Tariffs, Product Standards, and National Treatment at the WTO

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July, 2022

Abstract

This paper studies (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. This implies that NT may not improve welfare even when countries can choose their tariffs, and the welfare justification of NT is stronger when tariffs are constrained. These results suggest that the WTO's success in tariff liberalization can strengthen the case for its NT-based approach to product standards.

Keywords: Tariffs, product standards, consumption externalities, welfare, national treatment, WTO. *JEL Classifications*: F12, F13, L51.

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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). While the documented policy substitution may serve legitimate purposes such as protecting public safety, it can also be protectionist (Grundke and Moser, 2019). As a result, tariff liberalization can make product standards unjustifiably discriminatory against foreign firms.

Tariff liberalization is also associated with certain trade disputes over product standards.[1] 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). As another example, Ecuador brought its concern to the WTO in 2008 about the EU's excessive phytosanitary measures with respect to Ethephon, particularly that contained in pineapple which is a major product Ecuador exports to the EU. This concern was noted shortly after the accession of Romania to the EU which would reduce the country's tariff on Ecuadorian pineapple from 23.3% to zero. Such anecdotal observations might not imply causality, but they can echo the concern that tariff liberalization could engender greater discrimination in product standards.

To combat unjustifiably discriminatory product standards, the WTO and various FTAs adopt national treatment (NT) as one of their core institutional arrangements.[2]

[1] Trade disputes over national regulations are often about potentially discriminatory regulatory standards. For instance, the great majority of disputes under the WTO regarding national regulations involve complaints about excessive regulation by importing nations (Staiger and Sykes, 2011).

[2] For instance, NT is the core principle of all the trade agreements administered by the WTO,

In short, NT is a non-discrimination rule requiring that countries treat foreigners no worse than their own nationals.[3] The welfare impact of NT in product standards has been examined by previous studies which assume standards are the only policy instrument available in the toolkit. However, countries in practice normally 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.[4] 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 responses 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 theoretical 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 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 linkages between them remain poorly understood.

Methodologically, we introduce endogenous tariffs into a reciprocal dumping model of quality standards. Firms from different countries sell a homogeneous good across

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.

[3] 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."

[4] 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%.

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.[5] Examples of such type of standards include sanitary and phytosanitary measures as well as emission standards on vehicles. To address the main questions of the paper, we first analyze the case where only one policy measure (e.g. 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 assume 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. We define the welfare performance of NT as world welfare under NT relative to that under the unconstrained product standard regime (UC) where NT is absent.

The analysis starts by characterizing the impact of tariff changes on countries' choices of product standards. We show that tariff reductions lead countries to tighten their standards on foreign firms. This occurs because tariffs and product standards in our model serve two common purposes. One is the strategic purpose of shifting profits from foreign to domestic firms. The other is the legitimate purpose of containing negative consumption externalities. As tariff reductions make foreign firms more competitive, the strategic incentive leads countries to tighten the standards on imports in order to retain their firms' profits. Meanwhile, falling tariffs can raise low quality imports, which also calls for imposing stricter standards on foreign firms. Second, tariff reductions can induce countries to loosen the standards on their own firms. On one hand, this is driven by the strategic motive: given stronger foreign competition, relaxing the standards for domestic firms helps retain their profits. On the other hand, lowering the standards on domestic firms gives rise to higher local externalities. It turns out that the strategic motive dominates so that countries end up deregulating their own firms.

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

We next analyze how a country's product standards may affect its tariff. To this end, we solve for non-cooperative (Nash) tariffs and show that they fall as countries' standards become more discriminatory against foreign firms. This suggests that there can exist two-way substitution between a country's tariff and standards (in terms of the policy toughness on foreign firms). Notably, our analysis indicates that such policy substitution may not necessarily be protectionist and can arise from legitimate purposes such as curtailing consumption externalities. We then solve for globally optimal tariffs that maximize world welfare and show that they are lower than Nash tariffs due to the strategic consideration of countries. This implies that countries would benefit from mutual tariff reductions provided standards remain unchanged.

We then address the key question about how the welfare justification of NT may depend on endogenous tariff barriers. To this end, we assume countries to choose both tariffs and standards and compare the welfare performance of NT under two scenarios: non-cooperative tariffs and an FTA that removes countries' tariffs on each other. In the former scenario, we show that imposing NT does not necessarily raise welfare even if countries can also choose their tariffs. Moreover, NT induces higher equilibrium tariffs than UC as standards under NT are less tough on foreign firms. This implies that the welfare gains from eliminating tariffs tend to be greater under NT, a mechanism that plays the key role in shaping the welfare implications of NT. In the second scenario, an FTA unambiguously improves world welfare regardless of NT provided product standards remain unchanged. When standards can adjust, however, an FTA may lower welfare for high compliance costs. This is because the removal of tariff barriers induces countries to strategically tighten the standards on imports, of which the efficiency losses can dominate the gains from tariff reductions if the compliance cost is high. Importantly, this result indicates that tariff liberalization may not guarantee welfare improvement if countries can adjust their behind-the-border measures such as product standards.

Finally, we compare the welfare performance of NT before and after the FTA. The key result is that an FTA improves the welfare justification of NT whether standards are flexible or not. When standards are fixed, NT performs relatively better under an FTA because it yields greater tariff reductions and thus larger welfare gains as compared to UC. When standards are flexible, the adjustment in standards has an ambiguous effect

on the performance of NT. Nevertheless, the welfare gains from tariff reductions always dominate so that an FTA necessarily improves the performance of NT. The key intuition for this result is that tariffs in our model are less effective than standards for curtailing large consumption externalities, so when tariffs are unconstrained, their substitution for standards induced by NT tends to be welfare-reducing. Importantly, this insight suggests a novel benefit of tariff liberalization — it not only produces welfare gains per se but also can improve the case for NT in product standards. Our analysis thus lends support to the institutional design of the WTO by identifying a positive linkage between two of its fundamental rules: tariff liberalization and NT. More generally, our analysis implies that a holistic approach is important to the design of product standard agreements: when countries can strategically employ multiple policy measures, the gains from policing product standards would depend on the rules set for the related policy instruments.

We further demonstrate that our results are robust under various extensions of the model. This is because our analysis hinges on two empirically grounded premises. One is that product standards and tariffs serve common objectives (e.g. reducing externalities and shifting profits). This renders the two policy measures substitutable for each other. The other premise is that product standards are more efficient than tariffs in combatting sizable consumption externalities. This drives the result that the tariff increases induced by the implementation of NT tend to undermine welfare, which explains why tariff liberalization can strengthen the case for NT. As these premises are not specific to our model specification, the results of the paper would remain in more general settings.

The policy substitution between tariffs and non-tariff measures (NTMs) has been documented by extensive empirical research (e.g. Kee et al., 2009; Orefice, 2017; Herghelegiu, 2018; Beverelli et al., 2019; Niu et al., 2020).[6] Our paper provides a theoretical characterization of this empirical pattern and shows that it can arise in oligopolistic markets with negative consumption externalities. Moreover, we identify novel normative implications of the observed policy interdependence: on one hand, the welfare justification of NT can be weakened by the substitution of tariffs for standards;

[6] Earlier papers obtaining similar findings include Ray (1981), Gawande (1999), Eliste and Fredriksson (2002) and Ederington and Minier (2003).

on the other hand, the welfare gains from tariff reductions may also be undermined by the induced adjustment in product standards.

This paper contributes to the theoretical literature that analyzes the policy linkage between tariffs and regulatory standards (Bagwell and Staiger, 2001; Ederington, 2001; Grossman et al., 2021; Mei, 2021; Rebeyrol, 2022). Our paper differs from this literature in several aspects. First, previous studies mainly consider exogenous tariffs and their impact on product standards. By incorporating endogenous tariff policy, we are able to examine mutual policy interaction between standards and tariffs, as well as how such interaction may affect the welfare justification of NT.[7] Second, the literature focuses on product markets that are perfectly or monopolistically competitive. This implies that the strategic incentives of countries are mainly driven by terms-of-trade manipulation or firm delocation.[8] The present paper complements the literature by examining another major type of market structure with oligopolistic firms. The key strategic incentive in this case is profit-shifting from foreign to domestic firms.

This paper also relates to a large literature on strategic product standards in the open economy (e.g. Barrett, 1994; Boom, 1995; Fischer and Serra, 2000; Gandal and Shy, 2001; Klimenko, 2009; Maggi and Ossa, 2022). Some papers from this literature pay particular attention to the welfare effect of NT in product standards (e.g. Battigalli and Maggi, 2003; Costinot, 2008; Gulati and Roy, 2008; Staiger and Sykes, 2011; Edwards, 2012; Ferrara et al. 2019; Geng, 2019; Mei, 2021; Rebeyrol, 2022).[9] 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 linkage between tariff liberalization and NT as two pillars of the WTO.[10]

[7] This of course comes at a cost. We have to focus on a partial equilibrium model in order to tractably characterize equilibrium tariffs and standards. By contrast, previous work has adopted a general equilibrium approach which allows for identifying interesting general equilibrium effects of policy reforms.

[8] Rebeyrol (2022) introduces firm heterogeneity and shows that it can create a new strategic incentive which is shifting profits from less to more productive firms within sectors.

[9] 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.

[10] This paper also contributes to the studies that examine the effect of tariff barriers on the implications

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 the variable compliance cost. For simplicity, our benchmark model abstracts from fixed compliance costs which also have great empirical relevance. We will discuss the importance case of fixed compliance costs 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

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

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 important form of NTMs. A robust insight yielded by these studies including ours is that tariff liberalization is conducive to the welfare justification of NT.

[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 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

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

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

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

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

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 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:

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

[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.

Again, it is useful to decompose ww into two parts, each of which is affected by one country's policies alone. 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 the appendix. 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, $\sigma_{k\widetilde{k}}$. 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] Note that 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 tariffs 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 the domestic 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. 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.[17] 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.[18]

Proposition 1 has direct empirical implications. First, part (i) of the proposition is consistent with the ample evidence on the substitution of NTMs for tariff barriers (e.g. Ray, 1981; Kee et al., 2009; Orefice, 2017; Beverelli et al., 2019; Niu et al., 2020). Importantly, our analysis suggests that such policy substitution can be driven not only by protectionism but also by the legitimate purpose of containing negative consumption externalities. In this way, the discriminatory adjustment in standards due to tariff reductions may not necessarily be welfare-reducing, an implication consistent with the finding in Rebeyrol (2022). Second, part (ii) of the proposition implies that countries

[17] This can be easily 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.

[18] 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.

may respond to trade 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

Proposition 1 indicates that with tariff reductions, countries have an incentive to adjust either of their standards conditioning on the other. We now allow countries to simultaneously choose both of their standards. The following lemma summarizes each country's policy decision:

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' standards indeed become more discriminatory against foreign firms as their tariffs fall. This can been seen from Figure 1 which depicts the regions of the (t_k, c) space over which different equilibrium standards arise. First consider the case of extremely high tariffs (e.g. part (iv) of the lemma) which corresponds to region D in Figure 1. In this region, countries may actually enforce adverse discrimination by choosing (H, L). This is because the draconian tariffs make import competition too low, which needs to be countervailed by more favorable standards on foreign firms. When tariffs fall to intermediate levels as in region C, import competition rises to the extent that it becomes optimal for countries to impose identical standards on firms. Lastly, when tariffs are low as in region A and B, (L, H) becomes optimal for countries in order to curb the higher levels of import competition and imported externalities.

Lemma 2 is a formal representation of the concern that tariff liberalization can give rise to more discriminatory product standards against foreign producers. The lemma has several notable implications. First, it indicates that tariff liberalization indeed makes NT more necessary for achieving non-discrimination in product standards. Second, 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 the introduction (e.g. Chines honey exports to the EU). Third, Lemma 2 echoes Horn (2006) and Geng and Saggi (2022) who study NT in government taxation and intellectual property (IP) protection respectively. These papers show that tariff reductions can lead countries to choose more discriminatory taxes or IP protection against foreign firms. Our analysis indicates that this pattern of policy response can also occur when the internal measure is product standards.

4 Endogenous tariffs and exogenous standards

In this section, we analyze countries' 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 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, conditional on their product standards.[19] 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 also 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

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

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

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

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

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. A corollary of this result is that $t_k^n(L, H) = 0$ 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 properties of Nash and globally optimal tariffs can be complex depending on the level as well as the origin of the negative consumption externality. Now compare Nash tariffs under different product 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.[20] An important implication is that countries may use tariffs as a policy substitute for product standards. Thus, Lemmas 2 and 3 together imply that the policy substitution between tariffs and standards can be mutual. We can further compare Nash and globally optimal tariffs to obtain the following important 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

[20] 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.

of the product standards.[21] Importantly, Lemma 4 suggests that there exist potential welfare gains from trade 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.

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 as well as 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.

[21] 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.

Proposition 2 suggests that discriminatory standards (i.e. (L, H)) can be persistent in the sense that it can arise in equilibrium even when countries have the tariff instrument at their disposal. This implies that tariffs are not a perfect substitute for product standards from each country's point of view. The intuition for this result is the following. When externalities are small, countries view tariffs as more efficient than standards for controlling the externalities of foreign goods, because tariffs can be fine-tuned without significantly reducing imports. When externalities are large, however, reducing imported externalities calls for extremely high tariffs which can significantly lower imports and dampen domestic market competition. In this case, imposing the strict standard on foreign firms is less costly: it eliminates the externalities from foreign goods without stifling imports. As expected, this mechanism hinges on the condition that standards are more effective than tariffs for controlling high-level externalities. Such a condition is ensured by our assumption that the compliance cost c does not increase with the level of the consumption externality.[22] The condition can be justified by the fact that product standards are design specifically for addressing negative consumption externalities but tariffs are not. Particularly, the cost of meeting certain standards can decline to feasible levels because of technological progress. By contrast, tariffs can only lower consumption externalities from foreign goods via proportionally reducing the quantities of imports.

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)*.*

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

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 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 simply due to the policy substitution effect between tariffs and standards shown in 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 other policy measures such as 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 NT only improves world welfare for relatively large externalities. The intuition for this result is the following. 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. 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. Importantly, Proposition 5 implies that implementing NT in product standards does ensure welfare gains as it does not eliminate the strategic incentives of countries. Costinot (2008) establishes this result under free trade. Here we show that the result remains true when countries can set import tariffs as an additional policy instrument.[23]

[23]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.

5.1 Impact of tariff liberalization

We now examine how the welfare performance of NT may depend on the availability of the tariff instrument. Specifically, we consider two major forms of trade coordination between countries that lower their tariff barriers on each other. One is an 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 section 6.4. Also note that the insights yielded by our analysis should apply well to the WTO although it is not an 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 entering into an FTA. In the first scenario countries do not change their standards following the tariff reductions under the FTA; in the second, countries can reoptimize their standards. There are two important reasons for differentiating between these two scenarios. First, whether standards are adjustable may capture the time horizon. In particular, the equilibrium that obtains under fixed standards can be considered as the short-run outcome of an FTA, while that under flexible standards may reflect the FTA's long-run impact. Second, the long-run consequence of an 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 an FTA must be due to the elimination of tariffs. As mentioned earlier, since globally optimal tariffs can be positive for large θ, an 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 bringing about "overshooting" in tariff reductions, an FTA unambiguously improves welfare:

Proposition 6: *Suppose countries form an 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, an FTA that simply removes all tariffs between countries can ensure welfare improvement (provided standards are fixed).

Now consider the second scenario where product standards are reoptimized after an FTA is formed. 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 do 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 entering into an FTA. Then:*

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

(ii) Under NT, an 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, an FTA improves world welfare for all levels of the externality provided the compliance cost is small, i.e. $c < 0.12$*. When* $c > 0.12$*, an 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 with and without the FTA when the policy regimes are UC and NT respectively.

Part (i) of Proposition 7 describes how standards under UC may adjust to the formation of an FTA. Particularly, 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 under NT, free trade makes countries more likely to raise their standards on both firms. 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 channel turns out to dominate so that countries end up enforcing higher standards on both firms. Notably, Proposition 7 suggests 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 coordination over border measures such as import tariffs. This result echoes that from recent research such as Berti and Falvey (2018).[24] Intuitively, although an FTA can generate welfare gains by eliminating internal tariff barriers, 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 an 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

[24] 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.

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.[25] Applying r to the analysis, we can show the following important proposition regarding how tariff liberalization may affect the effectiveness of NT:

Proposition 8: *(i) When product standards are held fixed, the tariff reductions mandated by an FTA make NT more effective.*

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

(iii) Even if product standards can adjust, an FTA makes NT more effective.

Proof: see the appendix.

Part (i) and (ii) of Proposition 8 identify two channels through which an FTA 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 indicates that as the FTA eliminates the tariff barriers, the adjustment in standards under NT may not necessarily be 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

[25] 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 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.

of NT. Hence, part (iii) establishes a novel benefit of tariff liberalization: it can improve the welfare gains from enforcing NT in product standards. Importantly, this result is in support of the institutional arrangements of the WTO and many FTAs. These trade agreements adopt NT as a core approach to product standards; meanwhile, they set tariff bounds or eliminate 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 in the paper but is not necessary for obtaining the main results. This is because our main findings hinge on two empirically relevant premises. On one hand, the policy substitution effect is driven by the premise that tariffs and standards serve common objectives. On the other hand, the effect of tariff liberalization on the welfare performance of NT is due to standards being more effective than tariffs for addressing large negative consumption externalities. Specifically, it can be checked that these premises are robust under various extensions such as multiple countries, multiple firms from each country, ad-valorem tariffs, etc. That being said, below we further discuss several other 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.

6.4 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.

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 the 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.[26]

8 Appendix A: supporting calculation results

Equilibrium sales and prohibitive tariffs

[26] 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.[27] Hence (L,L)

[27]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 $c < 0.11$.

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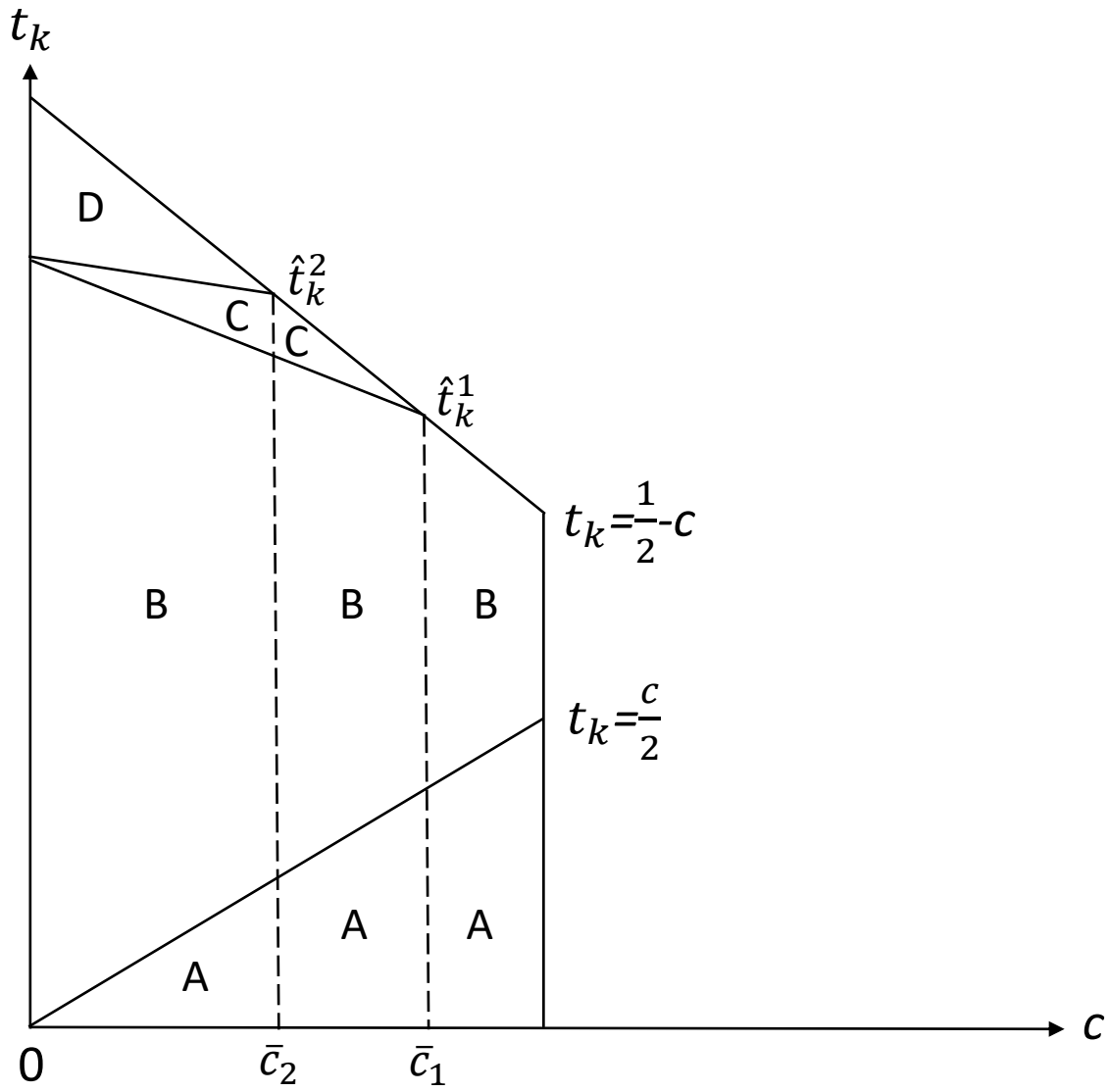

Figure 1: Equilibrium outcome under exogenous tariffs (Lemma 2)

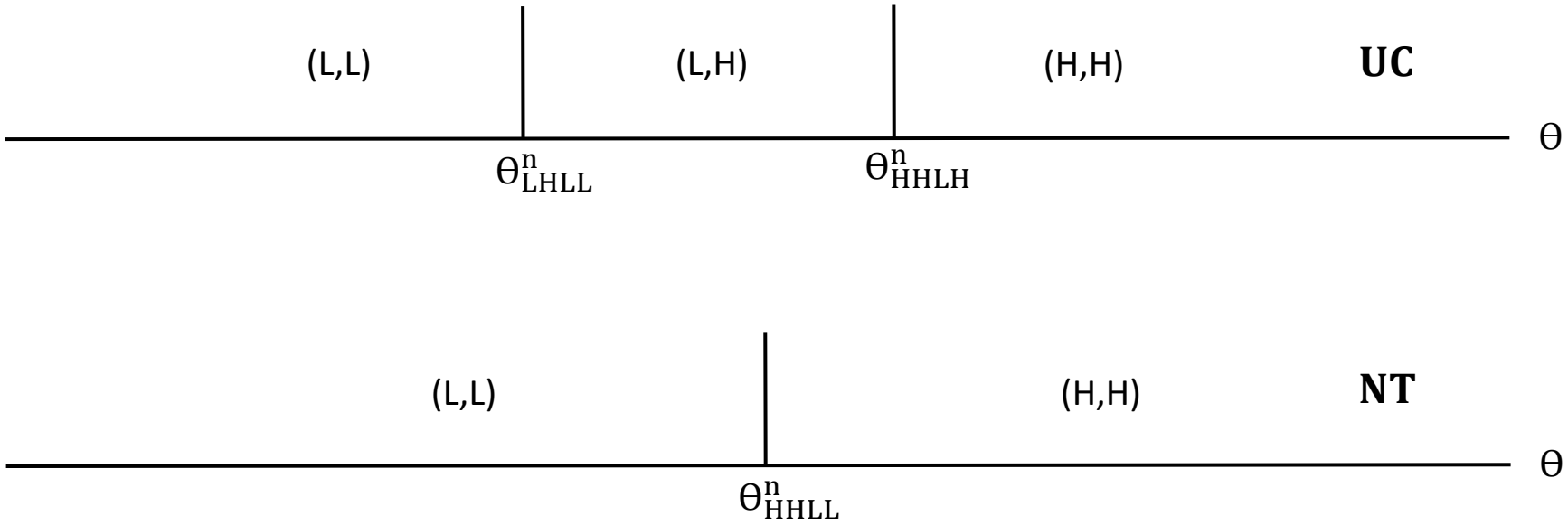

Figure 2: Equilibrium standards under UC and NT given Nash tariffs

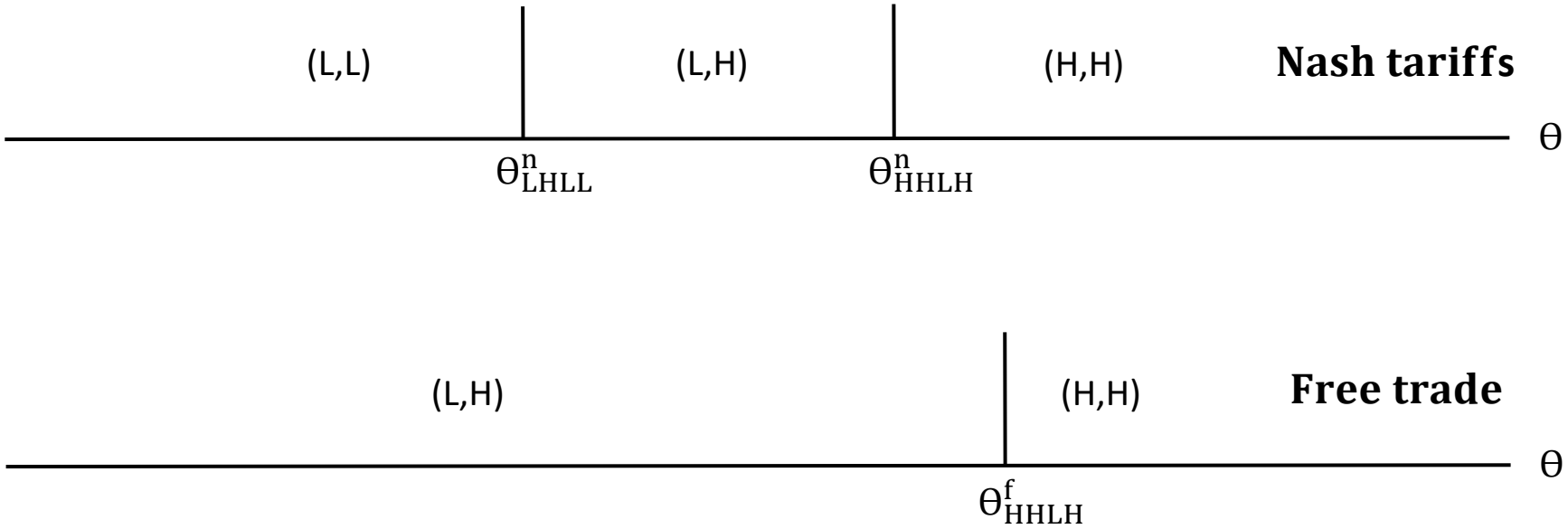

Figure 3: Equilibrium standards under Nash tariffs and free trade – UC

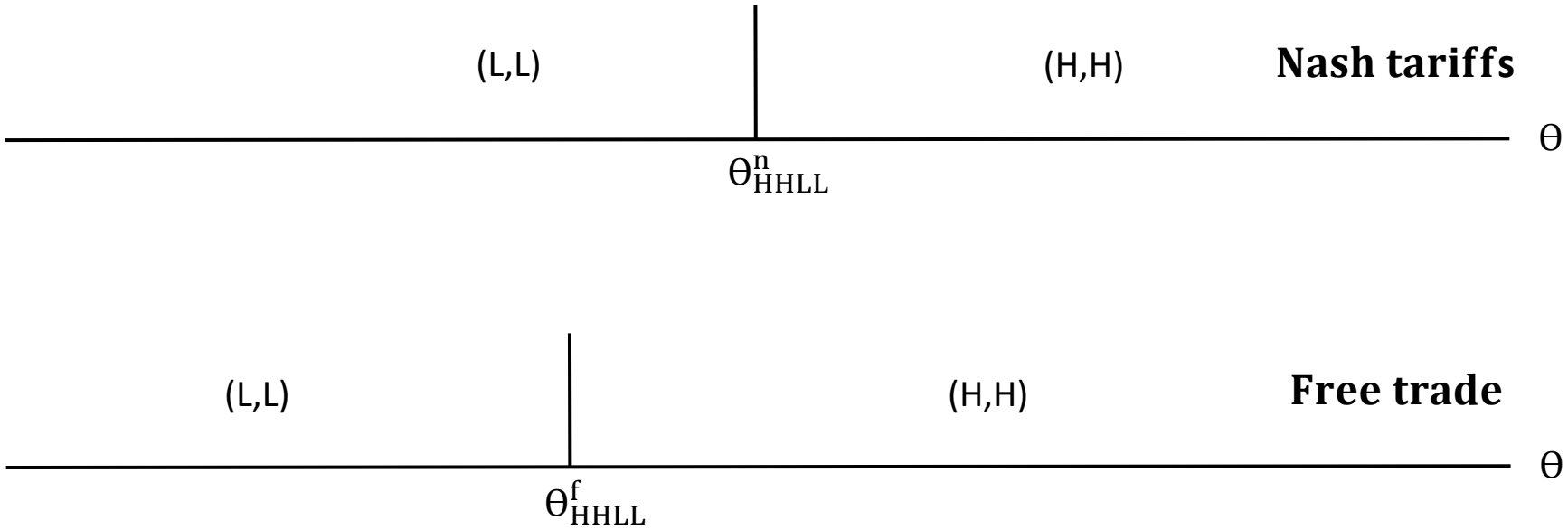

Figure 4: Equilibrium standards under Nash tariffs and free trade – NT