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Abstract

We investigate how a domestic subsidy is treated in an international agreement, when a government, having incentive to use its subsidy as a means of import protection, can disguise its protective use of subsidy as a legitimate intervention with which to address a market imperfection in the import-competing sector. We show that any optimal agreement permits the use of a positive domestic subsidy, but it restricts the home government's freedom to select domestic subsidy in order to increase the market-access level for foreign exporters. Our finding implies that proper restrictions on domestic subsidies are somewhere between GATT and WTO rules.

1 Introduction

Domestic subsidies have aroused disputes in the international trading system. International disputes over domestic subsidies are not surprising in that a proper treatment of domestic subsidies in an international agreement is not obvious. Two contrasting perspectives are often stated on theoretical and actual trade-policy levels. A domestic subsidy, for instance, is a "legitimate" instrument with which to address a market imperfection that leads to under-production. At the same time, however, it may be used as a means of import protection that offsets the benefits of tariff liberalization. Indeed, this latter perspective has long provided a justification for the continuing attempts by the World Trade Organization (WTO) to treat domestic subsidies in a strict manner: WTO has introduced additional regulations on subsidies that were not present in the General Agreement on Tariffs and Trade (GATT). The Agreement on Subsidies and Countervailing Measures (the SCM agreement) represents a significant strengthening of disciplines on subsidies.[1]

A recent study by Bagwell and Staiger (2006) asserts, however, that a proper treatment of domestic subsidies is the non-violation nullification-or-impairment complaints of GATT rules. They emphasize that domestic subsidies were treated in a fairly tolerant manner under GATT rules: subsequent to a tariff commitment, a government was granted the freedom to alter its domestic subsidies provided that such adjustments do not erode the market-access level implied by the tariff commitment. As Bagwell (2008) highlights, a key difference between GATT and WTO rules is that the SCM agreement now restricts the freedom and allows that a domestic subsidy may be actionable *independently of* whether it nullifies or impairs the market-access level associated with a prior tariff commitment.[2] From a somewhat different angle, Sykes (2005, 2009) argues that the problem with the WTO's restrictions on domestic subsidies arises mainly from the conceptual and practical difficulties of determining which domestic subsidies are used as undesirable protective measure; without the difficulties, restrictions on domestic subsidies might be negotiated to target only the protective use of subsidies.[3] Sykes maintains that it is arguably impossible to develop general principles that

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[1] For more discussion, see Sykes (2005, 2009), Bagwell (2008) and Bagwell and Staiger (2006).

[2] As Bagwell (2008) reports, a domestic subsidy may now be actionable even if the relevant product is not subject to any tariff commitment or the subsidy already existed at the time of any tariff commitment.

[3] The non-violation complaints of GATT rules had also proved difficult to carry out in practice. From 1947 through 1995 only 14 out of the more than 250 Article XXIII proceedings had centered on such complaints (Petersmann, 1997).

distinguish permissible subsidies from impermissible subsidies.

In this paper, motivated by these thorny and yet important issues featured on theoretical and actual trade-policy levels, we investigate how a domestic subsidy is treated in an international agreement. The model contains two key ingredients. First, a domestic subsidy is a legitimate instrument with which to address a market imperfection that leads to under-production in the import-competing sector: the first-best government intervention is to use a domestic subsidy and internalize the affected margin directly, as prescribed by the *targeting principle* (Bhagwati and Ramaswami, 1963 and Johnson, 1965). Second, the government, having incentive to use its subsidy as a means of import protection, can disguise its protective use of subsidy as a legitimate intervention: its trading partner or a third party cannot determine whether its subsidy is used as protective measure to circumvent the tariff commitment. We consider a 2-country 2-good model in which trade occurs in two countries, home and foreign countries, where markets are perfectly competitive. To formalize the two features, our model is augmented in two respects. First, a domestic production of import good by the home country generates a positive externality within the border. Second, the home government has private information about externality levels and thus about subsidy levels that are necessary to internalize the production externality. In particular, we develop an incomplete-information model with a continuum of possible externality types. To deliver our main points simply, the model focuses on the home government's intervention only in its import-competing sector. Instead, it allows for *two policy instruments*: a domestic production subsidy and an import tariff.

The starting point of our analysis is to identify a central incentive problem posed in the model: subsequent to a tariff-reduction commitment, the home government has incentive to raise its subsidy for the protective purpose. When the home government neglects foreign exporters and raises its subsidy, it can lower the world price of the foreign export good and thus bring a terms-of-trade gain (loss) to the home (foreign) country.[4] This problem causes

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This fact might reflect the difficulties of determining the trade effects of domestic policy changes.

[4]The terms-of-trade approach to international agreements is robust in various theoretical settings. Recent empirical evidence is also consistent with the terms-of-trade theory of agreements (e.g., Bagwell and Staiger, forthcoming and Broda, Limao and Weinstein, 2008). On actual policy levels, by contrast, terms of trade are not featured as much as the market-access level implied by trade policy. As Bagwell (2008) and Bagwell and Staiger (1999, 2002) show, however, the loss in market access that foreign exporters experience when the home government raises its tariff (or subsidy) is simply the "quantity effect" that accompanies the "price effect" of a deterioration in the foreign

the concern that the subsidy may offset the benefits of the negotiated tariff commitment. Our model makes this concern clearly evident, by assuming that the home government with private information can disguise its protective use of subsidy as a legitimate intervention and circumvent the tariff commitment.[5]

In this paper, when governments reach an international agreement, they specify the policy set from which they can select their policy pairs. We assume that an international agreement is enforceable if and only if the associated policy set is *incentive compatible*: if the policy set is (not) incentive compatible, the agreement is (not) enforceable. A policy set is incentive compatible if it is specified such that the home government with one externality type must not gain from selecting the policy mix that is prescribed for this government when it has a different externality type. This incentive constraint is analogous to the standard truth-telling constraint encountered in mechanism-design problems. We say that an agreement is *optimal* when the associated policy set is incentive compatible and generates at least as high expected global welfare as any incentive compatible policy set. We consider the following stage game: (i) two governments write an agreement that specifies the policy set, (ii) the home government privately observes its own externality types and (iii) the home government selects its policy mix from the policy set specified by the agreement.

We begin with a hypothetical agreement in which the home government is granted the flexibility (freedom) to select any policy mix from the policy set that preserves the world price of the foreign export good at a constant level. Since the home government can lower the world price by raising tariff or subsidy, this policy set can be represented by a decreasing function on which tariff falls as subsidy rises. Along this iso-world-price function where the foreign country's terms of trade is constant, the home government, having no incentive to manipulate terms of trade, selects the Pigouvian subsidy that internalizes the production externality at the margin. The policy set acts as a sorting (separating) scheme along which the home government truthfully reveals its externality type.

Our first finding is that the separating agreement is not optimal: it can be improved on

country's terms-of-trade.

[5] A related concern is raised by the European Communities (WTO, 2002, pp. 2-3): "Significant amounts of financial support are increasingly granted by governments for ostensibly general activities which in fact directly benefit the production of certain products. These disguised subsidies can have equally severe trade-distorting effects and they are potentially much more harmful than more direct subsidies since they confer benefits in a largely non-transparent manner."

by an alternative agreement that entails pooling at the top (i.e., the interval of externality types adjoining the highest type). The agreement has strength and weakness: it addresses the market imperfection with a first-best instrument and yet it entails the use of high import tariffs especially for low-externality types. Governments may look for some way to keep the subsidy-efficiency advantage while reducing tariffs by developing another policy set that has a flatter slope than before. This new set, however, induces lower-externality types to raise their subsidies and mimic higher-externality types. Hence, the (global) welfare gain associated with the first-best intervention can be enjoyed only if the welfare loss associated with the "informational cost" in the form of high import tariffs is also experienced. This finding indicates that no optimal agreement adheres strictly to the targeting principle in its subsidy choice. Intuitively, if an agreement uses a first-best instrument to remedy the market failure that leads to under-production in the import-competing sector, then it entails the use of high import tariffs that additionally stimulates domestic production and thus results in excessive import protection. The alternative agreement, sacrificing the first-best intervention at the top, can lower import tariffs and raise the world price and import volume.

We next explore a pooling agreement in which policy choices are fully rigid (state-independent). Within the class of pooling agreements, the optimal agreement restricts subsidy choice to the expected value of externality types and achieves zero tariff. We show that this agreement is not optimal: it can be improved on by an alternative agreement that entails sorting at the bottom (i.e., the interval of externality types adjoining the lowest type). This alternative agreement acts to extend the original policy set for types at the bottom while preserving the original world price at the optimal pooling agreement. The associated home-welfare improvement thus does not impose the negative terms-of-trade externality on the foreign welfare.

We augment this finding and investigate the possibility that an agreement may tailor the degree to which the use of subsidy is regulated, together with a commitment to zero tariff. This possibility occurs when governments adjust the degree of restrictions on subsidy choice in order to maximize the benefits of their tariff liberalization. Our second finding is that, regardless of the degree to which the use of subsidy is regulated, an agreement in which tariffs are bound to zero is not optimal: it can be improved on by an alternative agreement that entails sorting at the bottom. Intuitively, when contemplating an agreement,

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governments face a tension between the objective of promoting domestic efficiency and the objective of reducing import tariffs. In the three suboptimal agreements stated above, one objective is overly emphasized and is achieved at the expense of the other objective. The first agreement adjusts import tariffs to utilize the first-best intervention with which to internalize the externality margin; it can be improved on by an agreement that entails pooling at the top. The second and third agreements tailor the degree of restrictions on subsidy choice to maximize the benefits of zero-tariff commitment; they can be improved on by an agreement that entails sorting at the bottom.

We next investigate how an optimal agreement resolves the tension between the two objectives. We proceed to establish the monotonicity result: in any optimal agreement, the world price is nonincreasing in externality levels. In an optimal agreement, the world price cannot be higher for an externality type than for the lowest type. Intuitively, if the world price is higher for an externality type than for the lowest type, then an alternative agreement can be developed to contain a sorting scheme at the bottom up to the policy mix for that type along an iso-world-price function. Inclusion of such a sorting scheme improves the home welfare without causing a deterioration in the foreign country's terms of trade. With this monotonicity in place, our third finding confirms that any optimal agreement entails sorting at the bottom.[6] If an optimal agreement entails pooling at the bottom, then it involves the highest world price at the bottom because of the monotonicity. A contradiction is then caused by an alternative agreement that entails sorting and preserves the original world price at the bottom; this alternative agreement extends the policy set and thus improves the home welfare without imposing a negative terms-of-trade externality on the foreign welfare. Our fourth finding subsequently confirms that any optimal agreement entails pooling at the top; pooling at the top is necessary to lower import tariffs and raise the world price and import volume.

We next establish our fifth finding: no optimal agreement includes a sorting scheme (as its policy subset) in which the world price is constant. If an agreement includes such a sorting scheme, then a new sorting scheme can be developed by shifting the original sorting scheme towards lower import tariffs. The new sorting scheme instead includes a jump from

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[6]The sorting at the bottom here is different from the sorting at the bottom stated above where the world price is constant. As we show below, in any optimal agreement, the world price is strictly increasing in externality levels over the sorting scheme at the bottom.

its endpoint to the endpoint of the original sorting scheme such that it entails pooling at the original endpoint. Intuitively, if a small jump is made to shift the original sorting scheme slightly, then the marginal (global) welfare gain associated with the tariff reduction is strictly positive, but the marginal welfare loss associated with the new pooling is close to zero, since this welfare loss is measured on the original iso-world-price function where the foreign welfare is held constant.[7] Using linear demand and supply functions and uniform distribution of externality types, we numerically confirm that an agreement creates the net global welfare gain when it shifts any sorting scheme towards lower import tariffs and includes a new jump. We then ask an important question: for any externality type, is the home government granted the freedom to select any policy mix from the policy set that preserves the world price at a constant level? Our finding asserts that the home government is not granted the freedom in any optimal agreement. An optimal agreement resolves the tension between the two objectives only when it restricts the home government's subsidy choice and thus its use of first-best intervention, in order to respect terms of trade for the foreign country and increase the market-access level for foreign exporters.[8]

Despite the mounting interest and evident importance, a treatment of domestic subsidies in an international agreement has not received much attention from analytical literature. Bagwell and Staiger (2001, 2006) offer formal analyses of this issue and show that the *market-access focus* of GATT rules is well qualified to be a proper treatment of domestic subsidies: if market access is secured by the non-violation complaint at the negotiated (efficient) level, then negotiations with tariffs alone can achieve a policy mix that is efficient from a global perspective. The policy prescription implied by their finding is that governments need to be granted the freedom to select any policy mix from the policy set that preserves market access at the efficient level. In particular, the non-violation complaint plays an important

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[7]Along the original sorting scheme, the original policy choices maximize the home welfare while preserving the foreign welfare at a constant level; the first-order differentiation of the home welfare at the original policy choices is zero. If the jump becomes smaller, then the new pooling point approaches the original policy choices made along the original scheme; the first-order differentiation of the home welfare at the new pooling point approaches zero. The marginal home-welfare loss associated with the new pooling then becomes close to zero.

[8]As Bagwell and Staiger (1999, 2002) illuminates, whether an increase in tariff or subsidy by the home government is said to cause a terms-of-trade loss for the foreign country or a loss of maket-access level for foreign exporters is a matter of semantics. Following their logic, we here define a market-access level that the home government affords to the foreign country by the import volume implied by policy mixes along an iso-world price function.

role in achieving an efficient policy mix in Bagwell and Staiger (2001) when governments, subsequent to their tariff negotiation, are allowed to adjust tariffs to preserve market access at the negotiated level, and in Bagwell and Staiger (2006) when governments, with tariffs bound by their negotiation, have sufficient policy redundancy to keep market access at the negotiated level.[9]

Our model contains the standard features found in Bagwell and Staiger (2001, 2006): a government, under a market-access commitment, has no incentive to distort subsidy choice away from the efficient level, and an essential factor that leads to an inefficient policy mix is an insufficient consideration for the foreign country's terms of trade. In their model, the foreign country's terms of trade are duly respected when an agreement leads the home government to a first-best intervention with which to address the market imperfection. In our model, by contrast, the foreign country's terms of trade are duly respected when an agreement restricts the home government's subsidy choice and its use of first-best intervention. Our findings convey two distinct policy implications. First, restrictions on subsidy choice are necessary, and moreover, proper restrictions are stricter than what is implied by the market-access focus of GATT rules. We show that, in any optimal agreement, two different policy mixes deliver two different terms of trade for the foreign country: an optimal policy set can be achieved by a *policy-mix agreement*, not by a commitment to a specific market-access level. Second, despite such necessary restrictions on subsidy choice, proper restrictions are far milder than the de facto prohibition of domestic production subsidies seen under WTO rules.[10] We show that the home government is surely granted the use of a positive subsidy in any optimal agreement: probability of using zero subsidy is zero under sorting at the bottom and continuous distribution of externality types.

We may also compare the pooling points present at the top and potentially in other places with the rigid (state-independent) treatment of domestic subsidies shown in Horn, Maggi and Staiger (2010). Horn, Maggi and Staiger show that trade agreements may exhibit a rigid use

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[9]Sufficient policy redundancy is present in their model when governments have an import tariff, a domestic production subsidy and a domestic consumption tax.

[10]Bagwell and Staiger (2006) argue that a key WTO innovation is that virtually any positive domestic subsidy can be challenged and potentially removed. In a limited-instrument setting where policy redundancy is absent, they show that the SCM agreement may have a "chilling" effect on tariff negotiations: if the legal restrictions on domestic subsidies permit trading partners to secure the removal of subsidies, then governments may hesitate to negotiate tariff liberalization, since tariffs then may be the best remaining means of assisting the import-competing sector.

of subsidy when the import volume is large. Adopting the approach that the WTO/GATT regulation is regarded as an incomplete contract, they offer a rationale for the existence of rigidity. In their model, the use of subsidy is made partially or fully rigid in order to save contracting costs when the import volume is large. In our model, it is made partially rigid in order to raise the market-access level for foreign exporters and so increase the import volume.

At a methodological level, this paper contributes to the theory of trade agreements among governments with private information. Amador and Bagwell (2010), Bagwell (2009), Bagwell and Staiger (2005), Beshkar (2010), Feenstra and Lewis (1991), Martin and Vergote (2008) and Park (forthcoming) develop theoretical models of this kind. Importantly, all these models focus on agreements on tariffs, whereas this paper explores agreements on two policy instruments. Lee (2007) develops a private-information model with two policy instruments, assuming two externality types and linear demand and supply functions. Our model, however, allows for any continuous distribution function of externality types and for general demand and supply functions.

The paper is organized as follows. Section 2 introduces the basic trade model and states the standard features that are similarly found in the literature. In Section 3, we consider various hypothetical agreements that are not optimal. In Section 4, we present important features found in any optimal agreement. Section 5 concludes. In the Appendix, we offer additional expositions not contained in the text and provide proofs.

2 The Model

The model contains two key ingredients. First, a domestic subsidy is a legitimate instrument with which to address a market imperfection that leads to under-production in the import-competing sector: the first-best government intervention is to use a domestic subsidy and internalize the affected margin directly, as prescribed by the targeting principle. Second, a government, having incentive to use its subsidy as a means of import protection, can disguise its protective use of subsidy as a legitimate intervention with which to address a market imperfection that leads to under-production: its trading partner or a third party cannot determine whether its subsidy is used as protective measure to circumvent the negotiated tariff commitments.

2.1 The Basic Trade Model

We consider a 2-country 2-good model in which trade occurs in two countries, home and foreign countries, where markets are perfectly competitive. The home country exports one good to the foreign country in exchange for imports of the other good. We proceed with the good in the import (export) sector of the home (foreign) country. For the good, the home country has a downward-sloping demand function $D(p^d)$ for the local consumer price p^d and an upward-sloping supply function $Q(p^s)$ for the local supplier price p^s. For the same good, the foreign country has the corresponding demand and supply functions, $D^*(p^{*d})$ and $Q^*(p^{*s})$, respectively, where asterisks denote foreign variables. All functions are positive and twice-continuously differentiable.

To formalize the two key features stated above, the model is augmented in two respects. First, a domestic production of the import good by the home country generates a positive externality within the border. Second, the home government has private information about externality levels and thus about subsidy levels that are necessary to internalize the production externality. In particular, we consider an incomplete-information model with a continuum of possible externality types. Externality types are represented by the (marginal) production externality, denoted by θ. Externality type θ is drawn from the support $[0, \overline{\theta}]$ according to the twice-continuously differentiable distribution function, $F(\theta)$, where $\overline{\theta} > 0$. The density is defined as $f(\theta) \equiv F'(\theta)$ where $f(\theta) > 0$ for all $\theta \in [0, \overline{\theta}]$. Producers ignore the external effects of their production on the aggregate production, and thus their supply functions are not directly affected by θ. The aggregate value of the production externality may then be represented by $\theta Q(p^s)$ for the home country with externality type θ.[11]

To deliver our main points simply, the model focuses on policy intervention by the home government only in its import-competing sector. Instead, it allows for two policy instruments: a domestic production subsidy, s, and an import tariff, τ.[12] We assume that all policy instruments are non-prohibitive and expressed in specific terms. In the absence of policies

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[11] The aggregate value of externality is similarly represented in Ederington (2002), Lee (2007) and Horn, Maggi and Staiger (2010). A similar setting is commonly found in collusion literature where firms have private information about their marginal production costs. For example, see Athey and Bagwell (2001, 2008) and Athey, Bagwell and Sanchirico (2004), Bagwell and Lee (2010) and Lee (2010).

[12] We can readily extend the model by assuming a symmetric structure: externality types are iid across sectors and the foreign government also intervenes in its import sector.

by the foreign government, the foreign consumer and supplier prices are equal to the world (offshore) price, p^w: $p^{*s} = p^{*d} = p^w$. The markets in two countries are integrated, and so a foreign supplier receives the same price for sales in the foreign country that it receives for sales in the home country after paying the tariff: $p^w = p^d - \tau$. The wedge between the home supplier price and the home consumer price is the domestic subsidy: $p^s = p^d + s$. These pricing equations may be rewritten in a useful form:

$$p^d = p^w + \tau \text{ and } p^s = p^w + \tau + s. \tag{1}$$

Equilibrium prices, denoted by $\widehat{p}^w$, $\widehat{p}^d$ and $\widehat{p}^s$, are determined by the market-clearing condition:

$$D(p^d) + D^*(p^w) = Q(p^s) + Q^*(p^w). \tag{2}$$

Plugging the consumer and supplier prices into the market-clearing condition, we may find the equilibrium world price $\widehat{p}^w(s, \tau)$. The equilibrium consumer and supplier prices may then be written as $\widehat{p}^d(s, \tau) = \widehat{p}^w(s, \tau) + \tau$ and $\widehat{p}^s(s, \tau) = \widehat{p}^w(s, \tau) + \tau + s$. It is also immediate from the condition (2) that, if the home government raises s or τ, then it can lower the world price of the foreign export good:

$$\frac{\partial \widehat{p}^w}{\partial s} = \frac{Q'}{D' - Q' - (Q^{*\prime} - D^{*\prime})} < 0 \tag{3}$$

$$\frac{\partial \widehat{p}^w}{\partial \tau} = -\frac{D' - Q'}{D' - Q' - (Q^{*\prime} - D^{*\prime})} < 0. \tag{4}$$

As seen in the Appendix, an increase in s or τ promotes the home production of the foreign export good, $Q(\widehat{p}^s)$, and reduces the home import, $D(\widehat{p}^d) - Q(\widehat{p}^s)$. Observe also that an increase in s or τ imposes a negative terms-of-trade externality on the foreign welfare. The policy change that lowers the world price (the foreign local prices) is harmful to the foreign exporters and beneficial to the foreign consumers. The benefit to the foreign consumers amounts to a transfer from the foreign producers to the foreign consumers. The net foreign welfare decreases when the world price falls.

We now describe government preferences. The welfare function of each country is separable across import and export sectors; thus, we can again focus on the welfare function in the home import sector which is the foreign export sector. The home welfare includes consumer surplus, profits, revenue from the import tariff, expenditures on the production subsidies and the aggregate value of the production externality. The home welfare for externality type

θ is

$$W(s,\tau;\theta) \equiv CS(\widehat{p}^d) + \Pi(\widehat{p}^s) + \tau \cdot M(s,\tau) - s \cdot Q(\widehat{p}^s) + \theta \cdot Q(\widehat{p}^s), \qquad (5)$$

where $M(s,\tau) \equiv D(\widehat{p}^d) - Q(\widehat{p}^s)$. Consumer surplus and profits are given by $CS(\widehat{p}^d) \equiv \int_{\widehat{p}^d}^{\overline{p}} D(p)dp$ and $\Pi(\widehat{p}^s) \equiv \int_{\underline{p}}^{\widehat{p}^s} Q(p)dp$, where $\overline{p} = \sup\{p : D(p) > 0\}$ and $\underline{p} = \inf\{p : Q(p) > 0\}$. A policy mix selected by the home government affects the foreign welfare through the world price. The foreign welfare is the sum of the foreign consumer surplus and profits:

$$W^*(s,\tau) \equiv CS^*(\widehat{p}^w) + \Pi^*(\widehat{p}^w). \qquad (6)$$

The home government cares about the negative terms-of-trade externality on the foreign welfare, when it maximizes the global welfare:

$$W^G(s,\tau;\theta) \equiv W(s,\tau;\theta) + W^*(s,\tau). \qquad (7)$$

It is noteworthy that the iso-welfare function for the home country, $\{(s,\tau) : W(s,\tau;\theta) = \kappa$ for a constant $\kappa\}$, satisfies the single-crossing property: as we show in the Appendix, for $\theta_2 > \theta_1$, the iso-welfare function for θ_2 crosses the iso-welfare function for θ_1 from above only once if it crosses.

2.2 First-Best and Nash Policies

The home government faces a finite choice set $\{s \mid s : [0,\overline{\theta}] \to \mathbb{R}_+\} \times \{\tau \mid \tau : [0,\overline{\theta}] \to \mathbb{R}_+\}$ and selects a policy mix conditional on its externality type. A typical policy mix selected by the home government with externality type θ may be denoted by $(s(\theta),\tau(\theta))$. Given the policy mix, the expected home welfare and expected global welfare may be represented by $\mathbb{E}_\theta W(s(\theta),\tau(\theta);\theta) = \int_0^{\overline{\theta}} W(s(\theta),\tau(\theta);\theta)dF(\theta)$ and $\mathbb{E}_\theta W^G(s(\theta),\tau(\theta);\theta) = \int_0^{\overline{\theta}} W^G(s(\theta),\tau(\theta);\theta)dF(\theta)$, respectively.

We first characterize the first-best policy mix $(s^E(\theta),\tau^E(\theta))$ that maximizes the global welfare $W^G(s,\tau;\theta)$:[13]

$$s^E(\theta) = \theta \text{ and } \tau^E(\theta) = 0 \text{ for all } \theta. \qquad (8)$$

In the first-best policy mix, the home government selects its subsidy at the marginal externality and achieves zero tariff. Assuming that $W(s,\tau;\theta)$ is strictly concave in s and τ, we next characterize the (non-cooperative) Nash policy mix $(s^N(\theta),\tau^N(\theta))$ that maximizes the

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[13]In the Appendix, we derive the first-best and Nash policies.

home welfare $W(s, \tau; \theta)$:

$$s^N(\theta) = \theta \text{ and } \tau^N(\theta) = \frac{E^*(\widehat{p}^w)}{E^{*\prime}(\widehat{p}^w)} \text{ for all } \theta, \tag{9}$$

where $\widehat{p}^w = \widehat{p}^w(s = s^N(\theta), \tau = \tau^N(\theta))$ and $E^*(\widehat{p}^w) = Q^*(\widehat{p}^w) - D^*(\widehat{p}^w)$.[14] In the Nash policy mix, the home government selects its subsidy at the marginal externality and raises its import tariff above zero to capture the terms-of-trade gain. In fact, the findings in (8) and (9) require that the highest externality type $\overline{\theta}$ should be below a certain level for government intervention to be non-prohibitive.

For the agreements we explore below, we now make the following assumption:

Assumption 1. *(i)* $W(s, \tau; \theta)$ *and* $W^*(s, \tau)$ *are strictly concave in* s *and* τ*. (ii)* $M(s = \overline{\theta}, \tau = 0) > 0$.

The assumption (i) is satisfied for a large family of demand and supply functions, including linear functions. This assumption implies that the global welfare $W^G(s, \tau; \theta)$ is also strictly concave in s and τ. The assumption (ii) ensures that government intervention is non-prohibitive for the policy mixes we consider below.

2.3 Objective of Agreement

In this paper, we consider the following stage game: (i) two governments write an agreement that specifies the policy set, (ii) the home government privately observes its own externality types and (iii) the home government selects its policy mix from the policy set specified by the agreement. This stage game indicates that, when arranging an agreement, governments specify the policy set from which they can select their policy pairs. We assume that an agreement is enforceable if and only if the associated policy set is *incentive compatible*: if the policy set is (not) incentive compatible, the agreement is (not) enforceable. A policy set is incentive compatible if it is specified such that the home government with one externality type must not gain from selecting the policy mix that is prescribed for this government when it has a different externality type. This incentive constraint is analogous to the standard truth-telling constraint encountered in mechanism-design problems.

We say that an agreement is *optimal* when the associated policy set is incentive compatible and generates at least as high expected global welfare as any incentive compatible policy set.

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[14]Note that $\tau^N(\theta) = \frac{\widehat{p}^w}{\varepsilon^*}$ where $\varepsilon^* = \frac{\widehat{p}^w E^{*\prime}(\widehat{p}^w)}{E^*(\widehat{p}^w)}$ is the elasticity of the foreign country's export supply.

Formally, let $(s(\theta), \tau(\theta))$ represent the policy mix selected by the home government with type θ under the policy set $\{(\mathbf{s}, \boldsymbol{\tau})\}$, and let $(\tilde{s}(\theta), \tilde{\tau}(\theta))$ denote the policy mix selected by the home government with type θ under an alternative policy set $\{(\tilde{\mathbf{s}}, \tilde{\boldsymbol{\tau}})\}$. An agreement is optimal if its policy set $\{(\mathbf{s}, \boldsymbol{\tau})\}$ is incentive compatible,

$$W(s(\theta), \tau(\theta); \theta) \geq W(s(\widehat{\theta}), \tau(\widehat{\theta}); \theta) \text{ for all } \theta \text{ and } \widehat{\theta} \neq \theta, \tag{IC(θ)}$$

and satisfies

$$\mathbb{E}_\theta W^G(s(\theta), \tau(\theta); \theta) \geq \mathbb{E}_\theta W^G(\tilde{s}(\theta), \tilde{\tau}(\theta); \theta)$$

for any incentive compatible policy set $\{(\tilde{\mathbf{s}}, \tilde{\boldsymbol{\tau}})\}$.[15] Equivalently, an agreement is not optimal if there exists an alternative policy set in which the expected global welfare is higher than in the original set and the incentive compatibility constraint is satisfied.

2.4 Incentive Problem

The starting point of our analysis is to identify a central incentive problem contained in our model. We emphasize that the incentive problem is standard and is commonly observed on theoretical and actual policy levels. We begin with a hypothetical agreement in which the policy set is given by:[16]

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}. \tag{10}$$

The home government with externality type θ then selects the policy mix that maximizes $W(s, \tau; \theta)$ under the policy set (10). Since the world price is constant at $\widehat{p}^w(s = \overline{\theta}, \tau = 0)$ for any (s, τ) in the set, the foreign welfare $W^*(s, \tau)$ is constant. Given that an increase in s or τ lowers the world price, the policy set (10) can be uniquely represented by an iso-world-price function, $\tau = \tau^{sep}(s)$:

$$\tau^{sep}(s) = \frac{Q'}{D' - Q'}[s - \overline{\theta}]. \tag{11}$$

This function is strictly decreasing and crosses the policy point $(s, \tau) = (\overline{\theta}, 0)$. The slope, $\frac{d\tau^{sep}}{ds} = \frac{Q'}{D' - Q'} < 0$, is given by (3) and (4). Along this function, having no incentive to use its

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subsidy and manipulate terms of trade, the home government uses the first-best instrument to internalize the production externality at the margin. We formalize this finding.

Lemma 1. *In the policy set (10), the home government's subsidy choice satisfies $s(\theta) = \theta$ for all θ.*

The proof is in the Appendix. Given $s(\theta) = \theta$, the home government with externality type θ selects $\tau^{sep}(\theta)$ from the iso-world-price function $\tau = \tau^{sep}(s)$. Thus, the policy set (10) acts as a "sorting" (separating) scheme that elicits a truthful revelation of all externality types.

Lemma 1 leads to additional points. Consider first an alternative policy set in which tariffs are now *fixed* and close or equal to zero for all θ. This alternative policy set raises a central incentive problem: subsequent to a tariff-reduction commitment, the home government has incentive to raise its subsidy for the protective purpose. Under the alternative policy set, if the home government neglects foreign exporters and raises its subsidy, then it can lower the world price of the foreign export good and thus bring a terms-of-trade gain (loss) to the home (foreign) country. In practice, this concern has been a justification of the WTO's continuing attempts to regulate the use of domestic subsidies. Consider next another policy set in which the world price is constant at $\widehat{p}^w(s = \overline{\theta}, \tau = 0)$:

$$\{(s_1, \tau_1), (s_2, \tau_2)\} \text{ where } \widehat{p}^w(s_1, \tau_1) = \widehat{p}^w(s_2, \tau_2) = \widehat{p}^w(s = \overline{\theta}, \tau = 0). \tag{12}$$

Since the policy set (12) includes only two possible choices, it entails pooling for some types. We can infer from Lemma 1 that the home welfare is higher in (10) than in (12) if $\theta \notin \{s_1, s_2\}$. We can generalize this point.

Lemma 2. *For all θ, the home welfare is at least as high in (10) as in any policy set where the world price is constant at $\widehat{p}^w(s = \overline{\theta}, \tau = 0)$.*

Lemma 1 and 2 hold at a general level where the policy set (10) is modified to

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = \kappa) \text{ for a constant } \kappa \geq 0\}. \tag{13}$$

By changing κ, we may develop many sorting schemes in which $s(\theta) = \theta$. Suppose that κ increases from zero and so the iso-world-price function shifts up from (10). Subsidy choice then remains the same, $s(\theta) = \theta$, and import tariffs rise along the new sorting scheme. Thus, for each type θ, the world price falls and at the same time, the foreign welfare and the global

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welfare fall.[17] The effect of an increase in κ on the *home* welfare is less clear; it depends on the initial level of κ and parameters. We now assume that, if κ increases slightly from zero, then the home welfare increases for all θ.

Assumption 2. *For all θ, an increase in κ from zero in the set (13) increases the home welfare.*

This assumption is satisfied if and only if tariffs are lower in the set (10) than in the Nash policies: $\tau^{sep}(\theta) < \tau^N(\theta)$ for all θ. This inequality holds for a large family of demand and supply functions, if $\overline{\theta}$ is below a certain level and the term $\frac{E^*(\widehat{p}^w)}{E^{*\prime}(\widehat{p}^w)}$ in (9) is sufficiently large. Indeed, $\frac{E^*(\widehat{p}^w)}{E^{*\prime}(\widehat{p}^w)}$ is large when the home country is large and has a significant incentive to manipulate terms of trade. Assumption 2 ensures that the central incentive problem stated above occurs in the region $\{(s, \tau) : \widehat{p}^w(s, \tau) \geq \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$: for any policy mix in the region (below the Nash policies), there exists some θ for which the home government has incentive to raise its subsidy and bring a terms-of-trade gain to the home country.

3 Suboptimal Agreement

In this section, we explore three different hypothetical agreements: (i) a separating agreement in which the home government uses the first-best intervention to internalize the externality margin, (ii) a pooling agreement in which policy choices are fully rigid (state-independent) and (iii) an agreement in which tariffs are bound to zero with adjustments of restrictions on subsidy choice. We show that none of these agreements are optimal. The findings established below are quite general, in that they hold for any distribution function F.[18]

3.1 Separating Agreement

In this subsection, we consider a (full) separating agreement in which the home government uses the first-best instrument, $s(\theta) = \theta$, to internalize the production externality. The policy set specified by the agreement must satisfy the incentive compatibility: $\theta = \arg\max_s W(s, \tau; \theta)$ for all (s, τ) in the policy set. While looking for incentive compatible

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[17]This part of proof is detailed in the proof of Lemma 3 in the Appendix.

[18]Our main findings established in this and next sections are founded on quite standard features: (i) the home and foreign welfare functions are strictly concave in s and τ and (ii) along an iso-welfare function, having no incentive to manipulate the terms of trade, the home government selects its subsidy at the marginal externality.

policy sets, governments would contemplate the tariff schedule, $\tau(\theta)$, to maximize the expected global welfare.

Two findings can be established to maximize the expected global welfare. First, among the policy sets in which the world price is constant at $\widehat{p}^w(s = \overline{\theta}, \tau = \kappa)$ where $\kappa \geq 0$, the policy set that entails full sorting is preferred to any policy set that entails a partial or full pooling. This result is immediate from our previous argument. Second, among the policy sets that entail full sorting, the policy set in which the world price is higher is preferred to the policy set in which the world price is lower. This result directly follows from the policy set (13): if the iso-world-price function shifts up as κ rises, then the global welfare $W^G(s(\theta), \tau(\theta); \theta)$ decreases for all θ. These two findings lead to the following lemma.

Lemma 3. *The expected global welfare is at least as high in the policy set (10) as in any policy set in the region* $\{(s, \tau) : \widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$.

The separating agreement with the policy set (10) has strength and weakness.[19] The agreement uses the first-best intervention to address the market imperfection. The home government is granted the freedom to select any policy mix as long as its policy choices preserve the world price at $\widehat{p}^w(s = \overline{\theta}, \tau = 0)$. This freedom ensures that the home government, having no incentive to manipulate terms of trade, selects the Pigouvian subsidy that internalizes the production externality at the margin. The agreement, however, entails the use of high import tariffs especially for low externality types. Governments may thus look for some way to keep the subsidy-efficiency advantage while reducing tariffs by developing another policy set that is strictly decreasing and is flatter than the function $\tau = \tau^{sep}(s)$. This new policy set, however, induces lower-externality types to mimic higher-externality types and raise their subsidies. Hence, the (global) welfare gain associated with the first-best intervention can be enjoyed only if the welfare loss associated with the "informational cost" in the form of high import tariffs is also experienced.[20] This finding indicates that the policy set (10) acts as the best full sorting scheme.

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[19] Given that $\tau^{sep}(\theta) < \tau^N(\theta)$ for all θ under Assumption 2, the agreement with the policy set (10) strictly improves on the (non-cooperative) Nash policies.

[20] Consider *any* alternative agreement in which the policy set is represented by a decreasing function $\tau = \tau^{alt}(s)$ that is flatter than $\tau = \tau^{sep}(s)$ for all s. We can show that this alternative agreement is not optimal. The limiting case is that tariffs are bound to zero for all θ. As we show below, this agreement in the limiting case is not optimal.

We next develop an alternative policy set:

$$\{(s,\tau) : \widehat{p}^w(s,\tau) = \widehat{p}^w(s = \theta^c, \tau = 0) \text{ for } \theta^c \in (0,\overline{\theta})\}. \tag{14}$$

This policy set grants the home government the freedom to select any policy mix as long as its policy choice preserves the world price at $\widehat{p}^w(s = \theta^c, \tau = 0) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)$, while it restricts subsidy choice to $s \le \theta^c$. For all $\theta < \theta^c$, it entails sorting: $s(\theta) = \theta$ and $\tau(\theta) < \tau^{sep}(\theta)$. For all $\theta \ge \theta^c$, it entails pooling at the policy mix $(\theta^c, 0)$. Observing that, if $\theta^c \to \overline{\theta}$, then the alternative agreement approaches the separating agreement, we differentiate the expected global welfare under the alternative agreement with respect to θ^c. We then establish that the separating agreement can be improved on by an alternative agreement that entails pooling at the top (i.e., the interval of θ adjoining the highest type $\overline{\theta}$). Intuitively, if θ^c falls slightly from $\overline{\theta}$, then the alternative agreement decreases import tariffs along the new sorting scheme while keeping the pooling at $(\theta^c, 0)$ close to the efficient policy mix $(\theta, 0)$ for $\theta \in [\theta^c, \overline{\theta}]$.

Proposition 1. *A separating agreement in which subsidy choice satisfies $s(\theta) = \theta$ for all θ is not optimal: it can be improved on by an alternative agreement that entails pooling at the top.*

The proof is in the Appendix. Proposition 1 shows that no optimal agreement adheres strictly to the targeting principle in its subsidy choice. If an agreement uses the first-best instrument to remedy the market failure that leads to under-production in the import-competing sector, then it entails the use of high import tariffs which additionally stimulates domestic production and thus results in excessive import protection. This finding indicates that any optimal agreement entails at least partial pooling: it restricts the use of first-best intervention at least for some θ in order to reduce import tariffs and raise the world price and import volume.

3.2 Tariff Liberalization and Restriction on Subsidy Choice

In this subsection, we consider the possibility that an agreement may save the informational cost in the form of import tariffs by imposing a restriction on subsidy choice. We first explore a pooling agreement in which policy choices are fully rigid. The policy set can then be represented by a point, (s^p, τ^p), where s^p and τ^p are constant. Incentive compatibility is trivial

and is apparently satisfied. The optimal pooling agreement maximizes the expected global welfare $\mathbb{E}_\theta W^G(s^p, \tau^p; \theta)$. Since all equilibrium prices are constant for θ in this agreement, it is immediate from (7) that

$$\mathbb{E}_\theta W^G(s^p, \tau^p; \theta) = W^G(s^p, \tau^p; \mathbb{E}[\theta]). \tag{15}$$

The optimal pooling agreement is thus characterized by $s^p = \mathbb{E}[\theta]$ and $\tau^p = 0$. We show that this agreement can be improved on by an alternative agreement that entails sorting at the bottom (i.e., the interval of θ adjoining the lowest type 0). An alternative policy set is

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \mathbb{E}[\theta], \tau = 0)\}. \tag{16}$$

The alternative agreement extends the original policy set from a point $(\mathbb{E}[\theta], 0)$ to the set (16) while preserving the original world price $\widehat{p}^w(s = \mathbb{E}[\theta], \tau = 0)$. It entails sorting for $\theta \leq \mathbb{E}[\theta]$ and pooling at the point $(\mathbb{E}[\theta], 0)$ for $\theta > \mathbb{E}[\theta]$. Since the policy-set extension preserves the original world price, the associated home-welfare improvement does not impose a negative terms-of-trade effect on the foreign producers. Hence, the expected global welfare is higher in the alternative agreement than in the original agreement.

We next augment this finding and consider the possibility that an agreement may tailor the degree to which the use of subsidy is regulated, together with a commitment to zero tariff. This possibility occurs when governments adjust the degree of restrictions on subsidy choice, in order to maximize the benefits of their tariff liberalization. Since an optimal policy set is not a singleton by Proposition 2, we begin with the policy set $\{(s_1, 0), (s_2, 0)\}$ where s_1 and s_2 are constant and $s_2 > s_1$. We restrict the subsidy s_1 to satisfy $s_1 < \overline{\theta}$. If $s_1 \geq \overline{\theta}$, then the policy set is in the region $\{(s, \tau) : \widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$. By Lemma 3 and Proposition 1, the agreement is not optimal. We also assume that both policy mixes are selected by at least some θ; the policy set would otherwise be equivalent to a singleton in which case the agreement is not optimal. We can then show that this agreement is not optimal, whether $s_1 > 0$ or $s_1 = 0$. For the first case $(s_1 > 0)$, we may develop an alternative policy set that has two subsets:

$$\{\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = s_1, \tau = 0)\}, (s_2, 0)\}. \tag{17}$$

The first subset is extended from a point $(s_1, 0)$. Since $\widehat{p}^w(s = s_1, \tau = 0) > \widehat{p}^w(s = s_2, \tau = 0)$, the policy-set extension preserves the higher world price and so does not cause a decrease in the world price for any θ. The associated home-welfare improvement does not impose

a negative terms-of-trade effect on the foreign producers, which indicates that the original agreement is not optimal. For the second case ($s_1 = 0$), as we show in the Appendix, we may develop an alternative policy set under two possibilities: (i) $(0,0)$ is selected only by the lowest type 0 and (ii) $(0,0)$ is selected by types $\theta \in [0, \widehat{\theta}]$ for some $\widehat{\theta} > 0$.

Governments may further reduce the degree of restrictions on subsidy choice by offering more subsidy options. We can show that an agreement with $\{(s_1, 0), (s_2, 0), ..., (s_K, 0)\}$ is not optimal, by applying the previous argument to the first two choices, $(s_1, 0)$ and $(s_2, 0)$. The limiting case is that subsidy choice is left to the home government's discretion while import tariffs are bound to zero for all θ. The home government' subsidy choice would then be above a certain level, $\underline{s} > 0$. We restrict this level $\underline{s}$ to satisfy $\underline{s} < \overline{\theta}$. If $\underline{s} \geq \overline{\theta}$, then all policy choices are made in the region $\{(s, \tau) : \widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$. Lemma 3 and Proposition 1 then imply that the agreement in the limiting case is not optimal. We now develop an alternative policy set that has two parts:

$$\{\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \underline{s}, \tau = 0)\}, \{(s, \tau) : s \in [\underline{s}, \overline{\theta}] \text{ and } \tau = 0\}\}. \tag{18}$$

The first subset is extended from a point $(\underline{s}, 0)$, and the second subset represents the discretionary choice for any subsidy $s \in [\underline{s}, \overline{\theta}]$ under zero tariff. Observe that, for some $\theta < \underline{s}$, the policy-set extension increases the home welfare while it preserves the highest world price $\widehat{p}^w(s = \underline{s}, \tau = 0)$ in the original set.[21] Hence, the agreement in the limiting case is not optimal.

Based on our discussion to this point, we state the following proposition:

Proposition 2. *A pooling agreement in which policy choices are fully rigid is not optimal: it can be improved on by an alternative agreement that entails sorting at the bottom. Moreover, regardless of the degree to which the use of subsidy is regulated, an agreement in which import tariffs are bound to zero for all θ is not optimal: it can be improved on by an alternative agreement that entails sorting at the bottom.*

In summary, when contemplating an agreement, governments face a tension between the objective of promoting domestic efficiency and the objective of reducing import tariffs. In the suboptimal agreements stated above, one objective is overly emphasized and is achieved

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[21] We may extend our argument and show that an agreement is not optimal when the policy set includes some line segments under zero tariff such as $\{(s, \tau) : s \in \{[\underline{s}_1, \overline{s}_1], ..., [\underline{s}_K, \overline{s}_K]\} \text{ and } \tau = 0\}$.

at the expense of the other objective. Proposition 1 considers an agreement in which import tariffs are adjusted to utilize the first-best intervention with which to internalize the externality margin. This agreement can be improved on by an alternative agreement that entails pooling at the top. Proposition 2 explores an agreement in which the degree of restrictions on subsidy choice is tailored to maximize the benefits of zero-tariff commitment. This agreement can also be improved on by an alternative agreement that entails sorting at the bottom.

4 Optimal Agreement

In this section, we investigate how an optimal agreement resolves the tension between the objective of promoting domestic efficiency and the objective of reducing import tariffs. We first confirm that any optimal agreement entails sorting at the bottom and pooling at the top. We next show that any optimal agreement restricts the home government's subsidy choice and thus its use of first-best intervention. In this way, an optimal agreement respects terms of trade for the foreign country and increases the market-access level for foreign exporters.

4.1 Sorting at the Bottom

In this subsection, we confirm that any optimal agreement entails sorting at the bottom, $[0, \theta_c]$. We proceed to present two monotonicity results. We first show that $s(\theta)$ is nondecreasing in θ. Suppose that an agreement allows $s(\theta_2) < s(\theta_1)$ for some $\theta_2 > \theta_1$. Incentive compatibility of type θ_1 implies that $(s(\theta_2), \tau(\theta_2))$ must be located in the region:

$$\{(s, \tau) : W(s, \tau; \theta_1) \leq W(s(\theta_1), \tau(\theta_1); \theta_1) \text{ and } s < s(\theta_1)\}. \tag{19}$$

We then use the single-crossing property: the iso-welfare function for θ_2 that crosses the point $(s(\theta_1), \tau(\theta_1))$ also crosses the iso-welfare function for θ_1 from above only once. Any policy mix in (19) is thus less preferred to $(s(\theta_1), \tau(\theta_1))$ for type θ_2, which violates incentive compatibility.[22]

We next show that, in any optimal agreement, the world price is nonincreasing in θ: $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) \leq \widehat{p}^w(s(\theta_1), \tau(\theta_1))$ for $\theta_2 > \theta_1$. Suppose that, in an agreement, type θ_1 (type θ_2) involves the highest world price for all $\theta \leq \theta_1$ (for all $\theta > \theta_1$) and $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) >$

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[22]Incentive compatibility also implies that the domestic production of import good, Q, is nondecreasing in θ.

$\widehat{p}^w(s(\theta_1), \tau(\theta_1))$.[23] We develop an alternative policy set in which a sorting scheme at the bottom extends up to the policy mix that maximizes the world price on the iso-welfare function for type θ_2, $\{(s, \tau) : W(s, \tau; \theta_2) = W(s(\theta_2), \tau(\theta_2); \theta_2)\}$. Then types $\theta \leq \theta_2$ do not mimic types $\theta > \theta_2$ but selects their policy mixes along the sorting scheme. The incentive of types $\theta > \theta_2$ to mimic types $\theta \leq \theta_2$ can be ignored: the potential home-welfare gain by types $\theta > \theta_2$ from mimicking types $\theta \leq \theta_2$ does not cause a deterioration in the foreign country's terms of trade, since the sorting scheme at the bottom involves the world price that is at least as high as $\widehat{p}^w(s(\theta_2), \tau(\theta_2))$. Thus, inclusion of the sorting scheme for $\theta \leq \theta_2$ increases the expected global welfare, which indicates that the original agreement is not optimal. We summarize the monotonicity results.

Lemma 4. *(i) Subsidy choice is nondecreasing in θ. (ii) In any optimal agreement, the world price is nonincreasing in θ.*

We next show that, in any optimal agreement, the policy choice by the lowest type 0, $(s(0), \tau(0))$, is in the region:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}. \tag{20}$$

If an agreement is optimal and allows $\widehat{p}^w(s(0), \tau(0)) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)$, then Lemma 4 implies that $\widehat{p}^w(s(\theta), \tau(\theta)) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)$ for all $\theta \in [0, \overline{\theta}]$. Lemma 3 and Proposition 1, in turn, indicate that the agreement is not optimal. The policy choice by the lowest type can be further specified: in any optimal agreement, $s(0) = 0$ and $\tau(0) > 0$ and thus $\widehat{p}^w(s(0), \tau(0)) < \widehat{p}^w(s = 0, \tau = 0)$. If an agreement allows $s(0) > 0$, then we may develop an alternative agreement that includes a sorting scheme at the bottom up to the point $(s(0), \tau(0))$:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s(0), \tau(0)) \text{ for } s \leq s(0)\}. \tag{21}$$

The policy set for $s > s(0)$ remains the same. The policy-set extension in (21) increases the home welfare for some $\theta \in [0, s(0)]$. Since $\widehat{p}^w(s(0), \tau(0)) \geq \widehat{p}^w(s(\theta), \tau(\theta))$ for all $\theta > 0$ by Lemma 4, the associated home-welfare gain does not cause a decrease in the world price for any θ. Hence, the agreement with $s(0) > 0$ is not optimal. Given $s(0) = 0$, if an agreement allows $\tau(0) = 0$, we may then explore two possibilities: (i) $(0, 0)$ is selected only by the lowest type 0 and (ii) $(0, 0)$ is selected by types $\theta \in [0, \widehat{\theta}]$. A similar procedure used in the proof

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[23]The proof is provided in greater detail in the Appendix.

of Proposition 2 confirms that the agreement with $(s(0), \tau(0)) = (0,0)$ is not optimal. We summarize the results.

Lemma 5. *In any optimal agreement, the policy mix for type 0, $(s(0), \tau(0))$, is in the region (20) and satisfies $s(0) = 0$ and $\tau(0) > 0$.*

We are now ready to show that any optimal agreement entails sorting at the bottom, $[0, \theta_c]$. Assume that an agreement is optimal and entails pooling for $\theta \in [0, \widehat{\theta}]$ at (s_p, τ_p). Lemma 5 then implies that (s_p, τ_p) is in the region (20) and satisfies $s_p = 0$ and $\tau_p > 0$. We can then develop an alternative agreement in which a sorting interval at the bottom extends up to the policy mix that maximizes the world price on the iso-welfare function for type $\widehat{\theta}$, $\{(s, \tau) : W(s, \tau; \widehat{\theta}) = W(s_p, \tau_p; \widehat{\theta})\}$. Then the home government with types $\theta \leq \widehat{\theta}$ does not mimic types above $\widehat{\theta}$. The incentive of types $\theta > \widehat{\theta}$ to mimic types $\theta \leq \widehat{\theta}$ can be ignored: since $\widehat{p}^w(s_p, \tau_p) \geq \widehat{p}^w(s(\theta), \tau(\theta))$ for all θ by Lemma 4, the potential home-welfare gain by types $\theta > \widehat{\theta}$ from mimicking types $\theta \leq \widehat{\theta}$ does not lower the world price for any type. Inclusion of the sorting at the bottom for types $\theta \leq \widehat{\theta}$ increases the home welfare, without causing a deterioration in the foreign country's terms of trade. Hence, the original agreement is not optimal, which causes a contradiction.

Proposition 3. *Any optimal agreement entails sorting at the bottom: there exists $\theta_c \in (0, \overline{\theta})$ such that the policy set entails sorting for $\theta \in [0, \theta_c]$.*

A formal proof is in the Appendix. As we characterize below, the sorting at the bottom here is different from the sorting at the bottom stated in Proposition 2 where the world price is *constant* and $s(\theta) = \theta$. It is thus premature to conclude that, along the sorting scheme at the bottom, the home government is granted the freedom to select any policy mix provided that its policy choices do not impose a negative terms-of-trade externality on the foreign country.

4.2 Pooling at the Top

In this subsection, we confirm that any optimal agreement entails pooling at the top, $[\theta^c, \overline{\theta}]$. We first extend Lemma 5 and show that any policy mix with a positive tariff is restricted to the region (20) in any optimal agreement: for any θ, if $\tau(\theta) > 0$, then $\widehat{p}^w(s(\theta), \tau(\theta)) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)$. Assume that an agreement is optimal and $\tau(\widetilde{\theta}) > 0$ and $\widehat{p}^w(s(\widetilde{\theta}), \tau(\widetilde{\theta})) \leq$

$\widehat{p}^w(s = \overline{\theta}, \tau = 0)$ for some $\widetilde{\theta} > 0$. Lemma 4 and 5 imply that there always exists a type $\widehat{\theta} < \widetilde{\theta}$ where

$$\widehat{\theta} = \sup\{\theta : \widehat{p}^w(s(\theta), \tau(\theta)) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}. \tag{22}$$

Suppose that the iso-welfare function for type $\widehat{\theta}$, $\{(s, \tau) : W(s, \tau; \widehat{\theta}) = W(s(\widehat{\theta}), \tau(\widehat{\theta}); \widehat{\theta})\}$, crosses the iso-world-price function, $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$, from below at a point $(\widehat{s}, \widehat{\tau})$ where $\widehat{\tau} > 0$ and $(\widehat{s}, \widehat{\tau}) \neq (s(\widehat{\theta}), \tau(\widehat{\theta}))$.[24] We develop an alternative agreement that includes a sorting scheme at the top from the point $(\widehat{s}, \widehat{\tau})$:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = 0) \text{ for } s \geq \widehat{s}\}. \tag{23}$$

The policy set for $s < \widehat{s}$ remains the same. The policy set (23) for $s \geq \widehat{s}$ is arranged to make type $\widehat{\theta}$ indifferent between $(s(\widehat{\theta}), \tau(\widehat{\theta}))$ and $(\widehat{s}, \widehat{\tau})$. The alternative agreement then entails pooling for $\theta \in (\widehat{\theta}, \widehat{s})$ at $(\widehat{s}, \widehat{\tau})$ and sorting for $\theta \in [\widehat{s}, \overline{\theta}]$ along the iso-world-price function (23). For all affected types $\theta > \widehat{\theta}$, the global welfare is at least as high in the alternative agreement as in the original agreement. Intuitively, for $\theta \in (\widehat{\theta}, \widehat{s})$, the alternative agreement involves a weakly lower domestic distortion in the form of "over-subsidy" ($s(\theta) > \theta$) at a weakly higher world price than does the original agreement, and for $\theta \in [\widehat{s}, \overline{\theta}]$, the alternative agreement involves sorting at a weakly higher world price than does the original agreement. Further, we can develop another agreement in which the sorting scheme (23) shifts down to entail pooling at the top for $\theta \in [\theta^c, \overline{\theta}]$:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \theta^c, \tau = 0) \text{ for } s \geq \widehat{s}'\}, \tag{24}$$

where $\widehat{s}' < \widehat{s}$. The policy set for $s < \widehat{s}'$ remains the same. The policy set for $s \geq \widehat{s}'$ is arranged to make type $\widehat{\theta}$ indifferent between $(s(\widehat{\theta}), \tau(\widehat{\theta}))$ and $(\widehat{s}', \widehat{\tau}')$. As in Proposition 1, when θ^c is close to $\overline{\theta}$, the expected global welfare is higher in the new agreement than in the original agreement. Hence, the original agreement is not optimal, which causes a contradiction.

Lemma 6. *In any optimal agreement, any policy mix with a positive tariff is restricted to the region (20):* $\{(s, \tau) : \widehat{p}^w(s, \tau) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$.

We next use Lemma 6 and establish two findings. First, any optimal agreement entails pooling at the top, $[\theta^c, \overline{\theta}]$. Assume that an agreement is optimal and entails sorting for $\theta \in [\widehat{\theta}, \overline{\theta}]$. The policy set for $\theta \in [\widehat{\theta}, \overline{\theta}]$ cannot be placed within the region (20), since any

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[24]In the Appendix, Proof of Lemma 6 considers all other possibilities.

sorting scheme within the region (20) causes pooling at the top. Outside the region (20), however, any sorting scheme at the top involves positive tariffs. Lemma 6 then indicates that the original agreement is not optimal. Second, any optimal agreement uses zero tariff in the pooling at the top: $\tau(\theta) = 0$ for all $\theta \in [\theta^c, \overline{\theta}]$. Assume that an agreement is optimal and entails pooling for $\theta \in [\widehat{\theta}, \overline{\theta}]$ at (s_p, τ_p) with a positive tariff $\tau_p > 0$. Lemma 6 then implies that (s_p, τ_p) is in the region (20). We consider an alternative policy set that includes a sorting scheme from the point (s_p, τ_p):

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s_p, \tau_p) \text{ for all } s \geq s_p\}. \tag{25}$$

The policy set for $s < s_p$ remains the same. The one endpoint of (25) is (s_p, τ_p). The other endpoint is on the zero-tariff line and may be denoted by $(s_0, 0)$. It follows that $s_p < s_0$.[25] Lemma 4 implies that the original policy set for types $\theta < \widehat{\theta}$ is in the region $\{(s, \tau) : \widehat{p}^w(s, \tau) \geq \widehat{p}^w(s_p, \tau_p) \text{ and } s < s_p\}$. If types $\theta < \widehat{\theta}$ did not select (s_p, τ_p) under the original policy set, then they still prefer their original choices to any choice now under the alternative set. The policy-set extension in (25) thus does not cause a fall in the world price for any θ. Lemma 4 also implies that any policy mix (s, τ) for $s < s_p$ is in the region $\{(s, \tau) : \widehat{p}^w(s, \tau) \geq \widehat{p}^w(s_p, \tau_p)\}$; types $\theta \in (s_p, s_0)$ then select their policy mixes along the sorting scheme (25). Hence, inclusion of this sorting scheme increases the expected home welfare, which indicates that the original agreement is not optimal. We now state the two findings.

Proposition 4. *Any optimal agreement entails pooling at zero tariff at the top: there exists $\theta^c \in [\theta_c, \overline{\theta})$ such that the policy set entails pooling at zero tariff for $\theta \in [\theta^c, \overline{\theta}]$.*

In summary, Proposition 3 shows that sorting at the bottom is necessary to address the market imperfection and promote domestic efficiency, while Proposition 4 shows that pooling at the top is necessary to lower import tariffs and raise the world price and import volume. An important policy implication of our findings is that the home government is surely granted the use of a positive subsidy in any optimal agreement: probability of using zero subsidy is zero under sorting at the bottom and continuous distribution F. Therefore, the degree of restrictions on subsidy choice implied by our findings is far milder than the

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[25] The inequality, $s_p < s_0$, is immediate from $\widehat{p}^w(s_p, \tau_p) = \widehat{p}^w(s = s_0, \tau = 0)$.

de facto prohibition of domestic production subsidies seen in the legal environment under WTO.

4.3 Restriction on Subsidy Choice

In this subsection, we develop general features that hold for the entire range of θ. A difficulty with characterizing an optimal policy set is that the world price may change over externality levels. Our analysis therefore proceeds from the simplest policy set that conveys the two features of an optimal agreement: sorting at the bottom and pooling at the top. This policy set involves only one world price: the home government is then granted the freedom to select any policy mix from the policy set that preserves the world price at a constant level. This policy set can be represented by

$$\{(s,\tau) : \widehat{p}^w(s,\tau) = \widehat{p}^w(s = \theta^c, \tau = 0)\}. \tag{26}$$

We restrict attention to $\theta^c \in (0,\overline{\theta})$, since optimality requires $\theta^c > 0$ by Proposition 2 and $\theta^c < \overline{\theta}$ by Proposition 1. The policy set entails sorting for $\theta \le \theta^c$ and pooling at $(\theta^c, 0)$ for $\theta > \theta^c$. As noted above, the sorting scheme for $\theta \le \theta^c$ has strength and weakness: it uses the first-best intervention to address the market imperfection and yet it entails the use of high import tariffs.

We next develop an alternative agreement in which the policy set consists of two separate subsets and includes a jump between the two. The jump is made from $(s(\theta_c), \tau(\theta_c))$ to $(s(\theta^c), \tau(\theta^c))$ such that type $\theta_c < \theta^c$ is indifferent between the two choices.[26] It follows that types $\theta \in (\theta_c, \theta^c)$ pool at $(s(\theta^c), \tau(\theta^c))$ and also that $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) > \widehat{p}^w(s(\theta^c), \tau(\theta^c))$.[27] In particular, we consider the policy set in which the second subset is a singleton and endpoint of the original sorting scheme (26) so that $(s(\theta^c), \tau(\theta^c)) = (\theta^c, 0)$. The alternative agreement thus entails sorting for all $\theta \le \theta_c$ along a new sorting scheme

$$\{(s,\tau) : \widehat{p}^w(s,\tau) = \widehat{p}^w(s(\theta_c), \tau(\theta_c)) \text{ for } s \le s(\theta_c)\} \tag{27}$$

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[26] Incentive compatibility implies that $(s(\theta^c), \tau(\theta^c))$ is in the region $\{(s,\tau) : W(s,\tau;\theta_c) \le W(s(\theta_c), \tau(\theta_c); \theta_c)\}$, and optimality implies that type θ_c is indifferent between $(s(\theta_c), \tau(\theta_c))$ and $(s(\theta^c), \tau(\theta^c))$, $W(s(\theta_c), \tau(\theta_c); \theta_c) = W(s(\theta^c), \tau(\theta^c); \theta_c)$; if $W(s(\theta_c), \tau(\theta_c); \theta_c) > W(s(\theta^c), \tau(\theta^c); \theta_c)$, then the expected global welfare can be increased by including a sorting scheme between a new point (s', τ') and $(s(\theta^c), \tau(\theta^c))$ such that $W(s(\theta_c), \tau(\theta_c); \theta_c) = W(s', \tau'; \theta_c)$ and $\widehat{p}^w(s', \tau') = \widehat{p}^w(s(\theta^c), \tau(\theta^c))$.

[27] If θ_c is indifferent between $(s(\theta_c), \tau(\theta_c))$ and $(s(\theta^c), \tau(\theta^c))$, then $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) > \widehat{p}^w(s(\theta^c), \tau(\theta^c))$; Lemma 4 implies $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) \ge \widehat{p}^w(s(\theta^c), \tau(\theta^c))$, and if $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) = \widehat{p}^w(s(\theta^c), \tau(\theta^c))$, then θ_c cannot be indifferent between the two different choices.

and pooling at the policy mix $(\theta^c, 0)$ for all $\theta > \theta_c$.

Let $\Delta(\theta) \equiv W_A^G(\cdot; \theta) - W_O^G(\cdot; \theta)$, where $W_A^G(\cdot; \theta)$ and $W_O^G(\cdot; \theta)$ represent the global welfare under the alternative and original agreements, respectively. The global welfare is affected for $\theta \leq \theta_c$ and for $\theta \in (\theta_c, \theta^c)$: the alternative agreement shifts the original sorting scheme towards lower import tariffs and brings the (global) welfare gain, $\Delta(\theta) > 0$, for types $\theta \leq \theta_c$, but it causes the welfare loss, $\Delta(\theta) < 0$, for those types $\theta \in (\theta_c, \theta^c)$ that newly pool at $(\theta^c, 0)$. Observing that the alternative policy set approaches the original set (26) as $\theta_c \to \theta^c$, we differentiate $\mathbb{E}_\theta \Delta(\theta)$ with respect to θ_c and show that the original agreement can be improved on by the alternative agreement. If θ_c falls slightly from θ^c, then the *marginal* welfare gain associated with the tariff reduction for $\theta \leq \theta_c$ along the new sorting scheme is strictly positive, but the *marginal* welfare loss associated with the new pooling for $\theta \in (\theta_c, \theta^c)$ is close to zero, since this welfare loss is measured on the original iso-world-price function (26) where the foreign welfare is held constant. Intuitively, along the original sorting scheme, the original policy choices maximize the home welfare; the first-order differentiation of the home welfare at the original policy choices is zero. If θ_c approaches θ^c, then the new pooling point approaches the original policy choices made for $\theta \in (\theta_c, \theta^c)$ along the original sorting scheme; the first-order differentiation of the home welfare at the new pooling point approaches zero. The marginal home-welfare loss associated with the new pooling then approaches zero.

As we present in the Appendix, we may extend this result and show that no optimal agreement includes a sorting scheme (as its policy subset) in which the world price is constant. This finding leads to two general points. First, along the sorting at the bottom seen in any optimal agreement, the world price is strictly increasing in θ. The slope at any policy mix on the sorting scheme is flatter than the slope of the associated iso-world-price function other than at the policy mix for the lowest type 0 where the two slopes are the same; thus, $s(0) = 0$ and $s(\theta) > \theta$ for $\theta \in (0, \theta_c)$. Second, in any optimal agreement, two different policy mixes deliver two different terms of trade for foreign country. Suppose $\theta_2 > \theta_1$ and $(s(\theta_1), \tau(\theta_1)) \neq (s(\theta_2), \tau(\theta_2))$ in an optimal agreement. By Lemma 4, $\widehat{p}^w(s(\theta_1), \tau(\theta_1)) \geq \widehat{p}^w(s(\theta_2), \tau(\theta_2))$. Further, $\widehat{p}^w(s(\theta_1), \tau(\theta_1)) = \widehat{p}^w(s(\theta_2), \tau(\theta_2))$ is impossible; if this equality holds, the expected global welfare would then be maximized by including a sorting scheme between $(s(\theta_1), \tau(\theta_1))$ and $(s(\theta_2), \tau(\theta_2))$ in which the world price is constant. Hence, in any optimal agreement, if $\theta_2 > \theta_1$ and $(s(\theta_1), \tau(\theta_1)) \neq (s(\theta_2), \tau(\theta_2))$, then $\widehat{p}^w(s(\theta_1), \tau(\theta_1)) > \widehat{p}^w(s(\theta_2), \tau(\theta_2))$. We now

highlight this second point.

Proposition 5. *In any optimal agreement, two different policy mixes deliver two different terms of trade for the foreign country such that an increase (decrease) in domestic subsidy deteriorates (improves) terms of trade for the foreign country.*

We next present two additional points. First, in an optimal agreement, the sorting scheme present at the bottom or potentially in other places may be short; an alternative agreement would otherwise create the net global welfare gain by shifting the scheme towards lower tariffs and including a new jump. The difference here is that the sorting scheme is no longer an iso-world-price function; thus, the marginal welfare loss associated with the new pooling does not approach zero. This result indicates that, for a wide range of θ, an optimal policy set may consist of pooling points. Second, we can numerically confirm that an agreement creates the net global welfare gain when it shifts any iso-world-price function and includes a new jump. Suppose that θ is uniformly distributed on $[0, 1]$ and that demand and supply functions are linear: $D(p^d) = 10 - p^d$ and $Q(p^s) = \frac{1}{2}p^s$ for the home country and $D^*(p^{*d}) = 10 - p^{*d}$ and $Q^*(p^{*s}) = p^{*s}$ for the foreign country.[28] If an agreement involves only one world price with no jump, then the optimal agreement within the class entails a sorting scheme (iso-world-price function) for $\theta \in [0, 0.68]$ and a pooling point $(0.68, 0)$. This agreement can be improved on by an agreement that involves two world prices with one jump: a sorting scheme for $\theta \in [0, 0.478]$ and a pooling point $(0.697, 0)$. This alternative agreement can again be improved on by another agreement that involves three world prices with two jumps: a sorting scheme for $\theta \in [0, 0.335]$ and two pooling points, $(0.508, 0.052)$ and $(0.705, 0)$.

We finally answer the question: for any θ, is the home government granted the freedom to select any policy mix from the policy set that preserves the world price at a constant level? Proposition 5 asserts that the home government is not granted the freedom in any optimal agreement. An optimal agreement resolves the tension between the objective of promoting domestic efficiency and the objective of reducing import tariffs only when it restricts the home government's subsidy choice and thus its use of first-best intervention. In this way, an optimal agreement respects terms of trade for the foreign country and increases the market-access level for foreign exporters.

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[28] We could numerically observe similar findings under different forms of linear functions.

In comparison with existing literature, our model conveys distinct policy implications. Bagwell and Staiger (2006) show that the market-access focus of GATT rules is a proper treatment of domestic subsidies: if market access is secured by the non-violation complaint at the negotiated (efficient) level, then negotiations with tariffs alone can achieve a policy mix that is efficient from a global perspective. The policy prescription implied by their finding is that governments need to be granted the freedom to select any policy mix from the policy set that preserves market access at the efficient level. In particular, the non-violation complaint plays an important role in achieving an efficient policy mix in Bagwell and Staiger (2001) when governments, subsequent to their tariff negotiation, are allowed to adjust tariffs to preserve market access at the negotiated level, and in Bagwell and Staiger (2006) when governments, with tariffs bound by their negotiation, have sufficient policy redundancy to keep market access at the negotiated level.

Our finding is founded on the standard features that are similarly contained in Bagwell and Staiger (2001, 2006): a government, under a market-access commitment, has no incentive to distort subsidy choice away from the efficient level, and an essential factor that leads to an inefficient policy mix is an insufficient consideration for the foreign country's terms of trade. In their model, the foreign country's terms of trade are duly respected when an agreement leads the home government to a first-best intervention with which to address the market imperfection. In our model, by contrast, the foreign country's terms of trade are duly respected when an agreement restricts the home government's subsidy choice and its use of first-best intervention. Proposition 5 shows that an optimal policy set can be achieved by a policy-mix agreement, not by a commitment to a specific market-access level. Proper restrictions on the use of domestic subsidies implied by our finding are clearly stricter than what is implied by the non-violation complaint of GATT rules.

5 Conclusions

In this paper, we investigate how a domestic subsidy is treated, when a government can disguise its protective use of subsidy as a legitimate intervention with which to address a market imperfection in the import-competing sector. We show that any optimal agreement permits the use of a positive domestic subsidy, but it restricts the home government's freedom to select domestic subsidy in order to increase the market-access level for foreign exporters.

On the one hand, we show that restrictions on subsidy choice are necessary, and moreover, proper restrictions are stricter than what is implied by the non-violation complaint of GATT rules. In broad terms, this finding indicates that the difficulties with determining whether a domestic subsidy is used as a legitimate or protective instrument may offer an explanation for the reason why the international trading system departs from the fairly tolerant treatment of domestic subsidies shown under GATT rules. On the other hand, we argue that, despite such necessary restrictions on subsidy choice, proper restrictions are far milder than the de facto prohibition of domestic production subsidies seen in the legal environment under WTO.

6 Appendix A: Preliminary Results[29]

For here and later use, we first show that the world price decreases in s and τ in equilibrium. It is immediate from the market-clearing condition that

$$\frac{\partial \widehat{p}^w}{\partial s} = \frac{Q'}{D' - Q' - (Q^{*\prime} - D^{*\prime})} < 0 \tag{A1}$$

$$\frac{\partial \widehat{p}^w}{\partial \tau} = -\frac{D' - Q'}{D' - Q' - (Q^{*\prime} - D^{*\prime})} < 0. \tag{A2}$$

Letting $E^*(\widehat{p}^w) \equiv Q^*(\widehat{p}^w) - D^*(\widehat{p}^w)$, we can also show that the domestic import decreases in s and τ in equilibrium:

$$\frac{\partial M}{\partial s} = \frac{\partial E^*}{\partial s} = (Q^{*\prime} - D^{*\prime})\frac{\partial \widehat{p}^w}{\partial s} = \frac{(Q^{*\prime} - D^{*\prime})Q'}{D' - Q' - (Q^{*\prime} - D^{*\prime})} < 0 \tag{A3}$$

$$\frac{\partial M}{\partial \tau} = \frac{\partial E^*}{\partial \tau} = (Q^{*\prime} - D^{*\prime})\frac{\partial \widehat{p}^w}{\partial \tau} = -\frac{(Q^{*\prime} - D^{*\prime})(D' - Q')}{D' - Q' - (Q^{*\prime} - D^{*\prime})} < 0. \tag{A4}$$

Using $\widehat{p}^s = \widehat{p}^w + \tau + s$, we can finally show that the domestic production of import good increases in s and τ in equilibrium:

$$\frac{\partial Q}{\partial s} = Q'\frac{\partial \widehat{p}^s}{\partial s} = \frac{Q'(D' - (Q^{*\prime} - D^{*\prime}))}{D' - Q' - (Q^{*\prime} - D^{*\prime})} > 0 \tag{A5}$$

$$\frac{\partial Q}{\partial \tau} = Q'\frac{\partial \widehat{p}^s}{\partial \tau} = -\frac{Q'(Q^{*\prime} - D^{*\prime})}{D' - Q' - (Q^{*\prime} - D^{*\prime})} > 0. \tag{A6}$$

From (A1)-(A4), we find that

$$-\frac{\partial \widehat{p}^w/\partial s}{\partial \widehat{p}^w/\partial \tau} = -\frac{\partial M/\partial s}{\partial M/\partial \tau} = \frac{Q'}{D' - Q'} < 0. \tag{A7}$$

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[29]These lengthy Appendices are not all for publication; they can be substantially shortened.

We then obtain two findings: (i) if the world price $\widehat{p}^w(s,\tau)$ is constant in a policy set, then the import volume $M(s,\tau)$ is also constant in that set and (ii) the slope $\frac{d\tau}{ds}$ is strictly negative along the policy set.

First-best and Nash policies: With these results in place, we find the first-best and non-cooperative policy choices. We first find (s,τ) that maximizes the global welfare $W^G(s,\tau;\theta)$. Recall the pricing relationships: $\widehat{p}^d(s,\tau) = \widehat{p}^w(s,\tau)+\tau$ and $\widehat{p}^s(s,\tau) = \widehat{p}^w(s,\tau)+\tau+s$. Observe also that $\frac{dCS(\widehat{p}^d)}{d\widehat{p}^d} = -D(\widehat{p}^d)$ and $\frac{d\Pi(\widehat{p}^s)}{d\widehat{p}^s} = Q(\widehat{p}^s)$, and similarly that $\frac{dCS^*(\widehat{p}^w)}{d\widehat{p}^w} = -D^*(\widehat{p}^w)$ and $\frac{d\Pi^*(\widehat{p}^w)}{d\widehat{p}^w} = Q^*(\widehat{p}^w)$. We can then obtain the differentiation:

$$\frac{\partial W^G(s,\tau;\theta)}{\partial s} = \tau\frac{\partial M}{\partial s} + [\theta - s]\frac{\partial Q}{\partial s}$$

$$\frac{\partial W^G(s,\tau;\theta)}{\partial \tau} = \tau\frac{\partial M}{\partial \tau} + [\theta - s]\frac{\partial Q}{\partial \tau}.$$

The first equation implies that, for any $\tau \geq 0$, if $s > \theta$, then $\frac{\partial W^G(s,\tau;\theta)}{\partial s} < 0$. Hence, $s \leq \theta$. Given $s \leq \theta$, the second equation implies that, if $\tau > 0$, then $\frac{\partial W^G(s,\tau;\theta)}{\partial \tau} < 0$. Hence, $\tau = 0$. It follows from the first equation that, if $\tau = 0$, then $s = \theta$. Therefore, $W^G(s,\tau;\theta)$ is maximized by $\tau = 0$ and $s = \theta$. We next find (s,τ) that maximizes the home welfare $W(s,\tau;\theta)$. Under the assumption that $W(s,\tau;\theta)$ is strictly concave, we find the first-order conditions:

$$\frac{\partial W(s,\tau;\theta)}{\partial s} = -\frac{\partial\widehat{p}^w}{\partial s}M + \tau\frac{\partial M}{\partial s} + [\theta - s]\frac{\partial Q}{\partial s} = 0$$

$$\frac{\partial W(s,\tau;\theta)}{\partial \tau} = -\frac{\partial\widehat{p}^w}{\partial \tau}M + \tau\frac{\partial M}{\partial \tau} + [\theta - s]\frac{\partial Q}{\partial \tau} = 0.$$

These conditions are satisfied when

$$s = \theta \text{ and } \tau = \frac{\partial\widehat{p}^w}{\partial \tau}\frac{M}{\partial M/\partial \tau} = \frac{\partial\widehat{p}^w}{\partial s}\frac{M}{\partial M/\partial s} = \frac{E^*(\widehat{p}^w)}{E^{*\prime}(\widehat{p}^w)}.$$

The equality for τ is given by (A1)-(A4).

Single-crossing property: We show that the single-crossing property holds in the iso-welfare function for the home country, $\{(s,\tau) : W(s,\tau;\theta) = \kappa$ for a constant $\kappa\}$. The gradient vector of the home welfare function is given by

$$\nabla(\theta) \equiv \left(\begin{array}{c} \partial W(s,\tau;\theta)/\partial s \\ \partial W(s,\tau;\theta)/\partial \tau \end{array} \right).$$

Using the first-order conditions shown above, we can differentiate the gradient vector with respect to θ:

$$\frac{\partial\nabla(\theta)}{\partial \theta} = \left(\begin{array}{c} \partial Q/\partial s \\ \partial Q/\partial \tau \end{array} \right).$$

We know from (A5) and (A6) that $\frac{\partial Q}{\partial s} > \frac{\partial Q}{\partial \tau} > 0$ at any policy mix. Thus, for any θ_1 and θ_2 where $\theta_2 > \theta_1$, the iso-welfare function for θ_2 crosses the iso-welfare function for θ_1 from above only once if it crosses. For instance, if demand and supply functions are linear, then $\frac{\partial \nabla(\theta)}{\partial \theta}$ remains the same for any θ.

7 Appendix B: Proofs

Proof of Lemma 1. We show that the home government with externality type θ selects the subsidy $s = \theta$ under the policy set in which $\widehat{p}^w$ is constant. The policy set can be represented by a decreasing function $\tau = \tau(s)$ where $\tau'(s) < 0$. The home welfare can thus be rewritten as

$$W(s, \tau(s); \theta) \equiv CS(\widehat{p}^d) + \Pi(\widehat{p}^s) + \tau(s) \cdot M(s, \tau(s)) - s \cdot Q(\widehat{p}^s) + \theta \cdot Q(\widehat{p}^s),$$

where

$$\widehat{p}^d = \widehat{p}^w(s, \tau(s)) + \tau(s) \text{ and } \widehat{p}^s = \widehat{p}^w(s, \tau(s)) + \tau(s) + s.$$

Using $\frac{dCS(\widehat{p}^d)}{d\widehat{p}^d} = -D(\widehat{p}^d)$ and $\frac{d\Pi(\widehat{p}^s)}{d\widehat{p}^s} = Q(\widehat{p}^s)$, we find the differentiation:

$$\frac{\partial W(s, \tau(s); \theta)}{\partial s} = [Q - D]\left[\frac{\partial \widehat{p}^w}{\partial \tau}\frac{d\tau}{ds} + \frac{\partial \widehat{p}^w}{\partial s}\right] + \tau\frac{\partial M}{\partial \tau}\frac{d\tau}{ds} + \tau\frac{\partial M}{\partial s} + [\theta - s]\left[\frac{\partial Q}{\partial \tau}\frac{d\tau}{ds} + \frac{\partial Q}{\partial s}\right]. \quad (A8)$$

From (A7), it follows that the slope of the iso-world-price function is

$$\frac{d\tau}{\partial s} = -\frac{\partial \widehat{p}^w/\partial s}{\partial \widehat{p}^w/\partial \tau} = -\frac{\partial M/\partial s}{\partial M/\partial \tau}.$$

The RHS of (A8) is then reduced to the last term:

$$\frac{\partial W(s, \tau(s); \theta)}{\partial s} = [\theta - s]\left[\frac{\partial Q}{\partial \tau}\frac{d\tau}{ds} + \frac{\partial Q}{\partial s}\right] = [\theta - s]\frac{Q'D'}{D' - Q'}. \quad (A9)$$

The second equality in (A9) is given by (A5)-(A7). Since $\frac{Q'D'}{D' - Q'} > 0$, $\frac{\partial W(s, \tau(s); \theta)}{\partial s} < 0$ for $s > \theta$ and $\frac{\partial W(s, \tau(s); \theta)}{\partial s} > 0$ for $s < \theta$. Hence, the home government with externality type θ selects the subsidy $s = \theta$ under the policy set in which $\widehat{p}^w$ is constant. ∎

Proof of Lemma 3. In the sorting scheme (13), if κ rises from zero, the subsidy choice remains the same at $s(\theta) = \theta$ while $\tau(\theta)$ rises for all θ. Thus, a slight increase in κ from zero lowers the world price for all θ, which in turn decreases the foreign welfare for all θ:

$$\frac{dW^*(s, \tau)}{d\widehat{p}^w} = -D^*(\widehat{p}^w) + Q^*(\widehat{p}^w) = E^*(\widehat{p}^w) > 0.$$

The last inequality is given by the assumption 1 (ii), $M(s = \overline{\theta}, \tau = 0) > 0$. Further, given $s(\theta) = \theta$, it follows that

$$\frac{\partial W^G(s(\theta), \tau; \theta)}{\partial \tau} = \tau \frac{\partial M}{\partial \tau} < 0 \text{ for any } \tau > 0.$$

Hence, if κ rises from zero, then the global welfare falls for all θ. ∎

Proof of Proposition 1. We consider an alternative agreement that has the policy set:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \theta^c, \tau = 0)\} \text{ where } \theta^c < \overline{\theta}. \tag{A10}$$

The set can be represented by a strictly decreasing function, $\tau = \tau(s)$:

$$\tau(s) = \frac{d\tau}{ds}[s - \theta^c] = \frac{Q'}{D' - Q'}[s - \theta^c] > 0, \tag{A11}$$

where the slope, $\frac{d\tau}{ds} = \frac{Q'}{D' - Q'} < 0$, is determined by (A1) and (A2). This agreement entails pooling for $\theta \geq \theta^c$: for all $\theta \in [\theta^c, \overline{\theta}]$, $s(\theta) = \theta^c$ and $\tau(\theta) = 0$. It also involves sorting for $\theta < \theta^c$: for all $\theta \in [0, \theta^c)$, $s(\theta) = \theta$ and the tariff choice $\tau(\theta)$ is determined by the function $\tau = \tau(s)$. With such policy choices, we may write the expected global welfare under the alternative agreement as

$$\int_0^{\theta^c} W^G(s(\theta), \tau(\theta); \theta) dF(\theta) + \int_{\theta^c}^{\overline{\theta}} W^G(s = \theta^c, \tau = 0; \theta) dF(\theta). \tag{A12}$$

Since $W^G(s(\theta^c), \tau(\theta^c); \theta^c) = W^G(s = \theta^c, \tau = 0; \theta^c)$ by construction, differentiation of (A12) with respect to θ^c is reduced to two terms:

$$\int_0^{\theta^c} \frac{\partial W^G(s(\theta), \tau(\theta); \theta)}{\partial \theta^c} dF(\theta) + \int_{\theta^c}^{\overline{\theta}} \frac{\partial W^G(s = \theta^c, \tau = 0; \theta)}{\partial \theta^c} dF(\theta). \tag{A13}$$

If θ^c increases, then the function $\tau(s)$ in (A11) shifts up and thus for all $\theta \in [0, \theta^c)$, the tariff choice $\tau(\theta)$ rises while $s(\theta) = \theta$. With this subsidy choice for $\theta \in [0, \theta^c)$, we find the differentiation in the first term of (A13):

$$
\begin{aligned}
\frac{\partial W^G(s(\theta), \tau(\theta); \theta)}{\partial \theta^c} &= \frac{\partial W^G(s(\theta), \tau(\theta); \theta)}{\partial \tau} \frac{d\tau(\theta)}{d\theta^c} \\
&= \tau(\theta) \frac{\partial M}{\partial \tau} \frac{d\tau(\theta)}{d\theta^c} \\
&= -\left(\frac{Q'}{D' - Q'}\right)^2 [\theta - \theta^c] \frac{\partial M}{\partial \tau} < 0.
\end{aligned} \tag{A14}
$$

The third equality is given by (A11). The first term of (A13) is thus negative. We next show that the second term of (A12) is positive. In the pooling interval, if θ^c rises, then the

subsidy choice $s(\theta) = \theta^c$ rises given the tariff choice $\tau(\theta) = 0$. With this tariff choice for $\theta \in [\theta^c, \overline{\theta}]$, we find the differentiation:

$$\frac{\partial W^G(s = \theta^c, \tau = 0; \theta)}{\partial \theta^c} = [\theta - \theta^c]\frac{\partial Q}{\partial \theta^c} > 0 \text{ for } \theta > \theta^c. \tag{A15}$$

If $\theta^c \to \overline{\theta}$, then (A15) approaches zero while (A14) remains strictly negative: if θ^c decreases slightly from $\overline{\theta}$, then the expected global welfare in (A12) increases. Hence, the separating agreement can be improved upon by the alternative agreement that entails pooling at the top for $\theta \in [\theta^c, \overline{\theta}]$. ∎

Proof of Proposition 2. We here show that an agreement is not optimal when the policy set is $\{(s_1, 0), (s_2, 0)\}$ where $s_1 = 0$. We consider two possibilities: (i) $(0,0)$ is selected only by the lowest type 0 and (ii) $(0,0)$ is selected by types $\theta \in [0, \widehat{\theta}]$ where $\widehat{\theta} > 0$. We first show that the agreement under (i) can be improved on by an alternative agreement in which the policy set is the sorting scheme:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = s_2, \tau = 0)\}. \tag{A16}$$

This agreement entails sorting for $\theta \leq s_2$ and pooling at $(s_2, 0)$ for $\theta > s_2$. We assume $s_2 < \overline{\theta}$; if $s_2 \geq \overline{\theta}$, then it is immediate from the argument below to show that the agreement under (i) is not optimal. For the lowest type 0, the global welfare is higher in the original choice $(0,0)$ than in (A16). For types $\theta \in (0, s_2)$, however, the global welfare is higher in (A16) than in the original choice $(s_2, 0)$: inclusion of a sorting scheme in (A16) increases the home welfare while preserving the world price $\widehat{p}^w(s = s_2, \tau = 0)$. Since $prob(\theta = 0) = 0$ under the continuous distribution F, the expected global welfare is higher in the alternative agreement than in the original agreement. We next show that the agreement under (ii) is not optimal. We pick a subsidy $\widehat{s} \in (0, \widehat{\theta})$ and develop an alternative policy set $\{(\widehat{s}, 0), (s_2, 0)\}$. This set entails pooling for $\theta \in [0, \widehat{\theta}]$ at $(\widehat{s}, 0)$: since $(0,0)$ and $(s_2, 0)$ are indifferent for type $\widehat{\theta}$ in the original set, it is immediate that $(\widehat{s}, 0)$ is preferred to $(s_2, 0)$ for types $\theta \leq \widehat{\theta}$ in the alternative set. This alternative set also motivates some types $\theta > \widehat{\theta}$ to mimic lower types and select $(\widehat{s}, 0)$. The associated home-welfare gain by those types from mimicking lower types raises the world price and thus the foreign welfare for those types. It thus suffices to show that the global welfare over the range $[0, \widehat{\theta})$ is higher in the alternative agreement than in the original

agreement. As hinted by the optimal pooling agreement, we find

$$\int_0^{\widehat{\theta}} W^G(s^p, \tau = 0; \theta) dF(\theta) = W^G(s^p, \tau = 0; \int_0^{\widehat{\theta}} \theta dF(\theta)),$$

where s^p is constant for $\theta \in [0, \widehat{\theta})$. The term on the LHS is maximized when $s^p = \int_0^{\widehat{\theta}} \theta dF(\theta)$. We can always set $\widehat{s} = \int_0^{\widehat{\theta}} \theta dF(\theta)$ in the alternative agreement. Further, this alternative agreement can be improved on by another agreement that entails sorting at the bottom:

$$\{\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \widehat{s}, \tau = 0)\}, (s_2, 0)\}.$$

Hence, an agreement with the policy set $\{(s_1, 0), (s_2, 0)\}$ is not optimal. ∎

Proof of Lemma 4. We here show that, in any optimal agreement, $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) \leq \widehat{p}^w(s(\theta_1), \tau(\theta_1))$ for any $\theta_2 > \theta_1$. Assume that an agreement is optimal and $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) > \widehat{p}^w(s(\theta_1), \tau(\theta_1))$ for some $\theta_2 > \theta_1$. Without loss of generality, we assume that there exists type $\theta_c \in [0, \theta_1)$ such that $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) \geq \widehat{p}^w(s(\theta), \tau(\theta))$ for all $\theta \in [0, \overline{\theta}]$, and also that $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) \geq \widehat{p}^w(s(\theta), \tau(\theta))$ for any $\theta > \theta_c$. The monotonicity of subsidy choice then implies

$$s(\theta_c) \leq s(\theta_1) \leq s(\theta_2).$$

Define (s_2, τ_2) as the policy mix that maximizes $\widehat{p}^w(s, \tau)$ subject to the set:

$$\{(s, \tau) : W(s, \tau; \theta_2) = W(s(\theta_2), \tau(\theta_2); \theta_2)\}. \tag{A17}$$

The world price within (A17) is maximized, when the iso-world-price function, $\{(s, \tau) : \widehat{p}^w(s, \tau) = \kappa$ for a constant $\kappa > 0\}$, shifts down either (a) until it is tangent to (A17) or (b) until it crosses (A17) from below at zero tariff. It then follows that

$$s(\theta_1) < s_2 \leq \theta_2.$$

The second inequality is immediate: $s_2 = \theta_2$ under (a) and $s_2 < \theta_2$ under (b). To show that the first inequality holds, suppose $s_2 \leq s(\theta_1)$. By the monotonicity, $s_2 \leq s(\theta_1) \leq s(\theta_2)$. Given that (s_2, τ_2) and $(s(\theta_2), \tau(\theta_2))$ are located on the the same iso-welfare function for θ_2 in (A17), the above assumption, $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) > \widehat{p}^w(s(\theta_1), \tau(\theta_1))$, implies that $(s(\theta_1), \tau(\theta_1))$ is preferred to $(s(\theta_2), \tau(\theta_2))$ for type θ_2, which violates incentive compatibility. Hence, $s_2 > s(\theta_1)$ holds. We below develop an alternative agreement under two cases: (i) $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) \leq \widehat{p}^w(s_2, \tau_2)$ and (ii) $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) > \widehat{p}^w(s_2, \tau_2)$.

Case (i): We develop an alternative policy set that includes a sorting scheme at the bottom up to the point (s_2, τ_2):

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s_2, \tau_2) \text{ for all } s \leq s_2\}. \tag{A18}$$

The policy set for $s > s_2$ remains the same as in the original agreement. We first show that incentive compatibility for types $\theta \leq s_2$ holds. The policy mix (s_2, τ_2) is in the set (A17) and any policy mix for $s > s_2$ is in the region $\{(s, \tau) : W(s, \tau; \theta_2) \leq W(s(\theta_2), \tau(\theta_2); \theta_2)\}$. Given $s_2 \leq \theta_2$ as shown above, types $\theta \leq s_2$ do not mimic types $\theta > s_2$ and their policy choices are made along the set (A18); hence, $s(\theta) = \theta$ for all $\theta \leq s_2$. We next show that incentive compatibility for $\theta > s_2$ can be ignored: if some types $\theta > s_2$ have incentive to mimic types $\theta \leq s_2$, then the associated home-welfare increase does not lower the foreign welfare for any θ, since the sorting scheme (A18) involves the highest possible world price $\widehat{p}^w(s_2, \tau_2)$. Therefore, in order to show that the alternative agreement improves the expected global welfare, it suffices to show that, for the range $[0, s_2]$, the global welfare is higher in the alternative agreement than in the original agreement:

$$\int_0^{s_2} W_A^G(\cdot; \theta) dF(\theta) > \int_0^{s_2} W_O^G(\cdot; \theta) dF(\theta)$$

where $W_A^G(\cdot; \theta)$ and $W_O^G(\cdot; \theta)$ represent the global welfare under the alternative and original agreements, respectively. Observe that the sorting scheme (A18) extends beyond the point $(s(\theta_1), \tau(\theta_1))$ at the world price $\widehat{p}^w(s_2, \tau_2) > \widehat{p}^w(s(\theta_1), \tau(\theta_1))$, given $s(\theta_1) < s_2$ as shown above and the assumption $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) > \widehat{p}^w(s(\theta_1), \tau(\theta_1))$. This result ensures that, in the original agreement, some types $\theta \in [0, s_2]$ selected their policies not from the sorting scheme (A18) but from the region in which the world price is lower than $\widehat{p}^w(s_2, \tau_2)$. Thus, inclusion of the sorting scheme (A18) increases the global welfare for the range $[0, s_2]$ and so the original agreement is not optimal, which causes a contradiction.

Case (ii): In this case, the iso-world-price function, $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s_2, \tau_2)\}$, crosses the iso-welfare function for θ_c, $\{(s, \tau) : W(s, \tau; \theta_c) = W(s(\theta_c), \tau(\theta_c); \theta_c)\}$. We can then define the crossing point as the policy mix (s_c, τ_c) that satisfies

$$\widehat{p}^w(s_c, \tau_c) = \widehat{p}^w(s_2, \tau_2) \text{ and } W(s_c, \tau_c; \theta_c) = W(s(\theta_c), \tau(\theta_c); \theta_c) \text{ where } s_c > \theta_c.$$

We next observe that

$$\theta_c < s_c < s(\theta_1) < s_2 \leq \theta_2. \tag{A19}$$

All inequalities are given above other than the inequality, $s_c < s(\theta_1)$. This inequality holds since $(s(\theta_1), \tau(\theta_1))$ satisfies

$$W(s(\theta_1), \tau(\theta_1); \theta_c) \leq W(s_c, \tau_c; \theta_c) = W(s(\theta_c), \tau(\theta_c); \theta_c) \tag{A20}$$

$$\widehat{p}^w(s(\theta_1), \tau(\theta_1)) < \widehat{p}^w(s_c, \tau_c) = \widehat{p}^w(s_2, \tau_2).$$

The first inequality is incentive compatibility of θ_c. The second inequality is given by the above assumption, $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) > \widehat{p}^w(s(\theta_1), \tau(\theta_1))$, and the definition of (s_2, τ_2) which implies $\widehat{p}^w(s_2, \tau_2) \geq \widehat{p}^w(s(\theta_2), \tau(\theta_2))$.

We now construct an alternative policy set that contains the sorting scheme for $s \in [s_c, s_2]$:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s_2, \tau_2) \text{ for all } s \in [s_c, s_2]\}. \tag{A21}$$

The policy set for $s \notin [s_c, s_2]$ remains the same as in the original agreement. This sorting scheme involves the highest possible world price for all $\theta > \theta_c$, since $\widehat{p}^w(s_2, \tau_2) \geq \widehat{p}^w(s(\theta_2), \tau(\theta_2))$ and $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) \geq \widehat{p}^w(s(\theta), \tau(\theta))$ for any $\theta > \theta_c$. We next check incentive compatibility of the alternative agreement. This agreement is arranged to make type θ_c indifferent between $(s(\theta_c), \tau(\theta_c))$ and (s_c, τ_c) and thus, types $\theta \in (\theta_c, s_c)$ pool at (s_c, τ_c). We also know that (s_2, τ_2) is in (A17) and the policy set for $s > s_2$ is in $\{(s, \tau) : W(s, \tau; \theta_2) \leq W(s(\theta_2), \tau(\theta_2); \theta_2)\}$. Thus, given $s_2 \leq \theta_2$, types $\theta \in [s_c, s_2]$ do not mimic types $\theta > s_2$ and their choices are made from the sorting scheme (A21).

We finally show that, for the affected range $(\theta_c, s_2]$, the global welfare is higher in the alternative agreement than in the original agreement. Consider first types $\theta \in [s_c, s_2]$. Together with $s_c < s(\theta_1) < s_2$ in (A19), the last inequality in (A20) ensures that, in the original agreement, some types $\theta \in [s_c, s_2]$ selected their policies not from the sorting scheme (A21) but from the region in which the world price is lower than $\widehat{p}^w(s_2, \tau_2)$. Hence,

$$\int_{s_c}^{s_2} W_A^G(\cdot; \theta) dF(\theta) > \int_{s_c}^{s_2} W_O^G(\cdot; \theta) dF(\theta).$$

Consider next types $\theta \in (\theta_c, s_c)$. In the original agreement, the policy mixes for the affected types $\theta \in (\theta_c, s_2]$ are in the region:

$$\{(s, \tau) : W(s, \tau; \theta_c) \leq W(s(\theta_c), \tau(\theta_c); \theta_c) \text{ and } \widehat{p}^w(s, \tau) \leq \widehat{p}^w(s_c, \tau_c)\}.$$

For any (s, τ) in this set, $s \geq s_c$. Thus, for $\theta \in (\theta_c, s_c)$, any policy mix selected under the original agreement takes the form of over-subsidy, $s(\theta) > \theta$, and involves a weekly lower world

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price than does the sorting scheme in (A21). Hence, for any original policy mix $(s(\theta), \tau(\theta))$ for $\theta \in (\theta_c, s_c)$, there exist $(\widehat{s}, \widehat{\tau})$ such that $\widehat{s} = s(\theta)$ and $\widehat{\tau} \le \tau(\theta)$ on the sorting scheme:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s_2, \tau_2) \text{ for } s \ge s_c\}. \tag{A22}$$

We now follow three logical steps. First, if any policy mix takes the form of over-subsidy, then a decrease in tariff increases the global welfare:

$$\frac{\partial W^G(s, \tau; \theta)}{\partial \tau} = \tau \frac{\partial M}{\partial \tau} + [\theta - s] \frac{\partial Q}{\partial \tau} < 0 \text{ for any } s > \theta. \tag{A23}$$

Second, we compare two scenarios: (a) given the original mix $(s(\theta), \tau(\theta))$, the home government with $\theta \in (\theta_c, s_c)$ is now "restricted" to select $(\widehat{s} = s(\theta), \widehat{\tau} \le \tau(\theta))$ from the set (A22), and (b) the home government with $\theta \in (\theta_c, s_c)$ is allowed to select any policy mix from the set (A22) with no such restriction. The home welfare is at least as high in (b) as in (a), while the foreign welfare is the same in both cases. To summarize the two results, for $\theta \in (\theta_c, s_c)$, the global welfare is at least as high in (A22) as in the original agreement. Third, for $\theta \in (\theta_c, s_c)$, both (A21) and (A22) entail pooling at the same point (s_c, τ_c) and thus generate the same global welfare. Finally, for the overall affected range $(\theta_c, s_2]$, we can compare the global welfare:

$$\int_{\theta_c}^{s_2} W_A^G(\cdot; \theta) dF(\theta) > \int_{\theta_c}^{s_2} W_O^G(\cdot; \theta) dF(\theta).$$

Hence, the original agreement is not optimal, which causes a contradiction. ∎

Proof of Proposition 3. Given that $s(0) = 0$ and $\tau(0) > 0$ by Lemma 5, we show that any optimal agreement entails sorting at the bottom. Assume that an agreement is optimal and involves pooling at $(s(0), \tau(0))$ for $\theta \in [0, \theta_0]$ where $\theta_0 > 0$. Incentive compatibility implies that the policy mixes for $\theta > \theta_0$ are in the region $\{(s, \tau) : W(s, \tau; \theta_0) \le W(s(0), \tau(0); \theta_0)\}$. Define (s_0, τ_0) as the policy mix that maximizes $\widehat{p}^w(s, \tau)$ subject to the set:

$$\{(s, \tau) : W(s, \tau; \theta_0) = W(s(0), \tau(0); \theta_0)\}. \tag{A24}$$

The world price within (A24) is maximized, when the iso-world-price function shifts down either (i) until it is tangent to (A24) or (ii) until it crosses (A24) at zero tariff. It then follows that

$$0 < s_0 \le \theta_0.$$

The second inequality is immediate: $s_0 = \theta_0$ under (i) and $s_0 < \theta_0$ under (ii). Under (i), the first inequality is given by $s_0 = \theta_0$ and $\theta_0 > 0$. Under (ii), given $s(0) = 0$, if $s_0 = 0$, then $\tau(0) = 0$, which is impossible by Lemma 5 and so $s_0 > 0$.

We now construct an alternative policy set that contains a sorting scheme at the bottom up to (s_0, τ_0):

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s_0, \tau_0) \text{ for all } s \leq s_0\}. \tag{A25}$$

The policy set for $s > s_0$ remains the same as in the original agreement. We next check incentive compatibility of the alternative agreement. The policy mix (s_0, τ_0) is in the set (A24) and any policy mix for $s > s_0$ is in $\{(s, \tau) : W(s, \tau; \theta_0) \leq W(s(0), \tau(0); \theta_0)\}$. Thus, given $s_0 \leq \theta_0$ as shown above, types $\theta \leq s_0$ do not mimic types $\theta > s_0$ and their choices are made from the sorting scheme (A25): $s(\theta) = \theta$ for all $\theta \leq s_0$. The incentive of types $\theta > s_0$ to mimic types $\theta \leq s_0$ can be ignored: the associated home-welfare gain does not cause a fall in the world price, since the original agreement satisfies the monotonicity: $\widehat{p}^w(s_0, \tau_0) \geq \widehat{p}^w(s(\theta), \tau(\theta))$ for all θ. Therefore, inclusion of the sorting scheme (A25) increases the global welfare for $\theta \leq s_0$ and so the original agreement is not optimal, which causes a contradiction. ∎

Proof of Lemma 6. We show that, in any optimal agreement, for any θ, if $\tau(\theta) > 0$, then $(s(\theta), \tau(\theta))$ is in the region:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}. \tag{A26}$$

Assume that an agreement is optimal and allows $\tau(\theta) > 0$ and $\widehat{p}^w(s(\theta), \tau(\theta)) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)$ for some $\theta > 0$. Lemma 5 implies that there exists type

$$\widehat{\theta} = \sup\{\theta : \widehat{p}^w(s(\theta), \tau(\theta)) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$$

such that (i) the welfare function for $\widehat{\theta}$, $\{(s, \tau) : W(s, \tau; \widehat{\theta}) = W(s(\widehat{\theta}), \tau(\widehat{\theta}); \widehat{\theta})\}$, crosses $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$ from below at a strictly positive tariff, or (ii) it crosses the zero-tariff line, $\{(s, \tau) : \tau = 0\}$. For those two cases, we below show that the agreement is not optimal, which cause a contradiction.

Case (i): Let the crossing point be $(\widehat{s}, \widehat{\tau})$:

$$W(\widehat{s}, \widehat{\tau}; \widehat{\theta}) = W(s(\widehat{\theta}), \tau(\widehat{\theta}); \widehat{\theta}) \text{ and } \widehat{p}^w(\widehat{s}, \widehat{\tau}) = \widehat{p}^w(s = \overline{\theta}, \tau = 0).$$

We may consider two possibilities: (a) $(\widehat{s}, \widehat{\tau}) \neq (s(\widehat{\theta}), \tau(\widehat{\theta}))$ and (b) $(\widehat{s}, \widehat{\tau}) = (s(\widehat{\theta}), \tau(\widehat{\theta}))$. The case (a) occurs when the point $(s(\widehat{\theta}), \tau(\widehat{\theta}))$ is located *within* the region (A26), which means $\widehat{p}^w(s(\widehat{\theta}), \tau(\widehat{\theta})) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)$. The case (b) occurs when $(s(\widehat{\theta}), \tau(\widehat{\theta}))$ is located *on* the iso-world-price function $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$. In particular, this case occurs when the policy set adjoining the point $(s(\widehat{\theta}), \tau(\widehat{\theta}))$ from the left is continuous and is flatter than the iso-world-price function.

We first consider the case (a). From the definition of $(\widehat{s}, \widehat{\tau})$, it follows that $\widehat{\theta} < \widehat{s}$. Observe also that the original agreement places any policy mix for $s \geq \widehat{s}$ in the region:

$$\{(s, \tau) : W(s, \tau; \widehat{\theta}) \leq W(s(\widehat{\theta}), \tau(\widehat{\theta}); \widehat{\theta}) \text{ and } \widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}. \tag{A27}$$

We now construct an alternative policy set that includes a sorting scheme from the point $(\widehat{s}, \widehat{\tau})$:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = 0) \text{ for } s \geq \widehat{s}\}. \tag{A28}$$

The policy set for $s < \widehat{s}$ is the same as in the original agreement. The alternative agreement entails pooling for $\theta \in (\widehat{\theta}, \widehat{s})$ at $(\widehat{s}, \widehat{\tau})$ and sorting for $\theta \in [\widehat{s}, \overline{\theta}]$ along the set (A28). For the affected types $\theta \in (\widehat{\theta}, \overline{\theta}]$, the global welfare is at least as high in the alternative agreement as in the original agreement. For $\theta \in [\widehat{s}, \overline{\theta}]$, the alternative agreement involves sorting at a weakly higher world price and thus generates at least as high global welfare as the original agreement does. For $\theta \in (\widehat{\theta}, \widehat{s})$, the original agreement entails over-subsidy, $s(\theta) > \theta$, and involves a weekly lower world price than does the sorting scheme in (A28). Adopting the argument used in the proof of Lemma 4, we can confirm that, for $\theta \in (\widehat{\theta}, \widehat{s})$, the alternative agreement generates at least as high global welfare as the original agreement does. In order to show that the original agreement is not optimal, it now suffices to show that the alternative agreement is improved on by a new policy set.

Suppose that the new policy set contains the sorting scheme for $s > \widehat{s}'$ at the world price that is higher than $\widehat{p}^w(s = \overline{\theta}, \tau = 0)$:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \theta^c, \tau = 0) \text{ for } s \geq \widehat{s}'\}, \tag{A29}$$

where $\theta^c < \overline{\theta}$ and $\widehat{s}' < \widehat{s}$. The policy set for $s < \widehat{s}'$ remains the same. As above, an endpoint in (A29), $(\widehat{s}', \widehat{\tau}')$, is defined as the crossing point that satisfies

$$W(\widehat{s}', \widehat{\tau}'; \widehat{\theta}) = W(s(\widehat{\theta}), \tau(\widehat{\theta}); \widehat{\theta}) \text{ and } \widehat{p}^w(\widehat{s}', \widehat{\tau}') = \widehat{p}^w(s = \theta^c, \tau = 0).$$

This policy set entails pooling for $\theta \in (\widehat{\theta}, \widehat{s}')$ at $(\widehat{s}', \widehat{\tau}')$, sorting for $\theta \in [\widehat{s}', \theta^c)$ along (A29) and pooling for $\theta \in [\theta^c, \overline{\theta}]$ at $(\theta^c, 0)$. The pooling for $\theta \in (\widehat{\theta}, \widehat{s}')$ causes over-subsidy. Observing that, if $\theta^c \to \overline{\theta}$, then $(\widehat{s}', \widehat{\tau}') \to (\widehat{s}, \widehat{\tau})$ and so (A29) approaches (A28), we differentiate the expected global welfare under (A29) with respect to θ^c. The derivative is reduced to three terms:

$$\int_{\widehat{\theta}}^{\widehat{s}'} \frac{\partial W^G(\widehat{s}', \widehat{\tau}'; \theta)}{\partial \theta^c} dF(\theta) + \int_{\widehat{s}'}^{\theta^c} \frac{\partial W^G(s(\theta), \tau(\theta); \theta)}{\partial \theta^c} dF(\theta) + \int_{\theta^c}^{\overline{\theta}} \frac{\partial W^G(s = \theta^c, \tau = 0; \theta)}{\partial \theta^c} dF(\theta).$$
(A30)

As seen in (A13) in the proof of Proposition 1, if $\theta^c \to \overline{\theta}$, then the second term in (A30) remains negative and the third term approaches zero. We next show that, if $\theta^c \to \overline{\theta}$, the first term is negative. To this end, supposing that θ^c falls slightly from $\overline{\theta}$, we show that, for $\theta \in (\widehat{\theta}, \widehat{s}')$, the global welfare is higher under pooling at $(\widehat{s}', \widehat{\tau}')$ than under pooling at $(\widehat{s}, \widehat{\tau})$. We first compare two scenarios: the home government with $\theta \in (\widehat{\theta}, \widehat{s}')$ is restricted to select a point $(\widehat{s}, \widetilde{\tau})$ from (A29) that satisfies $\widehat{p}^w(\widehat{s}, \widetilde{\tau}) > \widehat{p}^w(\widehat{s}, \widehat{\tau})$, and the home government with $\theta \in (\widehat{\theta}, \widehat{s}')$ is allowed to select any policy mix from (A29). For $\theta \in (\widehat{\theta}, \widehat{s}')$, the home welfare is at least as high in the second scenario as in the first scenario, while the foreign welfare is the same in both scenarios; the global welfare is at least as high in the second scenario as in the first scenario. Further, for $\theta \in (\widehat{\theta}, \widehat{s}')$, the global welfare is higher in the second scenario than in the pooling at $(\widehat{s}, \widehat{\tau})$, since tariffs are lower at $(\widehat{s}, \widetilde{\tau})$ than at $(\widehat{s}, \widehat{\tau})$ and $\frac{\partial W^G(s, \tau; \theta)}{\partial \tau} < 0$ for any $s > \theta$. We can thus claim that, for $\theta \in (\widehat{\theta}, \widehat{s}')$, the global welfare is higher under pooling at $(\widehat{s}', \widehat{\tau}')$ than under pooling at $(\widehat{s}, \widehat{\tau})$. Hence, if $\theta^c \to \overline{\theta}$, then the expected global welfare is higher in (A29) than in (A28).

We next consider the case (b) in which $(\widehat{s}, \widehat{\tau}) = (s(\widehat{\theta}), \tau(\widehat{\theta}))$. The original policy set entails an over-subsidy interval: types $\theta \in (\widehat{\theta}, \widehat{s})$ select their policies from the region (A27) for $s \geq \widehat{s} = s(\widehat{\theta})$. The remaining proof is analogous to the proof seen in the case (a), except that the endpoint in (A29), $(\widehat{s}', \widehat{\tau}')$, is now defined as the point at which the iso-world-price function (A29) crosses the original policy set that is continuous near $(\widehat{s}, \widehat{\tau})$. ∎

Case (ii): When the iso-welfare function $\{(s, \tau) : W(s, \tau; \widehat{\theta}) = W(s(\widehat{\theta}), \tau(\widehat{\theta}); \widehat{\theta})\}$ crosses the zero-tariff line, we may consider two possibilities: (a) the function crosses the zero-tariff line only once and (b) it has two crossing points, $(s_1, 0)$ and $(s_2, 0)$ where $s_2 > s_1$, such that

$$W(s_1, 0; \widehat{\theta}) = W(s_2, 0; \widehat{\theta}) = W(s(\widehat{\theta}), \tau(\widehat{\theta}); \widehat{\theta}).$$

The case (a) occurs when the iso-welfare function is tangent to the zero-tariff line at $(\overline{\theta}, 0)$; if the tangent point is not $(\overline{\theta}, 0)$, then the iso-welfare function crosses $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$ from below at a positive tariff, which corresponds to the case (i) seen above. The case (b) occurs when $s_1 \leq \overline{\theta} \leq s_2$; if $s_1 > \overline{\theta}$ or $s_2 < \overline{\theta}$, then the iso-welfare function crosses $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$ from below at a positive tariff, which corresponds to the case (i).

Consider first the case (a). In the original policy set, if $s < \overline{\theta}$, then (s, τ) is in the region (A26) and if $s \geq \overline{\theta}$, then (s, τ) is in the region:

$$\{(s, \tau) : W(s, \tau; \widehat{\theta}) \leq W(s = \overline{\theta}, \tau = 0; \widehat{\theta}) \text{ and } \widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}. \tag{A31}$$

Any policy mix (s, τ) that satisfies $\widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)$ is in the region (A31). Any (s, τ) in (A31) with a positive tariff, $\tau > 0$, satisfies $\widehat{p}^w(s, \tau) < \widehat{p}^w(s = \overline{\theta}, \tau = 0)$ and is improved on by the zero-tariff point $(\overline{\theta}, 0)$. Consider next the case (b). Any policy mix (s, τ) that satisfies $\tau > 0$ and $\widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)$ is in the region:

$$\{(s, \tau) : W(s, \tau; \widehat{\theta}) \leq W(s = s_2, \tau = 0; \widehat{\theta}) \text{ and } \widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = s_2, \tau = 0)\}. \tag{A32}$$

Any policy mix (s, τ) in (A32) with a positive tariff, $\tau > 0$, satisfies $\widehat{p}^w(s, \tau) < \widehat{p}^w(s = s_2, \tau = 0)$ and is improved on by the zero-tariff point $(s_2, 0)$. ∎

Proof of Proposition 5. We here show that no optimal policy set includes a sorting scheme in which the world price is constant. First, we show that an optimal agreement cannot have a sorting scheme at the bottom in which the world price is constant. Suppose that an agreement is optimal and entails sorting at the bottom for $\theta \leq \theta_c$ along an iso-world-price function $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s(\theta_c), \tau(\theta_c))\}$. We know from the text that an optimal policy set, involving more than one world price, includes a jump at $(s(\theta_c), \tau(\theta_c))$ such that type θ_c is indifferent between $(s(\theta_c), \tau(\theta_c))$ and (s_1, τ_1); types $\theta \in (\theta_c, s_1)$ pool at (s_1, τ_1). We develop an alternative set in which another jump at $(s(\theta'_c), \tau(\theta'_c))$ is made such that type $\theta'_c < \theta_c$ is indifferent between $(s(\theta'_c), \tau(\theta'_c))$ and $(s(\theta_c), \tau(\theta_c))$. This alternative scheme thus entails sorting for $\theta \in [0, \theta'_c]$ along a new sorting scheme $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s(\theta'_c), \tau(\theta'_c))\}$, pooling at $(s(\theta_c), \tau(\theta_c))$ for $\theta \in (\theta'_c, \theta_c)$ and pooling at (s_1, τ_1) for $\theta \in (\theta_c, s_1)$. Let $\Delta(\theta) \equiv W_A^G(\cdot; \theta) - W_O^G(\cdot; \theta)$ where $W_A^G(\cdot; \theta)$ and $W_O^G(\cdot; \theta)$ represent the global welfare under the alternative and original agreements, respectively. It follows that $\Delta(\theta) > 0$ for $\theta < \theta'_c$, $\Delta(\theta) < 0$ for $\theta \in (\theta'_c, \theta_c)$ and $\Delta(\theta) = 0$ for $\theta \geq \theta_c$. We find that differentiation of $\mathbb{E}_\theta \Delta(\theta)$

with respect to θ'_c is reduced to two terms:

$$\int_0^{\theta'_c} \frac{\partial \Delta(\theta)}{\partial \theta'_c} dF(\theta) + \int_{\theta'_c}^{\theta^c} \frac{\partial \Delta(\theta)}{\partial \theta'_c} dF(\theta).$$

If θ'_c falls slightly from θ_c, then import tariffs for $\theta \in [0, \theta'_c]$ falls along the new sorting scheme where $s(\theta) = \theta$. Thus, if $\theta'_c \to \theta_c$, then $\frac{\partial \Delta(\theta)}{\partial \theta'_c} < 0$ for $\theta \in [0, \theta'_c]$. This strict inequality holds, since the single-crossing property implies that, when θ'_c falls slightly from θ_c, the iso-welfare function for θ'_c, $\{(s, \tau) : W(s, \tau; \theta'_c) = W(s(\theta_c), \tau(\theta_c); \theta'_c)\}$, pivots on the point $(s(\theta_c), \tau(\theta_c))$. This is evident, since the gradient vector of the home welfare function, $\nabla(\theta)$, at $(s(\theta_c), \tau(\theta_c))$ has the differentiation:

$$\left. \frac{\partial \nabla(\theta)}{\partial \theta} \right|_{\theta = \theta_c} = \left. \begin{pmatrix} \partial Q/\partial s \\ \partial Q/\partial \tau \end{pmatrix} \right|_{(s,\tau) = (s(\theta_c), \tau(\theta_c))}$$

where $\frac{\partial Q}{\partial s} > \frac{\partial Q}{\partial \tau} > 0$ at $(s(\theta_c), \tau(\theta_c))$. On the other hand, if θ'_c falls slightly from θ_c, then the marginal welfare loss, $\frac{\partial \Delta(\theta)}{\partial \theta'_c}$ for $\theta \in (\theta'_c, \theta_c)$, associated with the new pooling at $(s(\theta_c), \tau(\theta_c))$ approaches zero. To see this, suppose that an iso-welfare function, $\tau = \tau(s)$, represents the original sorting scheme where the foreign welfare is held constant. Along this scheme, the original policy mix for $\theta \in (\theta'_c, \theta_c)$ maximizes the home welfare and satisfies the first-order condition in (A9):

$$\frac{\partial W(s, \tau(s); \theta)}{\partial s} = [\theta - s] \frac{Q'D'}{D' - Q'} = 0.$$

For types $\theta \in (\theta'_c, \theta_c)$, if $\theta'_c \to \theta_c$, then the new pooling point approaches the original policy mix along the original scheme; the first-order differentiation of the home welfare at the new pooling point approaches zero, which implies that the marginal home-welfare loss approaches zero. Hence, if $\theta'_c \to \theta_c$, then $\frac{\partial \Delta(\theta)}{\partial \theta'_c} \to 0$ for $\theta \in (\theta'_c, \theta_c)$. In summary, if θ'_c falls slightly from θ_c, then $\mathbb{E}_\theta \Delta(\theta)$ increases, which generates a contradiction.

Second, we extend this result beyond the interval at the bottom, $[0, \theta_c]$. Suppose that an agreement is optimal and includes a sorting scheme (as a policy subset) for $\theta \in (\theta_1, \theta_2)$ in which the world price is constant and $s(\theta) = \theta$. Without loss of generality, we assume that the continuous policy subset for $\theta \in [0, \theta_c]$ in which the world price is strictly increasing is followed by the sorting scheme for $\theta \in (\theta_1, \theta_2)$:

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s(\theta_2), \tau(\theta_2)) \text{ for } s \in [s(\theta_1), s(\theta_2)]\}. \tag{A33}$$

The policy set then generates pooling for $\theta \in (\theta_c, \theta_1)$ such that θ_c is indifferent between $(s(\theta_c), \tau(\theta_c))$ and $(s(\theta_1), \tau(\theta_1))$. As in the proof of Lemma 6, we may consider two possi-

bilities: (i) $(s(\theta_c), \tau(\theta_c)) \neq (s(\theta_1), \tau(\theta_1))$ and (ii) $(s(\theta_c), \tau(\theta_c)) = (s(\theta_1), \tau(\theta_1))$. The case (i) occurs when the policy set involves a jump at $(s(\theta_c), \tau(\theta_c))$, and the case (ii) occurs when the policy set adjoining the point $(s(\theta_c), \tau(\theta_c))$ from the left is continuous and is flatter than the function (A33).

For the case (i), we develop an alternative policy set in which a small jump at $(s(\theta_2'), \tau(\theta_2'))$ is made such that type $\theta_2' < \theta_2$ is indifferent between $(s(\theta_2'), \tau(\theta_2'))$ and $(s(\theta_2), \tau(\theta_2))$. This policy set differs from the original policy set, in that it entails pooling at $(s(\theta_1'), \tau(\theta_1'))$ for $\theta \in (\theta_c, \theta_1')$, sorting for $\theta \in [\theta_1', \theta_2']$ along a new sorting scheme

$$\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s(\theta_2'), \tau(\theta_2')) \text{ for } s \in [s(\theta_1'), s(\theta_2')]\}, \tag{A34}$$

and pooling at $(s(\theta_2), \tau(\theta_2))$ for $\theta \in [\theta_2', \theta_2]$. An endpoint in (A34), $(s(\theta_1'), \tau(\theta_1'))$, is defined by

$$W(s(\theta_1'), \tau(\theta_1'); \theta_c) = W(s(\theta_c), \tau(\theta_c); \theta_c) \text{ and } \widehat{p}^w(s(\theta_1'), \tau(\theta_1')) = \widehat{p}^w(s(\theta_2'), \tau(\theta_2')).$$

Note that the world price is higher in (A34) than in the original sorting scheme (A33), and also that over-subsidy $(s(\theta) > \theta)$ occurs in the pooling interval for $\theta \in (\theta_c, \theta_1')$. Defining $\Delta(\theta)$ as above, we find that $\Delta(\theta) > 0$ for $\theta \in (\theta_c, \theta_1')$, $\Delta(\theta) > 0$ for $\theta \in [\theta_1', \theta_2']$ and $\Delta(\theta) < 0$ for $\theta \in [\theta_2', \theta_2]$. The result, $\Delta(\theta) > 0$ for $\theta \in (\theta_c, \theta_1')$, is immediate from the proof of Lemma 6: for $\theta \in (\theta_c, \theta_1')$, the alternative agreement involves a lower domestic distortion in the form of over-subsidy at a higher world price than does the original agreement. We next find that differentiation of $\mathbb{E}_\theta \Delta(\theta)$ with respect to θ_2' is reduced to

$$\int_{\theta_c}^{\theta_1'} \frac{\partial \Delta(\theta)}{\partial \theta_2'} dF(\theta) + \int_{\theta_1'}^{\theta_2'} \frac{\partial \Delta(\theta)}{\partial \theta_2'} dF(\theta) + \int_{\theta_2'}^{\theta_2} \frac{\partial \Delta(\theta)}{\partial \theta_2'} dF(\theta).$$

If $\theta_2' \to \theta_2$, then the first two terms are negative, but the third (positive) term approaches zero; as we show above, if θ_2' falls slightly from θ_2, the marginal welfare loss for $\theta \in (\theta_2', \theta_2)$ associated with the new pooling at $(s(\theta_2'), \tau(\theta_2'))$ approaches zero. Hence, the original agreement is not optimal.

We next consider the case (ii) in which $(s(\theta_c), \tau(\theta_c)) = (s(\theta_1), \tau(\theta_1))$. The remaining proof is analogous to the proof in the case (i), except that the endpoint in (A34), $(s(\theta_1'), \tau(\theta_1'))$, is now defined as the point at which the new sorting scheme (A34) crosses the original policy set that adjoins $(s(\theta_c), \tau(\theta_c))$ from the left. $\blacksquare$

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