1-2012

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SMU ECONOMICS & STATISTICS
WORKING PAPER SERIES

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Jan 2012

Paper No. 26 – 2012

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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 domestic 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. We show that any optimal agreement, as opposed to the conventional message of the targeting principle, restricts the home government's freedom to select its domestic subsidy in order to increase the market-access level for foreign exporters. Our finding suggests that a proper restriction on domestic subsidy is somewhere between GATT and WTO rules.

Journal of Literature Classification numbers: F13
Keywords: Treatment of domestic subsidy, International agreement, GATT/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 been 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 its policy 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. Importantly, in contrast to the WTO's actual restrictions on domestic subsidies, the analytical literature on international agreements broadly supports the conventional theory of government intervention. A central message in the theory of government intervention is the *targeting principle* (Bhagwati and Ramaswami, 1963 and Johnson, 1965) under which the optimal intervention targets the associated market imperfection directly at the margin. From a somewhat different angle, Sykes (2005, 2010) 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 such difficul-

[1] For more discussion, see Sykes (2005, 2010), Bagwell (2008) and Bagwell and Staiger (2006).

ties, restrictions on domestic subsidies might be negotiated to target only the protective use of subsidies.[2] Sykes maintains that it is arguably impossible to develop general principles that 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. In particular, our main question is whether the targeting principle provides a theoretical guideline on the treatment of domestic subsidy as it does in the existing literature. Two key ingredients are contained in our model. First, a domestic subsidy is a legitimate instrument with which to address a market imperfection that leads to underproduction 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, 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 ingredients, our model is augmented in two respects. First, a domestic production of import good by the home country generates a positive external value within the border. Second, the home government has private information about its externality type and thus about the legitimate level of subsidy with which to internalize the affected margin. We develop an incomplete-information model with a continuum of possible externality types on an interval. 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.[3]

The starting point of our analysis is to identify a central incentive problem: subsequent to a tariff-reduction commitment, the home government has incentive to raise its domestic subsidy for the protective purpose.[4] When the home government neglects foreign exporters

[2] 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). This fact appears to reflect the difficulties of determining the trade effects of domestic policy changes.

[3] We also argue that our findings presented below can be extended to a richer policy environment in which a domestic consumption tax is additionally available.

[4] The home country's incentive to substitute one protective instrument for another is typically found in the theory of

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.[5] This problem causes the concern that the use of 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.[6]

In this paper, when governments reach an international agreement, they specify the policy set from which they can subsequently 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* if the policy set is incentive compatible and generates at least as high expected global welfare as any incentive-compatible policy set. We consider the stage game: (i) two governments write an agreement that specifies the policy set and (ii) the home government observes its externality type and selects its policy mix from the policy set.

We begin with a hypothetical agreement in which the home government is granted the flexibility (freedom) to select any policy mix as long as its policy choice preserves the world price at a constant level. Since the home government can lower the world price by raising subsidy or tariff, the policy set specified by the agreement is an iso-world-price function on

international agreements on two policy instruments.

[5] 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, 2011 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 market-access loss 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 country's terms-of-trade.

[6] 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."

which tariff falls as subsidy rises. Then the home government, having no incentive to manipulate the foreign country's 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 this separating agreement is not optimal: it can be improved on by an alternative agreement that entails pooling at the top (i.e., the interval of externality types adjoining the highest type). The separating agreement has strength and weakness. The freedom afforded by the agreement ensures that the home government uses the targeting principle in its subsidy choice. The use of the targeting principle, however, accompanies 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 has a flatter slope than before. This new set then 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 shows that no optimal agreement adheres to the targeting principle in its treatment of domestic subsidy. Intuitively, if an agreement uses a first-best instrument to remedy the market failure that leads to under-production, then it entails the use of high import tariffs, which additionally stimulates domestic production and thus results in excessive import protection. The alternative agreement, sacrificing the targeting principle at the top, can lower import tariffs and raise the world price and import volume.

We next explore a pooling agreement in which the targeting principle is neglected such that policy choices are fully rigid (state-independent). Within the class of pooling agreements, the optimal agreement restricts its subsidy choice to the expected external value 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 grants the home government the freedom to select any policy mix as long as its policy choice preserves the original world price. It then extends the original policy set along an iso-world-price function, which improves the home welfare without imposing a negative terms-of-trade externality on the foreign welfare. We augment this finding and investigate the possibility that governments tailor the degree of restriction on subsidy choice while reaching a zero-tariff agreement. This may occur when governments agree to 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 of restriction on subsidy choice, a zero-tariff agreement is not optimal.

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 at the expense of the other objective. The separating agreement adjusts import tariffs to utilize the targeting principle in its treatment of subsidy; its policy set can be improved by including pooling at the top. The zero-tariff agreement tailors the degree of restrictions on subsidy choice to maximize the benefits of zero-tariff commitment; its policy set can be improved by including sorting at the bottom.

These findings raise the question of how the tension between the two objectives is resolved in an optimal agreement. Our analysis begins with the monotonicity results: (i) subsidy is weakly increasing in externality type and (ii) in any optimal agreement, the world price is weakly decreasing in externality type. The result (i) is given by the single-crossing property: the home government with higher externality level is more willing to raise subsidy to increase its domestic production. For the result (ii), we claim that the policy mix for the lowest type involves the highest world price in an optimal agreement. If the world price is higher for another type, then the original policy set can be modified to include an iso-world-price "segment" as a policy subset for all types below that type. This new sorting segment at the bottom acts to improve the home welfare without imposing a negative terms-of-trade externality on the foreign welfare, which contradicts the optimality of the original agreement. With the monotonicity results in place, we present our third finding: any optimal agreement entails sorting at the bottom and thus "almost surely" permits the use of a positive subsidy.[7] 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

[7] Probability of using zero subsidy is zero under the sorting at the bottom and the continuous distribution of externality types. We can equivalently say that a positive subsidy is used in any optimal agreement with probability 1, or almost surely. In fact, 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, on the sorting segment seen in an optimal agreement, the world price is strictly increasing in externality type.

agreement that entails sorting at the bottom and preserves the original highest world price; this new agreement extends the original policy set and improves the home welfare without imposing a negative terms-of-trade externality on the foreign welfare. We subsequently state our fourth finding: any optimal agreement entails pooling at the top and thus sacrifices the targeting principle at the top.

We further establish the property that holds now for the entire externality range: an optimal agreement cannot include an iso-world-price segment as its policy subset. If such a sorting segment exists, then a new policy set can be developed by shifting the original sorting segment towards lower tariffs. Instead, this policy set newly includes a pooling point on the original segment. Intuitively, if the original segment shifts down slightly, then the marginal global-welfare gain associated with the tariff reduction is strictly positive, but the marginal global-welfare loss associated with the new pooling approaches zero, since this welfare loss is measured on the original segment where the foreign welfare is held constant.[8] This property delivers our fifth finding: (i) in its use of domestic subsidy, any optimal agreement violates the targeting principle "almost everywhere" on the entire interval of externality types and (ii) in any optimal agreement, an increase (a decrease) in domestic subsidy deteriorates (improves) the foreign country's terms of trade.[9] A proper treatment of subsidy implied by our finding is therefore markedly different from what is prescribed by the targeting principle: the home government is not granted the freedom to select any policy mix along an iso-world-price segment in any optimal agreement. The tension between the two objectives is resolved when an optimal agreement restricts the home government's subsidy choice and thus its use of first-best intervention, in order to respect the foreign country's terms of trade and increase the market-access level for foreign exporters.[10]

[8] The original policy choices, made along the original iso-world-price segment, maximize the home welfare; the first-order differentiation of the home welfare at the original policy choices is zero. If the original segment shifts down slightly, then the new pooling point approaches the original policy choices along the same segment; 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.

[9] The result (i) means that the first-best intervention is permitted not on subintervals of the entire externality-type interval but only on points (i.e., on a set of measure zero). In a probabilistic context, we can say that the result (i) holds with probability 1, or almost surely. The result (ii) is given by the monotonicity, together with the property stated above.

[10] 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

Despite the mounting interest and evident importance, a treatment of domestic subsidies in an international agreement has not received much attention from the analytical literature. Bagwell and Staiger (2001, 2006) offer formal analyses of this issue and 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. Their finding implies that governments need to be granted the freedom to select any policy mix provided that their policy adjustments preserve market access at the negotiated level. In particular, the non-violation complaint plays an important role in achieving an efficient policy mix in Bagwell and Staiger (2001) if governments, subsequent to their negotiation, are allowed to adjust tariffs to preserve market access at the negotiated level, and in Bagwell and Staiger (2006) if governments, with tariffs bound by their negotiation, have sufficient policy redundancy to keep market access at the negotiated level.[11]

Our model contains the features commonly observed 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 complete-information model, the foreign country's terms of trade can be duly respected while the home government addresses the market imperfection with a first-best intervention. In our model, by contrast, the foreign country's terms of trade can be sufficiently respected only if an agreement restricts the home government's subsidy choice and its use of first-best intervention. Consequently, the market-access focus of GATT rules is not a proper restriction on subsidy choice in our model; since any optimal agreement makes it impossible for the home government to adjust its domestic subsidy without affecting the market-access level for foreign exporters, an optimal agreement can be achieved by a *policy-mix agreement*, not by a commitment to a market-access level.

Our model bears a methodological similarity to the incomplete-information model by Lee

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.

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

(2007).[12] In broad terms, however, the two-type model by Lee inherits the findings in Bagwell and Staiger (2001, 2006), showing that domestic distortions are *never commonly* realized in an optimal agreement: an international agreement needs to be in favor of using the targeting principle in its treatment of domestic policies.[13] In our continuous-type model, by contrast, the use of the targeting principle is *almost surely* prevented in any optimal agreement due to the informational costs it accompanies to satisfy incentive compatibility. Indeed, whereas our basic setting adopts fairly standard features from the existing literature, our finding delivers a significantly different message: an international agreement, as opposed to the conventional prescription of the targeting principle, needs to restrict the home government's freedom to select its domestic subsidy in order to increase the market-access level for foreign exporters. Our finding thus provides an explanation for the international trading system to depart from the fairly tolerant treatment of domestic subsidies shown under GATT rules. At the same time, in common with the existing literature, our finding shows that the use of a positive subsidy is almost surely permitted in any optimal agreement. It thus offers an incomplete-information confirmation that the virtual prohibition of domestic production subsidies seen in the legal environment under WTO is far beyond a proper degree of restriction.

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 of subsidy when 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 import volume is large. In our model, it is made partially rigid in

[12] Our paper contributes to the theory of trade agreements among governments with private information. Amador and Bagwell (2011), Bagwell (2009), Bagwell and Staiger (2005), Beshkar (2010), Feenstra and Lewis (1991), Martin and Vergote (2008) and Park (2011) develop theoretical models of this kind. Importantly, all these models focus on agreements on tariffs. Agreements on two policy instruments are mostly found in complete-information models as in Bagwell and Staiger (2001, 2006) and Ederington (2001). Lee (2007) is an exception and develops a model in which privately-informed countries agree on two policy instruments, assuming two externality types and linear demand and supply functions. Our model allows for continuous externality types and for general demand and supply functions.

[13] Ederington (2001) also demonstrates a similar result: governments achieve an optimal agreement when they follow the targeting principle to select their domestic policies, and tailor tariff levels to prevent a country's deviation from the agreement. In his extension section, Lee (2007) conjectures that an optimal agreement may allow domestic distortions when externality types are continuously distributed, without offering a formal analysis.

order to raise the market-access level for foreign exporters and so increase import volume.

The paper is organized as follows. Section 2 introduces the basic trade model and states the incentive problem found in the model. In Section 3, we consider various hypothetical agreements that are not optimal. In Section 4, we present the features observed in any optimal agreement and their policy implications. 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: 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 $Q^*(p^{*s})$, where asterisks denote foreign variables. All functions are positive and twice-continuously differentiable.

To formalize the two ingredients stated above, the model is augmented in two respects. First, a domestic production of the import good by the home country generates a positive external value within the border. Second, the home government has private information about its externality type and thus about the legitimate level of subsidy with which to internalize the affected margin. In particular, we consider an incomplete-information model in which the external value generated by domestic production Q is represented by a non-negative function $v(Q, \theta)$. The function v is increasing and concave in Q and satisfies $\frac{\partial^2 v}{\partial \theta \partial Q} > 0$. The level of θ is private information and is drawn from the support $[0, \overline{\theta}]$ according to the twice-continuously differentiable distribution function $F(\theta)$. The density, $f(\theta) \equiv F'(\theta)$, is positive everywhere.

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.[14] We assume that all policy instruments are non-prohibitive and expressed in specific terms. In the absence of the foreign government's intervention, the foreign consumer and supplier prices are equal, $p^{*d} = p^{s*}$. This foreign local price may be called the world price 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 are then given by $\widehat{p}^d(s, \tau) = \widehat{p}^w(s, \tau) + \tau$ and $\widehat{p}^s(s, \tau) = \widehat{p}^w(s, \tau) + \tau + s$. It is also immediate from (2) that, if the home government raises s or τ, then it can lower the world price of the foreign export good:

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

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

[14] We can readily extend the model by assuming a symmetric structure: the levels of θ are iid across sectors and the foreign government also intervenes in its import sector. We argue later that our model can also be extended to a richer policy environment in which a domestic consumption tax is additionally available.

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, $D(\widehat{p}^d) - Q(\widehat{p}^s)$. At the same time, 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 is harmful to foreign exporters and is beneficial to foreign consumers. The benefit to foreign consumers amounts to a transfer from foreign producers to 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 consists of consumer surplus, profits, net revenue (revenue from the import tariff minus expenditures on the production subsidy) and the aggregate value of the production externality. The home welfare for externality type θ is

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

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:

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

The home government must care about a negative terms-of-trade externality on the foreign welfare, in order to maximize the global welfare:

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

A useful feature satisfied by the iso-welfare function for the home country, $\{(s, \tau) : W(s, \tau; \theta) = \kappa \text{ for a constant } \kappa\}$, is the single-crossing property: 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. As we show in the Appendix, this property holds, since the home government with higher θ is more willing to raise subsidy to increase its domestic production under the assumption $\frac{\partial^2 v}{\partial \theta \partial Q} > 0$. We make additional assumptions to simplify our analysis.

Assumption 1. *(i) $W(s, \tau; \theta)$ and $W^*(s, \tau)$ are strictly concave in s and τ. (ii) The function v takes a linear form: $v(Q(p^s), \theta) = \theta \cdot Q(p^s)$. (iii) $M(s = \overline{\theta}, \tau = 0) > 0$.*

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 linearity assumption (ii) greatly simplifies our exposition: given $\frac{\partial v}{\partial Q}=\theta$, the privately-observed parameter θ now directly represents the legitimate level of subsidy with which to internalize the affected margin. Our findings established below, however, would qualitatively remain unaffected without this assumption. The assumption (iii) ensures that government intervention is non-prohibitive for the policy mixes we consider below.

We lastly want to emphasize that our basic model builds on a familiar setting found in Ederington (2002), Lee (2007) and Horn, Maggi and Staiger (2010). Our objective is to adopt fairly standard features from the existing literature and deliver a significantly different message. We may readily develop an alternative model to deliver a similar message if we convey the two essential ingredients of the current model: the single-crossing property and the strict concavity of welfare functions.

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 externality type θ may be denoted by $(s(\theta),\tau(\theta))$. The expected home welfare and expected global welfare may then 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.

The first-best policy mix, $(s^E(\theta),\tau^E(\theta))$, maximizes the global welfare $W^G(s,\tau;\theta)$.[15] The home government then follows the targeting principle for its subsidy choice and achieves zero tariff:

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

The Nash (non-cooperative) policy mix, $(s^N(\theta),\tau^N(\theta))$, maximizes the home welfare $W(s,\tau;\theta)$. The home government then follows the targeting principle for its subsidy choice and selects its import tariff to capture the terms-of-trade gain:

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

where $\widehat{p}^w=\widehat{p}^w(s=s^N(\theta),\tau=\tau^N(\theta))$ and $E^*(\widehat{p}^w)=Q^*(\widehat{p}^w)-D^*(\widehat{p}^w)$. In fact, the findings

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

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.

2.3 Objective of Agreement

In this paper, we consider the stage game: (i) two governments write an agreement that specifies the policy set and (ii) the home government observes its externality type and selects its policy mix from the policy set. This stage game indicates that, when arranging an agreement, governments specify the policy set from which they can subsequently 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 also say that an agreement is *optimal* if the policy set is incentive compatible and generates at least as high expected global welfare as any incentive-compatible policy set. Formally, let $(s(\theta), \tau(\theta))$ represent the policy mix selected by type θ under a policy set $\{(\mathbf{s}, \boldsymbol{\tau})\}$, and let $(\widetilde{s}(\theta), \widetilde{\tau}(\theta))$ denote the policy mix selected by type θ under an alternative policy set $\{(\widetilde{\mathbf{s}}, \widetilde{\boldsymbol{\tau}})\}$. 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

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

for any incentive-compatible policy set $\{(\widetilde{\mathbf{s}}, \widetilde{\boldsymbol{\tau}})\}$.[16] Equivalently, an agreement is not optimal if there exists an alternative policy set that is incentive compatible and generates higher expected global welfare than does the original policy set.

2.4 Incentive Problem

The starting point of our analysis is to identify a central incentive problem. We emphasize that the incentive problem presented here is standard and commonly observed on theoretical

[16] Incentive compatibility of $\{(\widetilde{\mathbf{s}}, \widetilde{\boldsymbol{\tau}})\}$ can be written as $W(\widetilde{s}(\theta), \widetilde{\tau}(\theta); \theta) \geq W(\widetilde{s}(\widehat{\theta}), \widetilde{\tau}(\widehat{\theta}); \theta)$ for all θ and $\widehat{\theta} \neq \theta$.

and actual policy levels. We begin with a hypothetical agreement in which the policy set is given by:[17]

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

The home government with externality type θ then maximizes $W(s,\tau;\theta)$ subject to (10). For any policy mix (s,τ) in (10), the world price is constant and so the foreign welfare $W^*(s,\tau)$ is constant. Since 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 subsidy and manipulate terms of trade, the home government uses the first-best instrument and internalizes 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 the set (10), the home government with type θ follows the targeting principle for its subsidy choice, $s(\theta) = \theta$, and select its tariff level, $\tau^{sep}(\theta)$, to keep the world price at $\widehat{p}^w(s=\overline{\theta}, \tau=0)$. The iso-world-price function (10) thus acts as a sorting (separating) scheme that elicits a truthful revelation of all externality types.

Lemma 1 typically holds in terms-of-trade models and also 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 displays the central incentive problem: subsequent to the tariff-reduction commitment, the home government has incentive to raise its subsidy for the protective purpose. In other words, if the home government neglects foreign exporters and increases 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. Consider next another

[17] Assumption 1 (iii), $M(s=\overline{\theta}, \tau=0) > 0$, indicates that government intervention is non-prohibitive for any (s,τ) along the iso-world price function (10) where the trade volume, represented by $E^*(\widehat{p}^w)$, is constant. Further, since $E^*(\widehat{p}^w)$ increases in $\widehat{p}^w$, government intervention is non-prohibitive for any (s,τ) in the region $\{(s,\tau) : \widehat{p}^w(s,\tau) \geq \widehat{p}^w(s=\overline{\theta}, \tau=0)\}$ under the assumption.

policy set that preserves the same world price in (10):

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

This policy set offers only two policy points on the iso-world-price function (10) and so entails pooling. The home welfare is higher in (10) than in (12) except for $\theta \in \{s_1, s_2\}$. We 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

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

Suppose that κ increases from zero and so the iso-world-price function shifts up from (10). Subsidy choice then remains the same, $s(\theta) = \theta$, whereas import tariffs rise along the new sorting scheme. Thus, for each θ, the world price falls and at the same time, the foreign welfare and the global welfare fall.[18] The effect 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 policy set (13) raises 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 capture the terms-of-trade gain.

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

3 Suboptimal Agreement

In this section, we explore two different hypothetical agreements: an agreement in which subsidy choice is determined by the targeting principle, and an agreement in which subsidy choice is regulated to achieve zero tariff. We show that these agreements are not optimal. All findings established in this and next sections are quite general, in that they hold for any distribution function F without imposing any additional assumption or technical restriction.

3.1 Separating Agreement

We begin with a (full) separating agreement in which subsidy choice is determined by the targeting principle, $s(\theta) = \theta$ for all θ. 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. Looking for such incentive-compatible policy sets, we can establish two findings to maximize the expected global welfare. First, among the policy sets in which the world price is constant at the same world price $\widehat{p}^w(s = \overline{\theta}, \tau = \kappa)$ 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 Lemma 1 and 2. Second, among the policy sets that entail full sorting along different iso-world-price functions, 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. We rephrase these two findings.

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 agreement with the policy set (10) has strength and weakness.[19] In the agreement, 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 uses the targeting principle in its subsidy choice. The use of the targeting principle, however, accompanies 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

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

than the function $\tau = \tau^{sep}(s)$. This new policy set then induces lower-externality types to mimic higher-externality types and raise their subsidies beyond the legitimate levels. Hence, the global welfare gain associated with the first-best intervention can be enjoyed only if the global welfare loss associated with the informational cost in the form of high import tariffs is also experienced.[20] Indeed, among the agreements in which subsidy choice is determined by the targeting principle for all θ, the agreement with the policy set (10) is optimal.

We next show that this agreement can be improved on by an alternative agreement that entails pooling at the top (i.e., the subinterval of $[0, \overline{\theta}]$ adjoining the highest type $\overline{\theta}$) with the policy set:

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

The home government can now select any policy mix as long as its policy choice preserves the world price at $\widehat{p}^w(s = \theta^c, \tau = 0) > \widehat{p}^w(s = \overline{\theta}, \tau = 0)$. The alternative set (14) entails sorting with lower tariffs than before, $s(\theta) = \theta$ and $\tau(\theta) < \tau^{sep}(\theta)$ for $\theta < \theta^c$, and it entails pooling at the policy mix $(\theta^c, 0)$ at the top for $\theta \in [\theta^c, \overline{\theta}]$. Observing that the alternative agreement approaches the original agreement as $\theta^c \to \overline{\theta}$, we can differentiate the expected global welfare with respect to θ^c and show that the expected global welfare is higher in the alternative agreement. Intuitively, if θ^c falls slightly from $\overline{\theta}$, then the alternative agreement decreases tariffs along the new sorting scheme while keeping the pooling point $(\theta^c, 0)$ close to the first-best policy mix $(\theta, 0)$ at the top.

Proposition 1. *An agreement that adheres to the targeting principle in its use of domestic subsidy, $s(\theta) = \theta$ for all θ, is not optimal.*

The proof is in the Appendix. If an agreement uses the first-best instrument to remedy the market failure that leads to under-production, then it entails the use of high import tariffs, which additionally stimulates domestic production and thus results in excessive import protection. Proposition 1 shows that in its choice of domestic subsidy, any optimal agreement sacrifices the targeting principle at least for some θ; by sacrificing the first-best intervention for some θ, it can reduce import tariffs and raise the world price and import volume.

[20] Consider any alternative policy set that is represented by a decreasing function $\tau = \tau^{alt}(s)$ and is flatter than $\tau = \tau^{sep}(s)$ for all s. We can show that the alternative policy set 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 also not optimal.

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 restrictions on subsidy choice. We first explore a pooling agreement in which the targeting principle is neglected such that policy choices are fully rigid (state-independent). 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 apparently satisfied. Since all equilibrium prices are constant for θ in this agreement, the expected global welfare becomes

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

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 subinterval of $[0, \overline{\theta}]$ adjoining the lowest type 0) with the policy set:

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

The alternative agreement grants the home government the freedom to select any policy mix as long as its policy choice preserves the original world price $\widehat{p}^w(s = \mathbb{E}[\theta], \tau = 0)$; it extends the policy set along the iso-world-price segment (16) and entails sorting for $\theta \leq \mathbb{E}[\theta]$ and pooling at the point $(\mathbb{E}[\theta], 0)$ for $\theta > \mathbb{E}[\theta]$. The home-welfare improvement, made for $\theta < \mathbb{E}[\theta]$, 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 augment this finding and consider the possibility that governments tailor the degree of restriction on subsidy choice while reaching a zero-tariff agreement. This may occur when governments agree to adjust the degree of restrictions on subsidy choice, in order to maximize the benefits of their tariff liberalization. Since an optimal policy set cannot be a singleton as shown above, 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 attention to $s_1 < \overline{\theta}$; if $s_1 \geq \overline{\theta}$, the policy set would be in the region $\{(s, \tau) : \widehat{p}^w(s, \tau) \leq \widehat{p}^w(s = \overline{\theta}, \tau = 0)\}$ where the agreement cannot be optimal by Lemma 3 and Proposition 1. We also assume that each policy mix is selected by at least some θ; the policy set would otherwise be equivalent to a singleton. We can show that the agreement with $\{(s_1, 0), (s_2, 0)\}$ is not optimal, whether $s_1 > 0$ or $s_1 = 0$. For the first case ($s_1 > 0$), we 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 home government can then select any policy mix along an iso-world-price segment, or it can select $(s_2,0)$. The policy-set extension is made along the segment while preserving the higher world price in the original set, $\widehat{p}^w(s=s_1,\tau=0)\}>\widehat{p}^w(s=s_2,\tau=0)$; the associated home-welfare improvement, made for some $\theta<s_1$, 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, however, that a zero-tariff agreement with the policy set $\{(s_1,0),(s_2,0),...,(s_K,0)\}$ is not optimal, by applying the previous argument to the first two choices, $(s_1,0)$ and $(s_2,0)$. A zero-tariff agreement in the limiting case is that subsidy choice is left to the home government's discretion. Subsidy choice would then be above a certain level, $\underline{s}>0$. We restrict attention to $\underline{s}<\overline{\theta}$; if $\underline{s}\geq\overline{\theta}$, all policy choices would be made in the region $\{(s,\tau):\widehat{p}^w(s,\tau)\leq\widehat{p}^w(s=\overline{\theta},\tau=0)\}$ where the agreement cannot be optimal. We develop an alternative policy set that has two subsets:

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

The home government can then select any policy mix along an iso-world-price segment, or it can select any subsidy $s\in[\underline{s},\overline{\theta}]$ under zero tariff. The policy-set extension is made along the segment while preserving the highest world price in the original set, $\widehat{p}^w(s=\underline{s},\tau=0)$; the home-welfare improvement, made for some $\theta<\underline{s}$, does not impose a negative terms-of-trade effect on the foreign welfare, which indicates that the zero-tariff agreement in which subsidy choice is discretionary is not optimal.[21] The following proposition summarizes our discussion.

Proposition 2. *Regardless of the degree of restriction on subsidy choice, a zero-tariff agreement in which $\tau(\theta)=0$ for all θ is not optimal.*

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

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 at the expense of the other objective. The agreement in Proposition 1 adjusts import tariffs to utilize the targeting principle in its treatment of subsidy; the policy set can be improved by including pooling at the top. The agreement in Proposition 2 tailors the degree of restrictions on subsidy choice to maximize the benefits of zero-tariff commitment; the policy set can be improved by including sorting at the bottom.

4 Optimal Agreement

In this section, we show how the tension between the objective of promoting domestic efficiency and the objective of reducing import tariffs is resolved in an optimal agreement. 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. We proceed to present the monotonicity results: (i) $s(\theta)$ is weakly increasing in θ and (ii) in any optimal agreement, the world price is weakly decreasing in θ. The result (i) is given by the single-crossing property. Suppose that an agreement allows $s(\theta_2) < s(\theta_1)$ for some $\theta_2 > \theta_1$. Incentive compatibility of θ_1 implies that $(s(\theta_2), \tau(\theta_2))$ must be located in the region:

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

Select the iso-welfare function for θ_2 that crosses the point $(s(\theta_1), \tau(\theta_1))$. This iso-welfare function crosses the iso-welfare function for θ_1 from above only once. Any policy mix in (19) is then less preferred to $(s(\theta_1), \tau(\theta_1))$ for θ_2, which violates incentive compatibility.

The result (ii) is given by optimality. Suppose that an agreement allows $\widehat{p}^w(s(\theta_1), \tau(\theta_1)) < \widehat{p}^w(s(\theta_2), \tau(\theta_2))$ for some $\theta_2 > \theta_1$. These two types are selected such that type θ_1 (type θ_2) involves the highest world price for all $\theta \leq \theta_1$ (for all $\theta > \theta_1$).[22] Pick the point (s_2, τ_2)

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

that maximizes the world price on the iso-welfare function for θ_2, $\{(s,\tau) : W(s,\tau;\theta_2) = W(s(\theta_2),\tau(\theta_2);\theta_2)\}$. The original policy set can then be modified by including an iso-world-price segment up to the point (s_2,τ_2), $\{(s,\tau) : \widehat{p}^w(s,\tau) = \widehat{p}^w(s_2,\tau_2)$ for $s \leq s_2\}$. Then types $\theta \leq \theta_2$ do not mimic types $\theta > \theta_2$ but selects their policy mixes along the new sorting segment at the bottom. The incentive of types $\theta > \theta_2$ to mimic types $\theta \leq \theta_2$ can be ignored, since the potential home-welfare gain by types $\theta > \theta_2$ from mimicking types $\theta \leq \theta_2$ does not deteriorate the foreign country's terms of trade for any θ. The new sorting segment thus acts to increase the expected global welfare, which indicates that the original agreement is not optimal. We summarize the monotonicity results.

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

We next specify the policy mix for the lowest type, $(s(0),\tau(0))$, in two steps. First, in any optimal agreement, $(s(0),\tau(0))$ is in the region:

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

If an optimal agreement allows $\widehat{p}^w(s(0),\tau(0)) \leq \widehat{p}^w(s=\overline{\theta},\tau=0)$, then $\widehat{p}^w(s(\theta),\tau(\theta)) \leq \widehat{p}^w(s=\overline{\theta},\tau=0)$ for all $\theta \in [0,\overline{\theta}]$ by Lemma 4 (ii). Lemma 3 and Proposition 1, in turn, contradict the optimality of the agreement. Second, in any optimal agreement, $s(0)=0$ and $\tau(0)>0$. Assume that an optimal agreement allows $s(0)>0$. The policy set can then be modified by including an iso-world-price segment 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 subset for $s > s(0)$ remains the same. The policy-set extension is made along the segment while preserving the highest world price in the original set: $\widehat{p}^w(s(0),\tau(0)) \geq \widehat{p}^w(s(\theta),\tau(\theta))$ for all $\theta > 0$ by Lemma 4 (ii). The home-welfare improvement, made for some $\theta \leq s(0)$, does not impose a negative terms-of-trade effect on the foreign welfare for any θ, which contradicts the optimality assumption. Now, given $s(0)=0$, if an agreement allows $\tau(0)=0$, we may 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 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 finally show that any optimal agreement entails a sorting segment as a policy subset at the bottom for $\theta \in [0, \theta_c]$ where $\theta_c > 0$.[23] Assume that an optimal agreement entails pooling at $(s(0), \tau(0))$ for $\theta \in [0, \theta_0]$ for some $\theta_0 > 0$. Then $(s(0), \tau(0))$ satisfies the property in Lemma 5. Pick the point (s_0, τ_0) that maximizes the world price on the iso-welfare function for θ_0, $\{(s, \tau) : W(s, \tau; \theta_0) = W(s(0), \tau(0); \theta_0)\}$. The original policy set can then be modified by including an iso-world-price segment up to the point (s_0, τ_0), $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(s_0, \tau_0)$ for $s \leq s_0\}$. Then types $\theta \leq \theta_0$ do not mimic types $\theta > \theta_0$ but selects their policy mixes along the new segment. The incentive of types $\theta > \theta_0$ to mimic types $\theta \leq \theta_0$ can be ignored, since the potential home-welfare gain by types $\theta > \theta_0$ from mimicking types $\theta \leq \theta_0$ does not deteriorate the foreign country's terms of trade for any θ. The new sorting segment thus acts to increase the expected global welfare, which contradicts the optimality assumption.

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

An important implication, immediate from the sorting at the bottom, is that the use of a positive subsidy is "almost surely" permitted in any optimal agreement: probability of using zero subsidy is zero under the continuous distribution F. Thus, in consistent with the existing literature, our finding shows that the virtual prohibition of domestic production subsidies seen in the legal environment under WTO is far beyond a proper degree of restrictions. It is, however, premature to conclude that, in an optimal agreement, the home government is granted the freedom to select any policy mix along an iso-world-price segment at the bottom. As we characterize below, the sorting at the bottom here is different from the sorting segment in which the world price is *constant* and $s(\theta) = \theta$.

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[23] The sorting segment in this result is not necessarily an iso-world-price segment. This result does not hold if and only if there exists an optimal agreement in which (i) types $\theta \in [0, \theta_0]$ for some $\theta_0 > 0$ pool at $(s(0), \tau(0))$, or (ii) only the lowest type 0 selects $(s(0), \tau(0))$, while types $\theta \in (0, \theta_0]$ pool at a separate point $(\widehat{s}, \widehat{\tau})$ or select their policies from the region $\{(s, \tau) : s \geq \widehat{s}$ and $\widehat{p}^w(s, \tau) \leq \widehat{p}^w(\widehat{s}, \widehat{\tau})\}$ for some $\widehat{s} > 0$. The case (i) causes a contradiction as we show below; more detailed proof for this is in the Appendix. The case (ii) is also impossible, since the original policy set is easily improved by including an iso-world-price segment up to the point $(\widehat{s}, \widehat{\tau})$, $\{(s, \tau) : \widehat{p}^w(s, \tau) = \widehat{p}^w(\widehat{s}, \widehat{\tau})$ for $s \leq \widehat{s}\}$.

4.2 Pooling at the Top

In this subsection, we show that any optimal agreement entails pooling at the top. We first show that, in any optimal agreement, any policy mix with a positive tariff is restricted to the region (20): 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 optimal agreement allows $\tau(\widetilde{\theta}) > 0$ 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 5 implies that there exists a type $\widehat{\theta} < \widetilde{\theta}$ such that

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

Suppose that the iso-welfare function for $\widehat{\theta}$, $\{(s, \tau) : W(s, \tau; \widehat{\theta}) = W(s(\widehat{\theta}), \tau(\widehat{\theta}); \widehat{\theta})\}$, 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 $\widehat{\tau} > 0$.[24] The original policy set can be improved in two steps. First, it can be modified by including an iso-world-price segment 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 subset for $s < \widehat{s}$ remains the same. The segment (23) is arranged to make type $\widehat{\theta}$ indifferent between $(s(\widehat{\theta}), \tau(\widehat{\theta}))$ and $(\widehat{s}, \widehat{\tau})$. The new policy set thus entails pooling at $(\widehat{s}, \widehat{\tau})$ for $\theta \in (\widehat{\theta}, \widehat{s})$ and the sorting segment for $\theta \in [\widehat{s}, \overline{\theta}]$. For the affected types $\theta > \widehat{\theta}$, the global welfare is at least as high in the alternative agreement as in the original agreement. Intuitively, the policy-set modification induces the pooling for $\theta \in (\widehat{\theta}, \widehat{s})$ to involve a weakly lower domestic distortion in the form of "over-subsidy" $(s(\theta) > \theta)$ at a weakly higher world price, and induces the sorting for $\theta \in [\widehat{s}, \overline{\theta}]$ to involve a weakly higher world price. Second, the original policy set can be further modified by shifting the sorting segment (23) down, so as to entail a pooling point $(\theta^c, 0)$ at the top for $\theta \in [\theta^c, \overline{\theta}]$:

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

The policy subset for $s < \widehat{s}'$ remains the same. The segment (24) is arranged to make type $\widehat{\theta}$ indifferent between $(s(\widehat{\theta}), \tau(\widehat{\theta}))$ and $(\widehat{s}', \widehat{\tau}')$. As in Proposition 1, if $\theta^c \to \overline{\theta}$, then the expected global welfare is now strictly higher in the new agreement than in the original agreement. This contradicts the optimality of the original agreement.

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

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

We finally present the pooling at the top in two steps. First, any optimal agreement entails pooling at the top for $\theta \in [\theta^c, \overline{\theta})$ where $\theta^c < \overline{\theta}$.[25] Assume that an optimal agreement entails sorting for $\theta \in [\widehat{\theta}, \overline{\theta})$ for some $\widehat{\theta} < \overline{\theta}$. A sorting scheme at the top cannot exist in (20); in this region, given the monotonicity of the world price, any policy subset causes pooling at least for some range of θ at the top. A sorting scheme cannot exist outside (20) either; in this region, any policy subset with positive tariffs violates Lemma 6, and sorting with zero tariff also violates optimality.[26] Second, the pooling at the top seen in any optimal agreement involves zero tariff. Assume that an optimal agreement entails pooling for $\theta \in [\theta^c, \overline{\theta})$ at a policy mix (s^p, τ^p) with a positive tariff $\tau^p > 0$. Then (s^p, τ^p) must be in the region (20) by Lemma 6. The original policy set can then be modified by including an iso-world-price segment 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 subset for $s < s^p$ remains the same. Lemma 4 (i) and (ii) imply that the original policy subset for $s < s^p$ is in the region $\{(s, \tau) : \widehat{p}^w(s, \tau) \geq \widehat{p}^w(s^p, \tau^p) \text{ and } s < s^p\}$. The modification thus induces types $\theta \geq s^p$ to select their policy mixes along the sorting segment (25). Since types $\theta < \theta^c$ did not select (s^p, τ^p) under the original policy set, they stay with their original choices under the alternative set.[27] Hence, the policy-set extension in (25) increases the home welfare for some $\theta \geq s^p$ without decreasing the world price for any θ, which contradicts the optimality of the original agreement. Given the sorting at the bottom for $\theta \in [0, \theta_c]$, we now present the pooling at the top.

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 includes a pooling point with zero tariff for $\theta \in [\theta^c, \overline{\theta})$.*

[25] This result includes the circumstances under which (i) types $\theta \in [\theta^c, \overline{\theta}]$ pool at a policy point (s^p, τ^p) and (ii) types $\theta \in [\theta^c, \overline{\theta})$ pool at a point (s^p, τ^p) and only the highest type $\overline{\theta}$ selects another point $(s(\overline{\theta}), \tau(\overline{\theta}))$. In other words, the result means that any optimal agreement has an interval at the top $[\theta^c, \overline{\theta}]$ on which a pooling point (s^p, τ^p) is selected with probability 1. The result does not hold if and only if there exists an optimal agreement that entails sorting for $\theta \in [\widehat{\theta}, \overline{\theta})$ for some $\widehat{\theta} < \overline{\theta}$. The sorting for $\theta \in [\widehat{\theta}, \overline{\theta})$ here is not necessarily the sorting along an iso-world-price segment.

[26] In this region, sorting for $\theta \in [\widehat{\theta}, \overline{\theta})$ with zero tariff is possible only if subsidy increases beyond $\overline{\theta}$. Pick the policy point $(\underline{s}, 0)$ that has the lowest level of subsidy in the sorting scheme for $\theta \in [\widehat{\theta}, \overline{\theta})$. We can immediately find that, for these types, this sorting scheme can be improved on by the pooling point $(\underline{s}, 0)$.

[27] Note that $\theta^c \leq s^p$; if $\theta^c > s^p$, then types $\theta \in (s^p, \theta^c)$ must also have selected (s^p, τ^p) in the original policy set, which violates our assumption.

In summary, any optimal agreement contains two necessary features: sorting at the bottom and pooling at the top. Proposition 3 shows that any optimal agreement almost surely permits the use of a positive subsidy in order to address the market imperfection and promote domestic efficiency, and Proposition 4 shows that any optimal agreement prevents the use of targeting principle at the top in order to lower import tariffs and raise the world price and import volume.

4.3 Restriction on Subsidy Choice

In this subsection, we present a general feature of optimality that holds now for the entire range of θ. A difficulty with characterizing an optimal policy set is that the world price may change in θ. Our analysis therefore proceeds from the simplest policy set that entails sorting at the bottom and pooling at the top. This policy set involves only one world price:

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

We restrict attention to $\theta^c \in (0, \overline{\theta})$, since $\theta^c > 0$ is required by Proposition 2 and $\theta^c < \overline{\theta}$ by Proposition 1. The home government can then select any policy mix as long as its policy choice preserves the world price $\widehat{p}^w(s = \theta^c, \tau = 0)$. As noted above, the policy set (26) has strength and weakness: for $\theta \leq \theta^c$, the targeting principle is used in the subsidy choice, which however accompanies the use of high import tariffs.

We develop an alternative policy set that 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.[28] This jump then causes a new pooling point: types $\theta \in (\theta_c, \theta^c)$ now pool at $(s(\theta^c), \tau(\theta^c))$ and $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) > \widehat{p}^w(s(\theta^c), \tau(\theta^c))$.[29] In particular, we consider the policy set in which the second subset is a singleton and endpoint of the original sorting segment (26) so that $(s(\theta^c), \tau(\theta^c)) = (\theta^c, 0)$. The alternative agreement

[28] Incentive compatibility for θ_c implies that $(s(\theta^c), \tau(\theta^c))$ is in the region $\{(s, \tau) : W(s, \tau; \theta_c) \leq W(s(\theta_c), \tau(\theta_c); \theta_c)\}$, 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 $(s(\theta^c), \tau(\theta^c))$ is located to satisfy $W(s(\theta_c), \tau(\theta_c); \theta_c) > W(s(\theta^c), \tau(\theta^c); \theta_c)$, then the original policy set can be improved by including an iso-world-price segment between a new point (s', τ') and $(s(\theta^c), \tau(\theta^c))$ such that $W(s', \tau'; \theta_c) = W(s(\theta_c), \tau(\theta_c); \theta_c)$ and $\widehat{p}^w(s', \tau') = \widehat{p}^w(s(\theta^c), \tau(\theta^c))$.

[29] 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 (ii) implies $\widehat{p}^w(s(\theta_c), \tau(\theta_c)) \geq \widehat{p}^w(s(\theta^c), \tau(\theta^c))$ for $\theta^c > \theta_c$, 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.

thus entails sorting for all $\theta \leq \theta_c$ along a new sorting segment,

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

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 segment towards lower tariffs and brings the (global) welfare gain, $\Delta(\theta) > 0$, for $\theta \leq \theta_c$, but it causes the welfare loss, $\Delta(\theta) < 0$, for those types $\theta \in (\theta_c, \theta^c)$ that newly pool at $(\theta^c, 0)$.[30] Observing that the alternative policy set approaches the original set as $\theta_c \to \theta^c$, we may differentiate $\mathbb{E}_\theta \Delta(\theta)$ with respect to θ_c and show that the alternative agreement improves on the original 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 segment is strictly positive, but the *marginal* welfare loss associated with the new pooling for $\theta \in (\theta_c, \theta^c)$ approaches zero, since this welfare loss is measured on the original iso-world-price segment (26) where the foreign welfare is held constant. Intuitively, the original policy choices, made along the original iso-world-price segment, maximize the home welfare; the first-order differentiation of the home welfare at the original policy choices is zero. If $\theta_c \to \theta^c$, then for $\theta \in (\theta_c, \theta^c)$, the new pooling point $(\theta^c, 0)$ approaches the original policy choices along the same segment; 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 show in the Appendix, we may extend this result and show that an optimal agreement cannot include any iso-world-price segment as its policy subset. This finding means that any optimal agreement satisfies the following properties. First, on the sorting segment present at the bottom, the world price is not constant but increasing in θ.[31] The slope at a policy mix is flatter on this sorting segment than on the associated iso-world-price

[30] If the alternative agreement is to shift the original segment without including the new pooling point $(\theta^c, 0)$ on the original segment, then it will cause the welfare loss for types $\theta \in (\theta_c, \overline{\theta}]$.

[31] This result holds for any sorting segment present at the bottom or potentially in other places. Observe also that the sorting segment may not be too long; an alternative agreement would otherwise create the net global welfare gain by shifting the segment towards lower tariffs and including a new jump and pooling. At the same time, however, shortening the segment has a limitation; since the original segment is no longer an iso-world-price segment, the marginal welfare loss associated with the new pooling does not approach zero for a slight jump.

segment, 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, the first-best intervention, $s(\theta) = \theta$, is permitted not on subintervals of $[0, \overline{\theta}]$ but only on points of the interval. In other words, with respect to a measure μ, the targeting principle holds in a set of measure zero, $\mu\{\theta : s(\theta) = \theta\} = 0$, and it does not hold outside a set of measure zero. We can thus say that in its use of domestic subsidy, any optimal agreement violates the targeting principle "almost everywhere" on the interval $[0, \overline{\theta}]$.[32] Third, two different policy mixes deliver two different terms of trade for the foreign country: for $\theta_2 > \theta_1$, if $(s(\theta_1), \tau(\theta_1)) \neq (s(\theta_2), \tau(\theta_2))$, then $\widehat{p}^w(s(\theta_1), \tau(\theta_1)) > \widehat{p}^w(s(\theta_2), \tau(\theta_2))$. Equivalently, given the monotonicity of the world price, the equality, $\widehat{p}^w(s(\theta_1), \tau(\theta_1)) = \widehat{p}^w(s(\theta_2), \tau(\theta_2))$, cannot hold in an optimal agreement; if it holds, the expected global welfare would be maximized by including an iso-world-price segment between $(s(\theta_1), \tau(\theta_1))$ and $(s(\theta_2), \tau(\theta_2))$ that cannot exist in an optimal agreement. We summarize our findings.

Proposition 5. *(i) In its use of domestic subsidy, any optimal agreement violates the targeting principle almost everywhere on the interval* $[0, \overline{\theta}]$. *(ii) In any optimal agreement, an increase (a decrease) in domestic subsidy deteriorates (improves) the foreign country's terms of trade.*

A proper treatment of subsidy implied by our finding contrasts with what is prescribed by the targeting principle: the home government is not granted the freedom to select any policies along an iso-world-price segment in any optimal agreement. The tension between the objective of promoting domestic efficiency and the objective of reducing import tariffs is resolved when an 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. Remember also the GATT rules under which the treatment of domestic subsidies was tolerant and focused on market access: subsequent to a tariff negotiation, a governments was granted the freedom to alter its domestic subsidies provided that such policy adjustments preserve market access at the negotiated level. Our finding shows that the market-access focus of GATT rules is not a proper restriction on subsidy choice; since any optimal agreement makes it impossible

[32] We can equivalently say that in its use of domestic subsidy, any optimal agreement almost surely violates the targeting principle.

for the home government to adjust its domestic subsidy without affecting the market-access level for foreign exporters, an optimal agreement can be achieved by a policy-mix agreement, not by a commitment to a market-access level.

We finally present two additional points. First, we may numerically confirm that an agreement can create the net global welfare gain by shifting an iso-world-price segment towards lower tariffs and including a new jump and pooling. Suppose that θ is uniformly distributed on $[0, 1]$ with linear functions: $D(p^d) = 10 - p^d$ 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.[33] If an agreement involves only one world price, then the optimal agreement within this class entails an iso-world-price segment for $\theta \in [0, 0.68]$ and a pooling point $(s, \tau) = (0.68, 0)$. This agreement can be improved by involving one jump: an iso-world-price segment for $\theta \in [0, 0.478]$ and a pooling point $(0.697, 0)$. This agreement can be further improved by including two jumps: an iso-world-price segment for $\theta \in [0, 0.335]$ and two pooling points, $(0.508, 0.052)$ and $(0.705, 0)$. Second, we next argue that our findings can be extended to a richer policy environment in which a domestic consumption tax, t, is also available.[34] The pricing equations in (1) then becomes

$$p^d = p^w + \tau + t \text{ and } p^s = p^w + \tau + s. \tag{28}$$

The home welfare defined in (5) now includes an additional term for revenue from the consumption tax, $t \cdot D(\widehat{p}^d)$, and the home government has an additional instrument to lower the world price:

$$\frac{\partial \widehat{p}^w}{\partial t} = -\frac{D'}{D' - Q' - (Q^{*\prime} - D^{*\prime})} < 0. \tag{29}$$

Assuming that the welfare functions, $W(s, \tau, t; \theta)$ and $W^*(s, \tau, t)$, are strictly concave in (s, τ, t), we can find that first-best and Nash policies take the same form as before: the consumption tax remains unused (zero) for all θ in both policies. Consider next a hypothetical agreement with the policy set:

$$\{(s, \tau, t) : \widehat{p}^w(s, \tau, t) = \widehat{p}^w(s = \overline{\theta}, \tau = 0, t = 0)\}. \tag{30}$$

The home government can then select any policy mix on the iso-world-price "plane" (30).

[33] We could numerically observe a similar pattern under different forms of linear functions.

[34] The home government may impose an internal tax, t_h, on consumption of the domestically produced good and an internal tax, t_f, on consumption of the imported good. It then follows that $p^w = p^d - \tau - t_f$ and $p^s = p^d + s - t_h$. Following Horn, Maggi and Staiger (2010), we suppose that the WTO's National Treatment Clause restricts the relationship between t_h and t_f to satisfy $t_h = t_f = t$.

This freedom ensures that the government follows the targeting principle to select its domestic policies, $s(\theta) = \theta$ and $t(\theta) = 0$ for all θ, and tailors its tariff level, $\tau(\theta) = \tau^{sep}(\theta)$, to keep the world price at the specified level; despite the additional instrument, it prefers to use only the policy mix (s, τ) along the iso-world-price function (10).[35] Our argument can be further generalized to show that the extra instrument is redundant: the addition of the new instrument does not relax incentive compatibility to increase the expected global welfare, and any optimal policy set can be constructed by (s, τ) only.

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. On the one hand, in common with the existing literature, we show that any optimal agreement almost surely permits the use of a positive domestic subsidy. This finding offers an incomplete-information confirmation that the virtual prohibition of domestic production subsidies seen in the legal environment under WTO is beyond a proper level of restriction. On the other hand, as opposed to the conventional prescription for the treatment of domestic subsidy, we show that any optimal agreement almost surely prevents the use of the targeting principle. Whereas our basic setting conveys fairly standard features commonly found in the existing literature, our finding delivers a significantly different message: an international agreement needs to restrict the home government's freedom to select its domestic subsidy in order to increase the market-access level for foreign exporters. This finding provides an explanation for the international trading system to depart from the fairly tolerant treatment of domestic subsidies shown under GATT rules.

6 Appendix A: Preliminary Results[36]

We know from the market-clearing condition that

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

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

[35] This result is shown in Lemma A1 in the Appendix.

[36] These lengthy Appendices may be substantially shortened.

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

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

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

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:

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

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

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

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

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 the set and (ii) the slope $\frac{d\tau}{ds}$ is strictly negative along the set.

First-Best and Nash Policies: We first find the first-best policy mix 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, for each policy instrument $x \in \{s, \tau\}$,

$$\frac{\partial CS(\widehat{p}^d)}{\partial x} = CS'(\widehat{p}^d)\frac{\partial \widehat{p}^d}{\partial x} = -D(\widehat{p}^d)\frac{\partial \widehat{p}^d}{\partial x}$$

$$\frac{\partial \Pi(\widehat{p}^s)}{\partial x} = \Pi'(\widehat{p}^s)\frac{\partial \widehat{p}^s}{\partial x} = Q(\widehat{p}^s)\frac{\partial \widehat{p}^s}{\partial x}.$$

Similarly, $\frac{\partial CS^*(\widehat{p}^w)}{\partial x} = -D^*(\widehat{p}^w)\frac{\partial \widehat{p}^w}{\partial x}$ and $\frac{\partial \Pi^*(\widehat{p}^w)}{\partial x} = Q^*(\widehat{p}^w)\frac{\partial \widehat{p}^w}{\partial x}$. The first-order conditions become

$$\frac{\partial W^G(s, \tau; \theta)}{\partial x} = \tau\frac{\partial M}{\partial x} + [\theta - s]\frac{\partial Q}{\partial x} = 0 \text{ for } x \in \{s, \tau\}. \quad \text{(A8)}$$

Hence, under Assumption 1 (i), $W^G(s, \tau; \theta)$ is maximized when the home government with type θ selects $\tau = 0$ and $s = \theta$. We next find the Nash policy mix that maximizes the home welfare $W(s, \tau; \theta)$. The first-order conditions are

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

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: To show that the property holds in the home iso-welfare function $\{(s, \tau) : W(s, \tau; \theta) = \kappa \text{ for a constant } \kappa\}$, we refer to the gradient vector of the function:

$$\nabla(\theta) \equiv \begin{pmatrix} \partial W(s, \tau; \theta)/\partial s \\ \partial W(s, \tau; \theta)/\partial \tau \end{pmatrix}.$$

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

$$\frac{\partial \nabla(\theta)}{\partial \theta} = \begin{pmatrix} \partial Q/\partial s \\ \partial Q/\partial \tau \end{pmatrix}.$$

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. If the function v takes the general form $v(Q, \theta)$ without Assumption 1 (ii), then the corresponding differentiation becomes

$$\frac{\partial \nabla(\theta)}{\partial \theta} = \begin{pmatrix} \frac{\partial^2 v}{\partial \theta \partial Q} \frac{\partial Q}{\partial s} \\ \frac{\partial^2 v}{\partial \theta \partial Q} \frac{\partial Q}{\partial \tau} \end{pmatrix}.$$

Since $\frac{\partial^2 v}{\partial \theta \partial Q} \frac{\partial Q}{\partial s} > \frac{\partial^2 v}{\partial \theta \partial Q} \frac{\partial Q}{\partial \tau} > 0$ at any policy mix under the assumption $\frac{\partial^2 v}{\partial \theta \partial Q} > 0$, the single-crossing property again holds.

7 Appendix B: Proofs

Proof of Lemma 1. We maximize the home welfare $W(s, \tau; \theta)$ subject to the constraint: $\widehat{p}^w(s, \tau)$ is constant at $\widehat{p}^w(s = \overline{\theta}, \tau = 0)$. The constraint can be represented by an iso-world-price function, $\tau = \tau(s)$. We plug the constraint into the home welfare:

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

where $\widehat{p}^d = \widehat{p}^w(s, \tau(s)) + \tau(s)$ and $\widehat{p}^s = \widehat{p}^w(s, \tau(s)) + \tau(s) + s$. Using $\frac{\partial CS(\widehat{p}^d)}{\partial s} = -D(\widehat{p}^d) \frac{\partial \widehat{p}^d}{\partial s}$ and $\frac{\partial \Pi(\widehat{p}^s)}{\partial x} = Q(\widehat{p}^s) \frac{\partial \widehat{p}^s}{\partial s}$, we find the differentiation:

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

We know from (A7) 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 (A9) is thus reduced to the last term:

$$\frac{\partial W(s,\tau(s);\theta)}{\partial s}=[\theta-s]\left[\frac{\partial Q}{\partial\tau}\frac{d\tau}{ds}+\frac{\partial Q}{\partial s}\right]=[\theta-s]\frac{Q'D'}{D'-Q'}. \tag{A10}$$

The second equality 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 type θ selects its subsidy $s=\theta$. ■

Proof of Lemma 3. In the policy set (13), a slight increase in κ from zero preserves the same subsidy choice, $s(\theta)=\theta$, while it raises $\tau(\theta)$ for all θ. It thus 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 inequality, $E^*(\widehat{p}^w)>0$, is given by the assumption 1 (iii), $M(s=\overline{\theta},\tau=0)>0$. 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 with the policy set (14):

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

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

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

The slope, $\frac{d\tau}{ds}=\frac{Q'}{D'-Q'}<0$, is determined by (A1) and (A2). This agreement entails pooling at $(\theta^c,0)$ for $\theta\geq\theta^c$: for $\theta\in[\theta^c,\overline{\theta}]$, $s(\theta)=\theta^c$ and $\tau(\theta)=0$. It also involves sorting for $\theta<\theta^c$: for $\theta\in[0,\theta^c)$, $s(\theta)=\theta$ and $\tau(\theta)$ is determined by the function $\tau=\tau(s)$. The expected global welfare under the alternative agreement is

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

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

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

We first show that, for $\theta \in [0, \theta^c)$, the global welfare $W^G(s(\theta), \tau(\theta); \theta)$ falls if the iso-world-price function in (A11) shifts up as θ^c rises. Since an increase in θ^c raises the tariff choice $\tau(\theta)$ and keeps the same subsidy choice, $s(\theta) = \theta$, for $\theta \in [0, \theta^c)$, we may rewrite the first integrand in (A13) as

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

The second equality is given by (A8) and the third equality by (A11). The first term of (A13) is thus negative. We next show that the second term of (A12) is positive. Since in the pooling interval, an increase in θ^c raises the subsidy choice, $s(\theta) = \theta^c$, and keeps the same tariff, $\tau(\theta) = 0$, we may rewrite the second integrand in (A13) as

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

The equality is given by (A8). 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 original policy set under (i) can be improved on by an alternative policy set:

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

The alternative set entails sorting for $\theta \leq s_2$ and pooling at $(s_2, 0)$ for $\theta > s_2$. We restrict attention to $s_2 < \overline{\theta}$; if $s_2 \geq \overline{\theta}$, then it is immediate from the argument stated below that the agreement under (i) is not optimal. The global welfare is affected for $\theta \in [0, s_2)$ by the change of policy set. For $\theta \in (0, s_2)$, the sorting segment (A16) generates higher global welfare than does the original policy set by increasing the home welfare while preserving the world price $\widehat{p}^w(s = s_2, \tau = 0)$. Hence, given $prob(\theta = 0) = 0$, the expected global welfare is higher in the alternative agreement than in the original agreement.

We next show that the original policy set under (ii) is not optimal. We restrict attention to $\widehat{\theta} \in (0, \overline{\theta})$; if $\widehat{\theta} > \overline{\theta}$, then the policy set is equivalent to a singleton that is not optimal. Pick a subsidy $\widehat{s} \in (0, \widehat{\theta})$ and develop an alternative policy set $\{(\widehat{s}, 0), (s_2, 0)\}$. This new set entails pooling at $(\widehat{s}, 0)$ for $\theta \in [0, \widehat{\theta}]$: 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 new set. Some types $\theta > \widehat{\theta}$ also select $(\widehat{s}, 0)$ in the new set; the associated home-welfare gain by those types raises the world price and thus the foreign welfare for those types. It thus suffices to show that the global welfare in the range $[0, \widehat{\theta})$ is higher in the alternative set than in the original set. Since the policy point $(\widehat{s}, 0)$ is fixed for $\theta \in [0, \widehat{\theta}]$, we find

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

This value is maximized when $\widehat{s} = \int_0^{\widehat{\theta}} \theta dF(\theta)$. When developing the alternative set, we can always set $\widehat{s} = \int_0^{\widehat{\theta}} \theta dF(\theta)$. The expected global welfare is then higher in the alternative set than in the original set. This alternative set can be further improved by including a sorting segment at the bottom:

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

Hence, the original agreement 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 optimal agreement allows $\widehat{p}^w(s(\theta_2), \tau(\theta_2)) > \widehat{p}^w(s(\theta_1), \tau(\theta_1))$ for some $\theta_2 > \theta_1$. Without loss of generality, we assume that there exists type $\theta_c < \theta_1$ 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

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

Pick the policy mix (s_2, τ_2) that maximizes $\widehat{p}^w(s, \tau)$ on the iso-welfare function for θ_2:

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

The world price on (A17) is maximized when the iso-world-price function, $\{(s, \tau) : \widehat{p}^w(s, \tau) = \kappa \text{ for a constant } \kappa > 0\}$, shifts down either (a) until it is tangent to (A17) or (b) until it crosses (A17) from below at zero tariff. We can then show 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 $s_2 \leq s(\theta_1)$. Then $s_2 \leq s(\theta_1) \leq s(\theta_2)$ by the monotonicity. Given that (s_2, τ_2) and $(s(\theta_2), \tau(\theta_2))$ are located on 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 segment 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 subset for $s > s_2$ remains the same. We first show that incentive compatibility for types $\theta \leq s_2$ holds. The policy mix (s_2, τ_2) on (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 make their policy choices along the segment (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 segment (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 segment (A18) extends beyond the point $(s(\theta_1),\tau(\theta_1))$ at the higher world price $\widehat{p}^w(s_2,\tau_2) > \widehat{p}^w(s(\theta_1),\tau(\theta_1))$, given $s(\theta_1) < s_2$ 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 $\theta \leq s_2$ selected their policies not from the segment (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 segment (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, $\{(s,\tau) : W(s,\tau;\theta_c) = W(s(\theta_c),\tau(\theta_c);\theta_c)\}$. Pick the crossing point (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 $s_c < s(\theta_1)$. This inequality is given by construction, since $(s(\theta_1),\tau(\theta_1))$ satisfies

$$\begin{aligned} W(s(\theta_1),\tau(\theta_1);\theta_c) &\leq W(s_c,\tau_c;\theta_c) = W(s(\theta_c),\tau(\theta_c);\theta_c) \\ \widehat{p}^w(s(\theta_1),\tau(\theta_1)) &< \widehat{p}^w(s_c,\tau_c) = \widehat{p}^w(s_2,\tau_2). \end{aligned} \tag{A20}$$

The first inequality is incentive compatibility of θ_c. The second inequality is given by the above assumption, $\widehat{p}^w(s(\theta_2),\tau(\theta_2)) > \widehat{p}^w(s(\theta_1),\tau(\theta_1))$.

We now construct an alternative policy set that contains the sorting segment:

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

The policy subset for $s \notin [s_c, s_2]$ remains the same. This segment involves the highest possible world price for all $\theta > \theta_c$. We next check incentive compatibility. The segment is arranged to make type θ_c indifferent between $(s(\theta_c),\tau(\theta_c))$ and (s_c,τ_c) and so types $\theta \in (\theta_c, s_c)$ pool at (s_c,τ_c). We also know that (s_2,τ_2) is on the iso-welfare function for θ_2 in (A17), and the policy subset 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 $\theta > s_2$ but make their choices along the sorting segment (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 $\theta \in [s_c, s_2]$ selected their policies not from the sorting segment (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:

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

Any (s, τ) in this region satisfies $s \geq s_c$. Thus, for $\theta \in (\theta_c, s_c)$, any original policy mix takes the form of over-subsidy, $s(\theta) > \theta$, and involves a weekly lower world 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 $\widehat{\tau} \leq \tau(\theta)$ on the sorting segment:

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

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 "restricted" to select $\widehat{s} = s(\theta)$ and $\widehat{\tau} \leq \tau(\theta)$ 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 under (b) as under (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 entire 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 an optimal agreement cannot entail pooling at $(s(0), \tau(0))$ for $\theta \in [0, \theta_0]$ for some $\theta_0 > 0$. Suppose that an optimal agreement entails such a pooling interval. The policy mixes for $\theta > \theta_0$ are in the region $\{(s, \tau) : W(s, \tau; \theta_0) \leq W(s(0), \tau(0); \theta_0)\}$. Pick the policy mix (s_0, τ_0) that maximizes $\widehat{p}^w(s, \tau)$ on the iso-welfare function for θ_0:

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

The world price on (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

$$0 < s_0 \leq \theta_0.$$

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 segment 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 subset for $s > s_0$ remains the same. We next check incentive compatibility of the alternative agreement. The policy mix (s_0, τ_0) on (A24) and any policy mix for $s > s_0$ is in the region $\{(s, \tau) : W(s, \tau; \theta_0) \leq W(s(0), \tau(0); \theta_0)\}$. Thus, given $s_0 \leq \theta_0$ as shown above, types $\theta \leq s_0$ do not mimic types $\theta > s_0$ but select their policies along the sorting segment (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 segment (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 optimal agreement 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 iso-welfare function for $\widehat{\theta}$, $\{(s,\tau) : W(s,\tau;\widehat{\theta}) = W(s(\widehat{\theta}),\tau(\widehat{\theta});\widehat{\theta})\}$, 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 strictly positive tariff, or (ii) it crosses the zero-tariff line, $\{(s,\tau) : \tau = 0\}$. For those two cases, we show that the original agreement is not optimal, which causes a contradiction.

Case (i): Pick the crossing point $(\widehat{s},\widehat{\tau})$ that satisfies

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

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 subset 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:

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

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

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

The policy subset for $s < \widehat{s}$ remains the same. 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 alternative agreement. 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. In order to show that the original agreement is not optimal, it now suffices to show that the alternative agreement is further improved on by a new policy set.

Suppose that the new policy set contains the new sorting segment 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 subset for $s < \widehat{s}'$ remains the same. Pick the new crossing point $(\widehat{s}', \widehat{\tau}')$ 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 at $(\theta^c, 0)$ for $\theta \in [\theta^c, \overline{\theta}]$. Again, 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 with respect to θ^c. The differentiation is reduced to three terms:

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

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 can thus claim that, if the first term is negative for θ^c close to $\overline{\theta}$, then the expected global welfare is higher with (A29) than with (A28). To show that this claim holds, we show that, if θ^c falls slightly from $\overline{\theta}$, then for $\theta \in (\widehat{\theta}, \widehat{s}')$, the global welfare is higher at the new pooling point $(\widehat{s}', \widehat{\tau}')$ than at the previous pooling point $(\widehat{s}, \widehat{\tau})$. We follow three steps. First, if any policy mix takes the form of over-subsidy, then a decrease in tariff increases the global welfare: $\frac{\partial W^G(s,\tau;\theta)}{\partial \tau} < 0$ for any $s > \theta$ as shown in (A23). Second, we compare two scenarios: (c) the home government with $\theta \in (\widehat{\theta}, \widehat{s}')$ is "restricted" to select a point $(\widehat{s}, \widetilde{\tau})$ from the segment (A29), where $\widetilde{\tau} < \widehat{\tau}$, and (d) the home government with $\theta \in (\widehat{\theta}, \widehat{s}')$ is allowed to select any policy mix from (A29) with no such restriction. For $\theta \in (\widehat{\theta}, \widehat{s}')$, the global welfare is at least as high under (d) as under (c); for $\theta \in (\widehat{\theta}, \widehat{s}')$, the home welfare is at least as high under (d) as under (c), while the foreign welfare is the same in both scenarios. To summarize the two steps, for $\theta \in (\widehat{\theta}, \widehat{s}')$, the global welfare is higher under (d) than at the pooling point $(\widehat{s}, \widehat{\tau})$, since tariffs are lower at $(\widehat{s}, \widetilde{\tau})$ than at $(\widehat{s}, \widehat{\tau})$. Third, under the scenario (d), the home government with $\theta \in (\widehat{\theta}, \widehat{s}')$ selects the pooling point $(\widehat{s}', \widehat{\tau}')$. Hence, the above claim holds.

We next consider the case (b) in which $(\widehat{s},\widehat{\tau})=(s(\widehat{\theta}),\tau(\widehat{\theta}))$. Again, the original agreement entails an over-subsidy interval: there exist types $\theta\in(\widehat{\theta},\widehat{s})$ that select their policies from the region (A27) for $s\geq\widehat{s}=s(\widehat{\theta})$. The remaining proof is analogous to the proof for the case (a), except that the crossing point in (A29), $(\widehat{s}',\widehat{\tau}')$, is now defined as the point at which the iso-world-price segment (A29) crosses the original policy subset that is continuous, adjoining $(\widehat{s},\widehat{\tau})$ from the left. ■

Case (ii): 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 under the two possibilities: (a) it 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). Any policy mix (s,τ) that involves a positive tariff $\tau>0$ and $\widehat{p}^w(s,\tau)\leq\widehat{p}^w(s=\overline{\theta},\tau=0)$ is in the region:

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

Any policy mix (s,τ) with $\tau>0$ in (A31) is improved on by the zero-tariff point $(\overline{\theta},0)$; the global welfare for any θ is higher at $(\overline{\theta},0)$ than at any policy mix (s,τ) with $\tau>0$, since for any θ, the over-subsidy is smaller and tariff is lower at $(\overline{\theta},0)$ than at any other policy mix (s,τ) with $\tau>0$ in (A31). Consider next the case (b). Any policy mix (s,τ) that involves $\tau>0$ and $\widehat{p}^w(s,\tau)\leq\widehat{p}^w(s=\overline{\theta},\tau=0)$ is in the region:

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

For the same reason as above, any policy mix (s,τ) with $\tau>0$ in (A32) is improved on by the zero-tariff point $(s_2,0)$. ■

Proof of Proposition 5. We here show that an optimal policy set cannot include a sorting segment in which the world price is constant. First, we show that an optimal agreement cannot have an iso-world-price segment at the bottom. Suppose that an optimal agreement entails sorting at the bottom for $\theta \leq \theta_c$ along an iso-world-price segment $\{(s,\tau) : \widehat{p}^w(s,\tau) = \widehat{p}^w(s(\theta_c),\tau(\theta_c))\}$. 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 segment $\{(s,\tau) : \widehat{p}^w(s,\tau) = \widehat{p}^w(s(\theta_c'),\tau(\theta_c'))\}$, 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 the 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 segment where $s(\theta) = \theta$. Hence, if $\theta_c' \to \theta_c$, then $\Delta(\theta) \to 0$ and $\frac{\partial \Delta(\theta)}{\partial \theta_c'} < 0$ for $\theta \in [0,\theta_c']$. This strict inequality is given by the single-crossing property: if θ_c' falls slightly from θ_c, then 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 $(s(\theta_c),\tau(\theta_c))$ counterclockwise. This is evident, since the gradient vector of the home welfare function, $\nabla(\theta)$, at the point $(s(\theta_c),\tau(\theta_c))$ 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 associated with the new pooling point $(s(\theta_c),\tau(\theta_c))$, $\frac{\partial \Delta(\theta)}{\partial \theta_c'}$ for $\theta \in (\theta_c',\theta_c)$, approaches zero. To see this, suppose that a function, $\tau = \tau(s)$, represents the original sorting segment where the foreign welfare is held constant. Along this segment, the original policy mix for $\theta \in (\theta_c',\theta_c)$ maximizes the home welfare and satisfies the first-order condition in (A10):

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

For $\theta \in (\theta_c',\theta_c)$, if $\theta_c' \to \theta_c$, then the new pooling point approaches the original policy mix along the original segment; 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 $\Delta(\theta) \to 0$ and $\frac{\partial \Delta(\theta)}{\partial \theta_c'} \to 0$ 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 contradicts the optimality of the original agreement.

Second, we extend this result beyond the interval at the bottom, $[0, \theta_c]$. Suppose that an optimal policy set includes a sorting segment 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 now strictly increasing is followed by the sorting segment 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 possibilities: (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 subset adjoining the point $(s(\theta_c), \tau(\theta_c))$ from the left is continuous and is flatter than the iso-world-price segment (A33).

For the case (i), we shift the segment (A33) down, and 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 $(s(\theta_2), \tau(\theta_2))$. The new policy set then causes the difference: 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 segment,

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

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 segment (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 remain 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, if θ_2' falls slightly from θ_2, then $\mathbb{E}_\theta \Delta(\theta)$ increases, which contradicts the optimality assumption.

The remaining proof for the case (ii) is analogous, 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 subset that adjoins $(s(\theta_c), \tau(\theta_c))$ from the left. ■

Lemma A1. *In the policy set (30), the home government of type θ selects $s(\theta) = \theta$, $t(\theta) = 0$ and $\tau(\theta) = \tau^{sep}(\theta)$.*

Proof. We maximize $W(s, \tau, t; \theta)$ subject to the constraint: $\widehat{p}^w(s, \tau, t)$ is constant at $\widehat{p}^w(s = \overline{\theta}, \tau = 0, t = 0)$. The first-order conditions become

$$-\frac{\partial \widehat{p}^w}{\partial x} M + \tau \frac{\partial M}{\partial x} + [\theta - s] \frac{\partial Q}{\partial x} + t \frac{\partial D}{\partial x} - \lambda \frac{\partial \widehat{p}^w}{\partial x} = 0 \text{ for } x \in \{s, \tau, t\}$$

where λ is the Lagrange multiplier. Observe $\lambda < 0$ under Assumption 2, whereby the home welfare falls as the iso-world-price function shifts to raise $\widehat{p}^w$. Since $\frac{\partial M}{\partial x} = E^{*\prime} \frac{\partial \widehat{p}^w}{\partial x}$ for $x \in \{s, \tau, t\}$, the first-order conditions imply $s = \theta$, $t = 0$ and $\tau = \frac{E^*(\widehat{p}^w) + \lambda}{E^{*\prime}(\widehat{p}^w)}$. Hence, on the iso-world-price plane (30), the home government of type θ uses the targeting principle in its choice of domestic policies, $s = \theta$ and $t = 0$, and tailors its tariff level to satisfy the constraint. ■

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