tariffs and standards. On one hand, tariff reductions induce countries to raise their standards on imports while lowering that on domestic firms, leading to more discriminatory standards against foreign firms. On the other hand, as a country's standards become less discriminatory against the foreign firm, its import tariff tends to increase. Intuitively, the policy substitution arises because tariffs and product standards in our model serve two common purposes: the strategic purpose of shifting profits and the legitimate purpose of containing negative consumption externalities. As one policy instrument is relaxed for foreign firms, both purposes induce countries to tighten the other towards imports. This finding is important as it provides a theoretical characterization consistent with the ample evidence that tariffs and non-tariff measures (NTMs) are substitutes. Moreover, it suggests that tariff reductions, by increasing countries' incentives for discrimination, make NT a more necessary rule for achieving the objective of non-discriminatory regulation (Staiger and Sykes, 2011).[7]

Second, we show that having access to the tariff instrument does not eliminate countries' incentives for implementing discriminatory standards. Costinot (2008) shows that countries under free trade can choose discriminatory standards against foreign firms

imposed on the production cost function. This would not affect the fundamental channels we identify in the discrete framework.

[7]Note that this does not mean that tariff liberalization also makes NT more "justified" on welfare grounds. But our third main finding confirms that NT will indeed have better welfare performance when tariffs are constrained than when they are not.

absent NT. We show that even when countries can endogenously set both tariffs and standards, discrimination in standards will arise in equilibrium absent NT. Underlying this result is the fact that tariffs in our model are less effective than product standards in addressing high levels of consumption externalities. In particular, the working of tariffs implies that they can only help reduce externalities indirectly by lowering quantities of imports. When imported goods generate significant externalities, prohibitively high tariffs would be needed but this can stifle imports and cause large welfare costs. By contrast, the compliance cost in Costinot (2008) and our model does not rise without bounds as the levels of externalities increase.[8] This makes product standards less costly for curbing large externalities relative to tariffs. As a result, countries prefer to maintain some degree of discriminatory standards even when they can employ the tariff instrument.

Third and most importantly, tariff liberalization enhances the welfare justification of NT in product standards. The intuition for this result follows naturally from the above two findings. Particularly, although NT eliminates discriminatory standards, it can induce countries to raise their import tariffs due to the policy substitution effect. The upward tariff adjustment tends to reduce efficiency given that tariffs are more costly than product standards for combatting large consumption externalities. As a result, the welfare justification of NT is weaker if countries following NT are able to fall back on the tariff instrument. This insight is important as it reveals a potential implication of tariff liberalization the literature has not emphasized — it not only generates welfare gains per se but can also improve the welfare performance of NT in product standards. Our analysis thus uncovers a positive welfare linkage between tariff liberalization and NT in product standards which are two central pillars of the WTO as well as many existing FTAs. More broadly, our paper provides an illustration of the well-discussed proposition that it can be welfare-improving to constrain substitution from more to less effective policy instruments due to the implementation of certain institutional constraints (e.g. NT).

This paper contributes to the theoretical literature that analyzes the policy linkage between tariffs and regulatory standards (Bagwell and Staiger, 2001; Ederington, 2001;

[8]Both papers assume a constant compliance cost for simplicity. But the results will go through provided the compliance cost has a sufficiently low upper-bound.

Staiger and Sykes, 2011; Grossman et al., 2021; Mei, 2021; Kawabata and Takarada, 2021; Rebeyrol, 2022). Most of these studies consider exogenous tariffs. One exception is Staiger and Sykes (2011) who solve for Nash tariffs and analyze the policy interdependence between tariffs, consumption taxes and regulatory measures. But they consider a competitive market where terms-of-trade manipulation drives strategic policy setting. By contrast, we consider an oligopolistic market where the key strategic motive for policy use is profit-shifting. As Head and Spencer (2017) note, analyzing trade policy under oligopolistic markets is important because many markets for the goods traded internationally are highly concentrated.[9]

This paper also relates to a large literature on strategic product standards in oligopostic markets (e.g. Barrett, 1994; Boom, 1995; Fischer and Serra, 2000; Gandal and Shy, 2001; Klimenko, 2009). Some papers from this literature pay particular attention to the welfare effect of NT (e.g. Costinot, 2008; Gulati and Roy, 2008; Edwards, 2012; Ferrara et al. 2019; Geng, 2019).[10] These studies however abstract from the role of tariff policy. Our paper contributes to this literature by explicitly modeling endogenous tariff barriers, which allows us to identify tariff adjustment as a novel channel that can shape the welfare implications of NT. In this way, our analysis is able to reveal a positive welfare link between tariff liberalization and NT as two central pillars of the WTO.

Finally, this paper contributes to the studies that examine the effect of tariff barriers on the implications of NT in alternative NTMs. Horn (2006) analyzes NT in corporate taxation and shows that it can be useful for blunting the protectionist use of taxation induced by tariff reductions. Geng and Saggi (2015, 2022) examine NT in intellectual property protection and demonstrate how its welfare grounds may hinge on the levels of tariff barriers. Our paper complements this literature by focusing on product standards as an increasingly more important form of NTMs. A robust insight yielded by these studies including ours is that tariff liberalization can enhance the welfare justification of NT in NTMs.

[9]Kawabata and Takarada (2021) also study endogenous tariffs and standards in an oligopolistic market. But their focus is multilateral harmonization over product standards which is different from ours.

[10]Ferrara et al. (2019) study NT in taxation rather than standards as the measure for addressing negative consumption externalities, although their findings similarly apply to the case of standards.

The paper is structured as follows. Section 2 describes the model set-up. Section 3 characterizes how exogenous tariff changes may affect the incentives for countries to set their standards. Section 4 investigates the effect of exogenous changes in standards on nationally and globally optimal tariffs. Section 5 studies equilibrium outcome and welfare when both policy measures are endogenously determined. Particularly, it examines how tariff liberalization may shape the welfare implications of NT. Section 6 provides further discussions and section 7 concludes.

2 Set-up

Consider a world consisting of two countries: i and j.[11] Each country has one firm that produces a homogeneous good. Consumption of each unit of the good may cause a negative externality (e.g. pollution) of which the level is denoted with $\theta \geq 0$. The good has two versions: H and L. The levels of consumption externality associated with H and L are 0 and θ respectively. Hence H and L can be considered as the high and the low quality versions of the good. Firms have identical production technologies. The unit production costs of H and L are $c > 0$ and 0 so that H is more costly to produce. The parameter c can thus be interpreted as a variable compliance cost. For simplicity, our benchmark model abstracts from fixed compliance costs, the implications of which will be discussed in section 6.1.

Each consumer buys at most one unit of the good regardless of its version. Individual consumer surplus in country k is given as

$$U_k = \begin{cases} u - p_k - \varphi_k & \text{if she buys either version} \\ -\varphi_k & \text{if she buys nothing} \end{cases} \qquad k = i, j \tag{1}$$

where u represents consumer's willingness to pay for the good, p_k is the market price, φ_k denotes the aggregate consumption externality incurred by the country. In particular, φ_k can be written as

$$\varphi_k = \theta_{kk} q_{kk} + \theta_{\widetilde{kk}} q_{\widetilde{kk}}, \qquad k = i, j \tag{2}$$

[11] Assuming there are two countries is without loss of generality. As will be seen, there is no strategic interdependence in the policy decisions between countries. It follows that our main results readily carry over in a n-country model.

where $\widetilde{k}$ means not k; q_{kk} and $q_{\widetilde{k}k}$ represent the sales of firms k and $\widetilde{k}$ in country k; θ_{kk} and $\theta_{\widetilde{k}k}$ equal 0 or θ depending on the versions of the good sold by firm k and $\widetilde{k}$.

Following the literature, we assume u is uniformly distributed over $[0,1]$.[12] It follows that consumers in each country can be partitioned into two groups depending on their willingness to pay. Those in the range of $(p_k, 1]$ buy one unit of the good whereas those in $[0, p_k]$ do not make a purchase. Country k's market price can then be derived as

$$p_k = 1 - (q_{kk} + q_{\widetilde{k}k}) \tag{3}$$

Moreover, country k's aggregate consumer surplus is given by

$$cs_k = \int_{p_k}^{1} (u - p_k) du - \varphi_k$$

Firm k maximizes its global profit π_k which equals the sum of its profit in each country

$$\pi_k = \pi_{kk} + \pi_{k\widetilde{k}}$$

where π_{kk} and $\pi_{k\widetilde{k}}$ are firm k's domestic and foreign profits. Firms engage in Cournot competition in both countries and markets are segmented so that each firm's profits across countries are independent of each other. This implies that π_{kk} and $\pi_{k\widetilde{k}}$ depend on the policy choices of country k and $\widetilde{k}$ respectively.

Each country has two policy instruments available: a specific import tariff and a set of product standards. Denote country k's tariff with $t_k \geq 0$, and its tariff revenue is given by

$$TR_k = t_k q_{\widetilde{k}k}$$

Let σ be the product standard stipulating the version of the good that can be legally sold on a market. Countries can choose either a high standard (H) that mandates the supply of version H, or a low standard (L) that permits version L to be sold.[13] Denote country k's profile of standards with $\boldsymbol{\sigma}_k \equiv (\sigma_{kk}, \sigma_{k\widetilde{k}})$, where σ_{kk} and $\sigma_{k\widetilde{k}}$ represent its

[12] The demand structure originates from Mussa and Rosen (1978).

[13] It is easy to check that firms necessarily produce version L under the low standard as doing so always yields higher profits than producing version H.

standards on the domestic and the foreign firms respectively. It follows that firm k's domestic and foreign profits can be calculated as:

$$\pi_{kk} = (p_k - I(\sigma_{kk} = H)c)q_{kk},$$

$$\pi_{k\widetilde{k}} = (p_{\widetilde{k}} - t_{\widetilde{k}} - I(\sigma_{\widetilde{k}k} = H)c)q_{k\widetilde{k}}$$

where $I(\cdot)$ is an indicator function which equals one if the firm is subject to the high standard and zero otherwise.

Country k's national welfare is defined as the sum of its consumer surplus, firm's global profit and tariff revenue:

$$w_k(t_k, t_{\widetilde{k}}, \boldsymbol{\sigma}_k, \boldsymbol{\sigma}_{\widetilde{k}}) = cs_k(t_k, \boldsymbol{\sigma}_k) + \pi_k(t_k, t_{\widetilde{k}}, \boldsymbol{\sigma}_k, \boldsymbol{\sigma}_{\widetilde{k}}) + TR_k(t_k, \boldsymbol{\sigma}_k) \tag{4}$$

Note that country k's consumer surplus and tariff revenue depend only on its own policies t_k and $\boldsymbol{\sigma}_k$. Moreover, country k's policies affect all the components of its welfare w_k except firm k's foreign profit $\pi_{k\widetilde{k}}$, which depends on country $\widetilde{k}$'s policy choices. Hence it is convenient to define country k's welfare that is determined by its own policies as

$$\widehat{w}_k(t_k, \boldsymbol{\sigma}_k) = cs_k(t_k, \boldsymbol{\sigma}_k) + \pi_{kk}(t_k, \boldsymbol{\sigma}_k) + TR_k(t_k, \boldsymbol{\sigma}_k) \tag{5}$$

which simply excludes firm k's foreign profit. As a result, maximizing w_k or $\widehat{w}_k$ is equivalent from country k's point of view. Hence we can focus on $\widehat{w}_k$ when studying country k's optimal policies.

World welfare is defined as the sum of each country's welfare:

$$ww(t_i, t_j, \boldsymbol{\sigma}_i, \boldsymbol{\sigma}_j) \equiv w_i(t_i, t_j, \boldsymbol{\sigma}_i, \boldsymbol{\sigma}_j) + w_j(t_i, t_j, \boldsymbol{\sigma}_i, \boldsymbol{\sigma}_j) \tag{6}$$

Again, it is useful to decompose ww into two parts, each of which is affected by one country's policies only. In particular, we can write

$$ww \equiv \widehat{ww}_i(t_i, \boldsymbol{\sigma}_i) + \widehat{ww}_j(t_j, \boldsymbol{\sigma}_j)$$

where

$$\widehat{ww}_k(t_k, \boldsymbol{\sigma}_k) = \widehat{w}_k(t_k, \boldsymbol{\sigma}_k) + \pi_{\widetilde{k}k}(t_k, \boldsymbol{\sigma}_k) \quad k = i, j \tag{7}$$

is the component of world welfare affected by country k's policy choices. In particular, $\widehat{ww}_k$ equals $\widehat{w}_k$ plus the foreign firm's profit earned in country k, $\pi_{\widetilde{k}k}$. By country symmetry we have $ww = 2\widehat{ww}_k$, so it is sufficient to focus on $\widehat{ww}_i$ or $\widehat{ww}_j$ to evaluate world welfare.

We compare two product standard regimes depending on the presence of NT. One is UC where countries are free to choose their standards on domestic and foreign firms. It follows that each country can choose from four sets of standards: (H, H), (L, L), (L, H) and (H, L). The other regime is NT where each country has to treat the foreign firm no worse than its own. This rules out (L, H) which discriminates against foreign firms by subjecting them to a higher standard, leaving countries with three options: (H, H), (L, L) and (H, L).

Throughout the analysis, we assume the game proceeds in two stages. In the first stage, countries set one or both of their policy measures.[14] In the second stage, firms choose their sales in the two markets, and trade and consumption occur. When countries set both measures, we assume that they choose standards first. This allows us to study how the changes in standards induced by NT may affect countries' choices of tariffs. To examine the role of tariff barriers, we consider two scenarios depending on the presence of tariff policy coordination between countries. One is the scenario where countries noncooperatively choose their tariffs to maximize their national welfare. The other is tariff liberalization where countries coordinate to reduce their tariff barriers on each other. We solve this game by backward induction.

[14] Since there is no policy interaction between countries, our results would remain unchanged whether countries move simultaneously or sequentially.

3 Endogenous standards and exogenous tariffs

3.1 Market outcome

We start by characterizing how tariff changes may affect the incentives for countries to choose product standards. To this end, we focus on UC and assume that tariffs are exogenous and uniform across all levels of θ.[15] Given country k's tariff and standards, it is easy to calculate the sales of firms in the country: $q_{kk}(t_k, \boldsymbol{\sigma}_k)$ and $q_{\widetilde{kk}}(t_k, \boldsymbol{\sigma}_k)$. We present the calculation results in appendix A. It can then be checked that

$$\frac{\partial q_{kk}}{\partial t_k} > 0 \text{ and } \frac{\partial q_{\widetilde{kk}}}{\partial t_k} < 0$$

which indicates that regardless of a country's standards, a tariff reduces the country's import while increasing the output of the domestic firm. This implies that tariffs can be used to shift profits from foreign to domestic firms, which is a well-known insight from the strategic trade literature. To facilitate the analysis, it is also useful to calculate country k's "prohibitive" tariff $t_k^p(\boldsymbol{\sigma}_k)$ that reduces its import to zero. Comparing the prohibitive tariffs under different sets of standards yields the following useful lemma:

Lemma 1: Each country's prohibitive tariffs are ranked as: $t_k^p(L,H) < t_k^p(H,H) < t_k^p(L,L) < t_k^p(H,L)$.

The intuition for Lemma 1 is clear: a lower prohibitive tariff implies a tougher market from the exporting firm's view. As expected, a country's lowest prohibitive tariff occurs under (L,H) when its standards discriminate against the foreign firm. Similarly, a country's prohibitive tariff is highest under (H,L) which discriminates against the domestic firm. Also note that firms are treated equally under (H,H) and (L,L), but the former set of standards induces a lower prohibitive tariff as it mandates the supply of the high quality version which is more costly for firms to produce.

[15] The assumption of uniform tariffs simplifies the analysis while enabling us to identify some key mechanisms in the model. Dropping this assumption will not qualitatively change our main results.

3.2 Impact of tariff reductions on the choices of standards

We now solve for each country's optimal standards. For simplicity, we assume tariffs are non-prohibitive so that quantities of imports vary with tariff levels. Also recall that there is no strategic interaction between countries in their choices of standards. Hence we can analyze each country's standards separately.

Let us start with country k's choice of the standard on the foreign firm, $\sigma_{k\tilde{k}}$. First, when country k imposes the high standard on the domestic firm ($\sigma_{kk} = H$), we can calculate that

$$\widehat{w}_k(t_k, H, H) - \widehat{w}_k(t_k, H, L) > 0 \text{ if and only if } \theta > \theta_{HHHL}(t_k) \tag{8}$$

where θ_{HHHL} is a threshold of θ that depends on country k's tariff t_k.[16] Condition (8) says that country k would impose the high standard on the foreign firm when the externality is sufficiently large. The intuition for this result is straightforward. When tightening the standard on the foreign firm, each country faces the trade-off between lower externalities imported and increased price of the foreign good. For large externalities, the former benefit dominates in magnitude so that national welfare is greater under a high standard on imports. Next, to see how each country's tariff may affect its standard on the foreign firm, we can calculate that

$$\frac{\partial \theta_{HHHL}(t_k)}{\partial t_k} = \frac{c(1+2c)}{(1+c-2t_k)^2} > 0$$

so that a lower t_k leads θ_{HHHL} to fall. This implies that tariff reductions induce countries to tighten their product standards on foreign firms, that is, they impose the high standard on their imports over a larger range of the externality.

Now suppose each country sets the low standard on the domestic firm ($\sigma_{kk} = L$). In this case, there exists $\theta_{LHLL}(t_k)$ above which countries choose the high standard on

[16] The former two letters in the subscript of θ_{HHHL} (i.e. HH) represent country k's ex-post standards on the two firms, whereas the latter two letters (i.e. HL) represent its ex-ante standards. This notation will be applied to all the thresholds of θ obtained in the following analysis. Also, due to country symmetry we will simply omit k in the subscripts of thresholds of θ, as the thresholds will be the same for both countries. The expressions of all the thresholds of θ are collected and presented in Appendix B.

foreign firms

$$\widehat{w}_k(t_k, L, H) - \widehat{w}_k(t_k, L, L) > 0 \text{ if and only if } \theta > \theta_{LHLL}(t_k) \tag{9}$$

Moreover, we have

$$\frac{\partial \theta_{LHLL}(t_k)}{\partial t_k} = \frac{c(1-2c)}{(1-c-2t_k)^2} > 0$$

which says that tariff reductions make countries more likely to impose the high standard on foreign firms. Hence, regardless of a country's product standard on the domestic firm, tariff reductions always tighten its standard on the foreign firm.

We next show that tariff levels can also affect each country's standard on its own firm. Holding fixed country k's standard on the foreign firm, i.e. $\sigma_{k\widetilde{k}} = H$ or L, we can show that

$$\widehat{w}_k(t_k, H, H) - \widehat{w}_k(t_k, L, H) > 0 \text{ if and only if } \theta > \theta_{HHLH}(t_k) \tag{10}$$

and

$$\widehat{w}_k(t_k, H, L) - \widehat{w}_k(t_k, L, L) > 0 \text{ if and only if } \theta > \theta_{HLLL}(t_k) \tag{11}$$

so that each country sets the strict standard on its own firm for sufficiently high externalities. Direct calculations show that

$$\frac{\partial \theta_{HHLH}(t_k)}{\partial t_k} = -\frac{c(4-c)}{2(1+c+t_k)^2} < 0$$

and

$$\frac{\partial \theta_{HLLL}(t_k)}{\partial t_k} = -\frac{c(4-3c)}{2(1-c+t_k)^2} < 0$$

that is, a lower tariff raises $\theta_{HHLH}(t_k)$ and $\theta_{HLLL}(t_k)$. Hence tariff reductions make countries more likely to impose the low standard on domestic firms. The above results can be summarized in the following proposition:

Proposition 1: *Assume tariffs are non-prohibitive. Then the following hold:*

(i) Holding fixed the standards on domestic firms, tariff reductions induce countries to tighten their standards on foreign firms, i.e. $\frac{\partial \theta_{HHHL}(t_k)}{\partial t_k} > 0$ and $\frac{\partial \theta_{LHLL}(t_k)}{\partial t_k} > 0$.

(ii) Holding fixed the standards on foreign firms, tariff reductions induce countries to loosen their standards on domestic firms, i.e. $\frac{\partial \theta_{HHLH}(t_k)}{\partial t_k} < 0$ and $\frac{\partial \theta_{HLLL}(t_k)}{\partial t_k} < 0$.

To see the intuition for part (i) of Proposition 1, note that countries have two motives for raising the standards on foreign firms. One is the profit-shifting motive such that standards can be used to transfer profits from foreign to domestic firms.[17] As tariff reductions toughen foreign competition, countries would resort to higher standards on imports in order to extract more profits from foreign firms. The second motive, which is novel in the presence of negative consumption externalities, is the containment of local externalities. Given a low standard on imports, falling tariffs aggravate a country's local externalities by increasing its import of the low quality good.[18] This reinforces the need for countries to tighten their standards on imports.

The above two motives also explain part (ii) of the proposition albeit they now work in opposite directions. On one hand, as tariffs fall and foreign competition rises, the profit-shifting motive leads countries to lower their standards on domestic firms. On the other hand, the motive to curtail local externalities entails not relaxing the standards on domestic firms. The profit-shifting motive turns out to dominate so that each country ends up loosening the standard on its own firm.[19]

Proposition 1 echoes the finding in Staiger and Sykes (2011) who establishes substitution between a country's tariffs and regulatory standards under perfect competition. In their model, it is the terms-of-trade consideration that drives the substitution. Notably, putting their and our findings together suggests that discriminatory adjustment in domestic regulation induced by tariff reductions can be a rather robust policy response in the sense that it arises under different government motives for policy setting. This insight may explain why the substitution of NTMs for tariff barriers has been widely

[17] Grundke and Moser (2019) find suggestive evidence for protectionist use of regulatory standards that aim to protect profits of domestic firms.

[18] This can be seen by noting that $\frac{\partial \varphi_k(t_k,H,L)}{\partial t_k} = -\frac{2}{3}\theta < 0$, i.e. conditioning on a country standards being (H, L), a lower import tariff raises the level of domestic externality.

[19] Moreover, it can be shown that the net incentives to lower own standards are greater under $\sigma_{k\widetilde{k}} = H$ than under $\sigma_{k\widetilde{k}} = L$. In the former case, the foreign firm produces the high quality version, so a lower import tariff does not worsen domestic externalities. When $\sigma_{k\widetilde{k}} = L$, however, tariff reductions lead to greater imports of the low quality version and thus higher domestic externalities. This weakens the incentives for countries to lower the standards on their own firms.

observed in practice. That said, note that our analysis suggests that such policy substitution can be driven not only by profit-shifting but also by the legitimate purpose of containing negative consumption externalities. Thus, the discriminatory adjustment in standards due to tariff reductions may not necessarily be welfare-reducing, an implication consistent with the finding in Rebeyrol (2022). Also note that part (ii) of Proposition 1 implies that countries may respond to tariff liberalization by deregulating their own firms. Such a race-to-the-bottom outcome has been established in the trade and environment literature which primarily focuses on negative production externalities (e.g. Copeland, 2011). Here we show that the deregulation on domestic firms following tariff reductions can also take place under consumption externalities.

3.3 Nationally optimal standards under exogenous tariffs

We now allow countries to simultaneously choose their standards on both firms. The following lemma summarizes each country's policy choice:

Lemma 2: *Assume tariffs are non-prohibitive. Under the UC regime, each country's optimal standards given its tariff t_k are as follows:*

(i) For low tariffs, i.e. $t_k < \frac{c}{2}$, each country chooses (L, H) for $\theta < \theta_{HHLH}(t_k)$ and (H, H) for $\theta > \theta_{HHLH}(t_k)$.

(ii) For relatively low tariffs, i.e. $\frac{c}{2} < t_k < \widehat{t}_k^1$ and $c < \overline{c}_1$ or $\frac{c}{2} < t_k < t_k^p(L, H)$ and $\overline{c}_1 < c < \frac{1}{4}$, each country chooses (L, L) for $\theta < \theta_{LHLL}(t_k)$, (L, H) for $\theta_{LHLL}(t_k) < \theta < \theta_{HHLH}(t_k)$ and (H, H) over $\theta > \theta_{HHLH}(t_k)$, where

$$\widehat{t}_k^1 = \frac{1}{4}c - \frac{5}{2} + \frac{1}{4}\sqrt{17c^2 - 52c + 132} \text{ and } \overline{c}_1 = \frac{17}{4} - \frac{1}{4}\sqrt{265}$$

(iii) For relatively high tariffs, i.e. $\widehat{t}_k^1 < t_k < \widehat{t}_k^2$ and $c < \overline{c}_2$ or $\widehat{t}_k^1 < t_k < t_k^p(L, H)$ and $\overline{c}_2 < c < \overline{c}_1$, each country chooses (L, L) for $\theta < \theta_{HHLL}(t_k)$ and (H, H) over $\theta > \theta_{HHLL}(t_k)$, where

$$\widehat{t}_k^2 = \frac{7}{4}c - \frac{5}{2} + \sqrt{132 - 140c + 33c^2} \text{ and } \overline{c}_2 = \frac{31}{44} - \frac{1}{44}\sqrt{697}$$

(iv) For high tariffs, i.e. $\widehat{t}_k^2 < t_k < t_k^p(L, H)$, each country chooses (L, L) for $\theta < \theta_{HLLL}(t_k)$, (H, L) for $\theta_{HLLL}(t_k) < \theta < \theta_{HHHL}(t_k)$ and (H, H) for $\theta > \theta_{HHHL}(t_k)$.

Proof: see the appendix.

-Figure 1 here-

The central message of Lemma 2 is that countries' optimal standards indeed become more discriminatory against foreign firms as their tariffs fall. This can been readily seen from Figure 1 which depicts regions in the (t_k, c) space over which different equilibrium standards arise. The key observation is that discriminatory standards are more likely to be chosen as tariffs fall, that is, as one moves down from regions D to A.

Lemma 2 has interesting implications. First, so long as exporting countries are more likely to file complaints when they are discriminated against more by the importing countries, Lemma 2 is consistent with the timing of certain trade disputes over product standards as discussed in footnote 2 (e.g. Chinese honey exports to the EU). Second, Lemma 2 relates to Horn (2006) and Geng and Saggi (2022) who study NT in government taxation and intellectual property (IP) protection respectively. They show that tariff reductions can lead countries to choose more discriminatory corporate taxes or IP protection. Thus, the current findings suggest that the discriminatory adjustment in internal measures due to tariff reductions is rather robust to the nature of the measure.

4 Endogenous tariffs and exogenous standards

In this section, we analyze countries' optimal choices of tariffs conditioning on their product standards. This analysis is important for two reasons. First, it can predict tariffs that vary with goods depending on the levels of their consumption externalities, which is in line with the fact that countries in practice tend to impose higher tariffs on the imports of more polluting goods. Second, solving for endogenous tariffs is essential for identifying the channel of tariff adjustment which can shape the welfare implications of NT.

Specifically, we consider two scenarios depending on whether countries coordinate their tariff policy. In the first scenario, countries noncooperatively choose their tariffs

to maximize their national welfare.[20] Formally, country k chooses its tariff to maximize its welfare as

$$\max_{t_k} \widehat{w}_k(t_k, \sigma_{kk}, \sigma_{k\widetilde{k}}) \tag{12}$$

where $\widehat{w}_k(t_k)$ represents the component of country k's welfare that depends on its own policies, as defined in (5). In the second scenario, countries coordinate by choosing globally optimal tariffs that maximize world welfare

$$\max_{t_k} \widehat{ww}_k(t_k, \sigma_{kk}, \sigma_{k\widetilde{k}}) \tag{13}$$

where $\widehat{ww}_k(t_k)$ is the component of world welfare that depends on country k's tariff policy, as defined in (7). It is important to note that both nationally and globally optimal tariffs are independent across countries. This is because markets are segmented so that each firm's decisions about sales are independent across markets. As a result, each country's tariff can only affect the strategic interaction between firms on its own market. Because standards are also independent between countries, each country's choice of tariff is affected by its own standards only. Hence we can solve (12) and (13) for each country separately. This implies that unilaterally optimal tariffs are also Nash equilibrium tariffs.

a. When country k's standards are (H, H)

Under high standards on both firms, country k's Nash tariff can be solved as

$$t_k^n(H, H) = \frac{1}{3}(1 - c)$$

Note that $t_k^n(H, H)$ does not depend on θ since both firms produce the high quality version under uniformly strict standards. It is also readily seen that $t_k^n(H, H) > 0$ so that each country's Nash tariff is always positive due to the profit-shifting motive.

Under (H, H), globally optimal tariff for country k can be solved as

$$t_k^{so}(H, H) = 0$$

[20] Since there is no strategic interaction in tariff policy between countries, the analysis will remain the same whether countries move simultaneously or sequentially.

which says that world welfare is maximized under free trade. In the absence of externalities, tariffs only lower efficiency by reducing aggregate outputs and therefore are never globally optimal.

b. When country k's standards are (L, L)

Given a low standard on both firms, country k's Nash tariff can be solved as

$$t_k^n(L, L) = \frac{1}{3}(1 + \theta)$$

It is readily seen that $t_k^n(L, L) > 0$, i.e. Nash tariffs are always positive due to countries' motives of shifting profits and reducing externalities. Moreover, we have $\frac{\partial t_k^n(L,L)}{\partial \theta} = \frac{1}{3} > 0$ so that Nash tariffs rise in the level of the externality. The intuition for this is straightforward: higher externalities caused by foreign goods increase the welfare benefits for countries from raising import tariffs.

Globally optimal tariffs under (L, L) can be solved as

$$t_k^{so}(L, L) = -1 + 3\theta$$

Interestingly, we have $t_k^{so} > 0$ for $\theta > \frac{1}{3}$, which indicates that globally optimal tariffs can be positive for large consumption externalities. The intuition is that when standards are uniformly low, tariffs become the only policy instrument for combatting negative consumption externalities. Hence efficiency requires using positive tariffs to reduce low quality imports when the associated externalities are sufficiently high.

c. When country k's standards are (L, H)

Nash tariffs under (L, H) are given by

$$t_k^n(L, H) = \frac{1}{3}(1 - c - \theta)$$

An interesting observation is that $\frac{\partial t_k^n(L,H)}{\partial \theta} = -\frac{1}{3} < 0$ so that Nash tariffs actually decrease in the level of the externality. To see the intuition, note that under (L, H) all local externalities are caused by the consumption of domestic goods (which are low

quality). Hence countries can limit the consumption of domestic goods by reducing tariffs on the high quality imports. In fact, we have $t_k^n(L,H) = 0$ when $\theta > 1 - c$, that is, for large enough externalities it is possible for countries to eliminate tariffs so as to maximize imports.

We can further solve for globally optimal tariffs as

$$t_k^{so}(L,H) = -1 + 5c - 3\theta$$

which is decreasing in θ. Intuitively, as local externalities rise under (L,H), optimality calls for tariff reductions that encourages the consumption of imported goods. It is easily checked that $t_k^{so}(L,H) = 0$ for $\theta > \frac{1}{3}(5c-1)$, so that globally optimal tariffs would reduce to zero if the externalities of domestically produced goods are sufficiently high.

d. When country k's standards are (H,L)

Nash tariffs under (H,L) are given by

$$t_k^n(H,L) = \frac{1}{3}(1 + 2\theta)$$

It is readily seen that $\frac{\partial t_k^n(H,L)}{\partial \theta} = \frac{2}{3} > 0$ so that $t_k^n(H,L)$ increases in θ. The intuition for this result is clear. When foreign firms produce the low quality version, local externalities arise solely from imports. Hence, as such externalities increase countries simply raise tariffs to reduce their imports.

Globally optimal tariffs under (H,L) can be solved as

$$t_k^{so}(H,L) = -1 - 4c + 6\theta$$

We have $\frac{\partial t_k^{so}(H,L)}{\partial \theta} = 6 > 0$ so that $t_k^{so}(H,L)$ is increasing in the levels of externalities. Note that the profit-shifting motive is absent in achieving social optimality, so this result is driven only by each country's incentive to control externalities. It can be further shown that $t_k^{so}(H,L) = 0$ as $\theta < \frac{1}{6} + \frac{2}{3}c$, which says that free trade can be globally optimal if the externalities is not too large.

In sum, the above analysis shows that the behavior of Nash and globally optimal tariffs depend crucially on the level as well as the origin of the negative consumption externality. Now compare Nash tariffs under different standards to see how a country's standards may affect its choice of tariff:

Lemma 3: *Suppose Nash tariffs under alternative standards are non-prohibitive. Then they are ranked as:* $t_k^n(H,L) > t_k^n(L,L) > t_k^n(H,H) > t_k^n(L,H)$.

Proof: see the appendix.

Lemma 3 says that the more discriminatory a country's standards are against the foreign firm, the lower is its Nash tariff.[21] This implies that countries can use tariffs as a policy substitute for product standards. Thus, Lemmas 2 and 3 together imply that the policy substitution between tariffs and standards is mutual. We can further compare Nash and globally optimal tariffs to obtain the following useful result:

Lemma 4: *Suppose Nash tariffs are non-prohibitive. Then they are higher than globally optimal levels regardless of the standards being enforced.*

Proof: see the appendix.

The intuition for Lemma 4 is clear: Nash tariffs are sub-optimally high due to each country's profit-shifting motive. In particular, countries do not take into account the profit losses of foreign firms when setting their import tariffs, and this occurs regardless of the product standards.[22] Importantly, Lemma 4 suggests that there exist potential welfare gains from trade policy coordination that lowers the tariffs between countries. The rest of the paper will analyze how such tariff liberalization may affect the welfare performance of NT.

[21] Also note that when a country enforces identical standards on the two firms, its Nash tariff is higher under (L,L) than under (H,H) because the need to curb externalities is greater when firms produce the low quality version.

[22] Note that under a low standard on imports (e.g. (L,L) or (H,L)), Nash and globally optimal tariffs do converge to the prohibitive levels as θ rises. The reason is that as imported externalities increase, private and social incentives become aligned in terms of raising tariffs to contain local externalities.

5 Welfare analysis of NT when both standards and tariffs are endogenous

The above analysis indicates that implementing NT in product standards can give countries incentives to adjust their tariffs. Therefore, the welfare effect of NT would depend on the induced changes in standards *and* tariffs provided the use of tariffs is unconstrained. This section investigates how the channel of tariff adjustment may affect the welfare justification of NT. To this end, we assume both standards and tariffs as endogenously chosen by countries. As countries set their standards first, we can use backward induction to solve for equilibrium standards conditioning on the endogenously determined (i.e. Nash or globally optimal tariffs) tariffs. First consider the case of Nash tariffs. Equilibrium standards under UC can then be shown as follows:

Proposition 2: *Conditioning on Nash tariffs, equilibrium standards under UC are as follows:*

(i) For small externalities, i.e. $\theta < \theta^n_{LHLL}$*, each country chooses the low standard on both firms* (L, L)*.*

(ii) For intermediate levels of externalities, i.e. $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$*, each country chooses the low (high) standard on the domestic (foreign) firm* (L, H)*.*

(iii) For large externalities, i.e. $\theta > \theta^n_{HHLH}$*, each country chooses the high standard on both firms* (H, H)*.*

In particular, θ^n_{LHLL} *and* θ^n_{HHLH} *are* $\theta_{LHLL}(t_k)$ *and* $\theta_{HHLH}(t_k)$ *evaluated at the corresponding Nash tariffs.*

Proof: see the appendix.

Cosinot (2008) shows that under free trade, countries can choose discriminatory standards under UC. Proposition 2 suggests that discriminatory regulation can be persistent in the sense that it can arise in equilibrium even when countries have the tariff instrument at their disposal. This occurs as tariffs in our model are not a perfect substitute for product standards, as they are less effective than standards for addressing large consumption externalities. To see this, note that tariffs can only lower imported externalities via proportionally reducing the quantities of import. For large externalities this may lead to prohibitive tariffs which stifle imports. By contrast, setting the high

standard to curtail externalities requires a finite compliance cost c which does not rise in the level of the externality.[23] This premise can be justified by the fact that product standards are design specifically for addressing negative consumption externalities. Moreover, technological progress in the long run can help lower the cost of meeting certain standards to feasible levels. Thus a carefully formulated standard will likely be more cost-efficient in curbing significant externalities than an import tariff. In this case, imposing a high standard on imports with large externalities is less costly: it eliminates the externalities from foreign goods without having to significantly reduce imports. It follows that countries prefer a certain degree of regulatory discrimination against foreign firms even when they can freely set import tariffs.

Next consider equilibrium standards under NT. In this case, countries have three options: (L, L), (H, L) and (H, H). Note that (H, L) cannot be optimal as it is never chosen under UC as indicated by Proposition 2. It follows that countries under NT necessarily impose identical standards on domestic and foreign firms. We can show that the following equilibrium outcome holds:

Proposition 3: *Conditioning on Nash tariffs, equilibrium standards under NT are as follows:*

(i) For small externalities, i.e. $\theta < \theta^n_{HHLL}$*, each country chooses the low standard* (L, L)*.*

(ii) For large externalities, i.e. $\theta > \theta^n_{HHLL}$*, each country chooses the high standard* (H, H)*.*

In particular, θ^n_{HHLL} *is* $\theta_{HHLL}(t_k)$ *evaluated at the corresponding nationally optimal tariff.*

Proof: see the appendix.

Let us now compare equilibrium tariffs under the two product standard regimes. Figure 2 depicts the equilibrium standards under UC and NT respectively given Nash tariffs. Note from the Figure that equilibria under the two policy regimes differ only for intermediate levels of θ, i.e. $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$. Specifically, over this range of

[23] This assumption is more than necessary. As can be expected, all we need is that the compliance cost has a sufficiently low upper-bound.

θ, standards under NT (i.e. (L, L) and (H, H)) are always more favorable to foreign firms than that under UC (i.e. (L, H)). Then by Lemma 3 equilibrium tariffs over $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$ must be higher under NT. Hence we have the following important result:

Proposition 4: *Nash tariffs are weakly higher under NT than under UC. Particularly, they are strictly higher under NT over intermediate levels of the externality, i.e.* $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$.

-Figure 2 here-

Proposition 4 says that countries have stronger incentives to raise their tariffs under NT than under UC. This is due to the policy substitution effect between tariffs and standards as suggested by Lemma 3. To our best knowledge, this paper is the first to show that the enforcement of NT in product standards can influence countries' choices of tariffs. An important policy implication of this finding is that the welfare gains from tariff liberalization tend to be greater under NT than under UC, as the former regime allows for a larger scope of tariff reductions. As will be shown, this feature plays a key role in shaping the welfare performance of NT.

We now compare equilibrium welfare under UC and NT. The following proposition can be established:

Proposition 5: *Under Nash tariffs:*

(i) NT yields higher world welfare for relatively high levels of the externality, i.e. $\theta^{nw}_{HHLH} < \theta < \theta^n_{HHLH}$.

(ii) UC yields higher world welfare for relatively low levels of the externality, i.e. $\theta^n_{LHLL} < \theta < \theta^{nw}_{HHLH}$.

(iii) The two regimes yield identical world welfare for low and high levels of the externality, i.e. $\theta < \theta^n_{LHLL}$ *and* $\theta > \theta^n_{HHLH}$*; where* θ^{nw}_{HHLH} *is a threshold of* θ *such that* $\theta^n_{LHLL} < \theta^{nw}_{HHLH} < \theta^n_{HHLH}$.

Proof: see the appendix.

Proposition 5 says that imposing NT does not guarantee welfare improvement: it raises world welfare for relatively large externalities but lowers wefare when externalities are relatively small. Costinot (2008) establishes this welfare result under free trade. Here we show that the result is robust when countries can optimally choose import tariffs as an additional policy instrument.[24] The intuition behind this result is that NT does not eliminate countries' strategic incentives for setting standards. Particularly, starting with a high standard on both firms, each country is more likely to lower own standard under UC than under NT as doing so does not require relaxing the standard on the foreign firm. Hence countries under UC have an excessive incentive to use the low standard. This makes UC less efficient than NT when θ is relatively large and the high standard is preferred. By contrast, for relatively small θ it is globally optimal to have one firm produce the low quality version of the good.[25] Such an outcome can arise under UC but not NT as the latter regime mandates equal standards on firms, which makes countries less willing to switch to the low standard and thus use too much of the high standard. It follows that UC dominates NT for low levels of θ.

5.1 Impact of tariff liberalization

We now examine how the welfare performance of NT may depend on the presence of endogenous tariffs. Specifically, we consider two major forms of trade coordination between countries that constrain their tariffs on each other. One is a bilateral FTA that simply reduces tariffs between countries to zero; the other sets the internal tariffs to the globally optimal levels which may be positive depending on the level of the externality. It turns out that our central findings are qualitatively the same under the two types of coordination. Hence we will focus on the case of FTA due to its empirical relevance and will analyze the second form of trade coordination in appendix C. Also note that the

[24] It is worth noting that the efficiency implications of NT may depend on the market structure. As shown by Costinot (2008) and the present paper, NT in a Cournot model does not lead to efficiency because it does not nullify the strategic incentives which give rise to cross-border welfare externalities associated with each country's choice of standards. By contrast, in a Krugman-type model as studied in Mei (2021), NT eliminates the delocation incentives and thus can render Nash equilibrium efficient provided standards only affect the marginal cost of production.

[25] Intuitively, to address relatively small externalities, it will be too costly to have both firms produce the high quality version. On the other hand, the externalities are not so small that having both firms produce the low quality version is also not optimal.

insights yielded by our analysis should apply well to the WTO although it is not a FTA, because the WTO member countries' average applied tariffs are very low nowadays (e.g. below 5%).

To facilitate the analysis, we also consider two scenarios depending on whether countries can adjust their product standards after eliminating their tariffs on each other. In the first scenario countries do not change their standards following the tariff reductions; in the second, countries can reoptimize their standards. There are two reasons for differentiating between these two scenarios. First, whether standards are adjustable may capture the time horizon of tariff reductions. In particular, the equilibrium that obtains under fixed standards can be considered as the short-run outcome of a FTA, while that under flexible standards may reflect the FTA's long-run impact. Second, the long-run consequence of a FTA is a mix of the effects of two different policy changes - tariff reductions per se and the induced adjustment in product standards. Hence analyzing both scenarios is essential for separating these two effects.

Let us start with the case of fixed standards. Here, any welfare changes from entering into a FTA must be due to the elimination of tariffs. Since globally optimal tariffs can be positive for large θ, a FTA may lead to tariffs (i.e. zero) that are too low from the efficiency point of view. Nevertheless, the following proposition shows that even with the possibility of causing "overshooting" in tariff reductions, a FTA unambiguously improves welfare:

Proposition 6: *Suppose countries sign a bilateral FTA that removes internal tariffs and standards are held fixed. Then the FTA improves world welfare over all levels of θ under either NT or UC.*

Proof: see the appendix.

The intuition for Proposition 6 is that the welfare gains from eliminating the tariff barriers are sufficiently large so that they end up dominating the welfare losses from the excessive tariff reductions. The proposition has direct policy implications. It is well-recognized that incomplete contracts can affect the design of trade agreements (Horn et al., 2010). In the case where it is impossible to write a complete contract that

specifies the optimal levels of tariffs based on the size of consumption externalities, simply removing all tariffs between countries can ensure welfare improvement (provided standards are fixed).

Now consider the second scenario where product standards are reoptimized after tariffs are removed. In this case, the equilibrium outcome under free trade is characterized in Costinot (2008). Here we restate his results just for reference:

Lemma 5 (Costinot, 2008): *Equilibrium standards under free trade are as follows:*

(i) Under UC,

(i-a) for low externalities, i.e. $\theta < \theta^f_{HHLH}$*, each country chooses the low (high) standard on the domestic (foreign) firm, i.e.* (L, H)*;*

(i-b) for high externalities, i.e. $\theta > \theta^f_{HHLH}$*, each country chooses the high standard on both firms, i.e.* (H, H)*.*

(ii) Under NT,

(ii-a) for low externalities, i.e. $\theta < \theta^f_{HHLL}$*, each country chooses the low standard on both firms, i.e.* (L, L)*;*

(ii-b) for high externalities, i.e. $\theta > \theta^f_{HHLL}$*, each country chooses the high standard on both firms, i.e.* (H, H)*.*

Particularly, θ^f_{HHLH} *and* θ^f_{HHLL} *are* $\theta_{HHLH}(t_k)$ and $\theta_{HHLL}(t_k)$ *evaluated at* $t_k = 0$*.*

Lemma 5 says that absent NT, countries have incentives to choose discriminatory standards when the externality is low (part (i)). Mandating NT can thus ensure that countries impose identical standards on domestic and foreign firms (part (ii)). Comparing equilibrium standards and welfare before and after the FTA, we can show the following important result:

Proposition 7: *Suppose countries reoptimize their standards after signing a bilateral FTA. Then:*

(i) Under UC, the FTA makes countries more likely to choose the discriminatory standards (L, H)*, i.e.* $\theta^f_{HHLH} > \theta^n_{HHLH}$*;*

(ii) Under NT, the FTA makes countries more likely to enforce the high standard on both firms (H, H)*, i.e.* $\theta^f_{HHLL} < \theta^n_{HHLL}$*;*

(iii) Under either regime, the FTA improves world welfare for all levels of the externality provided the compliance cost is small, i.e. $c < 0.12$. *When* $c > 0.12$, *the FTA may lower global welfare.*

Proof: see the appendix.

-Figures 3 and 4 here-

Figures 3 and 4 depict the comparisons of the equilibrium outcome before and after removing tariffs when the policy regimes are UC and NT respectively.

Part (i) of Proposition 7 describes how standards under UC may adjust to the removal of Nash tariffs. The result resembles that for reductions in exogenous tariffs (Lemma 2): standards under free trade are more discriminatory against foreigners because the elimination of tariffs induces countries to enforce tighter standards on imports with low externalities. Part (ii) of the proposition says that free trade makes countries more likely to raise their standards even if they cannot practice discrimination. This is because falling tariffs increase the need for raising the standards on foreign goods, but in doing so countries also need to raise own standards in order to abide by NT. The first need turns out to dominate so that countries end up enforcing higher standards on both firms. Staiger and Sykes (2011) obtain a similar policy response under NT in their terms-of-trade model of trade policy. Here we show that such a policy response can also arise from the motive of profit-shifting. Parts (i) and (ii) of Proposition 7 together suggest that tariff reductions make countries tighten product standards on imports regardless of NT. Thus the proposition is consistent with the systematic as well as the anecdotal evidence that tariff reductions tend to induce stricter NTMs on imports.

Part (iii) of the proposition is important in indicating that the adjustment of product standards may alter the welfare effect of eliminating the Nash tariffs. This result echoes that from recent research such as Berti and Falvey (2018).[26] Intuitively, although moving

[26] One important difference between our paper and Berti and Falvey (2018) is in the nature of the policy experiment being conducted. While Berti and Falvey examine how standards may adjust when countries move from autarky to free trade, we analyze the policy change from Nash tariffs to free trade.

to free trade can generate welfare gains, it will also alter the level of import competition and thus each member country's choices of its product standards. This can in turn lead to beggar-thy-neighbor adjustment in standards which lowers efficiency. This mechanism also explains why a FTA reduces world welfare only for a large compliance cost c: as countries under free trade rely more on the strict standard for regulation, the possible efficiency loss from doing so can become significant only when the compliance cost is sufficiently high.

We now evaluate the welfare justification of NT. As shown in Proposition 5, NT does not always yield higher welfare than UC, and whether this is the case depends on the level of the consumption externality. Hence we will need a measure for the *overall* effectiveness of NT vis-à-vis UC which can capture the relative performance of NT across all values of θ. To this end, we formulate a tractable measure as follows:

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

$$r = \frac{m(\Omega)}{m(\Psi)}, \tag{14}$$

where $\Omega = \{\theta | \theta$ *for which NT yields strictly higher world welfare*$\}$, $\Psi = \{\theta | \theta$ *for which UC yields strictly higher world welfare*$\}$ *and* $m(\cdot)$ *denotes the length of* Ω or Ψ.

Intuitively, the measure r reflects the relative welfare dominance of NT over UC. A larger r indicates that NT yields strictly higher global welfare than UC over a relatively greater range of θ, and thus should be considered more effective. Note that the results obtained based on r would carry over if countries care more about goods with large externalities and therefore assign greater weights to high levels of θ. To see this, recall that NT tends to dominate for large values of θ, implying that r underestimates the effectiveness of NT given it assigns equal weights to all values of θ. Hence, provided an FTA increases the relative effectiveness of NT as well as its dominance over high levels of θ, our conclusion would be strengthened if countries attach more importance to larger externalities.[27] Applying r to the analysis, we can show the following important

[27] This can indeed be shown to be the case. As the proof of Proposition 7 demonstrates, under free trade NT dominates UC over both high and low levels of externalities, and this is true whether standards

proposition regarding how tariff liberalization may affect the effectiveness of NT:

Proposition 8: *(i) When product standards are fixed, a bilateral FTA that eliminates countries' tariffs on each other makes NT more effective.*

(ii) When standards are flexible, the adjustment in standards following the FTA makes NT more effective for a sufficiently low compliance cost, i.e. $c < 0.11$.

(iii) When standards are flexible, the FTA makes NT more effective.

Proof: see the appendix.

Part (i) and (ii) of Proposition 8 identify two channels through which constraining tariffs may impact the effectiveness of NT: tariff reductions and adjustment in product standards. Part (i) holds simply because NT induces higher Nash tariffs than UC and thus implies greater welfare improvement from the removal of tariffs. This makes tariff reductions unambiguously raise the effectiveness of NT. Part (ii) of the proposition is important in indicating that as tariffs decline, the adjustment in standards under NT is not necessarily more welfare-improving than that under UC. This occurs as NT does not remove the profit-shifting motive which induces countries to overuse the high standard on both firms. Moreover, such a problem tends to worsen under free trade, because the tariff instrument is not available so that countries would employ more of the high standard in order to substitute tariffs. Hence, for high compliance costs the welfare loss under NT due to the overuse of the high standard can be so large that it may become counterproductive for countries to adjust their standards while following NT.

Part (iii) of Proposition 8 is one of the central results of the paper: the effect of tariff reductions always dominates so that an FTA unambiguously increases the effectiveness of NT even if product standards can adjust. Hence, part (iii) establishes a novel implication of tariff liberalization: it can improve the welfare performance of enforcing NT in product standards. Importantly, this result is in support of the institutional arrangements of the WTO and various existing FTAs. These trade agreements adopt NT as a core approach to product standards; meanwhile, they set tariff bounds or eliminate

can adjust or not. Hence, to see whether the increased effectiveness of NT is driven by its dominance over high levels of θ *alone*, we can simply calculate r under free trade by excluding the lower ranges of θ over which NT performs better. It can be shown that r remains higher under free trade than under Nash tariffs.

tariff barriers between their member countries. Part (iii) suggests that imposing such restrictions on tariffs is indeed conducive to the welfare performance of NT. More broadly, our analysis suggests that product standard agreements can benefit from a holistic approach, that is, to maximize the gains from policing product standards, it is necessary to stipulate accompanying rules on related measures that are less effective substitutes for standards.

6 Further discussions

It is worth noting that our stylized model enables us to sharply identify the key mechanisms but is not necessary for obtaining the main results. This is because our analysis hinges on two intuitive premises that can hold in more general settings. One is that tariffs and standards serve common objectives. This drives the substitution between the two policy instruments. The other is that standards are more effective than tariffs in curtailing large externalities. This implies that the upward tariff adjustment induced by NT tends undermine efficiency, which is why NT has better welfare performance when tariffs are constrained. That being said, we further discuss several extensions of the benchmark model.

6.1 Fixed compliance cost

For simplicity we have assumed that meeting the high standard entails the payment of a variable compliance cost. It is important to consider a fixed compliance cost which is empirically relevant and can have substantive efficiency implications. Consider first the case where the fixed cost is small in the sense that it does not drive a firm out of the market. In this case, the fixed cost does not alter the strategic behavior of firms (which only depends on the variable production cost), and therefore will not affect countries' profit-shifting motive. Our results thus will remain qualitatively similar. For a large fixed cost, complying with the high standard can force a firm to exit the market by reducing its profits to negative levels. Interestingly, this can make product standards a more effective policy instrument for the protectionist purpose. So long as the negative welfare effect of reduced import competition is not too large, tariff liberalization can make countries even more willing to choose discriminatory standards against foreign

firms. This would make NT relatively more desirable from the welfare perspective. As a result, eliminating tariffs would still raise the effectiveness of NT.

6.2 Transboundary externalities

Our benchmark analysis focuses on the case of local consumption externalities. In practice, certain types of consumption externality such as pollution can travel across borders. It turns out that our main findings would carry over in the presence of such transboundary externalities. The reason is the following. First, countries under either UC or NT do not take into account the effects of their policies on their trading partners. Hence their choices of tariffs and standards would not change if the resulted externalities can affect other countries. Moreover, accounting for transboundary externalities can actually strengthen our main finding that the case for NT is stronger under free trade. To see this, note that it is more efficient to contain high-level externalities when they can cross borders. This would increase the relative effectiveness of NT because it tends to perform better under large externalities. Moreover, it can be shown that the removal of tariffs tends to enhance the dominance of NT over high externalities. It follows that when consumption externalities are transboundary, the relative effectiveness of NT would increase to a larger extent as tariffs are constrained.

6.3 Political economy

Firms in practice may lobby the government for their preferred policies. To capture the political economy of tariffs and standards, assume that countries assign larger weights to profits than to consumer surplus when evaluating their national welfare. First note that this will not alter the policy substitution between standards and tariffs as they continue to serve the common objectives of shifting profits and controlling consumption externalities. On the other hand, as countries value profits more, they tend to choose higher tariffs in order to extract larger profits from foreign firms. This implies that the upward tariff adjustment induced by NT would become even stronger. From the efficiency view, however, this is a worse scenario as compared to the benchmark case without lobbying because rising tariffs are increasingly more efficiency-reducing. Therefore, the presence of firm lobbying would make tariff liberalization even more conducive to improving the

welfare performance of NT.

7 Conclusion

This paper develops a model where both tariffs and product standards are endogenously determined. The model is then applied to study the interaction between the two policy instruments, as well as the role of tariff liberalization in shaping the welfare justification of NT. Our analysis yields several important results. First, there can exist policy substitution between a country's tariffs and product standards, a pattern consistent with the ample empirical evidence. Second, the case for NT is stronger under tariff liberalization which can prevent the upward tariff adjustment induced by NT. These insights indicate that in a world with falling tariff barriers, NT is not only more necessary for achieving non-discrimination in product standards, but also more desirable from the welfare perspective. Our analysis thus reveals a positive linkage between tariff liberalization and NT as core principles of the WTO and various major FTAs. In a broader sense, our analysis suggests that product standard agreements can benefit from a holistic approach which incorporates disciplining rules for policy substitutes of standards.

While this paper delivers various novel insights, it has several limitations that deserve further research. First, we have assumed country symmetry to keep the analysis focused. It would be interesting to study whether the welfare effect of NT may alter when countries have heterogeneous characteristics. Second, for simplicity we have abstracted from global value chains. Shapiro (2021) finds that the presence of supply chains along with firm lobbying can lead to relatively lower tariffs and NTMs in dirty upstream industries than in clean downstream industries. While his finding is not comparable to ours, as we focus on downstream industries, incorporating vertical linkages into the analysis is an important direction for future research.[28]

8 Appendix A: supporting calculation results

Equilibrium sales and prohibitive tariffs

[28] See Garetto (2013) who shows the quantitative importance of vertical linkages such as international input sourcing by multinational firms.

	(H,H)	(H,L)	(L,H)	(L,L)
$q_{kk}(t_k,\boldsymbol{\sigma}_k)$	$\frac{1}{3}-\frac{1}{3}c+\frac{1}{3}t_k$	$\frac{1}{3}-\frac{2}{3}c+\frac{1}{3}t_k$	$\frac{1}{3}+\frac{1}{3}c+\frac{1}{3}t_k$	$\frac{1}{3}+\frac{1}{3}t_k$
$q_{\widetilde{kk}}(t_k,\boldsymbol{\sigma}_k)$	$\frac{1}{3}+\frac{1}{3}c-\frac{2}{3}t_k$	$\frac{1}{3}+\frac{1}{3}c-\frac{2}{3}t_k$	$\frac{1}{3}-\frac{2}{3}c-\frac{2}{3}t_k$	$\frac{1}{3}-\frac{2}{3}t_k$
$t_k^p(\boldsymbol{\sigma}_k)$	$\frac{1}{2}-\frac{1}{2}c$	$\frac{1}{2}+\frac{1}{2}c$	$\frac{1}{2}-c$	$\frac{1}{2}$

Under exogenous tariffs

Thresholds of θ		
$\theta_{LHLL}(t_k)=\frac{c(2t_k-c)}{2(1-c-2t_k)}$	$\theta_{HHLH}(t_k)=\frac{c(4-c)}{2(1+c+t_k)}$	$\theta_{HLLH}(t_k)=\frac{c(2-c-t_k)}{3t_k}$
$\theta_{HHHL}(t_k)=\frac{c(c+2t_k)}{2(1+c-2t_k)}$	$\theta_{HLLL}(t_k)=\frac{c(4-3c)}{2(1-c+t_k)}$	$\theta_{HHLL}(t_k)=\frac{c(2-c-t_k)}{2-t_k}$

Under Nash tariffs

Thresholds of θ	
$\theta^n_{LHLL}=c$	$\theta^n_{HHLH}=4+2c-\sqrt{16+4c+7c^2}$
$\theta^n_{HLLL}=\frac{1}{3}(3c-4+\sqrt{16+12c-18c^2})$	$\theta^n_{HHLL}=5-\sqrt{25-14c+7c^2}$
$\theta^n_{HLLH}=\frac{1}{3}(c-3+\sqrt{9+24c-14c^2})$	$\theta^n_{HHHL}=\frac{1}{2}(1+c)$
$\theta^{nw}_{HHLH}=\frac{32}{17}+2c-\frac{1}{17}\sqrt{1024+544c+1105c^2}$	

Under free trade

Thresholds of θ	
$\theta^f_{HHLH}=\frac{c(4-c)}{2(1+c)}$	$\theta^f_{HHLL}=c-\frac{c^2}{2}$
$\theta^{fw}_{LHLL}=\frac{c(8-11c)}{6(1-c)}$	$\theta^{fw}_{HHLH}=\frac{c(8+3c)}{6(1+c)}$

9 Appendix B: proofs

Proof of Lemma 2.

The proof proceeds in two steps. First we analyze country k's choice between (L,L), (H,H), and (L,H). Second, we introduce (H,L) into the country's policy consideration and see when it is optimal.

Step 1: We start by comparing (L,H) and (L,L). It has been shown in (9) that $(L,H)\succ(L,L)$ iff $\theta>\theta_{LHLL}(t_k)$. This implies that (L,L) will be chosen iff $\theta_{LHLL}(t_k)>$

0. It can be checked that $\theta_{LHLL}|_{t_k=\frac{c}{2}} = 0$ and $\frac{\partial \theta_{LHLL}(t_k)}{\partial t_k} > 0$. Hence $\theta_{LHLL}(t_k) > 0$ iff $t > \frac{c}{2}$. It follows that for $t > \frac{c}{2}$ we have $(L,H) \succ (L,L)$ for $\theta > \theta_{LHLL}(t_k)$; and for $0 \leq t < \frac{c}{2}$ we have $(L,H) \succ (L,L)$ for all θ.

Next compare (L,H) and (H,H). We have $(H,H) \succ (L,H)$ iff $\theta > \theta_{HHLH}(t_k)$. Since $\theta_{HHLH}(t_k)$ is positive, (L,H) must be chosen for $\theta < \theta_{HHLH}(t_k)$.

Now we know (L,H) dominates (L,L) and (H,H) for $\theta_{LHLL}(t_k) < \theta < \theta_{HHLH}(t_k)$. The length of the interval $(\theta_{LHLL}(t_k), \theta_{HHLH}(t_k))$ can be calculated as

$$\theta_{HHLH}(t_k) - \theta_{LHLL}(t_k) = \frac{c(2c^2 - 4c + ct_k - 10t_k - 2t_k^2 + 4)}{2(1+c+t_k)(1-c-2t_k)}$$

It can be checked that $\theta_{HHLH}(t_k) - \theta_{LHLL}(t_k) < 0$ if and only if $t_k > \widehat{t}_k^1$ where

$$\widehat{t}_k^1 = \frac{1}{4}c - \frac{5}{2} + \frac{1}{4}\sqrt{17c^2 - 52c + 132}$$

Moreover, recall that we assume t_k to be non-prohibitive such that $0 \leq t_k < t_k^p(L,H) = \frac{1}{2} - c$. Comparing $\widehat{t}_k^1$ with $t_k^p(L,H)$ we have $\widehat{t}_k^1 < t_k^p(L,H)$ iff $c < \overline{c}_1 = \frac{17}{4} - \frac{1}{4}\sqrt{265} \approx 0.18 < \frac{1}{4}$, where $\frac{1}{4}$ is the assumed upper-bound of c. This implies that when $\widehat{t}_k^1 < t_k < t_k^p(L,H)$ and $c < \overline{c}_1$, the interval $(\theta_{LHLL}(t_k), \theta_{HHLH}(t_k))$ vanishes and (L,H) is never chosen. In this case countries choose between (L,L) and (H,H), and will prefer (H,H) iff $\theta > \theta_{HHLL}(t_k)$.

Finally, it is easily checked that $\widehat{t}_k^1 > \frac{c}{2}$. Thus, when $\frac{c}{2} < t_k < \widehat{t}_k^1$ and $c < \overline{c}_1$ or $\frac{c}{2} < t_k < t_k^p(L,H)$ and $c > \overline{c}_1$, (L,H) is chosen over $\theta_{LHLL}(t_k) < \theta < \theta_{HHLH}(t_k)$ while (L,L) and (H,H) are chosen for $\theta < \theta_{LHLL}(t_k)$ and $\theta > \theta_{HHLH}(t_k)$ respectively. When $0 \leq t_k < \frac{c}{2}$, we must have $(H,H) \succ (L,H)$ iff $\theta > \theta_{HHLH}(t_k)$ and (L,L) is never chosen.

To summarize, when (H,L) is excluded from consideration, equilibrium standards are given as follows:

(a) when $0 \leq t_k < \frac{c}{2}$ (region A in Figure 1): (L,H) for $\theta < \theta_{HHLH}(t_k)$ and (H,H) for $\theta > \theta_{HHLH}(t_k)$;

(b) when $\frac{c}{2} < t_k < \widehat{t}_k^1$ and $c < \overline{c}_1$ or $\frac{c}{2} < t_k < t_k^p(L,H)$ and $c > \overline{c}_1$ (e.g. region B in Figure 1): (L,L) for $\theta < \theta_{LHLL}(t_k)$, (L,H) for $\theta_{LHLL}(t_k) < \theta < \theta_{HHLH}(t_k)$ and (H,H) for $\theta > \theta_{HHLH}(t_k)$;

(c) when $\widehat{t}_k^1 < t_k < t_k^p(L,H)$ and $c < \overline{c}_1$ (region C and D in Figure 1): (L,L) for $\theta < \theta_{HHLL}(t_k)$ and (H,H) for $\theta > \theta_{HHLL}(t_k)$.

Step 2: Let us now incorporate (H,L) into the policy consideration. First consider region A. When $\theta < \theta_{HHLH}(t_k)$ we need to compare (H,L) and (L,H). It can be shown that there exists $\theta_{HLLH}(t_k)$ such that

$$\widehat{w}_k(t_k,H,L) - \widehat{w}_k(t_k,L,H) > 0 \text{ if and only if } \theta > \theta_{HLLH}(t_k)$$

which implies that $(H,L) \succ (L,H)$ iff $\theta > \theta_{HLLH}(t_k)$. However, we have $\theta_{HLLH}(t_k) > \theta_{HHLH}(t_k)$ because

$$\theta_{HLLH}(t_k) - \theta_{HHLH}(t_k) = \frac{4 + 2c - 2c^2 - 10t_k - ct_k - 2t_k^2}{6t_k(1 + c + t_k)} > 0$$

whenever $t_k < \frac{c}{2}$. Thus, given $\theta < \theta_{HHLH}(t_k)$ we must have $\theta < \theta_{HLLH}(t_k)$ and (H,L) is never optimal. Now suppose $\theta > \theta_{HHLH}(t_k)$ and compare (H,L) with (H,H). From (8) we know that $(H,L) \succ (H,H)$ iff $\theta < \theta_{HHHL}(t_k)$. Furthermore, we have

$$\theta_{HHLH}(t_k) - \theta_{HHHL}(t_k) = \frac{c(4 + 2c - 2c^2 - 10t_k - ct_k - 2t_k^2)}{2(1 + c - 2t_k)(1 + c + t_k)} > 0$$

whenever we are in region A. This implies that $\theta > \theta_{HHHL}(t_k)$ so that (H,L) is always dominated by (H,H).

Next consider region B. First compare (H,L) and (L,L) for $\theta < \theta_{LHLL}(t_k)$. From (11) we know that $(H,L) \succ (L,L)$ iff $\theta > \theta_{HLLL}(t_k)$. Direct calculations show that

$$\theta_{LHLL}(t_k) - \theta_{HLLL}(t_k) = -\frac{c(4 - 6c + 2c^2 - 10t_k + 9ct_k - 2t_k^2)}{2(1 - c - 2t_k)(1 - c + t_k)} < 0$$

i.e. $\theta_{LHLL}(t_k) < \theta_{HLLL}(t_k)$. This implies $\theta < \theta_{LHLL}(t_k) < \theta_{HLLL}(t_k)$ so that (H,L) is dominated by (L,L). Next compare (H,L) and (L,H) for $\theta_{LHLL}(t_k) < \theta < \theta_{HHLH}(t_k)$.

Recall that $(H,L) \succ (L,H)$ iff $\theta > \theta_{HLLH}(t_k)$, and $\theta_{HLLH}(t_k) > \theta_{HHLH}(t_k)$. This implies that (H,L) is never chosen over (L,H). Finally, for $\theta > \theta_{HHLH}(t_k)$ we need to compare (H,L) and (H,H), and we know that $(H,L) \succ (H,H)$ iff $\theta < \theta_{HHHL}(t_k)$. But it can then be shown that $\theta_{HHLH}(t_k) > \theta_{HHHL}(t_k)$ so that $\theta < \theta_{HHHL}(t_k)$ is impossible. This implies that (H,L) is always dominated by (H,H).

Finally consider region C. When $\theta < \theta_{HHLL}(t_k)$ we need to compare (H,L) and (L,L). We already know that $(H,L) \succ (L,L)$ iff $\theta > \theta_{HLLL}(t_k)$. Comparing $\theta_{HLLL}(t_k)$ and $\theta_{HHLL}(t_k)$ leads to

$$\theta_{HLLL}(t_k) - \theta_{HHLL}(t_k) = \frac{c(2c^2 - 7ct_k + 2t_k^2 + 10t_k - 4)}{2(2-t_k)(1-c+t_k)} < 0$$

for $t_k > \widehat{t}_k^2$ and

$$\widehat{t}_k^2 = \frac{7}{4}c - \frac{5}{2} + \sqrt{132 - 140c + 33c^2}$$

Moreover, it can be checked that $\widehat{t}_k^2 > \widehat{t}_k^1$ and $\widehat{t}_k^2 < t_k^p(L,H)$ iff $c < \overline{c}_2 = \frac{31}{44} - \frac{1}{44}\sqrt{697} \approx 0.10 < \frac{1}{4}$. This implies that when $\widehat{t}_k^2 < t_k < t_k^p(L,H)$, $(L,L) \succ (H,L)$ for $\theta < \theta_{HLLL}(t_k)$ while the converse is true over $\theta > \theta_{HLLL}(t_k)$. But (H,L) is not chosen when $\widehat{t}_k^1 < t_k < \widehat{t}_k^2$ and $c < \overline{c}_2$ or $\widehat{t}_k^1 < t_k < t_k^p(L,H)$ and $c > \overline{c}_2$.

Now assume $\theta > \theta_{HHLL}(t_k)$ and compare (H,L) and (H,H). We already know that $(H,H) \succ (H,L)$ iff $\theta > \theta_{HHHL}(t_k)$. Moreover, we have

$$\theta_{HHHL}(t_k) - \theta_{HHLL}(t_k) = \frac{c(2c^2 - 7ct_k + 2t_k^2 + 10t_k - 4)}{2(2-t_k)(1+c-2t_k)}$$

which is positive iff $t_k > \widehat{t}_k^3 = \widehat{t}_k^2$. This indicates that when $\widehat{t}_k^2 < t_k < t_k^p(L,H)$, $(H,L) \succ (H,H)$ for $\theta < \theta_{HHHL}(t_k)$ whereas the opposite holds for $\theta > \theta_{HHHL}(t_k)$. When $\widehat{t}_k^1 < t_k < \widehat{t}_k^2$ and $c < \overline{c}_2$ or $\widehat{t}_k^1 < t_k < \widetilde{t}_k^{LH}$ and $c > \overline{c}_2$, we must have (H,L) never chosen.

To summarize, (H,L) is only optimal over the range of $\theta_{HLLL}(t_k) < \theta < \theta_{HHHL}(t_k)$ when $\widehat{t}_k^2 < t_k < t_k^p(L,H)$. In other cases the equilibrium outcome is the same as that found in step 1 of the proof.

Proof of Lemma 3.

It is straightforward to check that $t_k^n(H,L)-t_k^n(L,L)=\frac{1}{3}\theta>0$; $t_k^n(H,L)-t_k^n(H,H)=\frac{1}{3}(c+2\theta)>0$ and $t_k^n(H,L)-t_k^n(L,H)=\frac{1}{3}c+\theta>0$. Hence $t_k^n(H,L)$ is the highest Nash tariff. Next, we have $t_k^n(L,L)-t_k^n(H,H)=\frac{1}{3}(c+\theta)>0$ and $t_k^n(L,L)-t_k^n(L,H)=\frac{1}{3}(c+2\theta)>0$. So $t_k^n(L,L)$ is the second highest. Also note that $t_k^n(H,H)-t_k^n(L,H)=\frac{1}{3}\theta>0$, implying that $t_k^n(H,H)$ is the third highest and $t_k^n(L,H)$ is the lowest Nash tariff.

Proof of Lemma 4.

We can calculate the differences between Nash and socially optimal tariffs as follows.

Under (H,H), we have $t_k^n(H,H)-t_k^{so}(H,H)=\frac{1}{3}(1-c)>0$.

Under (L,L), we have $t_k^n(L,L)-t_k^{so}(L,L)=\frac{4}{3}(1-2\theta)>0$ iff $\theta<\frac{1}{2}$. But we know $\theta<\frac{1}{2}$ is the condition under which t_k^n and t_k^{so} are non-prohibitive. Hence as long as tariffs are non-prohibitive, we have $t_k^n(L,L)>t_k^{so}(L,L)$.

Under (L,H), we have $t_k^n(L,H)-t_k^{so}(L,H)=\frac{4}{3}(1-4c+2\theta)>0$.

Under (H,L), we have $t_k^n(H,L)-t_k^{so}(H,L)=\frac{4}{3}(1+3c-4\theta)>0$ iff $\theta<\frac{1}{4}(1+3c)$. As with the case of (L,L), t_k^n and t_k^{so} are non-prohibitive iff $\theta<\frac{1}{4}(1+3c)$, under which we must have $t_k^n(H,L)>t_k^{so}(H,L)$.

Proof of Proposition 2.

Since $\frac{1}{4}+\frac{3}{4}c<\frac{1}{2}<1-c$, we need to examine four exhaustive and mutually exclusive intervals of θ: (i) when $\theta<\frac{1}{4}+\frac{3}{4}c$ and Nash tariffs are non-prohibitive and positive under all combinations of standards; (ii) when $\frac{1}{4}+\frac{3}{4}c<\theta<\frac{1}{2}$ and Nash tariffs are prohibitive under (H,L); (iii) when $\frac{1}{2}<\theta<1-c$ and Nash tariffs are prohibitive under (H,L) and (L,L); (iv) when $\theta>1-c$ and Nash tariffs are zero under (L,H) and prohibitive under (H,L) and (L,L).

(i) First consider $\theta<\frac{1}{4}+\frac{3}{4}c$ so that tariffs are non-prohibitive under all possible standards. Comparing (L,L) and (L,H), we have

$$\widehat{w}_k(t_k^n,L,H)-\widehat{w}_k(t_k^n,L,L)>0 \text{ if and only if } \theta>\theta_{LHLL}^n=c$$

where t_k^n represents the Nash tariff under the corresponding standards.[29] Hence (L,L)

[29]For example, t_k^n in $\widehat{w}_k(t_k^n,L,H)$ represents Nash tariff under (L,H).

is chosen for $\theta < \theta^n_{LHLL}$ and (L,H) is chosen for $\theta^n_{LHLL} < \theta < \frac{1}{4} + \frac{3}{4}c$. Next, compare (L,H) and (H,H) to obtain

$$\widehat{w}_k(t^n_k, H, H) - \widehat{w}_k(t^n_k, L, H) > 0 \text{ if and only if } \theta > \theta^n_{HHLH} = 4 + 2c - \sqrt{16 + 4c + 7c^2}$$

It can be checked that $\theta^n_{LHLL} < \theta^n_{HHLH} < \frac{1}{4} + \frac{3}{4}c$. Hence (L,H) is chosen for $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$ and (H,H) is chosen for $\theta > \theta^n_{HHLH}$.

Now let us incorporate (H,L) into the analysis. First, for $\theta < \theta^n_{LHLL}$ we need to compare (H,L) with (L,L). It can be shown that

$$\widehat{w}_k(t^n_k, H, L) - \widehat{w}_k(t^n_k, L, L) > 0 \text{ if and only if } \theta > \theta^n_{HLLL} = -\frac{4}{3} + c + \frac{1}{3}\sqrt{16 + 12c - 18c^2}$$

We can further show that $\theta^n_{LHLL} < \theta^n_{HLLL} < \frac{1}{4} + \frac{3}{4}c$. This implies that (L,L) always dominates (H,L) for $\theta < \theta^n_{LHLL}$. Then, for $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$ we need to compare (H,L) with (L,H), which yields the following result

$$\widehat{w}_k(t^n_k, H, L) - \widehat{w}_k(t^n_k, L, H) > 0 \text{ if and only if } \theta > \theta^n_{HLLH} = -1 + \frac{1}{3}c + \frac{1}{3}\sqrt{9 + 24c - 14c^2}$$

Since $\theta^n_{HLLH} > \theta^n_{HHLH}$, we know (H,L) is never chosen over (L,H). Next compare (H,L) with (H,H) over $\theta > \theta^n_{HHLH}$. We have

$$\widehat{w}_k(t^n_k, H, H) - \widehat{w}_k(t^n_k, H, L) = \frac{1}{9}(\theta - c)(c + 1 - 2\theta)$$

and

$$\frac{\partial[\widehat{w}_k(t^n_k, H, H) - \widehat{w}_k(t^n_k, H, L)]}{\partial \theta} = \frac{1}{9} - \frac{4}{9}\theta + \frac{1}{3}c > 0 \text{ for } \theta < \frac{1}{4} + \frac{3}{4}c$$

i.e. $\widehat{w}_k(t^n_k, H, H) - \widehat{w}_k(t^n_k, H, L)$ is increasing in θ. Moreover, we have $[\widehat{w}_k(t^n_k, H, H) - \widehat{w}_k(t^n_k, H, L)]|_{\theta = \theta^n_{HHLH}} > 0$, which implies that (H,H) dominates (H,L) for $\theta > \theta^n_{HHLH}$.

(ii) Consider $\frac{1}{4} + \frac{3}{4}c < \theta < \frac{1}{2}$, so that prohibitive tariff occurs under (H,L). We know that for θ in this range (H,H) must dominate (L,L) and (L,H). Moreover, we have $\widehat{w}_k(t^n_k, H, H) - \widehat{w}_k(t^n_k, H, L) = \frac{1}{72}(1-c)^2 > 0$ so that (H,H) dominates (H,L).

(iii) Consider $\frac{1}{2} < \theta < 1 - c$ so that prohibitive tariffs obtain under (H,L) and

(L, L). Applying the logic as in (ii), we know that (H, H) must still dominate all other combinations of standards.

(iv) Finally consider $\theta > 1 - c$ where Nash tariffs are zero under (L, H). In this case, we only need to check if (L, H) can dominate (H, H). But we have $[\widehat{w}_k(t_k^n, H, H) - \widehat{w}_k(t_k^n, L, H)]|_{\theta=1-c} = -\frac{7}{9}c - \frac{1}{9}c^2 + \frac{7}{18} > 0$ and $\frac{\partial[\widehat{w}_k(t_k^n,H,H) - \widehat{w}_k(t_k^n,L,H)]}{\partial\theta} = \frac{1}{3}(1+c) > 0$. This implies that (H, H) always dominates (L, H) for $\theta > 1 - c$.

Proof of Proposition 3.

Note that countries cannot choose (L, H) under NT. Hence let us consider two cases: $\theta < \frac{1}{2}$ and $\theta > \frac{1}{2}$. In the former case non-prohibitive tariffs are chosen under all combinations of standards, whereas in the latter they only occur under (L, L).

(i) Consider $\theta < \frac{1}{2}$. From the proof of part (i) of Proposition 2 we know that (H, L) is never optimal within this range of θ. Comparing (L, L) and (H, H), we have

$$\widehat{w}_k(t_k^n, H, H) - \widehat{w}_k(t_k^n, L, L) > 0 \text{ if and only if } \theta > \theta_{HHLL}^n = 5 - \sqrt{25 - 14c + 7c^2}$$

Since $\theta_{HHLL}^n - \frac{1}{2} < 0$, it follows that (L, L) and (H, H) are chosen for $\theta < \theta_{HHLL}^n$ and $\theta_{HHLL}^n < \theta < \frac{1}{2}$ respectively.

(ii) Consider $\theta > \frac{1}{2}$. In this case we have

$$\widehat{w}_k(t_k^n, H, H) - \widehat{w}_k(t_k^n, L, L) = \frac{1}{72} - \frac{7}{9}c + \frac{7}{18}c^2 + \frac{1}{2}\theta$$

which is increasing in θ. Moreover, it is readily checked that $[\widehat{w}_k(t_k^n, H, H) - \widehat{w}_k(t_k^n, L, L)]|_{\theta=\frac{1}{2}} = \frac{19}{72} - \frac{7}{9}c + \frac{7}{18}c^2 > 0$. This implies (H, H) is chosen for all $\theta > \frac{1}{2}$.

Proof of Proposition 5.

It can be checked that

$$\theta_{HHLL}^n - \theta_{LHLL}^n = 5 - c - \sqrt{25 - 14c + 7c^2} > 0$$

and

$$\theta^n_{HHLL} - \theta^n_{HHLH} = 1 - \sqrt{25 - 14c + 7c^2} + \sqrt{16 + 4c + 7c^2} < 0$$

for $c < \frac{1}{4}$, which implies $\theta^n_{LHLL} < \theta^n_{HHLL} < \theta^n_{HHLH}$.

Now consider alternative values of θ. When $\theta < \theta^n_{LHLL}$ and $\theta > \theta^n_{HHLH}$, both the UC and the NT regimes yield identical equilibrium outcome and thus equal welfare. For $\theta^n_{LHLL} < \theta < \theta^n_{HHLL}$, (L, H) and (L, L) obtain under UC and NT respectively. Thus we can calculate

$$\widehat{ww}(t^n_k, L, H) - \widehat{ww}(t^n_k, L, L) = \frac{17}{81}(1 - 2c)(\theta - c)$$

which is increasing in θ. Moreover, recall that $[\widehat{ww}(t^n_k, L, H) - \widehat{ww}(t^n_k, L, L)]|_{\theta=\theta^n_{LHLL}} = 0$, which implies that welfare is higher under (L, H) for all $\theta^n_{LHLL} < \theta < \theta^n_{HHLL}$.

When $\theta^n_{HHLL} < \theta < \theta^n_{HHLH}$, (L, H) and (H, H) obtain under UC and NT respectively. It can then be shown that

$\widehat{ww}(t^n_k, L, H) - \widehat{ww}(t^n_k, L, H) > 0$ if and only if $\theta > \theta^{nw}_{HHLH} = \frac{32}{17} + 2c - \frac{1}{17}\sqrt{1024 + 544c + 1105c^2}$

It can be further checked that

$$\theta^{nw}_{HHLH} - \theta^n_{HHLL} = -\frac{53}{17} + 2c - \frac{1}{17}\sqrt{1024 + 544c + 1105c^2} + \sqrt{25 - 14c + 7c^2} > 0$$

and

$$\theta^{nw}_{HHLH} - \theta^n_{HHLH} = -\frac{36}{17} - \frac{1}{17}\sqrt{1024 + 544c + 1105c^2} + \sqrt{16 + 4c + 7c^2} < 0$$

Hence welfare is higher under (L, H) for $\theta^n_{HHLL} < \theta < \theta^{nw}_{HHLH}$ and under (H, H) for $\theta^{nw}_{HHLH} < \theta < \theta^n_{HHLH}$. In sum, we have shown that UC and NT dominate over $\theta^n_{LHLL} < \theta < \theta^{nw}_{HHLH}$ and $\theta^{nw}_{HHLH} < \theta < \theta^n_{HHLH}$ respectively.

Proof of Proposition 6.

First consider the UC regime. For $\theta > \theta^n_{HHLH}$ the equilibrium standards are (H, H). Since this is the case with zero externality produced, optimal tariffs are zero. Hence an FTA necessarily improves world welfare for all $\theta > \theta^n_{HHLH}$. Next consider $\theta^n_{LHLL} <$

$\theta < \theta^n_{HHLH}$ over which the equilibrium is (L, H). The welfare change due to the FTA is given by

$$\widehat{ww}(0, L, H) - \widehat{ww}(t^n_k, L, H) = \frac{1}{162}(1 - c - \theta)(7 - 31c + 17\theta)$$

It is easy to check $\widehat{ww}(0, L, H) - \widehat{ww}(t^n_k, L, H)$ is increasing in θ for $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$. Moreover, we have $[\widehat{ww}(0, L, H) - \widehat{ww}(t^n_k, L, H)]|_{\theta=\theta^n_{LHLL}} = \frac{7}{162}(1 - 2c)^2 > 0$, which implies that $\widehat{ww}(0, L, H) - \widehat{ww}(t^n_k, L, H) > 0$ for all $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$. Now for $\theta < \theta^n_{LHLL}$ we have (L, L) as the equilibrium so that the FTA induced welfare change is

$$\widehat{ww}(0, L, L) - \widehat{ww}(t^n_k, L, L) = \frac{1}{162}(1 + \theta)(7 - 17\theta)$$

It is readily checked that $\widehat{ww}(0, L, L) - \widehat{ww}(t^n_k, L, L)$ is decreasing in θ and $[\widehat{ww}(0, L, L) - \widehat{ww}(t^n_k, L, L)]|_{\theta=\theta^n_{LHLL}} = \frac{1}{162}(1 + c)(7 - 17c) > 0$. This indicates that $\widehat{ww}(0, L, L) - \widehat{ww}(t^n_k, L, L) > 0$ for all $\theta < \theta^n_{LHLL}$.

Now let us examine the NT regime. First note that an FTA must improve welfare for $\theta > \theta^n_{HHLH}$ and $\theta < \theta^n_{LHLL}$, as NT induces the same equilibrium as UC over these ranges of θ. So we only need to consider $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$. When $\theta^n_{HHLL} < \theta < \theta^n_{HHLH}$ NT induces (H, H) so that no externalities are produced, which implies that welfare must improve as tariffs fall to zero. Next consider $\theta^n_{LHLL} < \theta < \theta^n_{HHLL}$ where NT induces (L, L). It is readily shown that $\widehat{ww}(0, L, L) - \widehat{ww}(t^n_k, L, L)$ is decreasing in θ also for $\theta^n_{LHLL} < \theta < \theta^n_{HHLL}$. Moreover, we have $[\widehat{ww}(0, L, L) - \widehat{ww}(t^n_k, L, L)]|_{\theta=\theta^n_{HHLL}} = \frac{1}{162}(6 - \sqrt{7c^2 - 14c + 25})(17\sqrt{7c^2 - 14c + 25} - 78) > 0$ for $c < \frac{1}{4}$. Hence an FTA increases world welfare for all $\theta^n_{LHLL} < \theta < \theta^n_{HHLL}$.

Proof of Proposition 7.

First consider UC. As Figure 3 shows, when $\theta^n_{LHLL} < \theta < \theta^n_{HHLH}$ and $\theta > \theta^f_{HHLH}$, both free trade and Nash tariffs yield the same equilibrium outcome (e.g. (L, H) and (H, H) respectively) and thus equal global welfare. For $\theta < \theta^n_{LHLL}$, we need to compare (L, H) under free trade with (L, L) under Nash tariffs. This leads to

$$\widehat{ww}(0, L, H) - \widehat{ww}(t^n_k, L, L) = \frac{7}{162} - \frac{4}{9}c + \frac{11}{18}c^2 + \frac{22}{81}\theta - \frac{1}{3}c\theta - \frac{17}{162}\theta^2$$

which can be checked to increase in θ for $\theta < \theta^n_{LHLL}$. It can then be solved that

$\widehat{ww}(0,L,H) - \widehat{ww}(t_k^n,L,L) > 0$ iff $\theta > \frac{1}{17}(22 - 3\sqrt{67} - 27c + 6\sqrt{67}c)$. In particular, $\frac{1}{17}(22 - 3\sqrt{67} - 27c + 6\sqrt{67}c) > 0$ iff $c > 0.12$. Hence (L,H) dominates (L,L) for all $\theta < \theta^n_{LHLL}$ when $c < 0.12$ but only for $\frac{1}{17}(22 - 3\sqrt{67} - 27c + 6\sqrt{67}c) < \theta < \theta^n_{LHLL}$ when $c > 0.12$. Next consider $\theta^n_{HHLH} < \theta < \theta^f_{HHLH}$ where we need to compare (L,H) under free trade and with (H,H) under Nash tariffs. To this end, we have

$$\widehat{ww}(0,L,H) - \widehat{ww}(t_k^n,H,H) = \frac{7}{162} + \frac{29}{81}c + \frac{17}{81}c^2 - \frac{1}{3}\theta - \frac{1}{3}c\theta$$

which is decreasing in θ. It follows that (L,H) dominates (H,H) iff $\theta < \frac{7+58c+34c^2}{54(1+c)}$. In particular, $\theta^n_{HHLH} < \frac{7+58c+34c^2}{54(1+c)} < \theta^f_{HHLH}$ iff $c > 0.18$. This implies that (L,H) dominates (H,H) for all $\theta^n_{HHLH} < \theta < \theta^f_{HHLH}$ when $c < 0.18$, but only for $\theta^n_{HHLH} < \theta < \frac{7+58c+34c^2}{54(1+c)}$ when $c > 0.18$.

Finally, consider the case of NT. As shown in Figure 4, the equilibrium outcome differs between free trade and Nash tariffs only for $\theta^f_{HHLL} < \theta < \theta^n_{HHLL}$. Over this range of θ, we have (L,L) under Nash tariffs and (H,H) under free trade. It follows that

$$\widehat{ww}(0,H,H) - \widehat{ww}(t_k^n,L,L) = \frac{7}{162} - \frac{8}{9}c + \frac{4}{9}c^2 + \frac{49}{81}\theta - \frac{7}{162}\theta^2$$

which is increasing in θ over $\theta^f_{HHLL} < \theta < \theta^n_{HHLL}$. It can be further solved that $\widehat{ww}(0,H,H) - \widehat{ww}(t_k^n,L,L) > 0$ iff $\theta > \frac{1}{17}(49 - 6\sqrt{70 - 68c + 34c^2})$. Now compare $\frac{1}{17}(49 - 6\sqrt{70 - 68c + 34c^2})$ with θ^f_{HHLL} to obtain that $\frac{1}{17}(49 - 6\sqrt{70 - 68c + 34c^2}) > \theta^f_{HHLL}$ iff $c > 0.16$. This indicates that for $c < 0.16$, (H,H) under free trade dominates (L,L) under Nash tariffs over all $\theta^f_{HHLL} < \theta < \theta^n_{HHLL}$. But for $c > 0.16$, we have (H,H) under free trade dominates (L,L) under Nash tariffs only for $\frac{1}{17}(49 - 6\sqrt{70 - 68c + 34c^2}) < \theta < \theta^n_{HHLL}$ and the opposite holds for $\theta^f_{HHLL} < \theta < \frac{1}{17}(49 - 6\sqrt{70 - 68c + 34c^2})$.

Taking the above results together, we see that the sufficient condition for an FTA to improve global welfare under both policy regimes is $c < 0.12$.

Proof of Proposition 8.

To prove part (i) of the proposition, assume standards are fixed. Then under Nash tariffs, NT dominates UC for $\theta^{nw}_{HHLH} < \theta < \theta^n_{HHLH}$, whereas UC performs better for

$\theta^n_{LHLL} < \theta < \theta^{nw}_{HHLH}$. Hence we can calculate the relative effectiveness of NT as

$$r^n = \frac{\theta^n_{HHLH} - \theta^{nw}_{HHLH}}{\theta^{nw}_{HHLH} - \theta^n_{LHLL}}$$

Now let us compare global welfare under the two policy regimes after the formation of an FTA. As Figure 2 shows, when $\theta^n_{LHLL} < \theta < \theta^n_{HHLL}$, UC induces (L, H) whereas NT induces (L, L). Thus we have

$$\widehat{ww}(0, L, H) - \widehat{ww}(0, L, L) = -\frac{4}{9}c + \frac{11}{18}c^2 + \frac{1}{3}\theta - \frac{1}{3}c\theta$$

which is increasing in θ. It follows that $\widehat{ww}(0, L, H) - \widehat{ww}(0, L, L) > 0$ iff $\theta > \theta^{fw}_{LHLL} = \frac{c(8-11c)}{6(1-c)}$. Moreover, it is readily checked that $\theta^n_{LHLL} < \theta^{fw}_{LHLL} < \theta^n_{HHLL}$, which indicates UC dominates over $\theta^{fw}_{LHLL} < \theta < \theta^n_{HHLL}$ while NT dominates over $\theta^n_{LHLL} < \theta < \theta^{fw}_{LHLL}$.

Next consider $\theta^n_{HHLL} < \theta < \theta^n_{HHLH}$ over which UC induces (L, H) and NT yields (H, H). We can calculate that

$$\widehat{ww}(0, L, H) - \widehat{ww}(0, H, H) = \frac{4}{9}c + \frac{1}{6}c^2 - \frac{1}{3}\theta - \frac{1}{3}c\theta$$

which is decreasing in θ. It follows that $\widehat{ww}(0, L, H) - \widehat{ww}(0, H, H) > 0$ iff $\theta < \theta^{fw}_{HHLH} = \frac{c(8+3c)}{6(1+c)}$. Moreover, it can be shown that $\theta^{fw}_{HHLH} < \theta^n_{HHLL}$ so that NT dominates over all $\theta^n_{HHLL} < \theta < \theta^n_{HHLH}$.

In sum, we have shown that under free trade, UC dominates over $\theta^{fw}_{LHLL} < \theta < \theta^n_{HHLL}$ whereas NT yields higher welfare over $\theta^n_{LHLL} < \theta < \theta^{fw}_{LHLL}$ and $\theta^n_{HHLL} < \theta < \theta^n_{HHLH}$. Hence the relative effectiveness of NT can be calculated as

$$r^f_1 = \frac{\theta^{fw}_{LHLL} - \theta^n_{LHLL} + \theta^n_{HHLH} - \theta^n_{HHLL}}{\theta^n_{HHLL} - \theta^{fw}_{LHLL}}$$

To identify how r changes from Nash tariffs to free trade, we can calculate the ratio between r^f_1 and r^n. It follows that as c drop from $1/4$, r^f_1/r^n increases monotonically from 34.85, which indicates that it is always above 1. This implies that the relative effectiveness of NT rises under free trade as compared to under Nash tariffs.

Now assume standards adjust after the formation of the FTA. In this case, the relative effectiveness of NT under Nash tariffs remains to be r^n. Under free trade, Costinot (2008) shows that NT dominates over two intervals of θ: $\theta < \theta^f_{HHLL}$ and $\theta^{fw}_{HHLH} < \theta < \theta^f_{HHLH}$. On the other hand, UC dominates over $\theta^f_{HHLL} < \theta < \theta^{fw}_{HHLH}$. Hence the effectiveness of NT can be calculated as

$$r^f_2 = \frac{\theta^f_{HHLL} + \theta^f_{HHLH} - \theta^{fw}_{HHLH}}{\theta^{fw}_{HHLH} - \theta^f_{HHLL}}$$

One can check that as c drops from 1/4, r^f_2/r^n increases monotonically from 71.58 and therefore is always above 1. This indicates that the effectiveness of NT relative to UC is greater under free trade.

Finally, to show how adjustment in standards may affect the effectiveness of NT, we can take the difference between r^f_1 and r^f_2. It is easy to check that

$$r^f_2 - r^f_1 > 0 \text{ iff } c < 0.11$$

which implies that adjustment in standards increases the effectiveness of NT iff $c < 0.11$.

10 Appendix C: trade coordination with socially optimal tariffs

This section examines trade coordination that reduces internal tariffs to the socially optimal levels which can be positive for certain levels of θ. When standards are fixed, it is straightforward that such coordination necessarily improves world welfare because Nash tariffs are too high. Moreover, the welfare gains from the coordination must be greater under NT as it induces higher Nash tariffs than UC. It follows that trade coordination must increase the effectiveness of NT.

Now consider the case where standards can adjust. Given that the general structure of the equilibrium standards is rather complex, we analyze two scenarios of small and large compliance costs, i.e. when $c = 0.05$ and $c = 0.25$. The results remain qualitatively the same for alternative values of c. First consider $c = 0.05$. It can be shown that under

UC, equilibrium standards with trade coordination are (L, H) for $\theta < 0.09$, (H, H) for $0.09 < \theta < 0.24$ and (H, L) for $\theta > 0.24$. On the other hand, standards under NT are the same as that under UC for $\theta > 0.09$ as these policy choices comply with non-discrimination. For $\theta < 0.09$, countries can no longer choose (L, H) and nationally optimal standards are (L, L). Comparing UC and NT for $\theta < 0.09$, we have NT yields higher welfare if and only if $\theta < 0.06$, which implies that r equals 2.24. This is greater than the effectiveness of NT under Nash tariffs which is 0.01.

When $c = 0.25$, equilibrium outcomes under globally optimal tariffs are qualitatively similar. It can be shown that standards under the two regimes differ for $\theta < 0.37$, with UC performing better for $0.21 < \theta < 0.29$ and NT dominating for $\theta < 0.21$ and $0.29 < \theta < 0.37$. We can then calculate that r equals 4.20 and 0.05 under globally optimal and Nash tariffs respectively. It follows that trade coordination makes NT more effective.

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