Trade agreements when profits matter*

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Abstract

This paper suggests a rationale for the ban of export subsidies by showing that, in a linear Cournot profit-shifting model in which countries invest in a policy infrastructure before imposing trade policy, this ban may lead to a more self-enforcing agreement. The presence of oligopoly introduces an asymmetry between import tariffs and export subsidies: for import tariffs terms-of-trade effects and profit-shifting effects go in the same direction while they go in opposite directions for export subsidies. This asymmetry, combined with the fact that any change in the policy infrastructure takes time, implies that payoffs on the off-equilibrium path from an import-tariff-only agreement tend to be lower than payoffs on the off-equilibrium path from an export-subsidy-only agreement. In particular, punishment with tariffs is harsher than punishment with subsidies. When the set of instruments is restricted to import tariffs, a trade agreement needs to neutralize both the terms-of-trade and profit-shifting externalities.

KEYWORDS: GATT/WTO, trade liberalization, multilateralism, export subsidies.
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1 Introduction

The postwar era has witnessed a spectacular liberalization of international trade: average ad valorem tariffs on industrial goods have been reduced from over 40 percent to less than 4 percent. It is generally acknowledged that the General Agreement on Tariffs and Trade (GATT), and later its successor, the World Trade Organization (WTO), played a key role in achieving these historically low tariff levels through a series of eight trade negotiation rounds (the ninth round - Doha Development Round - has not been concluded).[1,2] This past success stands in contrast to difficulties in multilateral trade negotiations in the last twenty years.[3] In order to understand the reasons for these difficulties, it is important to understand the reasons for the past success.

The GATT/WTO is a forum for governments to negotiate trade agreements according to a pre-agreed set of rules. Although these rules have attracted a significant amount of attention from economists, many of them are still puzzling. In particular, the ban of export subsidies, referred to in the literature as the *export subsidy puzzle* (see for example Maggi (2014) or Bagwell et al. (2016)) remains to a large extent unexplained. This paper suggests an economic rationale for the ban of export subsidies by showing that, in a linear Cournot profit-shifting model in which countries need to invest in a policy infrastructure before imposing trade policy, this ban may lead to a more self-enforcing agreement.

When firms make abnormal profits and interact strategically, governments use trade policy not only to improve their terms of trade, but also to shift profits from foreign to domestic firms. However, as highlighted by Bagwell and Staiger (2012b), when countries have both trade instruments at their disposal, the profit-shifting externality is neutralized. As a consequence, when acting non-cooperatively, countries choose to invest only in one instrument: all countries use either import tariffs only or export subsidies only. When countries cooperate and agree to use a single instrument, the self-enforceability

[1] The GATT was signed in 1947 by 23 contracting parties as an interim agreement in expectation of the creation of the much more ambitious International Trade Organization (ITO). The ITO was never ratified while the GATT survived and became the platform for multilateral trade agreements until January 1, 1995, when it was superseded by the WTO as the result of the Marrakech Agreement, the final act of the Uruguay Round. The GATT still continues to exist as the WTO's umbrella treaty for trade in goods and it has been supplemented by a set of additional agreements that extend the GATT to new areas (services, intellectual property etc.). I will therefore refer to the agreement as GATT/WTO.

[2] Rose (2004a,b) suggests that there may be no correlation between GATT/WTO membership and more liberal trade policies or higher trade volumes. However, Subramanian and Wei (2007), Tomz et al. (2007), Bagwell and Staiger (2006) and others challenge Rose's conclusions about the ineffectiveness of the WTO and offer empirical evidence supportive of an important role played by the GATT/WTO in trade liberalization.

[3] The Doha Development Round commenced in 2001 and was set to be concluded in four years, but talks have stalled over a divide between the developed nations and the major developing countries and not much progress has been achieved since. There is a general agreement among academics and policy makers alike that the GATT/WTO is in desperate need of reform. This need for reform to keep the GATT/WTO relevant has been for example stressed by the new Director-General Ngozi Okonjo-Iweala in her address to the WTO General Council on March 1, 2021. `https://www.wto.org/english/news_e/spno_e/spno1_e.htm`

of the agreement will differ depending on the choice of the instrument. The presence of oligopoly introduces an asymmetry between import tariffs and export subsidies: for import tariffs terms-of-trade effects and profit-shifting effects go in the same direction while they go in opposite directions for export subsidies. Given that any change to the policy infrastructure takes time, the consequence of this asymmetry is that the payoffs along the off-equilibrium path depend on the instrument chosen under cooperation. The payoffs along the off-equilibrium path from the tariff-only agreement tend to be lower than the payoffs along the off-equilibrium path from the subsidy-only agreement which makes the the tariff-only agreement more self-enforcing.

The paper further contributes to the trade agreements literature by showing that, when the set of available trade instruments is restricted to import tariffs only, and markets are oligopolistic, the rules of reciprocity and non-discrimination enable countries to neutralize both the terms-of-trade and profit-shifting externalities and to reach the internationally efficient outcome.

There is a vast literature on the treatment of export subsidies in the GATT/WTO, but as Bagwell et al. (2016) point out: "existing formal models that we review do not identify a reason for treating export subsidies more severely than import tariffs." Bagwell and Staiger (2012a) identify two challenges to the formalization of the GATT/WTO treatment of export subsidies. The first challenge is to find a situation where governments would actually *want* to use export subsidies. The second challenge is to show that, in such situations, it would be beneficial to ban them. It is generally pointed out that export subsidies give rise to inefficiencies by distorting market forces and therefore should be banned. Indeed, it is easy to show that two export-competing governments would benefit from an export subsidy restriction that would prevent harmful export subsidy wars (see for example Bagwell and Staiger (2002, ch. 10) for a discussion of this argument). However, this reasoning does not take into account the welfare of the importing country. Consumers in the importing country benefit from export subsidies of other countries and it can be shown that, from the world's perspective, export subsidies are welfare increasing due to their trade-expanding nature.[4] As Bagwell and Staiger (2012a) summarize this argument: the ban of export subsidies seems to "represent an inefficient victory for exporting governments that comes at the expense of importing governments."[5]

Bagwell and Staiger (2012a) give a new interpretation of the export subsidy ban in a linear Cournot delocation model. In this model, governments would want to tax exports at Nash equilibrium. However, at the efficient cooperative level they have an incentive to

[4] In the absence of cooperation, the volume of trade is inefficiently low, and subsidies, by at least partially neutralizing the imposed trade barriers, help to alleviate this inefficiency.

[5] Under additional assumptions, it is possible to show that the ban of export subsidies may increase world welfare. Bagwell and Staiger (1997) show that export subsidies can create inefficiencies when they affect entry into a natural monopoly export market. Collie (1997) shows that export subsidies can create inefficiencies when they are financed by distortionary taxation.

deviate from the agreement with an export subsidy. Bagwell and Staiger argue that this provides a compelling rationale for the GATT/WTO treatment of export subsidies for example in agriculture: the original GATT was permissive towards subsidies of primary products (these were subject mostly to a reporting requirement), but the restriction on subsidies has been gradually tightened until they were prohibited by the Agreement on Subsidies and Countervailing Measures (SCM) during the Uruguay Round. This approach, however, does not provide a rationale for the treatment of export subsidies in other areas such as aircraft industry or automotive industry. Export subsidies on non-primary products were banned by Article XVI of the original GATT.[6] The focus of this paper is to provide a rationale for the treatment of export subsidies in the latter areas.

A similar partial rationale is provided by Bagwell and Lee (2020) who show, in a monopolistic competition model with heterogenous firms and Melitz and Ottaviano (2008) preferences, that starting from global free trade countries have an incentive to unilaterally introduce a small export subsidy which is a beggar-thy-neighbor intervention in their setting. This motivates a restriction of export subsidies once countries are sufficiently close to global free trade. Beshkar and Lashkaripour (2020) propose a different partial explanation. Using a multi-industry general-equilibrium Ricardian trade model, they show that, provided that export taxes are forbidden, a ban on export subsidies leads to unilateral tariff cuts which increase the volume of trade.

In this paper, I offer a different perspective on the export subsidy puzzle from the papers above. My rationale for the ban of export subsidies is a self-enforcement-based rationale and not an efficiency-based one. I start by characterizing the non-cooperative equilibrium trade policies. I build on the insight from recent work in political economy (e.g. Besley and Persson (2009, 2010)) which argues that the use of a policy requires investing in a policy infrastructure such as legal or fiscal capacity.[7] To capture this insight, I assume that trade policy is determined in a three stage game. In the first stage, governments (simultaneously) decide on which policy infrastructure to build: import instrument only, export instrument only or both. In the second stage, governments

[6]The original intention for the treatment of export subsidies in the ITO was even more ambitious. As Hudec (1975, p. 13) notes, in the 1943 outline of the code of conduct: "All forms of non-tariff trade restriction were to be prohibited absolutely, the only exception being the authorization to use quantitative restrictions in times of balance-of-payments crisis. Other distortions of normal market forces such as export subsidies were to be eliminated, [...] Tariffs would remain, but they were to be progressively reduced by negotiations."

[7]In the context of trade policy, the use of an import instrument requires custom posts and custom officials at the border while the use of an export instrument requires a different legal infrastructure, payment centers, inspectors etc. The recent Brexit experience illustrates this point. When the UK was part of the EU, goods were moving freely between the UK and the rest of the EU. But since the UK has left the EU, European firms do not have a tariff-free access to the UK market and vice versa. But the border checkpost infrastructure is not yet ready. As The Guardian recently reported: "border checkposts will not be ready for the July deadline, while inland customs facilities being built are also behind schedule." `https://www.theguardian.com/business/2021/mar/07/british-ports-say-they-are-not-ready-for-brexit-customs-checks`

(simultaneously) set the optimal levels of the chosen instruments. They can only use the instruments in which they invested in stage one. In the third stage, firms (simultaneously) set quantities. I show that, depending on the parameters of the model, this trade-policy game has either a unique subgame-perfect Nash equilibrium in pure strategies or two such equilibria. When the terms-of-trade gain from the import tariff is large (goods are not very substitutable and foreign firms have lots of market power), there is a unique equilibrium in which all countries use import tariffs only. When foreign firms behave more competitively (good are sufficiently substitutable and foreign firms have less market power), there is one equilibrium in import tariffs only and another one in export subsidies only. The asymmetry between the two trade instruments discussed above implies that the subsidy-only equilibrium leads to a higher welfare than the tariff-only equilibrium.

I then characterize the efficient trade policy and show that the non-cooperative policy is inefficient. Using a cooperative counterpart of the trade-policy game in which countries first invest in policy infrastructure and then set chosen instruments to the efficient levels, I show that in an agreement countries will choose to cooperate on a single instrument. This follows from the fact that the same internationally efficient outcome can be achieved by any combination of the import and export instruments as only net instruments matter in equilibrium. So if the use of trade policy is costly, countries will choose a single instrument. The question I address next is which instrument should countries choose? The same outcome can be achieved with either instrument in terms of welfare, but because the presence of oligopoly introduces an asymmetry between the two trade instruments, the incentives to deviate from the agreement will not be the same depending on which instrument countries use. I then incorporate the one-shot trade-policy game into a repeated game structure to explore the differences in self-enforceability between a tariff-only and a subsidy-only agreement.

I start by considering a simple benchmark case where the investment in any given trade instrument is irreversible. This case is interesting not only because it helps build intuition, but also because various results established for this case turn out to be relevant in the more general case which I consider later. In the initial period, countries sign a single-instrument trade agreement. They invest in the infrastructure to use either import instruments or export instruments and they set the chosen instrument to the efficient level. The trade agreement will be self-enforcing if the net present value from cooperation is greater than the net present value from deviation followed by breakdown of the agreement (Nash reversion). The *tariff-only* agreement (in which countries use import instruments) is more self-enforcing than a *subsidy-only* trade agreement (in which countries use export instruments) because the punishment with tariffs is harsher than punishment with subsidies. In a trade war with import tariffs, countries impose on each other negative terms-of-trade and profit-shifting externalities whereas in a trade war with export subsidies, countries impose on each other a negative profit-shifting externality and a positive terms-of-trade externality.

I then consider the more general case in which the investment in the policy infrastructure is reversible, but takes time. It takes one period to be able to introduce a second instrument or replace an existing instrument by another one. I show that this investment lag together with the asymmetry between the two policy instruments implies that the off-equilibrium paths will not be the same for the two agreements. For a wide range of parameters, the punishment following deviation from a tariff-only agreement will be harsher than punishment following deviation from a subsidy-only agreement. As a consequence, the tariff-only agreement is more self-enforcing for a wide range of parameters. This suggests a self-enforcement-based rationale for the ban of export subsidies.

Finally, I turn to the question of how a trade agreement helps countries reach efficiency with import tariffs only. In particular, I focus on the role of the negotiating principles of reciprocity and non-discrimination. Broadly speaking, the principle of reciprocity requires countries to exchange reciprocal concessions in trade barrier reductions. The principle of non-discrimination, as the name suggests, forbids discrimination between GATT/WTO members. These principles have initially been thought not to have any economic rationale.[8] By building on the work of Johnson (1953-1954),[9] in their seminal paper, Bagwell and Staiger (1999) show that the principles of reciprocity and non-discrimination help countries to neutralize a terms-of-trade externality and reach an efficient outcome. In the absence of trade agreements, countries set tariffs inefficiently high because they want to improve their terms of trade at the expense of other countries. Because all countries do so, they end up in a Prisoner's Dilemma situation. By freezing the terms of trade, trade agreements help countries to come out of this Prisoner's Dilemma situation. More recently, Ossa (2011) provides an alternative and novel motivation for trade agreements. He assumes the set of trade instruments to be restricted to import tariffs only. In his 'new trade' model of trade negotiations, when acting non-cooperatively, countries impose inefficiently high tariffs because they want to attract firms to locate in the home country. Trade agreements enable countries to overcome the Prisoner's Dilemma driven by this production relocation externality.[10] In the oligopolistic framework of this paper, I show that Nash equilibrium import tariffs are inefficient because of terms-of-trade and profit-shifting externalities and that the principles of reciprocity and non-discrimination help countries neutralize both of them.[11]

[8]See for example Krugman (1992).

[9]The terms-of-trade argument has a long history. See for example Irwin (1996) for a thorough discussion.

[10]Another strand of literature rationalizes trade agreements as a commitment device: governments sign trade agreements to tie their hands ex ante and eliminate the possibility of being influenced by ex post lobbying. This approach is orthogonal to the beggar-thy-neighbor approach adopted in this paper and I will therefore not discuss it. See for example Maggi and Rodriguez-Clare (1998), or Bagwell and Staiger (2010) for an overview.

[11]The profit-shifting effect of trade policy has been quantified by Ossa (2014) although in his case the effect is actually closer to the production relocation effect of Venables (1987).

In terms of the underlying model, I build on a standard linear Cournot oligopoly model of trade à la Brander (1981) extended to allow for n countries. This is a well-established model in the trade literature and in particular in the field of trade agreements (see for example Yi (1996), Krishna (1998), Freund (2000), Ornelas (2005a,b, 2007) or Fujiwara (2008)), but it is important to mention why this model is relevant for the questions of this paper. First, large firms dominate international trade (see for example Bernard et al. (2007)) and large firms predominantly lobby governments for trade policy (see for example Blanga-Gubbay et al. (2020)), so it is important to study trade agreements in a setting where firms have market power and make abnormal profits. Second, in order to address the question of why the GATT/WTO bans export subsidies, we need a model in which countries would want to use export subsidies in the first place. Hence the choice of Cournot rather than Bertrand competition.[12] As shown by Kreps and Scheinkman (1983) and Maggi (1996), this is not as restrictive as it may seem. Price competition with capacity constraints would yield similar results. And third, the choice of the particular functional form for demand is driven by analytical tractability. In order to characterize the Nash equilibria of the n-player game, I need to evaluate welfare at different levels of trade instruments for different combinations of these instruments and so it is necessary to make an assumption about the functional form of demand. The version of linear demand I use allows for different degrees of product differentiation which enables me to see the effects of changes in market power.

The remainder of this paper proceeds as follows. Section 2 presents the basic underlying oligopolistic multi-country model of international trade. Section 3 solves for the optimal trade policies emerging from the non-cooperative trade-policy game. Section 4 characterizes internationally efficient trade policies and argues that when the use of trade policy requires a prior investment in a policy infrastructure, countries have an incentive to sign single-instrument agreements. Sections 5 and 6 show that an import-tariff agreement is more self-enforcing for a wide range of parameters. Section 5 assumes that the investment in policy infrastructure is irreversible while Section 6 assumes that this investment is reversible. Section 7 analyses trade agreements when the set of trade instruments is restricted to import tariffs only. It shows how the GATT/WTO fundamental principles of reciprocity and non-discrimination help countries neutralize both terms-of-trade and profit-shifting externalities and reach a superior cooperative outcome. Section 8 concludes. All proofs are presented in the Appendix.

[12] As Eaton and Grossman (1986) have shown, when firms compete à la Bertrand, the optimal export policy would be an export tax.

2 The Underlying Economic Structure

The underlying model is a Brander (1981) type model of trade with oligopoly. There are n symmetric countries. Each country has one oligopolistic firm producing one good q.[13] Each country also competitively produces an outside good M which I take to be the numéraire.

2.1 Preferences

Following Yi (1996), consumers have quasilinear-quadratic preferences of the form

$$u(\mathbf{q_i}, M_i) = aQ_i - \frac{\gamma}{2}Q_i^2 - \frac{1-\gamma}{2}\sum_{j=1}^{n} q_{ij}^2 + M_i, \tag{1}$$

where q_{ij} is country i's consumption of country j's product, $\mathbf{q_i} = (q_{i1}, q_{i2}, \ldots, q_{in})$ is country i's consumption vector, $Q_i \equiv \sum_{j=1}^{n} q_{ij}$, and M_i is country i's consumption of the numéraire good. This preference structure allows for a variable degree of (symmetrical) product differentiation. The parameter γ is the substitution index between goods, which ranges from 0 to 1: when $\gamma = 0$, goods are independent in demand and when $\gamma = 1$, they are homogeneous. Consumers have a taste for variety depending on the substitution index. When $\gamma = 1$ consumers do not care about variety, whereas, for lower values of γ, utility is higher the more balanced is the consumption bundle, for a given total consumption Q_i. Maximizing utility, country i's inverse demand function for firm j's good is

$$p_{ij} = a - (1-\gamma)q_{ij} - \gamma Q_i = a - q_{ij} - \gamma \sum_{\substack{k=1 \\ k \neq j}}^{n} q_{ik}. \tag{2}$$

2.2 Technology and trade costs

Both the oligopolistically and competitively produced goods are produced under constant returns to scale and require only labor as input. Technologies are identical and I assume that the labor supply is large enough so that the numéraire good is always produced in equilibrium. Hence the wage is pinned down in the numéraire good sector. I normalize units so that the production of one unit of M requires one unit of labor which sets the wage equal to one. In the oligopolistic sector, all firms produce at the same marginal cost c in terms of the numéraire good.

Trade in non-numéraire products is affected by trade policy. Domestic governments can impose specific trade barriers on their country's non-numéraire imports and exports.

[13] As I am interested in the role of profits (and more precisely the profit-shifting motive) for trade agreements, I assume that the number of firms per country is fixed and invariant to trade policy so that firms make abnormal profits.

The barrier imposed by country i on imports from country j is denoted by τ_{ij}. If $\tau_{ij} > 0$, it is an import tariff; if $\tau_{ij} < 0$, it is an import subsidy. The barrier imposed by country j on exports to country i is denoted by σ_{ij}. If $\sigma_{ij} > 0$, it is an export subsidy; if $\sigma_{ij} < 0$, it is an export tax.[14]

Revenues are collected and tax receipts distributed using a (non-distortionary) head tax or subsidy. I assume that no other policy instruments are available and so countries use trade policies to achieve any income redistribution between groups in the economy. In particular, there are no domestic instruments that could directly target the oligopolistic distortion: neither tariffs nor subsidies are imposed on home sales of domestic firms: $\tau_{ii} = 0$ and $\sigma_{ii} = 0$. This assumption allows to focus sharply on the use of trade policy for second-best objectives.[15] My model thus highlights the implications of oligopoly for trade policy and trade agreements in a second-best world.

2.3 Industry equilibrium

Markets are assumed to be segmented. Firms take trade policy as given and compete à la Cournot by choosing quantities in each country. For country j's firm, the effective marginal cost of serving country i's market is $c_{ij} = c + \tau_{ij} - \sigma_{ij}$. In country i, country j's firm solves $\max\limits_{\{q_{ij}\}} \pi_{ij} = (p_{ij} - c_{ij})q_{ij}$. The first-order condition for this maximization problem is

$$p_{ij} - c_{ij} - q_{ij} = 0. \tag{3}$$

Solving for the Cournot equilibrium yields

$$\begin{aligned} Q_i &= \frac{n - (T_i - S_i)}{\Gamma(n)}, \\ q_{ii} &= \frac{\Gamma(0) + \gamma(T_i - S_i)}{\Gamma(0)\Gamma(n)}, \\ \text{and for } i \neq j, \quad q_{ij} &= \frac{\Gamma(0) + \gamma(T_i - S_i) - \Gamma(n)(\tau_{ij} - \sigma_{ij})}{\Gamma(0)\Gamma(n)}, \end{aligned} \tag{4}$$

where T_i is the sum of tariffs imposed by country i on all imported goods, $T_i \equiv \sum_{j=1}^{n} \tau_{ij}$; S_i is the sum of subsidies for products exported to country i by all other countries, $S_i \equiv \sum_{j=1}^{n} \sigma_{ij}$; and where I have normalized $a - c = 1$. $\Gamma(.)$ is defined as $\Gamma(n) \equiv 2 - \gamma + n\gamma$ and can be interpreted as a measure of the degree of competition in the world which depends on

[14] Given that Nash equilibrium trade policy will consist of import tariffs and/or export subsidies, with a slight abuse of terminology, I will tend to refer to the import instrument as an import tariff and to the export instrument as an export subsidy.

[15] Grossman and Helpman (1995, p. 680) for example argue: "In reality, governments appear to have difficulty in using direct and transparent instruments to transfer income, so they resort to less direct means instead." Rodrik (1995, p. 1476) also points out that the use of trade policy for redistribution purposes is "a universal phenomenon".

the number of firms in the world n and the substitution index γ. The higher is γ (the greater the degree of substitutability between goods) and the higher is n (the greater the number of firms), the greater is the degree of competition.[16]

The equilibrium quantities have standard properties: if country i increases its tariff on imports from country j, the consumption of imports from country j and the total consumption in country i fall, but the consumption of all other goods increases. If country j increases its subsidy to exports to country i, the consumption of imports from country j and the total consumption in country i rise, but the consumption of all other goods falls. Note that, as for example Grossman and Helpman (1995) and Bagwell and Staiger (2001) show in other contexts, what matters for the equilibrium quantities is the *net trade instrument*, i.e. the difference between the export subsidy and the import tariff. If country i increases its tariff on imports from country j and country j increases its subsidy to exports to country i by the same amount, the equilibrium quantities in country i will remain unchanged.

The equilibrium export profit in country i of country j's firm can be obtained using the first-order condition (3):

$$\pi_{ij} = (p_{ij} - c_{ij})q_{ij} = q_{ij}^2, \tag{5}$$

so a change in trade instruments in country i that decreases country j's sales in country i, also decreases country j's profits in country i.

There are two sources of gains from trade in this setting: increased variety of goods and reduced market power of the domestic industry. The variety effect is more important for low values of the substitution index γ, when consumers greatly value variety and the strategic interaction among firms is limited. For high values of γ, the pro-competitive effect is relatively more important.

3 Non-cooperative Trade Policy

In this section I characterize optimal non-cooperative trade policies in the presence of oligopolistic competition introduced in Section 2. Governments set trade policy instruments to maximize national welfare. As is standard in the literature, I assume that governments act as Stackelberg leaders vis-à-vis both domestic and foreign firms in imposing trade policy. A novel aspect of my analysis is that I allow for an endogenous choice of the set of trade policy instruments. Indeed, an important theme in recent work on political economy (see especially Besley and Persson (2009, 2010)) is that policy choices in market regulation and taxation are constrained by investments in legal and fiscal ca-

[16]To simplify notation, I suppress in $\Gamma(.)$ the dependence on the substitution index γ and will make it explicit only when it will be of interest.

pacity. In the context of international trade policy, this insight implies that the use of trade instruments is also constrained by investments in institutional capacity. Export or import trade instruments require the existence of different kinds of administrative infrastructure: customs posts and custom officials in the import tariff case, inspectors and payment centers in the export subsidy case.

To capture this insight, I model the setting of trade policy as the following three-stage **trade-policy game:** In the first stage, governments (simultaneously) decide whether they want to build capacity to use import tariffs, export subsidies or both. In the second stage, governments (simultaneously) set the optimal levels of the chosen instruments. They can only use the instruments in which they invested in stage one. In the third stage, firms (simultaneously) choose output levels (as characterized in Section 2).

The objective of this section is to determine the subgame-perfect-equilibrium trade policies.

3.1 Welfare effects of unilateral trade policy

Before trying to determine equilibrium trade policies, it is helpful to build intuition by considering the welfare effects of a marginal change in trade policy. Country i's welfare W^i is the sum of five components: domestic consumer surplus (CS_i), the domestic firm's profits in the home market (π_{ii}), tariff revenue (TR_i), minus subsidy expenditure (E_i), and the domestic firm's export profits (π_{ji} for $j \neq i$)

$$W_i = \underbrace{CS_i + \pi_{ii} + TR_i}_{DS_i} \underbrace{- E_i + \sum_{\substack{j=1 \\ j\neq i}}^{n} \pi_{ji}}_{ES_i} . \tag{6}$$

The first three terms represent the domestic surplus (DS_i), i.e. the part of welfare arising in the Home market, while the last two terms represent the export surplus of Country i (ES_i).

A marginal increase in the import tariff τ_{il} and in the export subsidy σ_{li} on country i's welfare W_i (for $l \neq i$) can be decomposed into a terms-of-trade effect (ToT), a volume-of-trade effect (VoT) and a profit-shifting effect (PS):[17]

$$\frac{dW_i}{d\tau_{il}} = \underbrace{-\sum_{\substack{j=1\\j\neq i}}^{n} q_{ij}\frac{dp^*_{ij}}{d\tau_{il}}}_{ToT\geq 0} \qquad \underbrace{+\sum_{\substack{j=1\\j\neq i}}^{n} \tau_{ij}\frac{dq_{ij}}{d\tau_{il}}}_{VoT\leq 0} \qquad \underbrace{+(p_{ii}-c)\frac{dq_{ii}}{d\tau_{il}}}_{PS\geq 0}, \text{ and} \tag{7}$$

$$\frac{dW_i}{d\sigma_{li}} = \underbrace{q_{li}\frac{dp^*_{li}}{d\sigma_{li}}}_{ToT\leq 0} \qquad \underbrace{-\sigma_{li}\frac{dq_{li}}{d\sigma_{li}}}_{VoT\leq 0} \qquad \underbrace{+(p_{li}-c-\tau_{li}+\sigma_{li})\frac{dq_{li}}{d\sigma_{li}}}_{PS\geq 0}, \tag{8}$$

where p^*_{ij} is the mill price (the pre-tariff price) of country j's good sold in country i, $p^*_{ij} = p_{ij} - \tau_{ij}$. As markets are segmented, there is no unique world price as such for any given variety and the terms-of-trade effect of trade policy is the variation in the pre-tariff price that a firm receives for its exports: qdp^*. An increase in the import tariff improves country i's terms of trade, reduces its volume of trade, and, by reducing foreign firms' market access, increases domestic output ($\frac{dq_{ii}}{d\tau_{il}} \geq 0$). Through this last effect, the import tariff moves the domestic firm towards the Stackelberg leader output level and shifts profits from foreign to domestic firms. Note that this profit-shifting effect is entirely due to the oligopolistic distortion. In perfect competition, prices are equal to marginal cost and so the PS term of (7) would be zero. The PS term is also zero when there is no strategic interaction between the firms: when $\gamma = 0$, goods are independent in demand, every firm is a monopolist in its own market and $\frac{dq_{ii}}{d\tau_{il}} = 0$. When firms are monopolists, there is no profit-shifting motive for trade policy. But when oligopoly matters ($\gamma > 0$), there are two ways in which the import tariff improves domestic welfare: by improving the terms of trade and by shifting profits from foreign to domestic firms.

An increase in the export subsidy, on the other hand, deteriorates country i's terms of trade (the pre-tariff price of exports falls $\frac{dp^*_{li}}{d\sigma_{li}} \leq 0$), increases the volume of trade ($\frac{dq_{li}}{d\sigma_{li}} \geq 0$) and thus increases the subsidy expenditure, and it commits the domestic firm to a higher export volume which in turn induces the foreign firms to produce less and thus the subsidy shifts profits from foreign to domestic firms. So both in the case of the tariff and the subsidy, there is a profit-shifting motive for unilateral trade policy intervention. This motive becomes stronger as goods become more substitutable (γ increases). But in the case of the export subsidy, the profit-shifting effect goes in the opposite direction of the terms-of-trade effect whereas in the case of the import tariff, these two effects go in the same direction. Thus oligopoly introduces an *asymmetry* between the two trade instruments.

[17]This decomposition is standard in the literature, see for example Baldwin and Venables (1995). The derivation of this decomposition is given in Appendix A.

3.2 Endogenous choice of trade policy instruments

I will now characterize the Nash equilibria of the trade-policy game. The analysis is performed from the perspective of a "Home" country. In stage one of the game, Home has three trade-policy-instrument choices/strategies: invest in import tariffs, export subsidies or both. In stage two, if Home does not have the capacity to use a given trade instrument, this instrument is set to 0 on all Home's trade flows. For example, if Home did not invest in import tariffs in stage one, all Home's imports are subject to 0 tariffs in stage two. If Home has the capacity to use a given instrument, in stage two she sets this instrument to the welfare-maximizing level on all her trade flows knowing the instrument choices of other countries and taking their instrument levels as given.

In order not to prejudge the equilibrium, I assume for the moment that the cost of infrastructure that countries incur in stage one of the game is identical irrespective of their chosen strategy, i.e. countries pay the same cost whether they choose to build capacity to use import tariffs only, export subsidies only or both. This is obviously an unrealistic assumption. The point is precisely that building capacity to use both instruments is more costly than the capacity to use only one instrument. As I will show, the use of both instruments will not arise in equilibrium even in this case.

To determine the subgame-perfect-equilibrium trade policies, I proceed by backward induction. First, for a given configuration of trade-policy-instrument choices, I calculate the optimum instrument levels. In Appendix B, I show that, in a market protected by tariffs into which k countries subsidize exports, the optimal tariff on imports from subsidizing exporters is

$$\tau_\sigma(k) = \frac{(3-\gamma)\left[\Gamma(0)\Gamma(2(\Gamma(n-1)-\gamma^3(n-1)\right]}{\Omega_\tau(k)} > 0, \tag{9}$$

the optimal tariff on imports from non-subsidizing exporters is

$$\tau_0(k) = \frac{\Gamma(0)\Gamma(2)\left[6-8\gamma+3\gamma^2+\gamma(3-2\gamma)n\right]}{\Omega_\tau(k)} > 0, \tag{10}$$

and the optimal export subsidy is

$$\sigma_\tau(k) = \frac{\gamma^2(3-\gamma)(4-3\gamma)(n-1)}{\Omega_\tau(k)} \geq 0, \tag{11}$$

with $\Omega_\tau(k) \equiv \gamma^3(4-3\gamma)(n-1)k + B_\tau(n)\left[6-8\gamma+3\gamma^2+\gamma(3-2\gamma)n\right] > 0$ and $B_\tau(n) \equiv (4-3\gamma)\Gamma(n)+\Gamma(1)\Gamma(2) = 4(3-\gamma)+\gamma(4-3\gamma)(n-1) > 0$.

In a market not protected by import tariffs into which k countries subsidize exports, the optimal export subsidy is

$$\sigma_0(k) = \frac{\gamma^2\Gamma(0)(n-1)}{\Omega_\sigma(k)} \geq 0, \tag{12}$$

with $\Omega_\sigma(k) = B_\sigma(n) - \gamma^3(n-1)(n-k-1) > 0$ and $B_\sigma(n) \equiv \Gamma(n)\left[2\Gamma(n)(1-\gamma) + \gamma^2\right] + \gamma^3(n-1)^2 > 0$.[18]

Using these expressions of the optimal instruments, I evaluate Home's payoffs (maximum welfare levels that Home can achieve) from her three instrument choices for a given configuration of other countries' strategies. Appendix B shows that in each case, Home's welfare can be expressed as a function of the total number of other countries using subsidies k (both instruments and subsidies only) and the number of other countries using subsidies only r (as well as the fundamental parameters n and γ). Hence I will denote Home's maximized welfare by $W_\omega(k, r)$ from using tariffs only ($\omega = \tau$), subsidies only ($\omega = \sigma$) or both instruments ($\omega = \beta$). So for example $W_\tau(n-1, n-1)$ denotes maximized Home's welfare when all other countries use subsidies only and Home uses tariffs only. Comparing Home's payoffs from the three different strategies, I characterize Home's best response to a given configuration of other countries' strategies and determine the subgame-perfect equilibrium of the trade-policy game. I confine my attention to pure strategies.

The following two lemmas provide useful intermediate steps for the equilibrium determination. Lemma 1 considers the desirability of an export subsidy into a given export market.

Lemma 1. *When $\gamma > 0$, the optimal export subsidy into a given export market is strictly positive irrespectively of whether this market is protected by tariffs or not. The use of this optimal subsidy: (i) strictly increases the exporting country's welfare if the export market is not protected by tariffs; (ii) strictly decreases the exporting country's welfare if the export market is protected by tariffs.*

The first part of Lemma 1 is a well-known result on export subsidies in the presence of Cournot competition (see for example Brander and Spencer (1985) or Eaton and Grossman (1986)). When an export market is not protected by tariffs, an export subsidy enables the subsidized firm to expand its market share and thus increases its profits through the profit-shifting effect. Thus, when profit shifting matters ($\gamma > 0$), independently of how many other countries subsidize their exports into the given market, Home always gains from using an export subsidy when not facing an import tariff.

The second part of Lemma 1 may seem somewhat surprising at first sight. The (strictly positive) optimal export subsidy into an export market protected by tariffs leads

[18] To simplify notation, I do not make the dependence of the optimal instruments on the fundamental parameters n and γ explicit, but I will study the influence of these parameters when relevant.

to lower welfare compared to the case in which the export subsidy were not available. So why is the optimal subsidy not zero in this case? The reason is that a zero subsidy is not a best response to the importer's tariff. The exporter would prefer to impose a zero subsidy, but cannot commit to it when the export subsidy is available. This result is illustrated in Figure 1. If in stage one, the importer builds capacity to use import tariffs and the exporter builds capacity to use export subsidies, stage two instrument levels are represented by the intersection of their reaction functions at point $\mathcal{B}$. If in stage one, the exporter does not build capacity to use export subsidies, in stage two, the importer will impose a lower import tariff as indicated by point $\mathcal{T}$ (this is the importer's best response to a zero export subsidy). The exporter's export surplus at point $\mathcal{T}$ is higher than at point $\mathcal{B}$. This is because, as Bagwell and Staiger (2012b) show forcefully, when both an import tariff and export subsidy are applied to the same trade flow, the profit-shifting externality of trade policy is neutralized. So when facing an import tariff, there is no profit-shifting benefit in using an export subsidy. The use of export subsidy only creates a terms-of-trade loss, a transfer from the exporter to the importer. On the other hand, when the import market is not protected by a tariff, an export subsidy shifts profits to the subsidized firm and hence leads to a higher export surplus as illustrated by point $\mathcal{S}$.

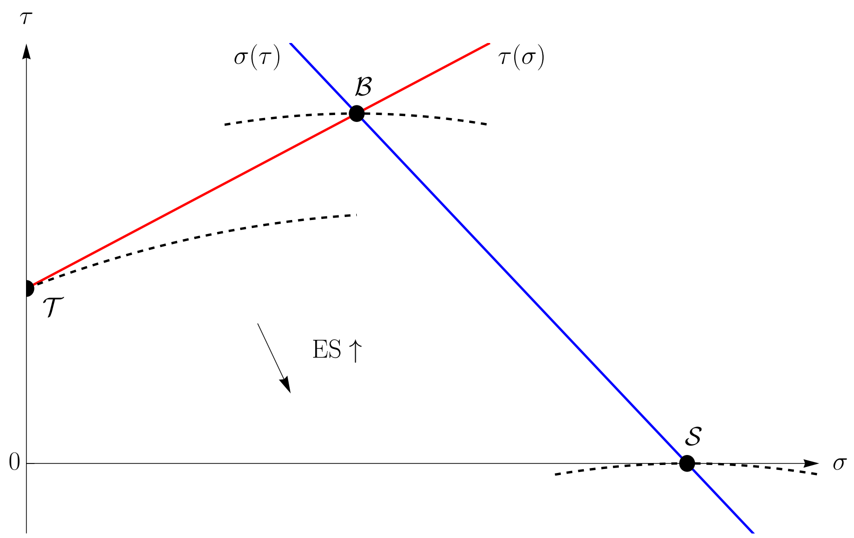


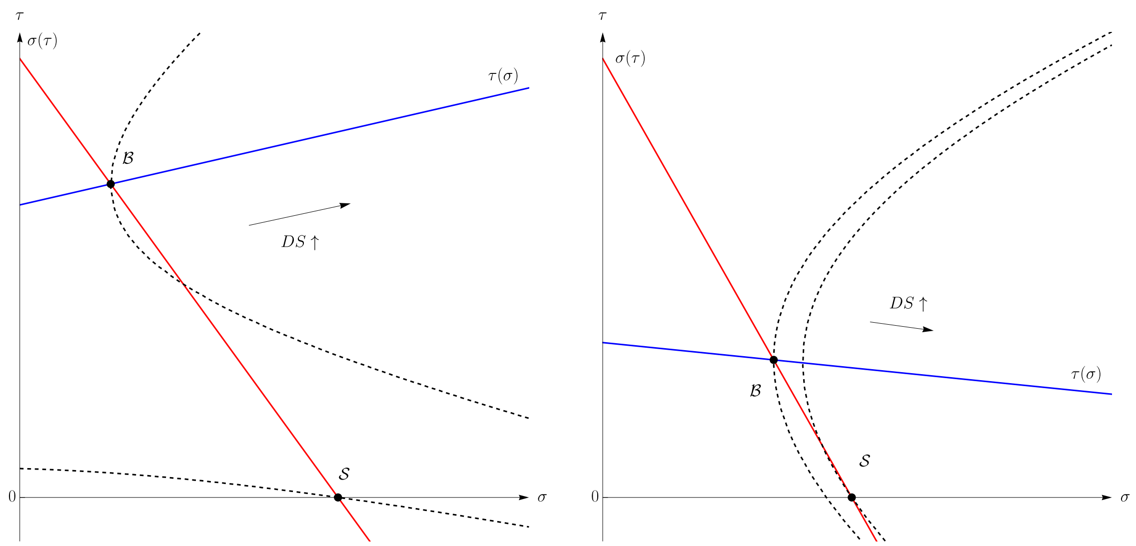
Figure 1: Trade-policy reaction functions and iso-export-surplus curves.

Note: The importer's best response tariff to the exporters' subsidies $\tau(\sigma)$ is represented in red. The exporters' best response export subsidy to the importer's tariff $\sigma(\tau)$ is represented in blue. Black dashed curves represent iso-export-surplus curves. Black arrow represents increasing levels of export surplus.

Let us now focus on the the desirability of an import tariff with respect to domestic surplus. Notice that when exporting countries do not subsidize exports, an import tariff is always desirable. This is the classic case of an optimal tariff in the presence of oligopoly. The tariff yields a ToT gain and a PS gain and when exporters do not use export subsidies there is no policy reaction to the import tariff which could affect these gains. Lemma 2 considers the desirability of an import tariff when all exporting countries subsidize their exports.

Lemma 2. *When all exporting countries subsidize their exports, the optimal import tariff is strictly positive. For $\gamma > 2-\sqrt{2}$, there exists a finite threshold number of countries in the world $n_\tau(\gamma)$ such that:*
(i) For $\gamma > 2-\sqrt{2}$ and $n \geq n_\tau(\gamma)$, the use of the optimal import tariff decreases the importer's domestic surplus.
(ii) For $\gamma \leq 2-\sqrt{2}$ or $\gamma > 2-\sqrt{2}$ and $n < n_\tau(\gamma)$, the use of the optimal import tariff increases the importer's domestic surplus.

Lemma 2 tells us that when an importer imports from subsidizing exporters, she may or may not benefit from using an import tariff. The desirability of the import tariff depends on the competitive conditions in the market. When an import tariff and an export subsidy are imposed on the same trade flow, the profit-shifting effect of trade policy is again neutralized. The import tariff thus yields two effects: a ToT gain and a VoT loss. When goods are not highly substitutable or when there are not many competitors, the ToT gain is large and the VoT loss is small and so the importer gains from imposing a tariff. This scenario is illustrated in Figure 2a. When firms behave sufficiently competitively (goods substitutable and enough competitors), the import tariff will yield a smaller ToT gain (notice that exporters will reduce their export subsidy as a response to the import tariff) and a larger VoT loss. The importer is thus better off in the absence of the import tariff. This scenario is illustrated in Figure 2b.[19]



(a) Desirable import tariff

(b) Undesirable import tariff

Figure 2: Trade-policy reaction functions and iso-domestic-surplus curves.
Note: The exporters' best response export subsidy to the importer's tariff $\sigma(\tau)$ is represented in red (assuming all exporters use symmetric subsidies). The importer's best response import tariff to the exporters' subsidy $\tau(\sigma)$ is represented in red. Black dashed curves represent iso-domestic-surplus curves. Black arrow represents increasing levels of domestic surplus.

It will be convenient to refer to the partition of the parameter space of (n, γ) identified by Lemma 2. I therefore introduce the following formal definition:

[19] A related result for the case of duopoly can be found in Dixit (1988).

Definition 1. $\mathcal{P} = \{(n,\gamma)/\gamma > 2-\sqrt{2} \text{ and } n \geq n_\tau(\gamma)\}$.

Figure 3 illustrates the parameter space $\mathcal{P}$ in which an importer receiving exports from $n-1$ subsidizing exporters would prefer not to impose an import tariff.

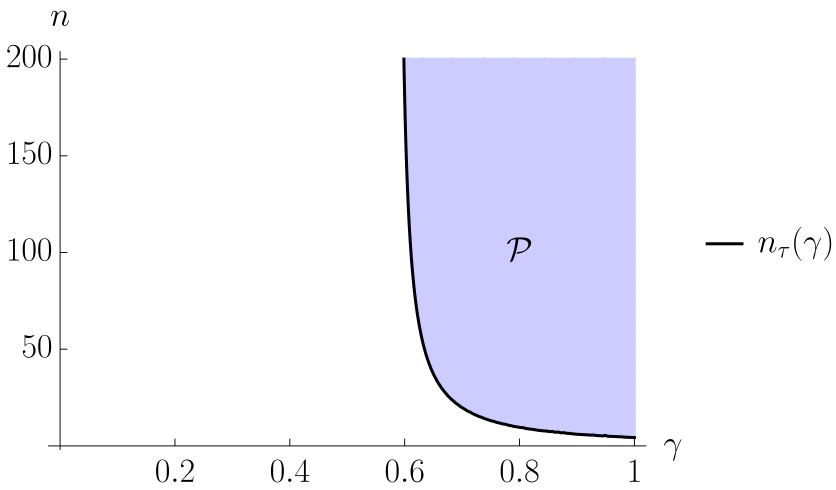


Figure 3: Parameter space $\mathcal{P}$.

Armed with lemmas 1 and 2, we are now ready to characterize the subgame-perfect Nash equilibria of the trade-policy game.

Proposition 1. *(i) When $(n,\gamma) \in \mathcal{P}$, the trade-policy game has two subgame-perfect Nash equilibria in pure strategies: one equilibrium with import tariffs only and one equilibrium with export subsidies only.*
(ii) When $(n,\gamma) \notin \mathcal{P}$, the trade-policy game has a unique subgame-perfect Nash equilibrium in pure strategies in which all countries use import tariffs only.

It is easy to prove that all countries using tariffs only is a Nash equilibrium of the trade-policy game. Indeed, when all other countries use tariffs only, Lemma 1 implies that Home would not want to use export subsidies. It would however benefit from protecting its domestic market with a tariff so it would also use only an import tariff. When all countries use subsidies only, Home gains from using export subsidies. From Lemma 2, when $(n,\gamma) \in \mathcal{P}$, Home would lose from using import tariffs and so it would also choose to use subsidies only. When $(n,\gamma) \notin \mathcal{P}$, Home would gain from using an import tariff and so using export subsidies only in not a Nash equilibrium is this case. I prove in the Appendix that there are no other pure-strategy subgame-perfect Nash equilibria of the trade-policy game. In particular, the use of both instruments is not an equilibrium outcome in this game. Notice that it is not the cost of policy infrastructure that is driving the result (the fact that it is more costly to invest in both instruments rather than one) as I have derived this result assuming that there is no extra cost associated with the additional necessary infrastructure. Such an additional cost would further strengthen this result.

Let us denote by W_τ^N the individual country payoff in the tariff-only equilibrium: $W_\tau^N = W_\tau(0,0)$; and by W_σ^N the individual country payoff in the subsidy-only equilibrium: $W_\sigma^N = W_\sigma(n-1, n-1)$. The following proposition compares the payoffs in the two equilibria which may arise when $(n,\gamma) \in \mathcal{P}$.

Proposition 2. *The export subsidy only Nash equilibrium strictly payoff-dominates the import tariff only equilibrium:* $W_\tau^N < W_\sigma^N$*.*

This result, which holds for all $n \geq 2$ and γ, is a consequence of the asymmetry between the two trade instruments. With import tariffs countries are imposing on each other ToT and PS losses while with export subsidies they are only imposing PS losses (and ToT gains). Thus a tariff war is worse than a subsidy war.

If the costs of infrastructure for the export and import instruments are identical as I assumed above, the export-subsidy-only equilibrium is Pareto superior to the import-tariff-only equilibrium and is therefore a more likely equilibrium of the trade-policy game in the sense of Harsanyi and Selten (1988).

4 Motivation for a trade agreement

In this section I first solve for internationally efficient trade policies in the presence of oligopolistic competition introduced in Section 2. I show that non-cooperative trade policies considered in Section 3 are inefficient. Finally, I characterize the cooperative equilibrium policies when the use of trade policy requires prior investment in a policy infrastructure.

4.1 Internationally efficient trade policy

Internationally efficient trade instruments maximize world welfare (the sum of all countries' welfare): $\max_{\{\tau_{jl},\sigma_{jl}\}_{j=1,l=1}^{n,\ \ n}} \sum_{i=1}^{n} W_i$, where $\tau_{ii} = 0$ and $\sigma_{ii} = 0$ for $i = 1 \dots n$, and where W_i is the welfare of country i. As in the case of unilateral trade policy above, let us characterize the effect on world welfare of a marginal change in trade policy of Country i. For $l \neq i$, we have:

$$\frac{d}{d\tau_{il}}\left(\sum_{j=1}^{n} W_j\right) = \sum_{j=1}^{n}(p_{ij}-c)\frac{dq_{ij}}{d\tau_{il}} \quad \text{and} \quad \frac{d}{d\sigma_{li}}\left(\sum_{j=1}^{n} W_j\right) = \sum_{j=1}^{n}(p_{ij}-c)\frac{dq_{ij}}{d\sigma_{li}} \tag{13}$$

Terms-of-trade and volume-of-trade effects cancel out among countries and the only remaining effect arises from the presence of oligopoly where prices are above marginal costs.

Setting the expressions in (13) equal to zero yields first-order conditions defining the internationally efficient trade policies. As shown in Appendix D, these two sets of equations are linearly dependent and determine only the difference between the internationally efficient instruments: the efficient net instrument. This is the consequence of the fact that equilibrium quantities depend only on the net instrument. There is thus an infinity of efficient import tariffs and export subsidies such that the difference between them satisfies the first-order conditions. The internationally efficient net instrument is

$$\tau^* - \sigma^* = -\frac{\Gamma(0)^2}{B(n)} \tag{14}$$

where $B(n) \equiv 2\Gamma(0)\Gamma(n) - \gamma^2(n-1) - 4 = 4(1-\gamma) + \gamma(4-3\gamma)(n-1) > 0$. The efficient net instrument is a subsidy. In the presence of oligopolistic markets, firms produce suboptimal quantities and it is therefore efficient to subsidize them.

4.2 Cooperative equilibrium policies

A simple inspection of the first-order conditions for unilateral Nash trade policy (expressions (7) and (8) set equal to zero) and for internationally efficient trade policy (expressions (13) set equal to zero) reveals that the unilateral Nash trade policy is not internationally efficient. The inefficiency of Nash equilibrium policies stems from the presence of two international externalities: a terms-of-trade and a profit-shifting externality. Indeed, when countries choose their unilateral trade policies non-cooperatively, they pursue beggar-thy-neighbor policies trying to improve their terms of trade and/or shift profits to their firms at the expense of other countries. This leads to a Prisoner's Dilemma situation which provides a motivation for a trade agreement: countries need a trade agreement to help them reach the international efficiency.[20]

The question I want to answer is what form should this trade agreement take? To answer this question, let us now consider a cooperative equivalent of the trade-policy game introduced in Section 3. The game consists again of three stages: In the first stage, governments simultaneously decide whether they want to build capacity to use import instruments, export instruments or both. In the second stage, governments set the chosen instruments to levels which maximize world welfare (given by (14)). In the third stage, firms choose outputs as in Section 2.

As I have shown above, any combination of the export and import instruments yielding the efficient net instrument leads to international efficiency.[21] Therefore, countries can

[20] As shown by Bagwell and Staiger (2012b), when countries have both import and export instruments at their disposal, the inefficiency of Nash equilibrium policies is due only to the terms-of-trade externality. The profit-shifting externality is neutralized by the interaction of the two trade instruments. On the other hand, when the set of instruments is restricted, for example to tariffs only, both externalities contribute to the inefficiency of Nash equilibrium policy as I show in Section 7.

[21] As long as the difference between the trade instruments is the efficient net instrument, world welfare

reach international efficiency with any type of trade policy infrastructure chosen in Stage 1 of the game provided that they set the instrument levels in Stage 2 as (14). If it is more costly to build infrastructure to use both instruments than a single instrument, countries should choose to invest only in a single instrument.[22]

There remains however an indeterminacy: if the costs of policy infrastructure for the export and import instruments are the same, both instruments yield exactly the same outcome in terms of welfare.[23] The question I explore in Sections 5 and 6 is whether there is a difference between using the export or the import instrument. And if yes, which instrument is better? I show that because the presence of oligopoly introduces an asymmetry between the two trade instruments, the incentives to deviate from the agreement will not be the same depending on which instrument countries use. So there will be differences in terms of self-enforceability of the two agreements.[24] I explore these differences in the next two sections,.

5 Self-enforcement with irreversible investment

The objective is to compare the potential for self-enforcement of two types of trade agreements: a *tariff-only* agreement, where countries agree to invest in the import instrument (which they set at the efficient level) and not to invest in the export instrument, and a *subsidy-only* agreement, where they agree to invest in the export instrument (which they set at the efficient level) and not to invest in the import instrument. To evaluate the potential for self-enforcement of these agreements, I consider the following repeated

is maximized, and the only difference between the equilibria corresponding to different absolute levels of the two trade instruments is the level of transfers created between countries. In the case of symmetric countries considered in this paper, countries export as much as they import and thus they are indifferent between the efficient outcomes resulting from different combinations of the trade instruments. In a world with asymmetric countries, additional lump-sum transfers between countries would be needed to ensure the equivalence of the different efficient outcomes.

[22]Notice that in this cooperative scenario the result that countries should use a single instrument hinges in the assumption of extra cost associated with the use of two instruments. This was not the case for the non-cooperative scenario where the use of a single instrument emerged as an equilibrium outcome even if there was no extra cost associated with the second instrument. I believe that the assumption of two instruments being more costly to use than one is plausible. Let me however add that there may be other reasons (outside of the model) for using a single instrument for cooperation. For example, it may be more difficult to contract on two instruments at the same time. Negotiating on the two instruments takes more time than on one only. The levels of the two instruments may be hard to verify etc. It is thus easier to set a focal point of zero for one of the two instruments and negotiate only the level of the other one.

[23]This reasoning obviously hinges on the assumption that at the beginning of the game, countries have no policy infrastructure. If the agreement was signed in a world where countries already had some policy infrastructure, the type of the agreement (choice of instruments) may be determined by the existing infrastructure. I abstract from these considerations here and simply assume that there are reasons why countries should choose to cooperate on a single instrument. See also Footnote 22.

[24]Note that in perfect competition, there would not be a difference between the two instruments: there would not be any profit-shifting rationale for trade policy and as we can see from (7) and (8), the two instruments would be symmetric.

game. In the initial period, countries sign a single-instrument agreement (tariff-only or subsidy-only). They invest in the infrastructure of the agreed instrument and set this instrument to the efficient level. Then they play an infinitely repeated game where in each period, they have the choice between continuing to cooperate or deviating to get a one-period gain followed by punishment. The punishment considered here is a permanent Nash-reversion: if a country deviates from the agreement, the multilateral agreement breaks down and countries revert to setting their trade policies unilaterally.[25] Cooperation will be sustained if the net present value of cooperation is greater than the net present value of deviation followed by punishment. The question is whether there is any difference between the self-enforcement of the two types of agreements. As highlighted in Section 3, the presence of oligopoly introduces an asymmetry between the two trade instruments. This asymmetry together with the fact that countries need to invest in the policy infrastructure before being able to use any instrument will have interesting implications for self-enforceability of the two types of agreement.

To fix ideas, I focus in this section on a simple benchmark case where the initial investment into the policy infrastructure is irreversible. In other words, the policy infrastructure chosen at the time when countries sign the agreement stays in place even when the agreement breaks down. In such a case, countries turn to setting policy non-cooperatively to maximize their individual welfare, but they can only use the same instrument as they chose in the agreement. This is obviously a stark assumption, but this benchmark case is interesting for two reasons. First, it helps to build intuition before considering the more complicated case of reversible investment in Section 6. And second, the benchmark case will also be relevant in the case of reversible investment where countries have the possibility to adjust their set of trade instruments on the off-equilibrium path.

5.1 On- and off-equilibrium payoffs

In the case of the tariff-only agreement, all countries invest in the import instrument infrastructure and set the import instruments at the internationally efficient level $\tau_E = -\frac{\Gamma(0)^2}{B(n)}$ which yields the efficient welfare level W^C. If there is deviation, the deviator gets a one period gain W_τ^D from deviating with the import tariff and imposing τ_D while

[25] Nash reversion punishment seems to be a plausible benchmark punishment for the case of trade agreements. The threat of the break-down of the GATT has for example been used in the dispute over the illegal imposition of U.S. dairy quotas in 1951. According to Hudec (1975, p. 167), "the Contracting Parties had brought out their biggest guns against the dominant partner. They had threatened everything that could be threatened, including the collapse of the Agreement itself." Maggi (1999) points out that "GATT commentators often argue that countries are deterred from violating trade agreements not just by the prospect of bilateral retaliation, but by the fear that the whole trading system may unravel as a consequence, or in other words, by the fear of a multilateral breakdown of cooperation." To support his claim, Maggi (1999) quotes John Croome, referring to a speech by the ex-Director-General of GATT, Arthur Dunkel: "Dunkel. . . concluded that governments are being restrained from a substantial slippage towards protectionism only by 'a kind of balance of terror': a fear that if they resorted to trade restrictions these would evoke retaliation, as well as undermining the trading system as a whole."

other countries cooperate with the import instrument and continue to impose τ_E. Then from the next period onwards, countries revert to Nash tariffs $\tau_N = \tau_0(0)$ which yields welfare level $W_\tau^N = W_\tau(0,0)$. In the case of the subsidy-only agreement, countries invest in the export instrument infrastructure and set internationally efficient export subsidies $\sigma_E = \frac{\Gamma(0)^2}{B(n)}$ which yields the efficient welfare level W^C. If there is deviation, the deviator gets a one period gain W_σ^D from deviating with the export subsidy and imposing σ_D while other countries cooperate with the export instrument and continue to impose σ_E. Then from the next period onwards, countries revert to Nash subsidies $\sigma_N = \sigma_0(n-1)$ which yields welfare level $W_\sigma^N = W_\sigma(n-1, n-1)$.

Whether the two agreements are self-enforcing depends on the on- and off-equilibrium-path payoffs which are summarized in Table 1.

	Tariff-only agreement		Subsidy-only agreement
Cooperation (C)	W^C	$=$	W^C
Deviation (D)	W_τ^D	$\gtreqless$	W_σ^D
Punishment (N)	W_τ^N	$<$	W_σ^N

Table 1: On- and off-equilibrium payoffs for the tariff-only and subsidy-only agreements.

To determine which agreement is more self-enforcing, the first step is to compare the welfare levels under the two agreements in each row of Table 1 to see under which agreement it is more tempting to deviate. The on-equilibrium-path payoff is the cooperation welfare: the internationally efficient welfare level. By construction, both agreements yield the same cooperation payoff: W^C. From Proposition 2, we already know that Nash reversion with tariffs always yields a lower welfare than Nash reversion with subsidies: $W_\tau^N < W_\sigma^N$. The next lemma compares the deviation welfare levels (second row of Table 1).

Lemma 3. *For any $\gamma \in (0,1)$, there exists a finite threshold number of countries in the world $n_D(\gamma)$ above which deviation from a tariff-only agreement yields a lower welfare than deviation from a subsidy-only agreement: $W_\tau^D < W_\sigma^D$.*

When goods are partial substitutes ($\gamma \in (0,1)$), variety matters to consumers. For small values of n, the gain from deviating with the import tariff is higher than the gain from deviating with the export subsidy, because the tariff yields both a terms-of-trade gain and a profit-shifting gain. But as n increases, a higher tariff hurts consumers while the deviation with the export subsidy has no downside for domestic consumers. Thus, for n sufficiently large, the gain from deviating with the export subsidy is greater than the gain from deviating with the import tariff. The threshold $n_D(\gamma)$ is illustrated by a dotted contour line in Figure 4.

Note that when goods are independent ($\gamma = 0$) or perfect substitutes ($\gamma = 1$), the one-instrument deviation from a tariff-only agreement yields higher welfare than the one-instrument deviation from a subsidy-only agreement: $W_\tau^D \geq W_\sigma^D$. This is because when goods are independent ($\gamma = 0$), there is no strategic interaction between firms, each firm is a monopolist in its own market and there is no profit-shifting reason for trade policy (each firm already extracts rents to the full extent). Both deviation with the import tariff and the export subsidy yield a terms-of-trade gain, but the gain from the import tariff is larger, because the import tariff is used to extract rents from foreign firms whereas there is no point in extracting rents from export profits of domestic firms (as monopolists, they already extract rents from foreign consumers fully). On the other hand, when goods are perfect substitutes ($\gamma = 1$), it is not possible to deviate very much with the export subsidy, because too large a deviation would result in zero export sales whereas it is possible to deviate with the import tariff. This yields high gains (variety is unimportant to consumers).

5.2 Critical discount factors

Having compared the payoffs under the two agreements, we are now ready to address the question which of the two agreements (tariff-only or subsidy-only agreement) is more self-enforcing. As the punishment in the tariff-only case is always harsher than in the subsidy-only case, it is obvious that, whenever deviation from the tariff-only agreement also yields a lower gain than deviation from the subsidy-only agreement, it will be less tempting to deviate from the tariff-only agreement than from the subsidy-only agreement and so the tariff-only agreement will be more self-enforcing. Lemma 2 thus provides a sufficient condition for when the tariff-only agreement is more self-enforcing.

The goal is now to determine a necessary and sufficient condition under which the tariff-only agreement is more self-enforcing. Given that in some cases, the deviation from the tariff-only agreement yields a higher gain, this makes it more tempting to deviate from the tariff-only agreement. On the other hand, the harsher punishment makes it less tempting to deviate from the tariff-only agreement. Thus, we cannot simply conclude by comparing individual payoffs of the deviation and punishment periods. We need to compare the net present values of the deviation followed by punishment for the two agreements.

For an agreement to be self-enforcing, the discounted welfare from cooperation, $\frac{W^C}{1-\delta}$, where δ is the discount factor, must be no less than the discounted welfare achieved by deviating and thereafter reverting to the punishment phase, $W^D + \frac{\delta W^N}{1-\delta}$. Comparison of these discounted welfare values defines a critical threshold discount factor above which cooperation is sustained. To determine which agreement is more self-enforcing, I will calculate this critical threshold discount factor for both the tariff-only and subsidy-only agreements (δ_τ and δ_σ respectively) and compare them. The agreement with lower critical threshold discount factor is more self-enforcing in that it is self-enforcing for a wider range of discount factors. The critical threshold discount factors for the two agreements are defined by

$$\delta_\tau = \frac{W_\tau^D - W^C}{W_\tau^D - W_\tau^N} \text{ and } \delta_\sigma = \frac{W_\sigma^D - W^C}{W_\sigma^D - W_\sigma^N} \tag{15}$$

Evaluating the welfare function at the appropriate instrument levels (derived in Appendices B and D) yields after simplification

$$\delta_\tau = \frac{B_\tau(n)}{2\left[B_\tau(n) - 4\right]} \text{ and } \delta_\sigma = \frac{\Phi(n)^2}{\Theta(n) + \Phi(n)^2} \tag{16}$$

where $\Upsilon(n) \equiv 2\Gamma(n-1)\left[(1-\gamma)\Gamma(n) + \gamma\right] \geq 0$, $\Phi(n) \equiv \Upsilon(n) + (n-2)\gamma^2\left[\Gamma(n) - 2\right] \geq 0$ and $\Theta(n) \equiv B(n)\Upsilon(n) \geq 0$.

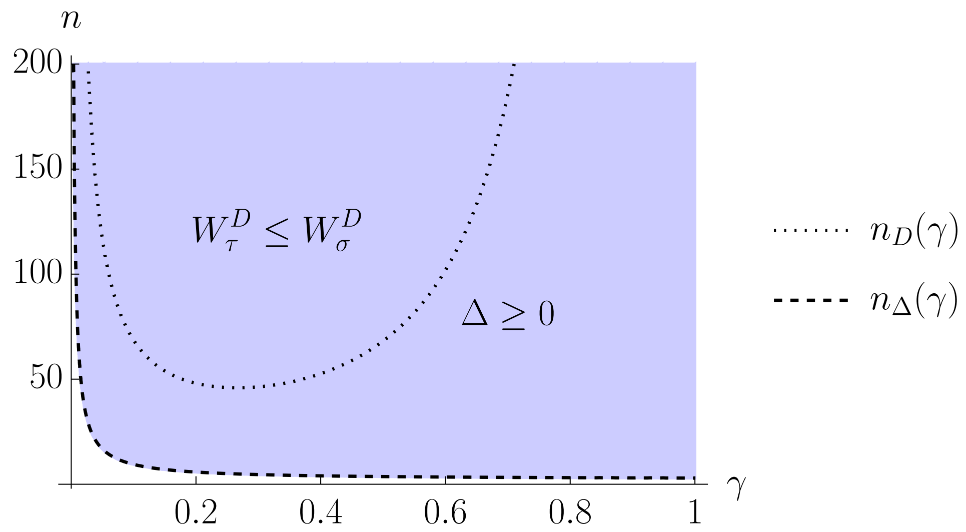


Figure 4: Range of parameters where $\Delta = \delta_\sigma - \delta_\tau > 0$ with irreversible investment.

The following proposition characterizes the difference between the two threshold discount factors, $\Delta \equiv \delta_\sigma - \delta_\tau$, and gives conditions under which $\Delta > 0$, i.e. when the tariff-only agreement is more self-enforcing.

Proposition 3.

1. *For $\gamma > 0$, δ_σ is an increasing function of n with $\lim_{n\to\infty} \delta_\sigma = 1$, δ_τ is a decreasing function of n with $\lim_{n\to\infty} \delta_\tau = \frac{1}{2}$, and so $\Delta \equiv \delta_\sigma - \delta_\tau$ is an increasing function of n with $\lim_{n\to\infty} \Delta = \frac{1}{2}$.*
2. *For any $\gamma > 0$, there exists a finite threshold number of countries in the world $n_\Delta(\gamma)$ above which $\Delta > 0$, i.e. the tariff-only agreement is more self-enforcing. For*

$\gamma = 1$*, the tariff-only agreement is more self-enforcing for a world with three or more countries.*

In the light of Lemma 3 and Proposition 2, the intuition for these results is simple: the deviation gain from the tariff-only agreement may or may not be higher than the deviation gain from the subsidy-only agreement, but the punishment is always harsher in the tariff-only case. When $\gamma > 0$, as the number of countries in the world n increases, the deviation from the tariff-only agreement becomes relatively less appealing (imports become more important and so an increase in the import tariff hurts more domestic consumers) while the punishment becomes relatively harsher (exports become more important and so facing higher tariffs on exports in the punishment phase hurts more domestic firms). On the other hand, a deviation with the export subsidy becomes more appealing while the punishment less threatening. So for any $\gamma > 0$, there is a threshold number of countries in the world $n_{\Delta}(\gamma)$ above which the asymmetry between the two instruments makes the punishment in the tariff-only case so strong that it deters deviation and the tariff-only agreement is more self-enforcing. The closed form solution of $n_{\Delta}(\gamma)$ is slightly unwieldy (since it requires solving a fourth-degree polynomial equation), but it is illustrated in Figure 4 with the area for which $\Delta \geq 0$ shaded in blue. We can see that the tariff-only agreement is more self-enforcing for a wide range of parameters. For example, when goods are perfect substitutes ($\gamma = 1$), $n_{\Delta}(1) \approx 2.92$ and the tariff-only agreement is more self-enforcing for any $n \geq 3$.[26]

This shows that, in the presence of oligopoly, when the choice of policy infrastructure at the time of the agreement is irreversible, the tariff-only trade agreement is more self-enforcing for a wide range of parameters.

6 Self-enforcement with reversible investment

In this Section, I relax the assumption of irreversible investment in the policy infrastructure. As in the previous section, in the initial period, countries agree on the instrument on which they will cooperate (import or export instrument), they invest in the infrastructure of this instrument and set the level of this instrument to the efficient level. In every subsequent period, they have again the choice between continuing to cooperate or deviating. But this time if deviation occurs, I assume that countries unilaterally optimize the set of instruments they use and the instrument levels. In other words, if the agreement breaks down, each country may alter the policy infrastructure and the choice of

[26]For $\gamma = 0$, $\delta_\tau = \frac{3}{4}$, $\delta_\sigma = \frac{2}{3}$ and $\Delta = -\frac{1}{12}$. We are in the monopoly case and there is no profit-shifting rationale for trade policy. The deviation gain from the tariff-only agreement is so much larger than from the subsidy-only agreement and the punishment not harsh enough in the tariff-only case to deter deviation and thus the subsidy-only agreement is more self-enforcing when oligopoly does not matter. For γ close to zero, firms are almost monopolists and their interaction is limited and so the tariff-only agreement is more self-enforcing only for higher values of n as shown in Figure 4.

policy instruments to individually maximize their welfare as in the policy-game described in Section 3.

Any change in the policy infrastructure (investment in a new instrument or disinvestment from an instrument) takes one period and is observable. Hence if a country decides to deviate from the agreement, it cannot suddenly start using both instruments and take the other countries by surprise. As a consequence, a deviating country deviates with the "legal" instrument and gets the same deviation gain as in Section 5 with the difference that it may now simultaneously invest and change its policy infrastructure in order to use its preferred set of instruments from the next period onwards. In order to assess the self-enforceability of the agreements, we need to determine the optimal behavior along the off-equilibrium path. We know from Section 3, that the outcome of the policy game depends on the parameters of the model. We need therefore to distinguish between two cases depending on whether $(n, \gamma) \in \mathcal{P}$ or $(n, \gamma) \notin \mathcal{P}$.

6.1 Trade-policy game has two equilibria: $(n, \gamma) \in \mathcal{P}$

Consider first the off-equilibrium path from the subsidy-only agreement. If a country decides to deviate, she gets the gain W_σ^D. At the same time, she may decide to invest to adapt the policy instrument infrastructure for the next period. However, other countries who are taken by surprise do not have the time to make this investment and so the deviator knows that in the period immediately following deviation (period two), she will be facing countries acting non-cooperatively with subsidies only. From lemmas 1 and 2, we know that, when $(n, \gamma) \in \mathcal{P}$, the deviator will get the highest welfare from continuing using export subsidies when faced with other countries using subsidies. Hence, even if the change in the policy infrastructure is costless, the deviator will not change her instrument set for period two and will get a payoff W_σ^N. From period three onwards, the game becomes the symmetric policy game from Section 3 (symmetric meaning the deviator no longer has any first-mover advantage) with the difference that all countries have the export instrument infrastructure in place and the cost of this infrastructure is sunk. From Section 3, we know that the subsidy-only equilibrium Pareto-dominates the tariff-only equilibrium. Countries therefore have no incentive to invest to change their policy infrastructure. The initial investment in the export instrument creates a path-dependence which then selects the non-cooperative subsidy-only equilibrium in case the agreement breaks down.

The present value of the deviator's payoffs on the off-equilibrium path from the subsidy-only agreement is thus the same as in the case of irreversible investment considered in Section 5:

$$PV_\sigma = W_\sigma^D + \delta W_\sigma^N + \frac{\delta^2}{1-\delta} W_\sigma^N \tag{17}$$

Consider now the off-equilibrium path from the tariff-only agreement. If a country decides to deviate, she gets the gain W_τ^D. At the same time, she may also decide to adapt the policy instrument infrastructure for the next period, but with similar reasoning as above, using lemmas 1 and 2, we know that the deviator will get the highest possible welfare from using tariffs only in period two when she knows that she will be facing countries with tariffs only: W_τ^N. From period three onwards, we are again back in the policy game from Section 3 with the difference that the tariff infrastructure is in place and the cost of this infrastructure is sunk. From Section 3, we know that there are two Nash equilibria of the policy game (tariffs only or subsidies only), the question is which equilibrium is more likely to arise when cooperation has broken down. One could argue that the tariff-only equilibrium is more likely in this case as the instrument infrastructure is already in place, the cost of this infrastructure is sunk, so this equilibrium arises more naturally and it is unlikely that countries would coordinate themselves after the breakdown of an agreement to collectively change their policy instrument infrastructure and switch to the Pareto-superior subsidy-only equilibrium. If this is the case, the present value of the deviator's payoffs on the off-equilibrium path from the tariff-only agreement is thus the same as in the case of irreversible disinvestment considered in Section 5:

$$PV_\tau = W_\tau^D + \delta W_\tau^N + \frac{\delta^2}{1-\delta} W_\tau^N \tag{18}$$

Period	Case (a)			Case (b)		
	τ-only		σ-only	τ-only		σ-only
1	W_τ^D	$\gtreqless$	W_σ^D	W_τ^D	$\gtreqless$	W_σ^D
2	W_τ^N	$<$	W_σ^N	$W_\tau^N - C_{\sigma,-\tau}$	$\ll$	W_σ^N
3+	W_τ^N	$<$	W_σ^N	W_σ^N	$=$	W_σ^N

Table 2: Off-equilibrium payoffs when $(n, \gamma) \in \mathcal{P}$.

Note: Case (a) assumes that deviation from tariff-only agreement leads to tariff-only Nash equilibrium. Case (b) assumes that after deviation from tariff-only agreement, countries collectively switch to the Pareto-superior subsidy-only Nash equilibrium from period 3 onwards.

The per-period off-equilibrium payoffs from this scenario are summarized and compared under Case (a) of Table 2. We know from Section 5 that when the present values of the off-equilibrium path payoffs are given by (17) and (18) for the subsidy agreement and tariff agreement respectively, the critical threshold discount factors above which the agreements are sustained are such that $\Delta = \delta_\sigma - \delta_\tau \geq 0$ for all $(n, \gamma) \in \mathcal{P}$. In other words, the tariff-only agreement is more self-enforcing for the entire parameter range under consideration $\mathcal{P}$ as illustrated in blue in Figure 5a.

One could also argue that because the subsidy-only equilibrium is Pareto-dominant, in the case of a deviation from the tariff-only agreement, countries may at some point switch to this equilibrium even in the absence of a formal agreement. For the sake of the argument, suppose that countries collectively switch to this equilibrium immediately from period three onwards, i.e. all countries invest in period two to change their infrastructure from the import instrument to the export instrument. They pay a cost C_σ to build the export instrument infrastructure and a disinvestment cost $C_{-\tau}$ to remove the import instrument infrastructure. To make the notation more compact, I will write that they pay a switching cost $C_{\sigma,-\tau} = C_\sigma + C_{-\tau}$. This off-equilibrium path would lead to the least severe punishment possible. From period three onwards, the punishment would be identical for the two agreements. However, in period two, the punishment in the tariff only case would be more severe and increasingly so if the switching cost $C_{\sigma,-\tau}$ increases. The per-period off-equilibrium payoffs from this scenario are summarized and compared under Case (b) of Table 2. The present value of the deviator's payoffs on the off-equilibrium path from the tariff-only agreement would be in such a case:

$$\tilde{PV}_\tau = W_\tau^D + \delta(W_\tau^N - C_{\sigma,-\tau}) + \frac{\delta^2}{1-\delta} W_\sigma^N \tag{19}$$

When the present value of payoffs from the off-equilibrium path from the tariff-only agreement is given by (19), we can also solve for the critical threshold discount factor $\tilde{\delta}_\tau$ above which cooperation is sustained. $\tilde{\delta}_\tau$ is the solution to the second degree equation:

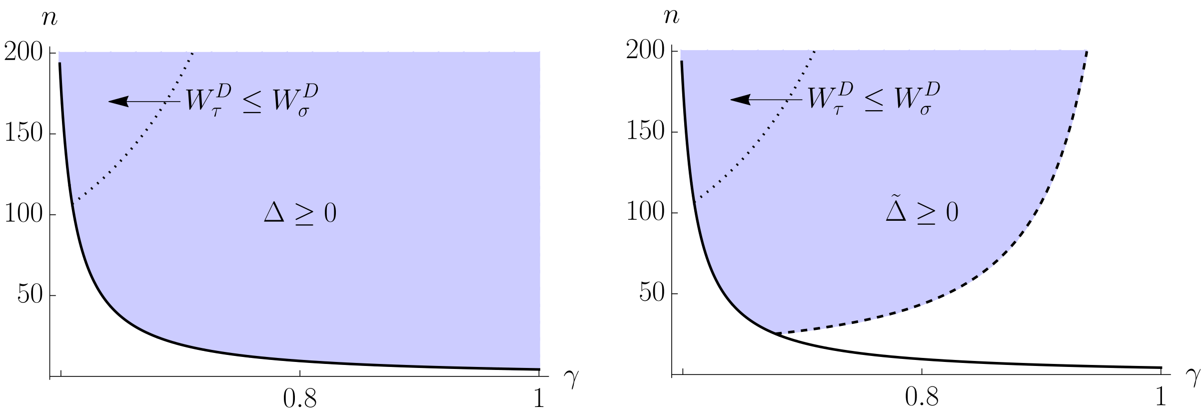
$$\frac{W^C}{1-\delta} = W_\tau^D + \delta(W_\tau^N - C_{\sigma,-\tau}) + \frac{\delta^2}{1-\delta} W_\sigma^N \tag{20}$$

The expression of $\tilde{\delta}_\tau$ is somewhat unwieldy, but note that it is decreasing with the infrastructure switching cost $C_{\sigma,-\tau}$. Figure 5b illustrates in blue the range of parameters for which $\tilde{\Delta} = \delta_\sigma - \tilde{\delta}_\tau \geq 0$. Notice that the range depicted in Figure 5b assumes that countries switch to the non-cooperative subsidy-only agreement immediately from period three onwards and that $C_{\sigma,-\tau} = 0$. It thus provides a *lower bound* on the range of parameters for which the tariff-only agreement is more self-enforcing. The range of parameters for which $\tilde{\Delta} \geq 0$ expands as $C_{\sigma,-\tau}$ increases or if the switch to the non-cooperative subsidy-only equilibrium happens in later periods.

Hence when $(n, \gamma) \in \mathcal{P}$, goods are sufficiently substitutable and strategic interaction between firms matters, the tariff-only agreement seems more self-enforcing than the subsidy-only agreement for a wide range of parameters. This result is stronger the higher are the switching costs of policy infrastructure.

6.2 Trade-policy game has a unique equilibrium: $(n, \gamma) \notin \mathcal{P}$

When $(n, \gamma) \notin \mathcal{P}$, the trade-policy game of Section 3 has a unique Nash equilibrium in which all countries use import tariffs. Let us assume that the investment cost incurred



(a) $\Delta = \delta_\sigma - \delta_\tau \geq 0$

(b) $\tilde{\Delta} = \delta_\sigma - \tilde{\delta}_\tau \geq 0$ with $C_{\sigma,-\tau} = 0$

Figure 5: Range of parameters where tariff-only agreement is more self-enforcing under two different assumptions about the off-equilibrium path: (a) deviation from tariff-only agreement leads to tariff-only equilibrium; (b) deviation from tariff-only agreement costlessly leads to subsidy-only equilibrium.

Note: The solid black line represents the frontier $n_\tau(\gamma)$ delimiting the parameter range $\mathcal{P}$ under consideration.

from changing the policy infrastructure is not too high such that it does not affect the existence and unicity of this Nash equilibrium.[27]

Let us consider the off-equilibrium path from the tariff-only agreement. If a country decides to deviate, in period one the deviator gets the gain W_τ^D. She knows that in period two, she will be facing other countries imposing non-cooperative tariffs only and so from Lemma 1, we know that the deviator will use only an import tariff in period two. Hence from period two onwards, we are in the unique Nash equilibrium of the trade-policy game and the deviator will be getting the payoff W_τ^N. The present value of the deviator's payoffs on the off-equilibrium path from the tariff-only agreement is therefore given by equation (18).

In the case of a deviation from the subsidy-only agreement, in period one the deviator gets the gain W_σ^D. She knows that in period two, she will be facing other countries imposing non-cooperative subsidies only and from Lemma 2, we know that, when $(n, \gamma) \notin \mathcal{P}$, the deviator can improve her welfare by using an import tariff. And so if the cost of investment in the tariff infrastructure C_τ is not too high, the deviator will choose to invest in this infrastructure in period one so that she can use import tariffs in period two. In period two, all countries will invest in the import tariff infrastructure such that from from period three all countries use import tariffs. Given that all countries use import tariffs from period three, no country will want to use export subsidies from period three onwards and so all countries disinvest from the export instrument infrastructure in period two. The per-period off-equilibrium-path payoffs of the deviator are summarized and compared in Table 3.

[27] If the cost of adapting the policy infrastructure is sufficiently high, we are back in the case of Section 5.

Period	Tariff-only agreement		Subsidy-only agreement
1	W_τ^D	$\gtreqless$	$W_\sigma^D - C_\tau$
2	W_τ^N	$<$	$W_\beta(n-1,n-1) - C_{-\sigma}$
3+	W_τ^N	$=$	W_τ^N

Table 3: Off-equilibrium payoffs when $(n,\gamma) \notin \mathcal{P}$.

The present value of the deviator's payoffs on the off-equilibrium path from the subsidy-only agreement is:

$$\tilde{PV}_\sigma = W_\sigma^D - C_\tau + \delta\left(W_\beta(n-1,n-1) - C_{-\sigma}\right) + \frac{\delta^2}{1-\delta} W_\tau^N \tag{21}$$

We can again solve for the critical threshold discount factor $\tilde{\delta}_\sigma$ above which cooperation is sustained. $\tilde{\delta}_\sigma$ is the solution to the second degree equation:

$$\frac{W^C}{1-\delta} = W_\sigma^D - C_\tau + \delta\left(W_\beta(n-1,n-1) - C_{-\sigma}\right) + \frac{\delta^2}{1-\delta} W_\tau^N \tag{22}$$

Notice that $\tilde{\delta}_\sigma$ is decreasing with the infrastructure costs $C_{-\sigma}$ and C_τ. Figure 6 illustrates the range of parameters for which the $\hat{\Delta} = \tilde{\delta}_\sigma - \delta_\tau \geq 0$ assuming $C_{-\sigma} = C_\tau = 0$. When the costs $C_{-\sigma}$ and/or C_τ increase, this range shrinks until the costs become sufficiently large to affect the Nash equilibria of the trade-policy game.

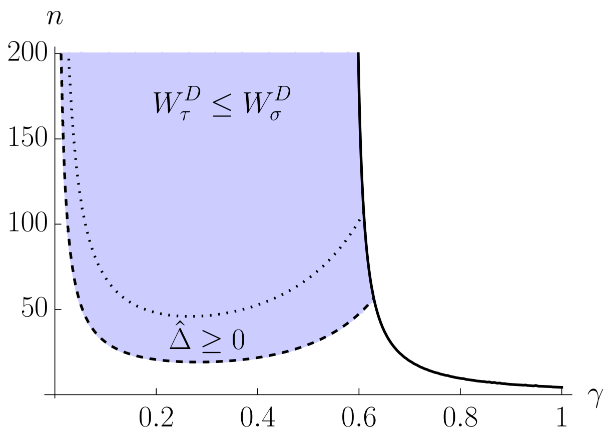


Figure 6: Range of parameters where $\hat{\Delta} = \tilde{\delta}_\sigma - \delta_\tau > 0$ with $C_{-\sigma} = C_\tau = 0$.

Hence when $(n,\gamma) \notin \mathcal{P}$, the tariff-only agreement is still more self-enforcing than the subsidy-only for a wide range of parameters, but only for a world with sufficiently many countries. So self-enforceability becomes a weaker argument for the cooperation on import tariffs as opposed to cooperation on export subsidies when goods are not very substitutable.

7 Trade agreements with import tariffs only

In this section, I want to examine how a single-instrument agreement can help countries reach the efficiency in the presence of oligopoly. I have shown that in the presence of oligopolistic industries, unilateral trade policy gives rise to two international externalities. Do both these externalities cause the international inefficiency? And if yes, are the GATT/WTO rules of reciprocity and non-discrimination sufficient to neutralize these externalities?

Bagwell and Staiger (2012b) answer these questions assuming that countries have at their disposal the full set of trade instruments: they show that it is only the terms-of-trade externality that leads to the inefficiency of unilateral trade policy, as countries are able to internalize (from the world's perspective) the profit-shifting externality through the import and export instruments. So when markets are oligopolistic and countries have both trade instruments available, the only potential role for a trade agreement is to neutralize the terms-of-trade externality as is the case in perfectly competitive markets (see Bagwell and Staiger (1999, 2002) for a discussion of rationales for trade agreements under perfect competition).

I will now revisit these questions when the set of trade instruments is restricted to import tariffs only in the context of the oligopolistic model of this paper.[28]

7.1 Potential role for trade agreements

To determine whether there is any other potential role for a trade agreement beyond neutralizing the inefficiency-inducing terms-of-trade externality, I follow the approach adopted by Bagwell and Staiger (1999) for competitive markets and Bagwell and Staiger (2012b) for oligopolistic markets with the full set of trade instruments. I consider the following hypothetical experiment: if countries did not value the terms-of-trade effects of their trade policy, would they set efficient import tariffs?

Lemma 4. *Nash equilibrium tariffs in the absence of terms-of-trade effects are inefficient:*

$$\tilde{\tau}_N = \frac{\gamma\Gamma(0)}{2\Gamma(0)\Gamma(n) - \gamma^2(n-1)} \geq 0 \textit{ while } \tau_E = -\frac{\Gamma(0)^2}{B(n)} < 0.$$

So when only import tariffs are available, even if governments did not want to manipulate their terms of trade, they would impose inefficiently high tariffs because they would use them to shift profits from foreign to domestic firms.[29] Hence, when the set of trade instruments is restricted, efficiency cannot be reached by neutralizing terms of trade

[28] I focus here on the tariff-only case as opposed to the subsidy-only case because a ban on export subsidies is a feature of the GATT/WTO and because, as I have shown in the previous sections, banning export subsidies leads to a more self-enforcing agreement for a wide range of parameters.

[29] Note that when $\gamma = 0$, $\tilde{\tau}_N = 0$: firms are monopolists and there is no room for profit-shifting.

only. In order to reach efficiency, a trade agreement needs to neutralize both the terms-of-trade and the profit-shifting externalities. The question is how can a trade agreement neutralize both externalities?

For ease of exposition, assume first that there are only two countries: i and j. (I will relax this assumption later.) Country i imposes an import tariff τ_{ij} on country j and country j imposes an import tariff τ_{ji} on country i. Recall that the internationally-efficient import tariff of country i must satisfy

$$\frac{d}{d\tau_{ij}}(W_i + W_j) = (p_{ii} - c)\frac{dq_{ii}}{d\tau_{ij}} + (p_{ij} - c)\frac{dq_{ij}}{d\tau_{ij}} = 0. \tag{23}$$

When countries change their tariffs simultaneously, the change in country i's tariff $d\tau_{ij}$ affects country i's welfare arising at home and the change in country j's tariff $d\tau_{ji}$ affects country i's export profits, so country i's welfare is affected by the simultaneous change in tariffs $d\boldsymbol{\tau} = (d\tau_{ij}, d\tau_{ji})$ as follows:[30]

$$\frac{dW^i}{d\boldsymbol{\tau}} = \underbrace{-q_{ij}\frac{dp^*_{ij}}{d\tau_{ij}} + \tau_{ij}\frac{dq_{ij}}{d\tau_{ij}} + (p_{ii} - c)\frac{dq_{ii}}{d\tau_{ij}}}_{\text{change in domestic welfare induced by } d\tau_{ij}} + \underbrace{\frac{d}{d\tau_{ji}}\left[(p_{ji} - c - \tau_{ji})q_{ji}\right]}_{\text{change in export profits induced by } d\tau_{ji}} \tag{24}$$

Comparing (23) with (24), we see that a trade liberalization $d\boldsymbol{\tau}$ yields international efficiency if and only if it is such that

$$\frac{d}{d\tau_{ji}}\left[(p_{ji} - c - \tau_{ji})q_{ji}\right] = q_{ij}\frac{dp^*_{ij}}{d\tau_{ij}} - \tau_{ij}\frac{dq_{ij}}{d\tau_{ij}} + (p_{ij} - c)\frac{dq_{ij}}{d\tau_{ij}} = \frac{d}{d\tau_{ij}}\left[(p_{ij} - c - \tau_{ij})q_{ij}\right]. \tag{25}$$

This result can be restated in the following way:

Proposition 4. *A bilateral trade liberalization yields international efficiency if and only if it keeps the profit balance constant $dPB_{ij} = 0$ where*

$$PB_{ij} = (p_{ji} - c - \tau_{ji})q_{ji} - (p_{ij} - c - \tau_{ij})q_{ij}. \tag{26}$$

By keeping the profit balance constant, both the terms-of-trade and profit-shifting externalities are neutralized, or more precisely, countries exchange equivalent terms-of-trade and profit-shifting concessions:

$$\frac{dPB_{ij}}{d\boldsymbol{\tau}} = 0 = \underbrace{q_{ji}\frac{dp^*_{ji}}{d\tau_{ji}} - q_{ij}\frac{dp^*_{ij}}{d\tau_{ij}}}_{ToT} + \underbrace{\left[(p_{ji} - c - \tau_{ji})\frac{dq_{ji}}{d\tau_{ji}}\right] - \left[(p_{ij} - c - \tau_{ij})\frac{dq_{ij}}{d\tau_{ij}}\right]}_{PS} \tag{27}$$

Notice that this result has both a local and global meaning: as shown in the appendix, if countries change reciprocally their tariffs in a marginal way, starting from above the

[30]Note that this is independent of the assumption of linear demands.

efficient tariffs, they will be unambiguously better off. And this is true all the way along the path until they reach efficiency.[31]

The following subsection discusses whether GATT/WTO trade agreements play the role of keeping the profit balance constant.

7.2 Reciprocity in a two-country world

The principle of reciprocity is considered to be one of the foundational principles of the GATT/WTO, but there is no formal definition of reciprocity in the GATT/WTO.[32] Hoda (2001, p. 8) for example points out that "there is no provision on the manner in which reciprocity is to be measured and even the rules of various rounds of negotiations did not spell out any guidelines on the issue. The understanding has always been that governments participating in negotiations should retain complete freedom to adopt any method for evaluating the concessions."

Broadly speaking, reciprocity requires countries to exchange reciprocal concessions when negotiating trade liberalization. Keohane (1986, p. 7) explains that "reciprocity is not defined in the General Agreement on Tariffs and Trade, but the Director-General of GATT defines it as 'the equivalence of concessions'."[33] Given that firms' profits seem to be on the mind of real-world trade negotiators, I define reciprocity as follows:

Definition 2. A tariff change $d\boldsymbol{\tau} = (d\tau_{ij}, d\tau_{ji})$ is bilaterally reciprocal if it keeps the bilateral profit balance constant: $dPB_{ij} = 0$.

It immediately follows that a bilaterally reciprocal trade liberalization enables countries to reach international efficiency.

Notice however, that the literature usually defines a tariff change as satisfying the principle of reciprocity if the change in import volumes, measured at existing world prices, is equal to the change in export volumes (see for example Bagwell and Staiger (1999, 2001, 2002)). This definition is equivalent to my definition under perfect competition and under oligopoly with linear demands.[34] But when markets are oligopolistic and demands are not

[31] Note that if countries were asymmetric, depending on the starting point of the trade liberalization, they would not necessarily both reach efficiency.

[32] The only mention of reciprocity in the GATT is that trade negotiations should be done on a"reciprocal and mutually advantageous basis" and the only way in which reciprocity is actually encoded in the GATT is that countries are allowed to retaliate reciprocally, i.e. if a trading partner raises previously bound tariffs on imports from the home country, the home country is entitled to withdraw equivalent concessions from the trading partner.

[33] Keohane is referring here to a lecture by then Director-General Arthur Dunkel.

[34] Following Bagwell and Staiger (2001), in the context of quasi-linear preferences, a tariff change $d\boldsymbol{\tau} = (d\tau_{ij}, d\tau_{ji})$ is bilaterally reciprocal if it is such that $p^*_{ij}dq_{ij} + d\tilde{M}_i - p^*_{ji}dq_{ji} = 0$, where $\tilde{M}_i$ denotes country i's imports of the numéraire good ($\tilde{M}_i = M_i - M_i^p$ with M_i (M_i^p) being the consumption (production) of the numéraire good). Trade is balanced and so we have $TB_{ij} = p^*_{ij}q_{ij} + \tilde{M}_i - p^*_{ji}q_{ji} = 0$. Total differentiation of this gives $dTB_{ij} = q_{ij}dp^*_{ij} - q_{ji}dp^*_{ji} + p^*_{ij}dq_{ij} + d\tilde{M}_i - p^*_{ji}dq_{ji} = 0$. And hence reciprocity interpreted by Bagwell and Staiger yields $q_{ji}dp^*_{ji} - q_{ij}dp^*_{ij} = 0$: it ensures an equivalent

linear, these two definitions are different and reciprocity as defined by Bagwell and Staiger (1999) does not yield efficiency. Therefore, when profits matter, it seems appropriate to use my definition above.

7.3 Non-discrimination in a many-country world

Reciprocal liberalization in a two-country world unambiguously increases both countries' welfare and enables countries reach efficiency, but what if there are more than two countries in the world? It is easy to show that if two countries liberalize trade between themselves, outsiders are made unambiguously worse off. Indeed, in this model, country l is affected by country i's tariffs only through its exports to country i. As we have seen in the preliminary section, when country i lowers its tariffs on country j (without changing its tariffs on country l), country l's export sales (and therefore also export profits) in country i decrease. This phenomenon is well known in the literature since Viner (1950) as trade diversion.

Lemma 5. *A discriminatory liberalization harms countries that are not involved in it.*

Thus the bilateral principle of reciprocity is not sufficient to ensure a monotonic increase in welfare of all countries in a many-country world. The role of the non-discrimination principle will be to prevent discriminatory trade liberalization.

The principle of non-discrimination requires that countries impose the same tariff on all their trading partners. Furthermore, I follow Ossa (2011) in interpreting the principle of non-discrimination as a way to 'multilaterize' the principle of reciprocity and define the two principles together in the following way:

Definition 3. A tariff change $d\boldsymbol{\tau}$ is multilaterally reciprocal if it keeps the multilateral profit balance constant: $dPB_i = 0$, where

$$PB_i = \sum_{\substack{j=1 \\ j \neq i}}^{n} (p_{ji} - c - \tau_j) q_{ji} - \sum_{\substack{j=1 \\ j \neq i}}^{n} (p_{ij} - c - \tau_i) q_{ij}. \tag{28}$$

The following proposition determines the effects of multilaterally-reciprocal trade liberalization:

Proposition 5. *Trade liberalization following both the principle of reciprocity and non-discrimination, starting from above the efficient import tariff levels, unambiguously increases the welfare of all countries until they reach internationally efficient tariff levels.*

exchange of terms-of-trade concessions. When demands are linear, we have $q_{ij} dp^*_{ij} = (p_{ij} - c - \tau_{ij}) dq_{ij}$ and so reciprocity also implies an equivalent exchange of profit concessions.

So the presence of oligopoly provides a new rationale for the rules of reciprocity and non-discrimination when the set of instruments is restricted to import tariffs: a profit-shifting externality. Trade agreements ensure a balanced exchange of profit concessions by keeping the profit balance fixed. Hence they undo both the terms-of-trade and profit-shifting externalities and unambiguously raise countries' welfare.

8 Conclusion

In a linear Cournot profit-shifting model, this paper has identified three new insights into trade agreements arising from the presence of oligopolistic markets. First, when the use of trade policy requires prior investment in policy infrastructure, non-cooperative setting of trade policy leads to countries using a single instrument. When firms have a lot of market power (goods are not closely substitutable or there are relatively few firms), countries will use import tariffs only. When firms have less market power, countries may either use import tariffs only or export subsidies only.

Second, when countries sign a single-instrument trade agreement, a tariff-only agreement is more self-enforcing than a subsidy-only agreement for a wide range of parameters. The fact that changing policy infrastructure requires time introduces a path dependence in case of a deviation from the agreement so the payoffs along the off-equilibrium path are not the same depending on whether countries initially signed an agreement using the import or the export instrument. The presence of oligopolistic markets introduces an asymmetry between the two instruments. An increase in the import tariff both improves the terms of trade of the importing country and shifts profits from foreign to domestic firms. A change in the export subsidy either shifts profits from foreign to domestic firms or improves the terms of trade of the exporting country, but not both. So in the case of the import tariff, the terms-of-trade and the profit-shifting effects go in the same direction whereas in the case of the export subsidy, they go in opposite directions. This makes the import tariff a more effective punishment instrument. As a consequence, deviation from a tariff-only agreement is more costly for a wide range of parameters.

Finally, when the set of available trade instruments is restricted to import tariffs only, as it is in the GATT/WTO, the presence of oligopolistic markets gives rise to a new rationale for the rules of reciprocity and non-discrimination: a profit-shifting externality. Governments use import tariffs not only to improve their terms of trade, but also as a second-best policy to increase domestic production and shift profits from foreign to domestic firms. This profit-shifting externality cannot be internalized with the restricted set of trade instruments and leads to inefficiently high import tariffs even in the absence of terms-of-trade effects. Therefore, neutralizing the terms of trade would not be sufficient to achieve the internationally efficient equilibrium. Interpreting the principle of reciprocity as keeping the profit balance constant, I show that reciprocity and non-discrimination neutralize both the terms-of-trade and the profit-shifting externalities and enable countries to reach the internationally efficient equilibrium.

The model I have used is a very stylized model with some stark assumptions which are needed for tractability (e.g. to compare welfare levels under different trade instrument regimes). In particular, I have assumed quasi-linear preferences, thereby assuming away any income effects of trade policy. I have modeled consumer demand as linear (although allowing for different degrees of product substitution), and I have considered that the break-down of negotiations corresponds to a Nash reversion. Although some of the important mechanisms of my model do not seem to hinge on these particular assumptions, further work is needed to establish the robustness of these results with different demand systems, different punishment strategies etc.[35] The contribution of this paper is therefore to be the first to highlight these interesting possibilities. Given the importance of large firms in the world economy and especially their major role in political economy, it seems very desirable to explore further consequences of oligopolistic behavior for international trade agreements.

[35]For example, one mechanism which drives many results of this paper is the fact that when all countries use both tariffs and subsidies, profit-shifting effect of trade policy is neutralized. This result has been proved to hold by Bagwell and Staiger (2012b) more generally. Another important insight is that oligopoly introduces an asymmetry between the two trade instruments and so a tariff was is worse that a subsidy war seems also to be not just a feature of linear demands.

Appendix

A Effect of a change in trade policy on welfare

A.1 Import tariff case: derivation of equation (7)

By definition, from (6) we have

$$W_i = \sum_{j=1}^{n} \frac{1}{2}(a - p_{ij})q_{ij} + (p_{ii} - c)q_{ii} + \sum_{\substack{j=1 \\ j\neq i}}^{n} \tau_{ij}q_{ij} - \sum_{\substack{k=1 \\ k\neq i}}^{n} \sigma_{ki}q_{ki} + \sum_{\substack{k=1 \\ k\neq i}}^{n} (p_{ki} - c - \tau_{ki} + \sigma_{ki})q_{ki}.$$

Country i's tariffs do not affect production or consumption decisions in other countries, so for $l \neq i$ we have

$$\frac{dW_i}{d\tau_{il}} = \sum_{j=1}^{n} -\frac{1}{2}\frac{dp_{ij}}{d\tau_{il}}q_{ij} + \sum_{j=1}^{n} \frac{1}{2}(a - p_{ij})\frac{dq_{ij}}{d\tau_{il}} + (p_{ii} - c)\frac{dq_{ii}}{d\tau_{il}} + \frac{dp_{ii}}{d\tau_{il}}q_{ii} + q_{il} + \sum_{\substack{j=1 \\ j\neq i}}^{n} \tau_{ij}\frac{dq_{ij}}{d\tau_{il}}, \quad (29)$$

where the first two terms are the derivative of consumer surplus, the next two terms are the derivative of domestic firms' profits in the home country and the last two terms are the derivative of tariff revenue. Differentiating country i's inverse demand function for firm j's good (2) gives

$$\frac{dp_{ij}}{d\tau_{il}} = -\Big(\frac{dq_{ij}}{d\tau_{il}} + \gamma \sum_{\substack{k=1 \\ k\neq j}}^{n} \frac{dq_{ik}}{d\tau_{il}}\Big). \quad (30)$$

Substituting (2) and (30) in (29), noting that $\sum_{j=1}^{n} q_{ij} \sum_{\substack{k=1 \\ k\neq j}}^{n} \frac{dq_{ik}}{d\tau_{il}} = \sum_{j=1}^{n} \frac{dq_{ij}}{d\tau_{il}} \sum_{\substack{k=1 \\ k\neq j}}^{n} q_{ik}$, pure transfers cancel out and we obtain

$$\frac{dW_i}{d\tau_{il}} = -\sum_{\substack{j=1 \\ j\neq i}}^{n} q_{ij}\frac{dp_{ij}}{d\tau_{il}} + (p_{ii} - c)\frac{dq_{ii}}{d\tau_{il}} + q_{il} + \sum_{\substack{j=1 \\ j\neq i}}^{n} \tau_{ij}\frac{dq_{ij}}{d\tau_{il}},$$

which can be further simplified using mill prices $p_{ij} = p^*_{ij} + \tau_{ij}$ to give (7).

A.2 Export subsidy case: derivation of equation (8)

Similarly to the case with import tariffs, the effect of country i's export subsidy on its welfare is

$$\frac{dW_i}{d\sigma_{li}} = \frac{d}{d\sigma_{li}}\left[\sum_{\substack{j=1 \\ j\neq i}}^{n} (p_{ji} - c - \tau_{ji})q_{ji}\right] = \sum_{\substack{j=1 \\ j\neq i}}^{n} \left[q_{ji}\frac{dp^*_{ji}}{d\sigma_{li}} + (p_{ji} - c - \tau_{ji})\frac{dq_{ji}}{d\sigma_{li}}\right],$$

which yields (8).

B Non-cooperative instrument levels and welfare

In this section I calculate the optimum non-cooperative trade-policy-instrument levels *for a given configuration* of trade-policy-instrument choices.

As markets are completely separable (due to the assumptions of segmented markets and constant marginal costs), instruments in one market are independent of instruments in other markets. Let us hence focus on a single market: market in Country i. The first-order conditions for trade instruments in country i are, $\forall l \neq i$,

$$\frac{dW_i}{d\tau_{il}} = -\sum_{\substack{j=1 \\ j\neq i}}^{n} q_{ij}\frac{dp^*_{ij}}{d\tau_{il}} + \sum_{\substack{j=1 \\ j\neq i}}^{n} \tau_{ij}\frac{dq_{ij}}{d\tau_{il}} + (p_{ii} - c)\frac{dq_{ii}}{d\tau_{il}} = 0 \tag{31}$$

$$\frac{dW_l}{d\sigma_{il}} = \frac{d}{d\sigma_{il}}\left[(p_{il} - c - \tau_{il})q_{il}\right] = 0 \tag{32}$$

From (4), we have $\forall l \neq i$,

$$\frac{dQ_i}{d\tau_{il}} = -\frac{1}{\Gamma(n)} \quad \text{and} \quad \frac{dQ_i}{d\sigma_{il}} = \frac{1}{\Gamma(n)} \tag{33}$$

$$\frac{dq_{ij}}{d\tau_{ij}} = \frac{\gamma - \Gamma(n)}{\Gamma(0)\Gamma(n)} \quad \text{and} \quad \frac{dq_{ij}}{d\sigma_{ij}} = -\frac{\gamma - \Gamma(n)}{\Gamma(0)\Gamma(n)} \tag{34}$$

$$\forall l \neq j, \frac{dq_{ij}}{d\tau_{il}} = \frac{\gamma}{\Gamma(0)\Gamma(n)} \quad \text{and} \quad \frac{dq_{ij}}{d\sigma_{il}} = -\frac{\gamma}{\Gamma(0)\Gamma(n)} \tag{35}$$

Substituting the inverse demand (2), the Cournot equilibrium quantity expressions (4) and the derivatives above into (31) yields the import-tariff first-order condition

$$\begin{aligned} \Gamma(0)\Gamma(2) + \gamma\{\Gamma(2) + \Gamma(n)\left[\Gamma(0)+1\right]\}T_i - \gamma\left[\Gamma(n) + \Gamma(2)\right]S_i \\ -\Gamma(n)^2\left[\Gamma(0)+1\right]\tau_{il} + \Gamma(n)^2\sigma_{il} = 0 \end{aligned} \tag{36}$$

Substituting the inverse demand (2), the Cournot equilibrium quantity expressions (4) and their derivatives into (32) yields the export-subsidy first-order condition

$$\begin{aligned} \Gamma(0)\gamma^2(n-1) + \gamma^3(n-1)(T_i - S_i) \\ -\Gamma(n)\gamma^2(n-1)\tau_{il} - \Gamma(n)\left[2\Gamma(n)(1-\gamma) + \gamma^2\right]\sigma_{il} = 0 \end{aligned} \tag{37}$$

B.1 k subsidies into a market protected by tariffs

Consider now the following configuration of trade-policy-instrument choices. Country i imposes import tariffs. Assume that out of the $n-1$ countries which export into Country i, $k \in [0, n-1]$ exporters subsidize their exports while $n-k-1$ do not. Invoking symmetry, I denote by $\tau_\sigma(k)$ the import tariff that Country i imposes on imports from subsidizing exporters and by $\tau_0(k)$ the import tariff on imports from non-subsidizing exporters. I use $\sigma_\tau(k)$ to denote the optimal subsidy imposed by subsidizing exporters who face an import tariff. Applying the import-tariff first-order condition (36) to $\tau_\sigma(k)$ and $\tau_0(k)$, and the export-subsidy first-order condition (37) to $\sigma_\tau(k)$ with $T_i = k\tau_\sigma(k) + (n-k-1)\tau_0(k)$ and $S_i = k\sigma_\tau(k)$, we obtain a system of three equations in three unknowns which yields the equilibrium instrument levels (9), (10) and (11) .

B.2 k subsidies into a market not protected by tariffs

Assume again that $k \in [0, n-1]$ exporters subsidize their exports into Country i and $n-k-1$ exporters do not, but this time Country i does not impose import tariffs. I denote by $\sigma_0(k)$ the optimal subsidy imposed by subsidizing exporters who do not face an import tariff. Applying the the export-subsidy first-order condition (37) to $\sigma_0(k)$ with $T_i = 0$ and $S_i = k\sigma_0(k)$, I solve for the optimum subsidy (12).

B.3 Welfare levels

For the sake of this section, I will refer to Country i as Home. I now compute the maximum level of welfare that Home would achieve from using a given trade instrument for the following configuration of other countries' instruments: There are $k \in [0, n-1]$ countries who use export subsidies and out of these k countries, r countries use subsidies only. $k-r$ countries are using both instruments, while $n-k-1$ countries are using tariffs only. Hence from Home's perspective, there are r export markets which are not protected by tariffs and $n-r-1$ export markets which are.

To evaluate Home's welfare, we need to consider Home's domestic market and all exports markets and for each we need to determine whether the market is protected by tariffs and how many countries subsidize their exports into this market. We can then use the equilibrium instrument levels derived above to express Home's welfare as a function of k and r (and n and γ).[36] Here I describe this evaluation for each case.

B.3.1 Home has tariffs only

Domestic market is protected by tariffs. k countries subsidize exports into this market with subsidy level $\sigma_\tau(k)$, Home imposes $\tau_\sigma(k)$ on these imports. $(n-k-1)$ countries do not subsidize exports into this market ($\sigma = 0$), Home imposes $\tau_0(k)$ on these imports. Sum of tariffs in the domestic market: $T = k\tau_\sigma(k) + (n-k-1)\tau_0(k)$. Sum of subsidies: $S = k\sigma_\tau(k)$.

[36] To simplify notation, I will not make the dependence on n and γ explicit at this moment.

Combining (4), (5) and (6) and evaluating quantities at the above instrument levels yields the domestic surplus from using import tariffs when facing export subsidies from k countries which I denote as $DS_\tau(k)$.

Export market where importer has subsidies only is not protected by tariffs. Home does not use subsidies and is facing 0 tariffs in this market. $(k-1)$ countries subsidize with $\sigma_0(k-1)$ and face 0 tariffs. Sum of tariffs: $T=0$. Sum of subsidies: $S=(k-1)\sigma_0(k-1)$. I denote by $ES_0^0(k-1)$ the export surplus Home derives from this market into which $k-1$ countries subsidize. The subscript 0 indicates that Home is not subsidizing, the superscript 0 indicates that Home is not facing a tariff. There are r such markets.

Export market where importer has tariffs only is protected by tariffs. k countries subsidize into this market with subsidy $\sigma_\tau(k)$ and face tariffs $\tau_\sigma(k)$. Home does not use subsidies ($\sigma=0$) and is facing tariff $\tau_0(k)$. Sum of tariffs imposed in this market: $T=k\tau_\sigma(k)+(n-k-1)\tau_0(k)$. Sum of subsidies: $S=k\sigma_\tau(k)$. Using the same convention, I denote Home's export surplus from this market as $ES_0^\tau(k)$. There are $n-k-1$ such markets.

Export market where importer has both instruments is protected by tariffs. $k-1$ countries subsidize into this market with subsidy $\sigma_\tau(k-1)$ and face tariffs $\tau_\sigma(k-1)$. Home does not use subsidies ($\sigma=0$) and is facing tariff $\tau_0(k-1)$. Sum of tariffs: $T=(k-1)\tau_\sigma(k-1)+(n-k)\tau_0(k-1)$. Sum of subsidies: $S=(k-1)\sigma_\tau(k-1)$. Using the same convention, I denote Home's export surplus from this market as $ES_0^\tau(k-1)$. There are $k-r$ such markets.

Hence Home's welfare from using tariffs only when r other countries use subsidies only, $k-r$ countries use both instruments and $n-k-1$ countries use tariffs only is

$$W_\tau(k,r)=DS_\tau(k)+rES_0^0(k-1)+(n-k-1)ES_0^\tau(k)+(k-r)ES_0^\tau(k-1) \tag{38}$$

B.3.2 Home has both instruments

Domestic market is identical as in the case where Home has tariffs only described above. The domestic surplus is thus $DS_\tau(k)$.

Export market where importer has subsidies only is not protected by tariffs. k countries (including Home) subsidize with $\sigma_0(k)$ and face 0 tariffs. Sum of tariffs: $T=0$. Sum of subsidies: $S=k\sigma_0(k)$. Home derives export surplus $ES_\sigma^0(k)$ from this market. There are r such markets.

Export market where importer has tariffs only is protected by tariffs. $k+1$ countries (including Home) subsidize into this market with $\sigma_\tau(k+1)$ and face tariffs $\tau_\sigma(k+1)$. Non-subsidizing countries face tariff $\tau_0(k+1)$. Sum of tariffs: $T=(k+1)\tau_\sigma(k+1)+(n-k-2)\tau_0(k+1)$. Sum of subsidies: $S=(k+1)\sigma_\tau(k+1)$. Using the same convention, I denote Home's export surplus from this market as $ES_\sigma^\tau(k+1)$. There are $n-k-1$ such markets.

Export market where importer has both instruments is protected by tariffs. k countries (including Home) subsidize into this market with $\sigma_\tau(k)$ and face tariffs $\tau_\sigma(k)$. Non-subsidizing exporters face tariff $\tau_0(k)$. Sum of tariffs: $T = k\tau_\sigma(k) + (n-k-1)\tau_0(k)$. Sum of subsidies: $S = k\sigma_\tau(k)$. Using the same convention, I denote Home's export surplus from this market as $ES_\sigma^\tau(k)$. There are $k-r$ such markets.

Hence Home's welfare from using both instruments when r other countries use subsidies only, $k-r$ countries use both instruments and $n-k-1$ countries use tariffs only is

$$W_\beta(k,r) = DS_\tau(k) + rES_\sigma^0(k) + (n-k-1)ES_\sigma^\tau(k+1) + (k-r)ES_\sigma^\tau(k) \tag{39}$$

B.3.3 Home has subsidies only

Domestic market is not protected by tariffs. k countries subsidize into this market $\sigma_0(k)$. Sum of tariffs: $T=0$. Sum of subsidies: $S = k\sigma_0(k)$. Home's domestic surplus is $DS_0(k)$.

Export markets are identical as in the case where Home has both instruments described above. Hence Home's welfare from using export subsidies only when r other countries use subsidies only, $k-r$ countries use both instruments and $n-k-1$ countries use tariffs only is

$$W_\sigma(k,r) = DS_0(k) + rES_\sigma^0(k) + (n-k-1)ES_\sigma^\tau(k+1) + (k-r)ES_\sigma^\tau(k) \tag{40}$$

C Proofs from Section 3

Proof of Lemma 1. Country i's export surplus arising in Country j is $ES_{ji} = (q_{ji} - \sigma_{ji})q_{ji}$. Given (4), this export surplus depends on the subsidy given by Country i to exports to Country j (σ_{ji}), the tariff applied by Country j on imports from Country i (τ_{ji}) as well as the sum of tariffs applied by Country j (T_j) and the sum of subsidies arriving into Country j (S_j).

For the purpose of this proof, I will refer to Country i as "Home" and to Country j simply as export market. Exploiting symmetry, I drop country subscripts.

Part (i): Assume that the export market is not protected by an import tariff and that k other countries subsidize their exports into this market. If Home uses an export subsidy, there are in total $k+1$ countries who subsidize their exports into this market and $n-k-2$ who don't. The optimal export subsidy is given by (12): $\sigma_0(k+1) > 0$ when $\gamma > 0$. Home derives export surplus $ES_\sigma^0(k+1)$ from this market. If Home does not use an export subsidy, there are only k countries subsidizing their exports. Their equilibrium subsidy is $\sigma_0(k)$. Home derives export surplus $ES_0^0(k)$ from this market.

Evaluating the difference between Home's export surplus from this market with and without the subsidy yields

$$ES_{\sigma}^{0}(k+1) - ES_{0}^{0}(k) = \frac{\gamma^{4}(n-1)e_{0}(n,\gamma,k)}{\Omega_{\sigma}(k)^{2}\Omega_{\sigma}(k+1)^{2}} \tag{41}$$

where $e_0(n,\gamma,k) \equiv \alpha_0^{e_0}(n,\gamma) + \alpha_1^{e_0}(n,\gamma)k + \alpha_2^{e_0}(n,\gamma)k^2$ with

$$\begin{aligned}
\alpha_0^{e_0}(n,\gamma) &= \Gamma(n-1)((1-\gamma)(2+\gamma n)+\gamma^2)(4-6\gamma+3\gamma^2+2\gamma n(1-\gamma))^2 > 0\\
\alpha_1^{e_0}(n,\gamma) &= 2\gamma^2\Gamma(n-1)((1-\gamma)(2+\gamma n)+\gamma^2)(4-6\gamma+3\gamma^2+2\gamma n(1-\gamma)) > 0\\
\alpha_2^{e_0}(n,\gamma) &= \gamma^5(n-1)(4-5\gamma+2\gamma^2+\gamma n(1-\gamma)) > 0
\end{aligned}$$

and so $ES_{\sigma}^{0}(k+1) - ES_{0}^{0}(k) > 0$ when $\gamma > 0$, $n \geq 2$ and $k \in [0, n-2]$. No matter how many other countries subsidize exports, if the export market is not protected by an import tariff, Home is better off with an export subsidy.

Part (ii): Assume now that the export market is protected by an import tariff and that k other countries subsidize their exports into this market. If Home uses an export subsidy, there are in total $k+1$ countries who subsidize their exports into this market and $n-k-2$ who don't. The equilibrium instruments imposed in this market are given by equations (9), (10) and (11) evaluated at $k+1$. In particular, the optimal export subsidy is $\sigma_{\tau}(k+1) > 0$ when $\gamma > 0$. The sum of subsidies arriving into this market is $(k+1)\sigma_{\tau}(k+1)$. The tariff imposed on subsidized exports is $\tau_{\sigma}(k+1)$ while the tariff imposed on non-subsidized imports is $\tau_0(k+1)$. The sum of tariffs imposed in this market is $(k+1)\tau_{\sigma}(k+1) + (n-k-2)\tau_0(k+1)$. Home derives $ES_{\sigma}^{\tau}(k+1)$ from this market.

If Home does not use an export subsidy, there are only k countries subsidizing their exports. Home's exports face import tariff $\tau_0(k)$. The tariff imposed on subsidized exports is $\tau_{\sigma}(k)$. The sum of tariffs imposed in this market is $k\tau_{\sigma}(k) + (n-k-1)\tau_0(k)$. The optimal subsidy of subsidizing countries is $\sigma_{\tau}(k)$ and the sum of subsidies arriving into this market is $k\sigma_{\tau}(k)$. Home derives $ES_{0}^{\tau}(k)$ from this market.

Evaluating the difference between Home's export surplus from this market with and without the subsidy yields

$$ES_{\sigma}^{\tau}(k+1) - ES_{0}^{\tau}(k) = -\frac{\gamma^{2}(4-3\gamma)(n-1)e_{\tau}(n,\gamma,k)}{\Omega_{\tau}(k)^{2}\Omega_{\tau}(k+1)^{2}} \tag{42}$$

where $e_\tau(n,\gamma,k) \equiv \alpha_0^{e_t}(n,\gamma) + \alpha_1^{e_t}(n,\gamma)k + \alpha_2^{e_t}(n,\gamma)k^2$ with

$$\begin{aligned}
\alpha_0^{e_\tau}(n,\gamma) &= (6-8\gamma+3\gamma^2+\gamma n(3-2\gamma^2))^2\tilde{e}(n,\gamma) > 0 \\
\alpha_1^{e_\tau}(n,\gamma) &= 2\gamma^3(4-3\gamma)(n-1)(6-8\gamma+3\gamma^2+\gamma n(3-2\gamma^2))\hat{e}(n,\gamma) \geq 0 \\
\alpha_2^{e_\tau}(n,\gamma) &= \gamma^6(4-3\gamma)^2(n-1)^2(6-14\gamma+9\gamma^2+3\gamma n(1-\gamma)+\gamma^3(n-2))) \geq 0
\end{aligned}$$

with

$$\begin{aligned}
\tilde{e}(n,\gamma) = 864 &- 2592\gamma + 3216\gamma^2 - 2400\gamma^3 + 1226\gamma^4 - 446\gamma^5 + 114\gamma^6 - 18\gamma^7 && (43)\\
&+ \gamma(1008 - 2688\gamma + 3184\gamma^2 - 2184\gamma^3 + 969\gamma^4 - 282\gamma^5 + 45\gamma^6)n && (44)\\
&+ \gamma^2(384 - 968\gamma + 1046\gamma^2 - 630\gamma^3 + 219\gamma^4 - 36\gamma^5)n^2 && (45)\\
&+ \gamma^3(48 - 120\gamma + 115\gamma^2 - 51\gamma^3 + 9\gamma^4)n^3 && (46)
\end{aligned}$$

and

$$\begin{aligned}
\hat{e}(n,\gamma) = 72 &- 192\gamma + 188\gamma^2 - 102\gamma^3 + 34\gamma^4 - 6\gamma^5 && (47)\\
&+ \gamma(60 - 122\gamma + 106\gamma^2 - 46\gamma^3 n + 9\gamma^4)n && (48)\\
&+ \gamma^2(12 - 21\gamma + 13\gamma^2 - 3\gamma^3)n^2 && (49)
\end{aligned}$$

and so $ES^\tau_\sigma(k+1) - ES^\tau_0(k) < 0$ when $\gamma > 0$, $n \geq 2$ and $k \in [0, n-2]$. No matter how many other countries subsidize exports, if the export market is protected by an import tariff, Home is better off without an export subsidy.

Proof of Lemma 2. In this proof, I focus on an importer country which is importing from $n-1$ subsidizing exporters. The objective is to compare the domestic welfare levels of the importer with and without an import tariff.

When the importer does not impose import tariffs, the export subsidies arriving into the import market are given by (12) with $k = n-1$:

$$\sigma_0(n-1) = \frac{\gamma^2\Gamma(0)(n-1)}{B_\sigma(n)} > 0 \text{ when } \gamma > 0 \tag{50}$$

When the importer does impose import tariffs, the equilibrium instruments are given by (9) and (11) evaluated at $k = n-1$:

$$\tau_\sigma(n-1) = \frac{\Gamma(0)\Gamma(2)\Gamma(n-1) - \gamma^3(n-1)}{B_\beta(n)} > 0 \tag{51}$$

$$\sigma_\tau(n-1) = \frac{\gamma^2(n-1)(4-3\gamma)}{B_\beta(n)} > 0 \text{ when } \gamma > 0 \tag{52}$$

where $B_\beta(n) \equiv B_\tau(n)\Gamma(n-1) - 4\gamma^2(n-1)$.

Evaluating the importer's domestic surplus with and without the import tariff yields

$$DS_\tau(n-1) - DS_0(n-1) = \frac{(3-\gamma)^2\Gamma(n-1)\left[\Gamma(0)\Gamma(2)\Gamma(n-1) - \gamma^3(n-1)\right]\hat{h}(n,\gamma)}{2B_\sigma(n)^2 B_\beta(n)^2}$$

where $\hat{h}(n,\gamma) \equiv \alpha_0^{\hat{h}}(\gamma) + \alpha_1^{\hat{h}}(\gamma)n + \alpha_2^{\hat{h}}(\gamma)n^2 + \alpha_3^{\hat{h}}(\gamma)n^3$ with

$$\begin{aligned}
\alpha_0^{\hat{h}} &\equiv 2(96 - 256\gamma + 320\gamma^2 - 244\gamma^3 + 126\gamma^4 - 37\gamma^5 + 3\gamma^6) \\
\alpha_1^{\hat{h}} &\equiv \gamma(256 - 688\gamma + 824\gamma^2 - 568\gamma^3 + 200\gamma^4 - 21\gamma^5) \\
\alpha_2^{\hat{h}} &\equiv \gamma^2(112 - 304\gamma + 332\gamma^2 - 154\gamma^3 + 21\gamma^4) \\
\alpha_3^{\hat{h}} &\equiv 2\gamma^3(4 - 3\gamma)(2 - 4\gamma + \gamma^2)
\end{aligned}$$

The difference in domestic surplus with and without tariffs $DS_\tau(n-1) - DS_0(n-1)$ is of the sign of $\hat{h}(n,\gamma)$. To determine the sign of $\hat{h}(n,\gamma)$, I proceed by successive differentiation of $\hat{h}$: $\frac{\partial^3}{\partial n^3}\hat{h}(n,\gamma) = 6\alpha_3^{\hat{h}}$ which is positive for $\gamma < 2-\sqrt{2}$ and negative for $\gamma > 2-\sqrt{2}$. Thus $\frac{\partial^2}{\partial n^2}\hat{h}(n,\gamma)$ is an increasing function of n for $\gamma \in [0, 2-\sqrt{2})$ and a decreasing function of n for $\gamma \in (2-\sqrt{2}, 1]$.

$\frac{\partial^2}{\partial n^2}\hat{h}(1,\gamma) = 2\gamma^2(112 - 256\gamma + 200\gamma^2 - 58\gamma^3 + 3\gamma^4) \geq 0$ for any $\gamma \in [0,1]$. Hence for $\gamma \in [0, 2-\sqrt{2})$, $\frac{\partial^2}{\partial n^2}\hat{h}(n,\gamma)$ is positive for any n and $\frac{\partial}{\partial n}\hat{h}$ is an increasing function of n. For $\gamma \in (2-\sqrt{2}, 1]$, $\frac{\partial^2}{\partial n^2}\hat{h}$ is a decreasing function of n with $\lim\limits_{n\to\infty}\dfrac{\partial^2}{\partial n^2}\hat{h}(n,\gamma) = -\infty$ (negative coefficient on the term with the highest power) and so there exists a threshold value of n above which $\frac{\partial^2}{\partial n^2}\hat{h}(n,\gamma) < 0$. Therefore, for $\gamma \in (2-\sqrt{2}, 1]$, $\frac{\partial}{\partial n}\hat{h}$ is initially an increasing function of n, but ultimately decreases with n.

$\frac{\partial}{\partial n}\hat{h}(1,\gamma) = (2-\gamma)\gamma(128 - 168\gamma + 48\gamma^2 + 6\gamma^3 - 3\gamma^4) \geq 0$ for any $\gamma \in [0,1]$. Hence for $\gamma \in [0, 2-\sqrt{2})$, $\frac{\partial}{\partial n}\hat{h}(n,\gamma)$ is positive for any n and $\hat{h}$ is an increasing function of n. For $\gamma \in (2-\sqrt{2}, 1]$, $\frac{\partial}{\partial n}\hat{h}$ is a decreasing function of n above a certain threshold value of n with $\lim\limits_{n\to\infty}\dfrac{\partial}{\partial n}\hat{h}(n,\gamma) = -\infty$ (negative coefficient on the term with the highest power) and so there exists a threshold value of n above which $\frac{\partial}{\partial n}\hat{h}(n,\gamma) < 0$. Therefore, for $\gamma \in (2-\sqrt{2}, 1]$, $\hat{h}$ is initially an increasing function of n, but ultimately decreases with n.

Finally note that $\hat{h}(1,\gamma) = 4(3-\gamma)(2-\gamma)^3(2+\gamma) > 0$ for $\gamma \in [0,1]$. For $\gamma \in [0, 2-\sqrt{2})$, $\hat{h}$ is an increasing function of n and so we know that for $\gamma \in [0, 2-\sqrt{2})$, $\hat{h}(n,\gamma) \geq 0$ for any $n \geq 1$. For $\gamma \in (2-\sqrt{2}, 1]$, $\hat{h}$ is a decreasing function of n above a certain threshold n with $\lim\limits_{n\to\infty}\hat{h}(n,\gamma) = -\infty$ (negative coefficient on the term with the highest power).

Therefore, there is a threshold value of n, denoted $n_\tau(\gamma)$, above which $\hat{h}(n,\gamma) < 0$ for $\gamma \in (2-\sqrt{2}, 1]$.

Proof of Proposition 1. Assume that there exists a mixed equilibrium in which t countries use import tariffs only, s countries use export subsidies only and b countries use both instruments, where $t+s+b=n$. This proof shows that when $(n,\gamma) \in \mathcal{P}$, the only possible equilibria are such that $t=n$ or $s=n$ and when $(n,\gamma) \notin \mathcal{P}$, the only equilibrium is such that $t=n$.

The core of the proof will make use of the following two claims which I derive first.

Claim 1. *$W_\tau(k,k) - W_\sigma(k,k)$ single-crosses 0 from above as k increases from 0 to $n-1$ or not at all.*

Proof of Claim 1.

$$W_\tau(k,k) - W_\sigma(k,k) = \frac{(n-1)w_{\tau\sigma}(k)}{2\Omega_\sigma(k-1)^2\Omega_\sigma(k)^2\Omega_\tau(k)^2\Omega_\tau(k+1)^2} \tag{53}$$

where $w_{\tau\sigma}(k)$ is a 7^{th} degree polynomial in k with coefficients polynomial functions of n and γ. By successive differentiation, it is possible to show that for any $\gamma \in [0,1]$ and any $n \geq 3$, $w_{\tau\sigma}(k)$ is either monotonically decreasing or initially increasing but ultimately decreasing with $k \in [0, n-1]$. $W_\tau(0,0) - W_\sigma(0,0) > 0$ follows from lemmas (1) and (2): when all other countries use import tariffs only, Home gains from not using a subsidy in the export markets and it gains from using a tariff in the domestic market. As a consequence, $W_\tau(k,k) - W_\sigma(k,k)$ can cross 0 at most once when k increases 0 to $n-1$ and the crossing is from above.

Claim 2. *For any $k \in [0, n-1]$, $W_\tau(k+r,r) - W_\beta(k+r,r)$ single-crosses 0 from above as r increases from 0 to $n-k-1$ or not at all.*

Proof of Claim 2.

$$W_\tau(k+r,r) - W_\beta(k+r,r) = \frac{\gamma^2(n-1)w_{\tau\beta}(r,k)}{\Omega_\sigma(k+r-1)^2\Omega_\sigma(k+r)^2\Omega_\tau(k+r-1)^2\Omega_\tau(k+r)^2\Omega_\tau(k+r+1)^2} \tag{54}$$

where $w_{\tau\beta}(r,k)$ is a 9^{th} degree polynomial in r with coefficients polynomial functions of k, n and γ. Tedious derivations show that $w_{\tau b}(r,k)$ either monotonically decreases with $r \in [0, n-k-1]$ or initially increases but ultimately decreases on this range. Lemma (1) implies that $W_\tau(k,0) - W_\beta(k,0) > 0$ for any $k \in [0, n-1]$: when $r=0$, all countries use tariffs and so using export subsidies decreases welfare. As a consequence, $W_\tau(k+r,r) - W_\beta(k+r,r)$ can cross 0 at most once when r increases 0 to $n-k-1$ and the crossing is from above.

Main proof: If there is an equilibrium such that t countries use import tariffs only, s countries use export subsidies only and b countries use both instruments (with $t+s+$

$b = n$), then no country must have an incentive to deviate. This implies the following conditions:

- For a country using tariffs only:

$$W_\tau(b+s,s) \geq W_\beta(b+s,s) \tag{55}$$
$$W_\tau(b+s,s) \geq W_\sigma(b+s,s) \tag{56}$$

- For a country using subsidies only:

$$W_\sigma(b+s-1,s-1) \geq W_\tau(b+s-1,s-1) \tag{57}$$
$$W_\sigma(b+s-1,s-1) \geq W_\beta(b+s-1,s-1) \tag{58}$$

- For a country using both instruments:

$$W_\beta(b+s-1,s) \geq W_\tau(b+s-1,s) \tag{59}$$
$$W_\beta(b+s-1,s) \geq W_\sigma(b+s-1,s) \tag{60}$$

Note that $W_\beta(k,r) - W_\sigma(k,r) = DS_\tau(k) - DS_0(k)$. For a given configuration of other countries' instruments, in *both instruments* and *export subsidies only* scenarios, Home uses export subsidies so export surpluses are identical in all export markets and the welfare difference comes only from the difference in the domestic market. This difference depends only on the total number of other countries using export subsidies k and not on the number of countries using export subsidies only r. Hence conditions (58) and (60) can only be compatible if we have one of the following:

1. $s = 0 \Rightarrow t + b = n$ so all countries use import tariffs and some may use both instruments. From Lemma 1, we have $W_\tau(k,0) - W_\beta(k,0) > 0$ for any $k \in [0, n-1]$ which is incompatible with (59). And so we must also have $b = 0$, i.e. all countries use import tariffs only.

2. $b = 0$. Then from conditions (56) and (57) we have

$$W_\tau(s,s) - W_\sigma(s,s) \geq 0 \tag{61}$$
$$W_\tau(s-1,s-1) - W_\sigma(s-1,s-1) \leq 0 \tag{62}$$

   which are incompatible by Claim 1. Hence we must have either $s = 0$ (all countries use import tariffs only) or $t = 0$ (all countries use export subsidies only). When $(n,\gamma) \notin \mathcal{P}$, we have from Lemma 2, $W_\beta(n-1,n-1) > W_\sigma(n-1,n-1)$ which is incompatible with (58). So when $(n,\gamma) \notin \mathcal{P}$, we must have $s = 0$.

3. Conditions (58) and (60) hold with equality, i.e. $s > 0$ and $b > 0$ are such that $k = s + b - 1$ is an integer root of

$$W_\sigma(k, \cdot) - W_\beta(k, \cdot) = 0 \tag{63}$$

with $k \in [1, n-2]$. It is possible to show that such an integer root does not exist for many values of γ (in particular $\gamma = 1$), but for the sake of this proof, assume that such an integer root exists for some γ in the range of interest. Then (63) with (57) implies

$$W_\beta(b + s - 1, s - 1) \geq W_\tau(b + s - 1, s - 1) \tag{64}$$

which is incompatible with (55) by Claim 2.

Proof of Proposition 2. Evaluating the welfare function in the tariff-only and subsidy-only equilibria yields:

$$W_\tau^N - W_\sigma^N = W_\tau(0,0) - W_\sigma(n-1, n-1) = -\frac{(n-1)\tilde{g}(n,\gamma)\hat{g}(n,\gamma)}{2B_\tau(n)^2 B_\sigma(n)^2} \tag{65}$$

with $\tilde{g}(n,\gamma) = 8 - 8\gamma - 6\gamma^2 + 5\gamma^3 + 4\gamma(1+\gamma-\gamma^2)n > 0$ and $\hat{g}(n,\gamma) = \alpha_0^r(\gamma) + \alpha_1^r(\gamma)n + \alpha_2^r(\gamma)n^2$ where

$$\begin{aligned}
\alpha_0^{\hat{g}} &= 224 - 608\gamma + 704\gamma^2 - 396\gamma^3 + 106\gamma^4 - 15\gamma^5 > 0 \\
\alpha_1^{\hat{g}} &= \gamma(208 - 504\gamma + 420\gamma^2 - 154\gamma^3 + 27\gamma^4) \gtreqless 0 \\
\alpha_2^{\hat{g}} &= 4\gamma^2(4 - 3\gamma)(3 - 3\gamma + \gamma^2) \geq 0
\end{aligned}$$

The function $\hat{g}$ is increasing with n and $\hat{g}(1,\gamma) = 4(2-\gamma)^2(14 - 11\gamma + \gamma^2) > 0$ so $\hat{g}(n,\gamma) > 0$ and thus $W_\tau^N - W_\sigma^N < 0$.

D On- and off-equilibrium-path instruments

D.1 Efficient instruments

When countries cooperate, they maximize their joint welfare. The first-order conditions of this optimization problem for trade instruments in country i are: $\forall l \neq i$,

$$\frac{d(W_1 + W_2 + \ldots + W_n)}{d\tau_{il}} = \sum_{j=1}^{n} (p_{ij} - c)\frac{dq_{ij}}{d\tau_{il}} = 0 \tag{66}$$

$$\frac{d(W_1 + W_2 + \ldots + W_n)}{d\sigma_{il}} = \sum_{j=1}^{n} (p_{ij} - c)\frac{dq_{ij}}{d\sigma_{il}} = 0 \tag{67}$$

Because equilibrium quantities depend only on the net instruments, (66) and (67) are linearly dependent. Substituting the inverse demand (2), the Cournot equilibrium quantities (4) and their derivatives above into either (66) or (67) yields

$$-\Gamma(0)^2 + \gamma\left[\Gamma(n)(1-\gamma) - \Gamma(0)\right](T_i - S_i) - \Gamma(n)^2(1-\gamma)(\tau_{il} - \sigma_{il}) = 0 \tag{68}$$

Invoking symmetry: $\tau_{il} = \tau$, $T_i = (n-1)\tau$, $\sigma_{il} = \sigma$ and $S_i = (n-1)\sigma$, we can solve for the efficient net instrument

$$\tau^* - \sigma^* = -\frac{\Gamma(0)^2}{B(n)} = -\frac{(2-\gamma)^2}{4(1-\gamma) + \gamma(4-3\gamma)(n-1)} < 0 \tag{69}$$

In the tariff-only agreement, the subsidy σ^* is zero and the cooperation tariff is $\tau_E = -\frac{\Gamma(0)^2}{B(n)}$ (it is an import subsidy) while in the subsidy-only agreement, the import tariff τ^* is zero and the cooperation subsidy is $\sigma_E = \frac{\Gamma(0)^2}{B(n)}$.

D.2 Deviation instruments

The deviator sets her instruments to maximize her own welfare knowing that other countries cooperate and set internationally efficient instruments. The first-order conditions for the deviator's optimization problem are therefore the Nash first-order conditions (36) and (37) where the instruments of other countries are at their efficient levels.

Deviation tariff: The first-order condition for Nash equilibrium tariffs (36) is independent of the other countries' tariffs (i.e. there is no strategic interdependence between tariffs which is consequence of the segmented markets and identical constant marginal costs assumptions). The deviation tariff is thus the Nash equilibrium tariff for the tariff-only case given by (10): $\tau_D = \tau_N = \tau_0(0)$

Deviation subsidy: The deviator's subsidy is given by equation (37) applied to the one instrument case (where tariffs are zero) where the subsidies of other countries are at their efficient levels $\sigma_E = \frac{\Gamma(0)^2}{B(n)}$. Solving the equation yields

$$\sigma_D = \frac{\gamma^2\Gamma(0)(n-1)\left[B(n) - \gamma(n-2)\Gamma(0)\right]}{2\Gamma(n-1)\left[(1-\gamma)\Gamma(n) + \gamma\right]B(n)} \geq 0. \tag{70}$$

E Proofs from Sections 5, 6 and 7

Proof of Lemma 3. The goal of this proof is to compare the gain from deviating in the tariff-only and subsidy-only agreement. Evaluating welfare at the corresponding instrument levels yields

$$W_\tau^D - W_\sigma^D = \frac{(n-1)g_1(n,\gamma)}{4\Gamma(n-1)\left[(1-\gamma)\Gamma(n) + \gamma\right]B_\tau(n)B(n)^2} \tag{71}$$

with $g_1(n,\gamma) \equiv \alpha_0^{g_1}(\gamma) + \alpha_1^{g_1}(\gamma)n + \alpha_2^{g_1}(\gamma)n^2 + \alpha_3^{g_1}(\gamma)n^3$ and

$$\begin{aligned}
\alpha_0^{g_1}(\gamma) &\equiv 1280 - 3584\gamma + 2368\gamma^2 + 3008\gamma^3 - 6672\gamma^4 + 5536\gamma^5 - 2488\gamma^6 + 620\gamma^7 - 75\gamma^8 \gtreqless 0 \\
\alpha_1^{g_1}(\gamma) &\equiv \gamma(1024 - 1344\gamma - 2816\gamma^2 + 8448\gamma^3 - 8880\gamma^4 + 4820\gamma^5 - 1416\gamma^6 + 195\gamma^7) \geq 0 \\
\alpha_2^{g_1}(\gamma) &\equiv 8(1-\gamma)\gamma^2(8 + 112\gamma - 282\gamma^2 + 256\gamma^3 - 111\gamma^4 + 21\gamma^5) \geq 0 \\
\alpha_3^{g_1}(\gamma) &\equiv -16(1-\gamma)^4\gamma^3(4-3\gamma) \leq 0
\end{aligned}$$

From (71) we see that the welfare difference is of the same sign as $g_1(n,\gamma)$. $g_1(n,\gamma)$ is a polynomial function of n with coefficients depending on γ. Notice that $g_1(n,0) = 1280 > 0$. When $\gamma = 1$, $\alpha_2^g(\gamma) = \alpha_3^g(\gamma) = 0$ and g_1 is a linear function of n with a positive coefficient on n and we have $g_1(n,1) > 0$ for any $n \geq 2$.

When $\gamma \in (0,1)$, g_1 is a cubic function of n with a negative coefficient on the third-degree term. By successive differentiation, it can be shown that on $[2,+\infty)$ g_1 is initially an increasing function of n with $g_1(2,\gamma) > 0$ and becomes a decreasing function of n with $\lim_{n\to\infty} g_1(n,\gamma) = -\infty$. By the intermediate value theorem, there exists a threshold n above which the difference in welfare $W_\tau^D - W_\sigma^D$ is negative. The threshold value $n_D(\gamma)$ is the solution of $g_1(n,\gamma) = 0$ on $[2,+\infty)$. The closed form expression for $n_D(\gamma)$ is a cumbersome rational function of γ which can be provided upon request.

Proof of Proposition 3. Properties of δ_τ: When $\gamma > 0$,

$$\frac{d\delta_\tau}{dn} = \frac{-8\frac{dB_\tau}{dn}}{4\left[B_\tau - 4\right]^2} = -\frac{8\gamma(4-3\gamma)}{4\left[B_\tau - 4\right]^2} \leq 0$$

and so δ_τ is decreasing with n with $\lim_{n\to\infty} \delta_\tau = \lim_{n\to\infty} \frac{B_\tau(n)}{2B_\tau(n)} = \frac{1}{2}$. When $\gamma = 0$, $\delta_\tau = \frac{3}{4}$.

Properties of δ_σ: When $\gamma > 0$,

$$\frac{d\delta_\sigma}{dn} = \frac{\Phi(n)h(n,\gamma)}{\left[\Theta(n) + \Phi(n)^2\right]^2}$$

where $h(n,\gamma) \equiv 2\frac{d\Phi}{dn}\Theta - \Phi\frac{d\Theta}{dn}$. Thus the derivative of δ_σ with respect to n is of the sign of $h(n,\gamma)$:

$$h(n,\gamma) = 2\gamma^2\left[\alpha_0^h(\gamma) + \alpha_1^h(\gamma)n + \alpha_2^h(\gamma)n^2 + \alpha_3^h(\gamma)n^3 + \alpha_4^h(\gamma)n^4\right]$$

with

$$\begin{aligned}
\alpha_0^h(\gamma) &\equiv\; -2(48-144\gamma+168\gamma^2-108\gamma^3+48\gamma^4-16\gamma^5+3\gamma^6)\\
\alpha_1^h(\gamma) &\equiv 64-352\gamma+640\gamma^2-588\gamma^3+328\gamma^4-116\gamma^5+21\gamma^6\\
\alpha_2^h(\gamma) &\equiv 3\gamma(32-112\gamma+156\gamma^2-116\gamma^3+48\gamma^4-9\gamma^5)\\
\alpha_3^h(\gamma) &\equiv \gamma^2(48-128\gamma+140\gamma^2-73\gamma^3+15\gamma^4)\\
\alpha_4^h(\gamma) &\equiv \Gamma(0)(1-\gamma)\gamma^3(4-3\gamma)\geq 0
\end{aligned}$$

$\frac{\partial^4 h}{\partial n^4}(n,\gamma)=24\Gamma(0)(1-\gamma)\gamma^3(4-3\gamma)\geq 0$ and so the third derivative of h with respect to n is an increasing function of n. Furthermore, $\frac{\partial^3 h}{\partial n^3}(2,\gamma)=6\gamma^2(48-64\gamma-4\gamma^2+31\gamma^3-9\gamma^4)\geq 0$, and so $\frac{\partial^3 h}{\partial n^3}$ is positive for any $n\geq 2$ and the second derivative of h is an increasing function of n. Also, $\frac{\partial^2 h}{\partial n^2}(2,\gamma)=6\gamma(32-16\gamma-36\gamma^2+20\gamma^3+6\gamma^4-3\gamma^5)\geq 0$ and so the second derivative is positive for any $n\geq 2$ and the first derivative is an increasing function of n. Finally, $\frac{\partial h}{\partial n}(2,\gamma)=64+32\gamma-128\gamma^2+4\gamma^3+40\gamma^4-3\gamma^6\geq 0$ and so the first derivative is positive for any $n\geq 2$ and h is an increasing function of n with $h(2,\gamma)=16(1-\gamma)(2-\gamma^2)\geq 0$ and so h is positive for any $n\geq 2$. Thus $\frac{\partial\delta_\sigma}{\partial n}(n,\gamma)\geq 0$ for any $\gamma\in[0,1]$ and any $n\geq 2$ and δ_σ is increasing with n. Notice that $\Phi(n,\gamma)^2$ is a polynomial of degree 4 in n while $\Theta(n,\gamma)$ is a polynomial of degree 3 in n and so $\lim_{n\to\infty}\delta_\sigma=\lim_{n\to\infty}\dfrac{\Phi(n,\gamma)^2}{\Phi(n,\gamma)^2}=1$. When $\gamma=0$, $\delta_\sigma=\frac{2}{3}$.

Properties of Δ: The difference between the critical threshold discount factors given by (16) is

$$\Delta=\delta_\sigma-\delta_\tau=\frac{B(n)r(n,\gamma)}{2\left[B_\tau(n)-4\right]\left\{\Theta(n)+\Phi(n)^2\right\}}$$

with $r(n,\gamma)\equiv\alpha_0^r(\gamma)+\alpha_1^r(\gamma)n+\alpha_2^r(\gamma)n^2+\alpha_3^r(\gamma)n^3+\alpha_4^r(\gamma)n^4$ and

$$\begin{aligned}
\alpha_0^r(\gamma) &\equiv 4(-8+38\gamma^2-56\gamma^3+35\gamma^4-9\gamma^5+\gamma^6)\\
\alpha_1^r(\gamma) &\equiv\; -2\gamma^2(76-168\gamma+140\gamma^2-45\gamma^3+6\gamma^4)\\
\alpha_2^r(\gamma) &\equiv \gamma^2(40-160\gamma+190\gamma^2-80\gamma^3+13\gamma^4)\\
\alpha_3^r(\gamma) &\equiv 2\gamma^3(12-25\gamma+15\gamma^2-3\gamma^3)\\
\alpha_4^r(\gamma) &\equiv \Gamma(0)^2\gamma^4
\end{aligned}$$

From the individual properties of δ_τ and δ_σ, we know that Δ is a monotonically increasing function of $n\geq 2$ and it is of the sign of $r(n,\gamma)$. We have $\Delta(2,\gamma)=-\frac{(4+\gamma^2)(4-3\gamma^2)}{2(8-3\gamma^2)(12-7\gamma^2)}<0$ and $\lim_{n\to\infty}\Delta=\dfrac{1}{2}$, so there is a threshold value of n above which Δ is positive. This threshold value $n_\Delta(\gamma)$ is the solution of $r(n,\gamma)=0$ on $[2,+\infty)$.

Proof of Lemma 4. If countries did not value the terms-of-trade effects of their trade policy, the first-order condition for the import tariff of country i on country l ($\forall l \neq i$) would be

$$\sum_{\substack{j=1 \\ j\neq i}}^{n} \tau_{ij} \frac{dq_{ij}}{d\tau_{il}} + (p_{ii} - c)\frac{dq_{ii}}{d\tau_{il}} = 0.$$

Substituting the inverse demand (2), imposing symmetry and rearranging terms yields the formula.

Proof of Proposition 4. To study the effect of a reciprocal trade liberalization on welfare, it is convenient to rewrite the welfare function in the following way:

$$W_i = NS_i + PB_i,$$

where $NS_i \equiv Q_i - \frac{\gamma}{2}Q_i^2 - \frac{1-\gamma}{2}\sum_{j=1}^{n} q_{ij}^2$ is the net benefit from consumption and $PB_i \equiv -\sum_{\substack{j=1 \\ j\neq i}}^{n}(q_{ij} - \sigma_{ij})q_{ij} + \sum_{\substack{j=1 \\ j\neq i}}^{n}(q_{ji} - \sigma_{ji})q_{ji}$ is the net profit balance.[37] The net benefit from consumption is a part of welfare arising in the home country, it is thus independent of import tariffs of other countries. The profit balance depends both on home and foreign countries' instruments. Using this definition, we can decompose the effect of a reciprocal liberalization $d\boldsymbol{\tau} = (d\tau_{ij}, d\tau_{ji})$ on welfare of country i into effects on the net benefit from consumption and on the profit balance: $\frac{dW_i}{d\boldsymbol{\tau}} = \frac{dNS_i}{d\tau_{ij}} + \frac{dPB_i}{d\boldsymbol{\tau}}$. In a two country world, the profit balance is just the bilateral profit balance. Bilaterally-reciprocal trade liberalization keeps the bilateral profit balance constant and so we have:

$$\frac{dW_i}{d\boldsymbol{\tau}} = \frac{dNS_i}{d\tau_{ij}} = -\frac{1}{[\Gamma(0)\Gamma(2)]^2}\{\Gamma(0)^2 + B(2)\tau_{ij}\}, \tag{72}$$

The net benefit from consumption is a decreasing function of country i's own tariff (consumers gain from trade liberalization) for tariff higher than $-\frac{\Gamma(0)^2}{B(2)}$ which is the internationally efficient tariff τ_E. So a bilaterally reciprocal trade liberalization starting from above the efficient tariff unambiguously increases welfare of country i until countries reach efficiency.

Proof of Lemma 5. From (4), for $j \neq l$, $\frac{dq_{il}}{d\tau_{ij}} = \frac{\gamma}{\Gamma(0)\Gamma(n)} > 0$.

Proof of Proposition 5. The effect on welfare of a trade liberalization following the principles of reciprocity and non-discrimination can again be decomposed into the effect on the net benefit from consumption and on the multilateral profit balance. The multilateral profit balance is kept constant by the principles of reciprocity and non-discrimination

[37] See for example Furusawa and Konishi (2004) for a general derivation of this decomposition for quasi-linear economies.

and so we have similarly to the two-country world case (see equation (72)):

$$\frac{dW_i}{d\boldsymbol{\tau}} = \frac{dNS_i}{d\tau_i} = -\frac{n-1}{[\Gamma(0)\Gamma(n)]^2}\left[\Gamma(0)^2 + B(n)\tau_i\right].$$

The effect of the liberalization on welfare of country i is the effect of the reduction in country i's own tariff on the net benefit from consumption. The net benefit from consumption is again a decreasing function of country i's own tariff, for tariff higher than $-\frac{\Gamma(0)^2}{B(2)}$ which is the internationally efficient tariff τ_E. So a trade liberalization following the principles of reciprocity and non-discrimination, starting from above the efficient tariff, unambiguously increases welfare of country i until countries reach efficiency.

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