Trade Policy under Monopolistic Competition with Firm Selection*

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April 30, 2015

Abstract

We analyze trade policy in a symmetric, two-country version of the Melitz-Ottaviano (2008) model. Our characterizations are influenced by three driving forces corresponding to the selection effect, the firm-delocation effect, and the entry-externality effect. Starting at global free trade, we show that a country gains from the introduction of (1) a small import tariff; (2) a small export subsidy, if transportation costs are low and the dispersion of productivities is high; and (3) an appropriately combined small increase in its import and export tariffs. The welfare of its trading partner, however, falls in each of these three cases. We also offer characterizations of efficient and Nash trade policies. We find that global free trade is generally not efficient, even within the class of symmetric trade policies; and we establish that the import tariff exceeds the export tariff in a symmetric Nash equilibrium. We also provide conditions under which efficient symmetric trade policies entail a total tariff that is positive but below that in a symmetric Nash equilibrium; and we show that, starting at the symmetric Nash equilibrium, countries can mutually gain by exchanging small reductions in import tariffs, export tariffs or combinations thereof.

1 Introduction

A large literature now exists that analyzes the economics of trade agreements.[1] As Bagwell and Staiger (1999, 2002) argue, in the standard competitive framework, the purpose of a

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[1]For recent surveys, see Bagwell and Staiger (2010) and Maggi (2014).

trade agreement is to facilitate an escape from a terms-of-trade driven Prisoners' Dilemma problem. This framework offers interpretations for GATT/WTO negotiations that lower tariff caps as well as for other key GATT/WTO design features.[2] The standard terms-of-trade approach to trade agreements, however, does not provide an easy interpretation for the WTO's strong restrictions on export subsidies. In addition, despite the explosion of research on gains from trade in heterogeneous-firms models, only a small literature as yet has analyzed trade policies in such models.[3] Motivated by these and other considerations, we analyze trade policies in the heterogeneous-firms model of Melitz and Ottaviano (2008). Among other findings, we identify conditions under which countries have unilateral incentives to introduce beggar-thy-neighbor export subsidies.

While export subsidies were treated in a fairly permissive manner under GATT rules, they are banned (with certain exceptions) in the WTO. By contrast, WTO member countries are free to impose positive (non-discriminatory) import tariffs that do not exceed their respective negotiated tariff caps. From the perspective of the standard terms-of-trade model, the relatively severe treatment of export subsidies in the WTO is puzzling. A higher import tariff typically generates a negative terms-of-trade externality for a country's trading partner, whereas a higher export subsidy normally provides the partner with a positive terms-of-trade externality. Indeed, the standard terms-of-trade model suggests that governments with political-economic objectives "under-supply" export subsidies in comparison to the level that would be efficient from their joint perspective. This implication contrasts sharply with the WTO's prohibition of export subsidies, indicating either that the rules on export subsidies are too severe or that the standard theory is missing something important. In this context, it is of particular interest to explore any new implications that heterogeneous-firms models may provide as regards the use and treatment of export subsidies.

We consider a symmetric, two-country version of the Melitz-Ottaviano model, which we modify slightly to include ad valorem import and export tariffs. In this model, firms observe trade policies, decide whether or not to incur the fixed cost associated with entry, observe their productivity realizations, and engage in monopolistic competition. Consumer preferences are described by a quadratic utility function that is defined over a continuum of varieties and that exhibits "love of variety." A homogeneous outside good enters linearly into the utility function and serves as a numeraire good. The two markets are segmented, and a firm that locates in one market incurs an iceberg trade cost when exporting to the other

[2] For broadly related analyses with imperfectly competitive markets and homogeneous firms, see Bagwell and Staiger (2012a,b, forthcoming) and Ossa (2011). We discuss Bagwell and Staiger (2012b) in greater detail below.

[3] See Melitz and Redding (2014) for a recent survey of the literature on heterogeneous-firms models of trade. Research that analyzes trade policies from this perspective is discussed below.

market. As Melitz and Ottaviano show, a reduction in trade costs impacts the selection of firms into the domestic and export markets. The least productive firms are forced to exit, average mark-ups fall, and product variety increases. To analyze trade policies in this framework, we allow that trade costs may also take the form of import and export tariffs. Unlike reductions in the costs of transportation, for example, reductions in tariffs have tariff-revenue implications and also impact welfare through this channel. We assume that tariff revenue is re-distributed to consumers in a lump-sum fashion.

To interpret our findings, we highlight three driving forces in the model. The first effect is a *selection effect*: an increase in the total tariff along a given direction of trade from country h to country l, whether achieved via an increase in country l's import tariff or in country h's export tariff, results in a lower critical cut-off cost level for domestic sales in country l and an increase in the critical cut-off cost level for domestic sales in country h. The second and related effect is a *firm-delocation effect*: an increase in country l's import tariff or in country h's export tariff likewise leads to an increase in the number of entrants into country l, a decrease in the number of entrants into country h, an increase in the number of varieties sold in country l, and a decrease in the number of varieties sold in country h. An important implication of these findings is that the model generates a *Metzler Paradox*: an increase in country l's import tariff or in country h's export tariff results in a decrease in the average price in country l and an increase in the average price in country h.[4] Finally, for the closed-economy version of the model, we decompose the externalities that would be generated were a social planner to raise entry beyond the level provided by the market. The *entry-externality effect* from additional entry derives in expectation from the direct consumer surplus gain from a new variety, the consumer surplus loss on pre-existing varieties, the benefit of an increase in the number of varieties, and a business-stealing effect. We sign each of these components and find that the sign of the net externality is determined by a simple relationship among model parameters, with a negative (positive) externality existing if and only if a demand parameter α is above (below) a critical level, where α impacts the substitution level between the differentiated varieties and the numeraire.

After highlighting these forces, we turn to the paper's primary focus and derive several trade-policy results. To assess changes in trade policy, we assume that each country evaluates trade policies from the perspective of its national welfare, which in this model is summarized by the consumer surplus enjoyed on the differentiated-goods sector plus income, where trade policy influences income by generating tariff revenue or subsidy expenses. The model entails

[4] We highlight the selection and firm-delocation effects in order to derive and interpret our trade-policy findings. These effects are originally derived by Melitz and Ottaviano in the context of their analysis of the consequences of unilateral reductions in trade costs (e.g., transportation costs). See Section 4 of their paper.

free entry, and so profits do not enter into the country's welfare function.

For our first set of results, we assume that countries start at global free trade, and we consider the implications of small trade-policy changes from this starting point. We first show that a country can gain by imposing a small import tariff, since it thereby generates both a lower average domestic price (Metzler paradox) and tariff revenue. Second, we also identify conditions under which a country can gain by imposing a small export subsidy, again from the initial situation of global free trade. A country contemplating the introduction of a small export subsidy faces a tradeoff: an export subsidy generates entry and lowers the average price in the intervening country, but it also gives rise to a subsidy expense. We find that the intervening country gains from the introduction of a small export subsidy if selection effects are strong in that transportation costs are small and the dispersion of productivity is high. A small export subsidy also can be attractive when selection effects are weak if in addition the demand parameter α that describes the relative appeal of the differentiated-goods sector is not too high. Third, starting from global free trade, we show that a country can gain by introducing a small import tariff and export tariff, where the tariffs are calibrated to keep the domestic cut-off cost level, and thus the average price in the domestic market, constant. This intervention maintains a constant domestic consumer surplus for the differentiated-goods sector while also generating tariff revenue (on both imports and exports).

All three of the described interventions are beggar-thy-neighbor interventions: starting at global free trade, when a country introduces a small import tariff, a small export subsidy, or combined small import and export tariffs of the described kind, its trading partner experiences a reduction in welfare. While the unilateral appeal of a small export subsidy is dependent upon model parameters, the negative international externality that is associated with such a policy is not. The key point is that all of the described policy interventions raise the critical cut-off cost level in the foreign country and thus increase the average price in this country, which in turn drives down foreign consumer surplus.

These findings support a relationship between key trade cost and dispersion parameters in the heterogeneous-firms literature and the nature of optimal trade-policy interventions. Our export-subsidy findings, under which a country may gain from the introduction of a small export subsidy that harms its trading partner, are perhaps of greatest interest. In the model considered here, a country has incentive to introduce such a policy when transportation costs are low and productivity dispersion is great, a setting which may be more likely in the current era and perhaps for some sectors more than others. Our findings for export subsidies also offer a partial perspective on the WTO's prohibition of export subsidies. To the extent that governments use trade agreements to limit the scope in the long run for beggar-thy-neighbor policies, our findings suggest that restrictions on export subsidies could be attractive once governments have achieved through preceding negotiations an outcome that is sufficiently close to global free trade.

We also consider the efficiency (i.e., joint welfare) effect of small policy interventions starting from global free trade. We find that a small and symmetric increase in the total tariff raises joint welfare if and only if the entry-externality effect is negative at free trade, indicating that the market provides excessive entry. Thus, if the market provides excessive entry under free trade, then a restriction on the introduction of small export subsidies would be efficiency enhancing, at least once countries get sufficiently close to free trade. In this case, however, the model does not provide an efficiency rationale for bindings on import tariffs that prevent the introduction of small import tariffs. There also exists one constellation of parameter values under which the introduction of a small policy intervention of any kind does not generate an efficiency gain. This case rationalizes limits on import tariffs and export subsidies but is a special case.

We offer as well a characterization of Nash policies. The characterization of Nash policies is more complicated than is the characterization of optimal small-policy interventions starting at global free trade, since an evaluation of a marginal tariff change starting at a non-zero tariff level requires consideration of the tariff-revenue impacts that are generated through the resulting changes in the value of trade. At symmetric policies, a small increase in a country's import tariff lowers the value of its imports and raises the value of its exports, with the opposite patterns being associated with an increase in a country's export tariff, and any small tariff increase also lowers the total value of trade. Drawing on these relationships, we show that, in a symmetric Nash equilibrium satisfying first-order conditions, the import policy must be more restrictive than the export policy (e.g., if both tariffs are positive, then the Nash import tariff is the higher of the two).

Finally, we analyze liberalization paths from Nash policies. When the entry-externality effect is negative at free trade, so that entry is excessive, and the total tariff under symmetric Nash policies is positive, we report conditions under which the efficient symmetric total tariff is positive but below that in the symmetric Nash equilibrium. We further find that, starting at the symmetric Nash equilibrium, countries can mutually gain by exchanging small reductions in import tariffs, export tariffs or combinations thereof. Our findings here thus provide an interpretation for why early GATT rounds emphasized negotiated reductions in import tariffs but not reductions in export subsidies.

We also present a numerical example that illustrates our findings as well as the possibility that the Nash import and export tariffs are both positive. This possibility can be understood in terms of our third finding mentioned above about unilateral trade-policy interventions (under which a country gains from an appropriate combined increase in its import and export tariffs, starting at global free trade).

Related Work Our work is related to previous work. Venables (1985) considers trade policies in an endogenous-entry model with segmented markets and Cournot competition. He establishes firm-delocation effects and a Metzler paradox in this model, and he further shows that a country gains from the introduction of a small import tariff or a small export subsidy, where the optimality of the latter intervention is more qualified (due to the tradeoff between consumer-surplus benefits and subsidy expenses) but holds for a linear-demand setting. Bagwell and Staiger (2012b) further analyze the Venables (1985) delocation model. Under the assumption of linear demand, they show that total tariffs that deliver free trade are efficient in the symmetric class, and they develop for this model unilateral trade-policy results that parallel the three results mentioned above.[5] They also develop related findings regarding liberalization paths from the symmetric Nash equilibrium; and they show as well that any symmetric interior Nash equilibrium entails positive import and export tariffs, where the import tariff is the higher of the two.

Relative to these papers, our contribution is to characterize unilateral, symmetric Nash and efficient symmetric policies in a model with monopolistic competition and heterogeneous firms. Our work thereby forges a link between the incentives for strategic and beggar-thy-neighbor export subsidy policies on the one hand and parameters related to product differentiation, transportation costs and productivity dispersion on the other hand. Further, since global free trade is not generally efficient in the model that we consider, a simultaneous ban on export subsidies and import tariffs receives less support in this model than in the linear Cournot delocation model that Bagwell and Staiger (2012b) analyze.

Venables (1987) is also related. In a homogeneous-firms model with monopolistic competition and CES preferences, he establishes that the introduction of a small import tariff can increase welfare in the intervening country, by expanding varieties and thereby generating a fall in the domestic price index.[6] In the heterogeneous-firms model analyzed here, by contrast, selection effects also exist, mark-ups are not constant, and the introduction of a small import tariff lowers the average price.

We develop our analysis of the entry-externality effect primarily as a means of interpreting our trade-policy results, but the analysis also relates in some ways to recent work by Dhingra and Morrow (2014) and Nocco, Ottaviano and Salto (2014). For a family of monopolistic

[5]With respect to findings for unilateral trade policies, one difference is that Bagwell and Staiger (2012b) do not establish for the linear Cournot delocation model that the introduction of a small import and export tariff results in a decrease in the trading partner's welfare.

[6]For a discussion of related work, see Helpman and Krugman (1989). See Bagwell and Staiger (forthcoming) and Ossa (2011) for more recent related work.

competition models with heterogeneous firms and additively separable preferences and no outside good, Dhingra and Morrow show that the market outcome with CES preferences is first best, where a first-best planner selects the number of entrants, quantities and the types of firms that produce. They also characterize the allocative inefficiencies that arise under other preferences. By comparison, we conduct our analysis in the context of the Melitz-Ottaviano model, wherein preferences are not additively separable and an outside good exists. In our analysis of the entry-externality effect, we also consider a second-best scenario, in which the social planner directly controls only the number of entrants.[7]

Nocco, Ottaviano and Salto offer an extensive analysis of the efficiency properties of the market outcome in the Melitz-Ottaviano model. They characterize the equilibrium and first-best outcomes and, among other results, show that the market equilibrium level of entry is above (below) that in the first-best allocation if the demand parameter α is higher (lower) than a critical level. As they show, the first-best outcome can be decentralized through firm-specific per-unit production subsidies accompanied by a lump-sum entry tax per entrant and a lump-sum tax on consumers. They also consider a second-best scenario that arises when any per-unit (i.e., specific) production subsidy must be offered to all firms and financed by a lump-sum tax on consumers. The second-best level of entry exceeds that provided by the market. Our analysis of the entry-externality effect is related but can be understood as a different second-best scenario in which production subsidies are unavailable and lump-sum transfers between consumers and firms can be used to subsidize or tax the fixed cost of entry.

A few other papers also consider trade-policy implications in heterogeneous-firms models. Building on the Melitz (2003) model, Demidova and Rodriguez-Clare (2009), Felbermayr, Jung and Larch (2013) and Haaland and Venables (2014) analyze trade policies when firms are heterogeneous and preferences are CES. Demidova and Rodriguez-Clare focus on a small-country version of the model and find that the optimal unilateral export policy in this context is an export tariff. Haaland and Venables analyze optimal unilateral trade and domestic taxes for a larger family of small-country models. Finally, Felbermayr, Jung and Larch allow for large countries and characterize a link between the level of Nash import tariffs and parameters related to transportation costs and productivity dispersion. In comparison, we study unilateral, Nash and efficient trade policies in a large-country model with quadratic preferences, where mark-ups are endogenous.

Other recent work examines trade policy while building on the Melitz-Ottaviano model. Spearot (2014) enriches that model to allow for heterogeneous dispersion parameters across countries. Among other results, he provides conditions under which a higher import tariff

[7] In the setting that we consider, we could equivalently let the planner directly choose the critical cut-off cost level, which is one-to-one with the number of entrants and the number of varieties, respectively.

increases competition in the domestic market.[8] Spearot (2015) further develops this analysis by considering a multi-sector, multi-country model with heterogeneous dispersion parameters, in which the outside good is removed. He estimates shape parameters and provides counterfactual analyses of several trade-policy shocks. Finally, Demidova (2015) characterizes optimal unilateral import tariffs for small and large countries when the outside good is removed from the Melitz-Ottaviano model. She finds that the Metzler paradox then no longer holds, and she shows that the resulting optimal tariffs are positive for both small and large countries.[9] Our work is complementary to this recent work. Like a large body of existing trade-policy research, we use an outside good to eliminate the general-equilibrium wage effects associated with trade-policy changes. This approach seems reasonable, for example, when analyzing import or export policies for specific sectors, such as is often the case in WTO disputes. Using the additional tractability that this approach offers, we characterize unilateral, Nash and efficient import and export policies, as well as liberalization paths.

Finally, a large literature exists that analyzes strategic roles for trade policies when profits exist and can be shifted across firms. See Brander (1995) for a survey and Amador and Bagwell (2013), Bagwell and Staiger (2012a), DeRemer (2013), Etro (2011), Mrazova (2011) and Ossa (2012) for recent contributions of this kind. By contrast, our analysis here considers trade policies in a setting with free entry and zero expected profits in both countries. We also allow for heterogeneous firms.

The paper is organized as follows. Section 2 presents a symmetric, two-country version of the Melitz-Ottaviano model, modified slightly to include tariffs. Section 3 highlights the driving forces that emerge from this model and inform our subsequent trade-policy analysis. Our three findings for unilateral trade-policy interventions are presented in Section 4, while our characterizations of efficient and Nash trade policies are contained in Section 5. Section 6 concludes. The Appendix contains remaining proofs.

2 Model

We develop our tariff analysis in the context of a symmetric, two-country version of the Melitz and Ottaviano (2008) model. There are two symmetric countries, home (H) and

[8] See Spearot (2013) for an empirical analysis of the implications of the Melitz-Ottaviano model in response to tariff liberalizations. Chen, Imbs and Scott (2009) also offer empirical support for predictions of the Melitz-Ottaviano model.

[9] The optimal unilateral tariff is higher for a large country, due to the terms-of-trade externality. In our (large-country) model, an import tariff also generates a terms-of-trade gain for the intervening country, and indeed the Metzler paradox acts to reinforce this gain. The terms-of-trade implications of export policies in our model are more novel, since an export subsidy results in a terms-of-trade gain for the exporting country. See Bagwell and Staiger (2012b, forthcoming) for related discussion and also our footnote 33 below.

foreign (F). The markets are segmented, and international trade entails trade costs that take the form of transportation costs as well as ad valorem export and import tariffs. The key difference between our setup and that of Melitz and Ottaviano is that we include import and export tariffs. We present the model with this modest adjustment in order to provide expressions that facilitate our analysis of tariff policies in subsequent sections.

2.1 Setup

We begin by describing the basic features of the model.

Consumer Behavior Each country has a unit mass of consumers. Consumer preferences are defined over a continuum of differentiated varieties and a numeraire good. All consumers in country $l \in \{H, F\}$ share the same preferences given by

$$U^l \equiv \max_{\left\{q_0^l, \left\{q_i^l\right\}_{i\in\Omega^l}\right\}} \left[q_0^l + \alpha \int_{i\in\Omega^l} q_i^l d_i - \frac{1}{2}\gamma \int_{i\in\Omega^l} \left(q_i^l\right)^2 di - \frac{1}{2}\eta \left(\int_{i\in\Omega^l} q_i^l d_i \right)^2 \right] \tag{1}$$

s.t.

$$q_0^l + \int_{i\in\Omega^l} p_i^l q_i^l d_i \leq w^l + TR^l + \Pi^l \equiv I^l$$

where q_0^l, q_i^l, and p_i^l represent the consumption of the numeraire good in country l, the consumption of differentiated good $i \in \Omega^l$ in country l, and the price of differentiated good i in country l. The set Ω^l represents a continuum of varieties that are potentially available for consumption in country l.[10] Consumer income consists of a numeraire-good holding w^l, aggregate profit Π^l, and government transfers TR^l. We discuss the determinants of consumer income, I^l, in greater detail below.

The preference parameters α, γ, and η are all positive. The parameters α and η capture the substitution level between the differentiated varieties and the numeraire, while the parameter γ measures the degree of product differentiation within the set of differentiated varieties. For example, in the limiting case where $\gamma = 0$, a consumer's preferences regarding the differentiated varieties are completely summarized by the aggregate consumption of these varieties: $Q^l \equiv \left(\int_{i\in\Omega^l} q_i^l d_i\right)$.

Following Melitz and Ottaviano, we assume that the numeraire good is consumed ($q_0^l > 0$) and proceed to derive the inverse demand for variety i as $p_i^l = \alpha - \eta Q^l - \gamma q_i^l$ for $i \in \Omega^{*l}$ where $\Omega^{*l} \subset \Omega^l$ denotes the set of varieties for which $q_i^l > 0$. The intercept for the demand for variety i is thus $\alpha - \eta Q^l$. We may now integrate over the corresponding demand functions

[10] Such varieties may be produced domestically or imported.

$q_i^l = (\alpha - \eta Q^l - p_i^l)/\gamma$ to express Q^l in terms of the average price and the measure N^l of consumed varieties in Ω^{*l}. Proceeding in this way yields

$$q_i^l = (p_{\max}^l - p_i^l)\frac{1}{\gamma} \text{ for } i \in \Omega^{*l} \tag{2}$$

where

$$p_{\max}^l \equiv \frac{\alpha\gamma + \eta N^l \overline{p}^l}{\gamma + \eta N^l} \tag{3}$$

defines the key demand intercept term and where

$$\overline{p}^l \equiv (\int_{i\in\Omega^{*l}} p_i^l di)(\frac{1}{N^l}) \tag{4}$$

is the average price of a consumed variety in country l. It is now evident that the set Ω^{*l} is defined as the largest subset of Ω^l for which $p_i^l \leq p_{\max}^l$. Notice that $\alpha \geq p_{\max}^l$ if and only if $\alpha \geq \overline{p}^l$.

To evaluate welfare, we require a representation of indirect utility. As Melitz and Ottaviano show, the indirect utility function takes the following convenient form:

$$U^l = I^l + \frac{1}{2}(\eta + \frac{\gamma}{N^l})^{-1}(\alpha - \overline{p}^l)^2 + \frac{1}{2}\frac{N^l}{\gamma}\sigma_{p^l}^2, \tag{5}$$

where

$$\sigma_{p^l}^2 \equiv \frac{1}{N^l}\int_{i\in\Omega^{*l}} (p_i^l - \overline{p}^l)^2 di \tag{6}$$

and where we recall also the assumption that the numeraire good is consumed: $q_0^l > 0$. This assumption in turn holds if and only if

$$I^l > \int_{i\in\Omega^{*l}} p_i^l q_i^l di = \overline{p}^l Q^l - N^l \sigma_{p^l}^2 \frac{1}{\gamma}, \tag{7}$$

where Q^l is calculated using (2). We also define consumer surplus in this setting as follows:

$$CS^l \equiv U^l - I^l, \tag{8}$$

and we note that consumer surplus is higher when the average price is lower, the variance of prices is higher, and the level of product variety is higher, where it is understood that we hold other terms constant when increasing any one term.

Firm Behavior Production in this economy utilizes labor, which is the only factor. Labor is supplied in an inelastic fashion in a competitive labor market. As is standard, labor can be used to produce the numeraire good under constant returns to scale in a one-to-one manner, where the numeraire good is sold in a competitive market. We thus set the wage in each country equal to one: $w^l = 1$. In the differentiated-variety sector, each variety $i \in \Omega^l$ is produced by a monopolistically competitive firm. To enter the market, a firm pays a fixed cost $f_e > 0$ and draws its marginal production cost c_i, which indicates the unit labor requirement. The cost c_i is drawn from a Pareto distribution with c.d.f.

$$G(c_i) = (c_i/c_M)^k,$$

where $k > 1$ represents a shape parameter and $c_M > 0$ represents the upper bound of c_i. The parameter k is important and determines the dispersion of productivity. Higher dispersion corresponds to a lower value for k. For example, in the limit where $k = \infty$, every firm has the same marginal cost c_M. Likewise, in the limiting case where $k = 1$, the level of dispersion is maximized and c_i follows a uniform distribution.

Depending on its productivity draw, a firm that enters country l may exit, produce only in country l, or produce in country l and also export to country h, where $h \in \{H, F\}$ and $h \neq l$.[11] Following Melitz and Ottaviano, we assume that markets are segmented and that firms engage in monopolistic competition in each market. Thus, a firm makes separate decisions about its domestic and export prices, and each firm takes as given the number of firms and the average price in a market when selecting its price for that market.

Consider first the domestic market. A firm located in country l with cost level c selects its price in the domestic market, p_D^l, to maximize domestic-market profit, $(p_D^l - c)(p_{\max}^l - p_D^l)\frac{1}{\gamma}$, where $p_{\max}^l$ is defined above in (3). Let the resulting profit-maximizing price for domestic sales be denoted as $p_D^l(c)$. Defining $q_D^l(c) \equiv (p_{\max}^l - p_D^l(c))\frac{1}{\gamma}$ and $\pi_D^l(c) \equiv (p_D^l(c) - c)q_D^l(c)$, it follows that $p_D^l(c) = \frac{p_{\max}^l + c}{2}$, $q_D^l(c) = \frac{p_{\max}^l - c}{2\gamma}$ and $\pi_D^l(c) = \frac{1}{4\gamma}(p_{\max}^l - c)^2$. Notice that $p_D^l(c) \geq c$ if and only if $p_{\max}^l \geq c$. We may define the critical cut-off cost level for sales in the domestic market, c_D^l, as

$$c_D^l \equiv p_{\max}^l, \tag{9}$$

With this definition, and following Melitz and Ottaviano, we may represent profit-maximizing

[11] Throughout, the use of index h is understood to mean the country other than country $l : h \neq l$.

domestic variables as follows:

$$p^l_D(c) = \frac{c^l_D + c}{2}, \tag{10}$$
$$q^l_D(c) = \frac{c^l_D - c}{2\gamma},$$
$$\pi^l_D(c) = \frac{1}{4\gamma}(c^l_D - c)^2,$$

for $c \leq c^l_D$. A firm with cost level c in country l sells in the domestic market if and only if $c \leq c^l_D$.

Consider next the export market. A firm located in country l with cost level c selects its (delivered) price for consumers in country h, which we denote as p^l_X, while taking as given the number of varieties sold and the average price in country h. A firm must incur an iceberg trade cost, $\tau > 1$, when selling in the export market. This trade cost, which we assume to be independent of the designation of the export market, indicates a higher cost to export sales: a firm that delivers a unit of its variety to the export market must incur the costs associated with producing $\tau > 1$ units. In addition, exported varieties are subjected to ad valorem export tariffs and import tariffs. For a variety that is exported from country l to country h, we let $\widetilde{t}^l$ and t^h respectively denote the export tariff of country l and the import tariff of country h, where a positive (negative) tariff indicates a tax (subsidy). We assume that $1 + t^h + \widetilde{t}^l > 0$.

We are now prepared to analyze profit-maximizing choices in the export market. A firm located in country l with cost level c selects its delivered export price, p^l_X, to maximize its export-market profit,

$$\left(\frac{p^l_X}{1 + t^h + \widetilde{t}^l} - \tau c\right)(p^h_{\max} - p^l_X)\frac{1}{\gamma},$$

where $p^h_{\max}$ is defined above in (3), once l is replaced with h. Let the resulting profit-maximizing price for export sales be denoted as $p^l_X(c)$, and define $q^l_X(c) \equiv (p^h_{\max} - p^l_X(c))\frac{1}{\gamma}$ and $\pi^l_X(c) \equiv (\frac{p^l_X(c)}{1+t^h+\widetilde{t}^l} - \tau c)q^l_X(c)$. The critical cut-off for sales in the export market, c^l_X, now may be defined as

$$c^l_X = \frac{p^h_{\max}}{\tau(1 + t^h + \widetilde{t}^l)} = \frac{c^h_D}{\tau(1 + t^h + \widetilde{t}^l)}. \tag{11}$$

With these definitions in place, we may represent profit-maximizing export variables as follows:

$$
\begin{aligned}
p^l_X(c) &= \tau(1+t^h+\widetilde{t}^l)(\frac{c^l_X+c}{2}), \\
q^l_X(c) &= \tau(1+t^h+\widetilde{t}^l)(\frac{c^l_X-c}{2\gamma}), \\
\pi^l_X(c) &= \tau^2(1+t^h+\widetilde{t}^l)\frac{1}{4\gamma}(c^l_X-c)^2
\end{aligned}
\tag{12}
$$

for $c \leq c^l_X$. A firm with cost level c in country l sells in the export market if and only if $c \leq c^l_X$.

Free Entry Conditions In the long run, each entrant expects zero profit. The expected profit for a firm located in country l is given as

$$\overline{\pi}^l \equiv \int_0^{c^l_D} \pi^l_D(c)dG\left(c\right) + \int_0^{c^l_X} \pi^l_X(c)dG\left(c\right). \tag{13}$$

We may thus express the free-entry conditions as two equations

$$\overline{\pi}^l = f_e \text{ for } l = H, F \tag{14}$$

which with (11) may be used to determine the cut-off levels, c^l_D and c^l_X for $l = H, F$. The domestic cut-off levels, c^l_D and c^h_D, in turn determine $p^l_{\max}$ and $p^h_{\max}$ and thus, by (3) and (4), the number of varieties sold in the domestic and export markets, N^l and N^h. From here, the number of entrants, N^l_E and N^h_E, may be determined, as confirmed below.

Following Melitz and Ottaviano, we now proceed in the described fashion and complete the solution of the model. Solving for the cut-off levels yields:

$$
\begin{aligned}
c^l_D &= [\frac{\phi\gamma(1-\rho^h)}{1-\rho^l\rho^h}]^{\frac{1}{k+2}} \\
c^l_X &= c^h_D(\frac{\rho^h}{\tau})^{\frac{1}{k+1}},
\end{aligned}
\tag{15}
$$

where

$$\phi \equiv 2(k+1)(k+2)(c_M)^k f_e > 0$$

and

$$\rho^l \equiv (\tau)^{-k}(1+t^l+\widetilde{t}^h)^{-(k+1)}. \tag{16}$$

We assume henceforth that $\rho^l \in (0,1)$.[12] Our assumptions above imply $\rho^l > 0$; thus, the new assumption is that $\rho^l < 1$.[13]

The next step is to determine the number of varieties sold in each market. To this end, we first compute $\overline{p}^l$. The expected price in country l is determined by prices from domestic firms as well as from exporters in country h. As Melitz and Ottaviano show, under the Pareto distribution, the expected price in country l from domestic producers is the same as that from foreign exporters, and takes the form:

$$\overline{p}^l = c_D^l \cdot \frac{2k+1}{2k+2}, \tag{17}$$

which indicates that a higher domestic cut-off level leads to a higher average price.[14] Substitution of (9) and (17) into (3) now yields a solution for N^l in terms of c_D^l :

$$N^l = \frac{2\gamma(\alpha - c_D^l)(k+1)}{\eta c_D^l}. \tag{18}$$

As reported in (15), the free-entry conditions yield a specific value for c_D^l, which may be plugged into (18) to determine the free-entry solution for N^l in terms of model parameters.[15]

The numbers of entrants, N_E^l, in the two countries can now be determined as the solutions to the following two equations

$$N^l = G(c_D^l)N_E^l + G(c_X^h)N_E^h, \tag{19}$$

assuming a positive mass of entrants in both countries. The solution to this system is given by

$$N_E^l = \frac{(c_M)^k}{1-\xi^l\xi^h}\left[\frac{N^l}{(c_D^l)^k} - \frac{\xi^l N^h}{(c_D^h)^k}\right]. \tag{20}$$

where $\xi^l \equiv \rho^l(1 + t^l + \widetilde{t}^h) < 1$ follows from our assumptions.[16] Substituting (18) into (20)

---

[12] We also assume throughout that $c_M > c_D^l$ for the tariffs under consideration. At global free trade, this assumption holds if and only if $c_M > [\frac{2(k+1)(k+2)f_e\gamma(1-(\tau^{-k}))}{1-(\tau)^{-2k}}]^{\frac{1}{2}}$.

[13] In a model without firm heterogeneity, Bagwell and Staiger (2012b) impose the related assumption that $\tau\left(1 + t^h + \tilde{t}^l\right) > 1$.

[14] The expected price on domestic and imported varieties can be respectively computed as

$$\frac{1}{G(c_D^l)}\int_0^{c_D^l} p_D^l(c)dG(c) = c_D^l\left[\frac{2k+1}{2(k+1)}\right] = \frac{1}{G(c_X^h)}\int_0^{c_X^h} p_X^h(c)dG(c).$$

[15] Given $\alpha > c_D^l$, the set Ω^{*l} is non-empty.

[16] Given $\rho^l < 1$, if $1 + t^l + \widetilde{t}^h \leq 1$, then $\xi^l \equiv \rho^l(1 + t^l + \widetilde{t}^h) < 1$. If instead $1 + t^l + \widetilde{t}^h > 1$, then $\xi^l \equiv \rho^l(1 + t^l + \widetilde{t}^h) = [\tau(1 + t^l + \widetilde{t}^h)]^{-k} < 1$ follows since $k > 1$, $\tau > 1$ and, by hypothesis, $1 + t^l + \widetilde{t}^h > 1$.

yields

$$N_E^l = \frac{2(k+1)(c_M)^k \gamma}{\eta[1-\xi^l \xi^h]}[\frac{\alpha - c_D^l}{(c_D^l)^{k+1}} - \frac{\xi^l(\alpha - c_D^h)}{(c_D^h)^{k+1}}] \tag{21}$$

A maintained assumption is that the trade policies under consideration are such that $N_E^l > 0$ for $l = H, F$. Given $\xi^l \in (0, 1)$, it is evident from (21) that this assumption implies $\alpha > c_D^l$ for $l = H, F$. In subsequent sections, we give particular consideration to trade policies that constitute global free trade (i.e., trade policies for which all import and export tariffs are set equal to zero). The content of our maintained assumption for this case is thus that $\alpha > c_D^{FT}$, where c_D^{FT} is the value taken by $c_D^H = c_D^F$ under global free trade.

Finally, we return to the expression for consumer welfare U^l given in (5). As indicated in (17), the Pareto distribution delivers a simple expression for $\overline{p}^l$. It is likewise true that the price variance confronted by domestic consumers is the same for varieties produced domestically as for varieties imported from abroad. The corresponding expression is

$$\sigma_{p^l}^2 = \frac{(c_D^l)^2}{4} \frac{k}{(k+1)^2(k+2)}. \tag{22}$$

Using (5), (17), (18) and (22), and following Melitz and Ottaviano, it is now possible to derive a simple expression for consumer welfare:

$$U^l = I^l + \frac{(\alpha - c_D^l)}{2\eta}[\alpha - c_D^l \frac{k+1}{k+2}]. \tag{23}$$

An immediate corollary is that consumer surplus takes the form

$$CS^l = \frac{(\alpha - c_D^l)}{2\eta}[\alpha - c_D^l \frac{k+1}{k+2}]. \tag{24}$$

Tariff Revenue In the model described above, consumer income is comprised of a unit of labor income, profits and tariff revenue. We have already discussed labor income; furthermore, in a free-entry equilibrium, expected profits are zero. The remaining income source to consider is thus tariff revenue.

To define import tariff revenue, we first define the pre-tax value of imports into country l from country h:

$$IMP^l = N_E^h \int_0^{c_X^h} \frac{p_X^h(c)}{1 + t^l + \widetilde{t}^h} q_X^h(c) dG(c).$$

Using (11), (16) and (12), we may substitute and derive that

$$IMP^l = N_E^h \frac{\rho^l (c_D^l)^{k+2}}{2\gamma(k+2)(c_M)^k}. \tag{25}$$

Import tariff revenue for country l is then $t^l \cdot IMP^l$.

In analogous fashion, we may define the pre-tax value of exports from country l to country h as

$$EXP^l = N_E^l \int_0^{c_X^l} \frac{p_X^l(c)}{1+t^h+\widetilde{t}^l} q_X^l(c) dG(c) .$$

Using (11), (16) and (12), we may substitute and derive that

$$EXP^l = N_E^l \frac{\rho^h (c_D^h)^{k+2}}{2\gamma(k+2)(c_M)^k}. \tag{26}$$

Export tariff revenue for country l is then $\widetilde{t}^l \cdot EXP^l$.

Welfare We are now prepared to define the welfare function that a national-income maximizing government would seek to maximize. This is the welfare function against which we will evaluate trade-policy interventions, and it is defined as

$$U^l = 1 + t^l \cdot IMP^l + \widetilde{t}^l \cdot EXP^l + \frac{(\alpha - c_D^l)}{2\eta}[\alpha - c_D^l \frac{k+1}{k+2}], \tag{27}$$

where we recall from (24) that the last term equals consumer surplus, CS^l. The indirect utility function in (27) takes the same form as that derived by Melitz and Ottaviano, except that we include tariff revenue as a source of consumer income. We notice that tariffs affect tariff revenue and thereby consumer income both directly and also indirectly through the induced long-run impact on trade values, IMP^l and EXP^l.

With the model now defined, we are prepared to consider the welfare impacts of trade policy. We preform this analysis in the next three sections. Throughout, we maintain the assumption that any trade policies under consideration are such that the model assumptions presented above are satisfied.

3 Driving Forces

For our purposes, the model has three main driving forces: the selection effect, the firm-delocation effect, and the entry-externality effect. In this section, we briefly highlight some key features of the model that are associated with these forces. We note that Melitz and Ottaviano also derive the selection and firm-delocation effects as part of their analysis of the consequences of unilateral reductions in trade costs (e.g., transportation costs). We briefly highlight these effects here in order to derive and interpret our trade-policy findings in subsequent sections.

3.1 Selection Effect

In the heterogeneous-firms model considered here, trade policy affects both the number and the efficiency of entering firms. A higher import tariff increases the number of entrants and generates a higher level of competition, so that firms must be more efficient to survive. In particular, a higher home import tariff (or a higher foreign export tariff) lowers the critical cut-off cost level for domestic sales in the home market and raises the critical cut-off cost level for domestic sales in the foreign market. We now summarize this discussion in a proposition.

Proposition 1 *(Selection effect) For countries l and h with $l, h \in \{H, F\}$ and $l \neq h$, an increase in country l's import tariff or in country h's export tariff results in a decrease in the critical cut-off cost level for sales in country l's domestic market and in an increase in the critical cut-off cost level for sales in country h's domestic market:*

$$\frac{\partial c_D^l}{\partial t^l} = \frac{\partial c_D^l}{\partial \tilde{t}^h} < 0 < \frac{\partial c_D^h}{\partial t^l} = \frac{\partial c_D^h}{\partial \tilde{t}^h}.$$

Proof. *Proofs are in the Appendix.* ■

Note that the impact of a change in the home import tariff and foreign export tariff are symmetric in this context, since firm profits are impacted only by the total tariff along a given trade channel.

3.2 Firm-delocation Effect and the Metzler Paradox

We now consider in more detail the impact of trade policy on the number of firms. Intuitively, an increase in the home import tariff makes it harder for foreign firms to export. As a result, the expected profit for home firms increases, and the expected profit for foreign firms decreases. To satisfy the free-entry conditions, the number of home entrants increases and the number of foreign entrants decreases, and the number of surviving varieties similarly increases in the home country and decreases in the foreign country. In this sense, a home import tariff "delocates" firms from the foreign country to the home country. A similar logic holds when the home country lowers its export tariff or equivalently increases its export subsidy. The following proposition summarizes this discussion:[17]

Proposition 2 *(Firm-delocation effect) For countries l and h with $l, h \in \{H, F\}$ and $l \neq h$, an increase in country l's import tariff or in country h's export tariff results in an increase*

[17] In Proposition 2, we express the effects of tariff changes on N_E^l and N^l using total derivatives, since N_E^l depends on tariffs directly and also indirectly through c_D^l and c_D^h, while N^l depends on tariffs through c_D^l.

in the number of entrants in country l, a decrease in the number of entrants in country h, an increase in the number of varieties sold in country l, and a decrease in the number of varieties sold in country h:

$$\frac{dN_E^l}{dt^l} = \frac{dN_E^l}{d\tilde{t}^h} > 0 > \frac{dN_E^h}{dt^l} = \frac{dN_E^h}{d\tilde{t}^h}$$
$$\frac{dN^l}{dt^l} = \frac{dN^l}{d\tilde{t}^h} > 0 > \frac{dN^h}{dt^l} = \frac{dN^h}{d\tilde{t}^h}$$

We consider next the implications of trade policy for average prices. In fact, the firm-delocation effect is strong enough in this model to generate a Metzler paradox. As Proposition 2 establishes, a higher home import tariff (or a higher foreign export tariff) increases the number of entering firms in the domestic market and ultimately results in a higher number of surviving firms selling in this market. A higher home import tariff thus results in a reduction in the critical cut-off cost level for sales in the domestic market, which by (17) implies in turn that the average price in the home market falls. A similar logic indicates that a higher home import tariff causes the average price in the foreign market to rise.[18]

Proposition 3 *(Metzler paradox) For countries l and h with $l, h \in \{H, F\}$ and $l \neq h$, an increase in country l's import tariff or in country h's export tariff results in a decrease in the average price in country l and an increase in the average price in country h:*

$$\frac{d\bar{p}^l}{dt^l} = \frac{d\bar{p}^l}{d\tilde{t}^h} < 0 < \frac{d\bar{p}^h}{dt^l} = \frac{d\bar{p}^h}{d\tilde{t}^h}$$

As noted in the Introduction, the Metzler paradox is a driving force in other models of trade policy, too, including the homogeneous-firms Cournot model used by Venables (1985) and Bagwell and Staiger (2012b).

3.3 Entry-externality Effect

An important consideration in characterizing efficient trade policies is whether the market is distorted in the absence of trade-policy interventions. We thus now consider the externalities associated with entry in the Melitz-Ottaviano model. In particular, our approach is to decompose the difference between the market and socially optimal entry levels so that we can intuitively explain the source of any market failure. This work provides a context in which to interpret subsequent results in our trade-policy analysis.

[18] In Proposition 3, we again use total derivatives, since $\bar{p}^l$ depends on tariffs indirectly through c_D^l.

Before we characterize the externalities associated with entry, we recall from (23) that consumer welfare is determined as the sum of income and consumer surplus:

$$U^l = I^l + \frac{(\alpha - c_D^l)}{2\eta}[\alpha - c_D^l \frac{k+1}{k+2}],$$

where this expression holds for any N^l and not just the value determined in the market equilibrium. In the market equilibrium, the free-entry conditions ($\bar{\pi}^l = f_e$ for $l \in \{H, F\}$) determine the entry level. The marginal entrant, however, does not consider the external effect of its entry decision on consumer welfare, and so the entry level in the market equilibrium need not coincide with the socially optimal entry level.

In order to decompose and clarify the externalities associated with entry, we consider a simple closed-economy setting. As Melitz and Ottaviano show, consumer surplus takes the same form in the closed-economy setting:

$$CS \equiv \frac{(\alpha - c_D)}{2\eta}[\alpha - c_D \frac{k+1}{k+2}], \tag{28}$$

where c_D denotes the critical cut-off cost level for the closed-economy model. We may now define

$$\bar{\pi} \equiv \int_0^{c_D} \pi_D(c) dG(c),$$

where $\pi_D(c) = \frac{1}{4\gamma}(c_D - c)^2$, and we likewise require that the number of entrants, N_E, and the number of surviving varieties, N, for the closed-economy setting satisfy $N = G(c_D)N_E$ and $N = 2\gamma(\alpha - c_D)(k+1)/(\eta c_D)$.

We now consider the problem of a social planner who selects the level of entry N_E in a closed economy with the objective:

$$\max_{N_E} CS + N_E (\bar{\pi} - f_e). \tag{29}$$

In this exercise, the social planner chooses the number of entrants N_E to maximize consumers' welfare, which is the sum of consumer surplus and aggregate profit $\Pi \equiv N_E (\bar{\pi} - f_e)$. Given the relationships just described, when the planner selects N_E, choices for c_D and N are implied and values for CS and $\bar{\pi}$ thus follow. We note that a change in the number of entrants could be implemented in a decentralized setting by using lump-sum transfers between consumers and firms so as to subsidize or tax the fixed costs of entry.[19]

[19] If the planner sought to decrease N_E below the market equilibrium level, then a per-entrant and lump-sum entry tax $T_E > 0$ could be imposed, so that entry would occur until $\bar{\pi} - f_e - T_E = 0$. Consumers would enjoy additional income of $N_E(\bar{\pi} - f_e)$ once the tax is redistributed. A lump sum subsidy to entry is similar

For the utility function (1) used by Melitz and Ottaviano, we can rewrite consumer surplus as follows:

$$CS = \int_{i\in\Omega} \frac{\gamma}{2} (q_i^*)^2 \, di + \frac{\eta}{2} \left(\int_{i\in\Omega} q_i^* di \right)^2 \tag{30}$$

where $q_i^* = (p_{\max} - p_i)/\gamma$ is the optimized consumption level for variety i at price p_i, given the number of entrants. An interesting feature is that $\frac{\gamma}{2} (q_i^*)^2$ corresponds to the triangular region under the demand curve for variety i and thus represents consumer surplus at variety i. The first term in (30) is thus the sum of consumer surplus at each variety; hence, the second term in (30) should be explained by variety effects.

Based on this understanding, and after allowing for profit-maximizing pricing by firms, we may represent consumer surplus as follows:

$$CS = N_E \cdot \overline{CS} + VE$$

where

$$\overline{CS} = \int_0^{c_D} \frac{\gamma}{2} (q_D(c))^2 \, dG(c) \tag{31}$$

represents expected consumer surplus at single varieties and $q_D(c) = (c_D - c)/(2\gamma)$. For a given value of c_D, the variety effect, VE, is then defined as the difference between CS as given in (30) and $N_E \cdot \overline{CS}$ with $\overline{CS}$ given by (31). As noted above, by choosing N_E, the planner effectively chooses c_D and N, and so values for CS, $\overline{CS}$, VE, $\bar{\pi}$ and Π follow.

The socially optimal N_E^* maximizes utility as defined in (29). The first-order condition takes the following form:

$$\overline{CS} + N_E \frac{d\overline{CS}}{dN_E} + \frac{dVE}{dN_E} + N_E \frac{d\bar{\pi}}{dN_E} + \bar{\pi} - f_e = 0$$

By contrast, the market determines the entry level to satisfy $\bar{\pi} = f_e$. We thus define the externalities that a market economy does not consider as follows:

$$EXT = \overline{CS} + \frac{dVE}{dN_E} + N_E \frac{d\overline{CS}}{dN_E} + N_E \frac{d\bar{\pi}}{dN_E} \tag{32}$$

where in expectation $\overline{CS} > 0$ represents the direct consumer surplus gain from a new variety, $\frac{dVE}{dN_E} > 0$ represents the beneficial variety effect from a new entrant, $N_E \frac{d\overline{CS}}{dN_E} < 0$ represents a substitution effect (i.e., the consumer surplus losses on pre-existing varieties when additional entry occurs), and $N_E \frac{d\bar{\pi}}{dN_E} < 0$ represents a business-stealing effect.

In the Appendix, we derive and sign all of the terms in (32) and establish the following

except that $T_E < 0$ and so consumers provide a lump-sum redistribution to entrants.

proposition:

Proposition 4 *(Entry-externality effect) Starting at the market equilibrium, additional entry generates a negative externality if and only if $\alpha > 2 \cdot c_D^m$; that is,*

$$EXT < 0 \text{ if and only if } \alpha > 2 \cdot c_D^m,$$

where c_D^m is the critical cutoff cost level in the market equilibrium under free entry.

To interpret this proposition, we can image starting with a market equilibrium, where the level of entry is determined by the free-entry conditions, and then considering the impact of a marginal change in the level of entry on welfare. In this scenario, $c_D^m = (\phi\gamma)^{\frac{1}{k+2}}$ corresponds to the critical cutoff cost level in the market equilibrium under free entry.[20] According to Proposition 4, if α is at least twice as large as this cutoff level, then the last entrant resulted in a drop in welfare, and so the social planner could generate a gain in welfare with a small reduction in the level of entry. Intuitively, the number of entrants is increasing in α in this model, and negative externalities such as the substitution effect and business-stealing effect are weighted by number of entrants.

As noted in the Introduction, Nocco, Ottaviano and Salto (2014) also report a critical value for α such that the market supplies too much entry relative to the first-best level when α exceeds this value. Our finding is related and complementary. Our result is derived in a second-best context, however, where the planner does not have direct control over firm-specific output levels.[21]

4 Unilateral Trade Policies

In the previous sections, we presented the solution to the model and highlighted three driving forces. Now we can discuss trade policies and welfare implications of this model. We focus in this section on unilateral trade-policy incentives when countries start at global free trade.

4.1 Introduction of a Small Import Tariff

We suppose that both countries initially adopt free trade with import and export tariffs. From this starting point, the introduction of a small home import tariff generates a welfare

[20] See Melitz and Ottaviano (2008) for the derivation of c_D^m.

[21] The critical value that Nocco, Ottaviano and Salto (2014) derive is closely related but has a different coefficient on c_D^m. Nocco, Ottaviano and Salto (2014) also consider a second-best setting in which the planner can use a per-unit production subsidy financed by a lump-sum tax on consumers. In this case, however, and as they show, c_D^m is unaffected by policy. In terms of our decomposition above, such a policy would eliminate all effects in EXT except $\overline{CS}$. As they show, the market thus under-supplies variety in this case.

gain for the home country and a welfare loss for the foreign country.[22]

Proposition 5 *(Small import tariff) For countries l and h with $l, h \in \{H, F\}$ and $l \neq h$, if both countries initially adopt a policy of free trade, then the introduction of a small import tariff by country l generates a welfare gain for country l and a welfare loss for country h:*

$$\begin{aligned}
\frac{dU^l}{dt^l} \mid_{t^h=\tilde{t}^h=t^f=\tilde{t}^f=0} &= \frac{dCS^l}{dt^l} + IMP^l \mid_{t^h=\tilde{t}^h=t^f=\tilde{t}^f=0} > 0 \\
\frac{dU^h}{dt^l} \mid_{t^h=\tilde{t}^h=t^f=\tilde{t}^f=0} &= \frac{dCS^h}{dt^l} \mid_{t^h=\tilde{t}^h=t^f=\tilde{t}^f=0} < 0.
\end{aligned}$$

When the home country introduces a small import tariff, the firm-delocation effect implies that the number of home entrants increases and the number of foreign entrants decreases. Under the Metzler paradox, the average price falls in the home country and rises in the foreign country. As well, consumers in the home country enjoy greater variety whereas foreign consumers experience a decrease in variety. Since the average price decreases and the variety effect increases in home country, consumer surplus increases in the home country while the opposite occurs in the foreign country. Finally, the introduction of a small home import tariff also generates a positive tariff-revenue gain for the home country, where this gain corresponds to the import value. Due to these price, variety and revenue effects, the introduction of a small import tariff by the home country results in a home-country welfare increase and a foreign-country welfare decrease.

Proposition 5 matches Venables' (1985) finding for the homogeneous-firm Cournot model. In his model, however, variety and selection effects are absent.[23]

4.2 Introduction of a Small Export Subsidy

We also consider the introduction of a small export subsidy under global free trade. The following proposition shows that the introduction of a small home export subsidy always decreases foreign welfare while it increases home welfare when the selection effect is strong (i.e., when the transportation cost is low and the dispersion of firms' productivities is high) or when the selection effect is weak and the demand parameter α is small.

[22] We make two comments here about Proposition 5. First, we assume that both countries initially adopt free trade for simplicity. More generally, the key requirement is that the country about which the welfare statement is made adopts a policy of free trade, while the other country adopts any initial policy that is consistent with positive entry. Second, we use total derivatives here, since U^l depends on tariffs through direct and indirect channels, and since CS^l depends on tariffs indirectly through c_D^l.

[23] See also Bagwell and Staiger (2012b) for further analysis of trade policies in Venables' (1985) model.

Proposition 6 *(Small export subsidy) For countries l and h with $l, h \in \{H, F\}$ and $l \neq h$, if both countries initially adopt a policy of free trade, then the introduction of a small export subsidy by country l has the following effects: 1). It generates a welfare gain for country l,*

$$\frac{dU^l}{d\tilde{t}^l} \mid_{t^h=\tilde{t}^h=t^l=\tilde{t}^l=0} = \frac{dCS^l}{d\tilde{t}^l} + EXP^l \mid_{t^h=\tilde{t}^h=t^l=\tilde{t}^l=0} < 0, \tag{33}$$

when (a) the selection effect is strong in that $\tau < (4+2k)^{1/k}$ or (b) the selection effect is weak in that $\tau \geq (4+2k)^{1/k}$ and

$$\alpha < \left(1 + \frac{\tau^k}{\tau^k - 2(k+2)}\right) c_D^{FT} \tag{34}$$

2). It generates a welfare loss for country h,

$$\frac{dU^h}{d\tilde{t}^l} \mid_{t^h=\tilde{t}^h=t^f=\tilde{t}^f=0} = \frac{dCS^h}{d\tilde{t}^l} > 0. \tag{35}$$

Proposition 6 indicates that the introduction of a small export subsidy (i.e., the introduction of a small negative export tariff) by the home country always hurts foreign welfare but can raise home welfare. The foreign welfare loss may be understood in terms of the firm-delocation effect and the logic identified in Proposition 5. The impact on home welfare, however, is more complicated. When a government introduces an export subsidy, it must balance any consumer-surplus gain against the tariff-revenue loss, where the tariff-revenue loss corresponds to the export value. Proposition 5 indicates that the net effect of a small export subsidy for the home country is positive if the selection effect is strong or if the selection effect is weak and the demand parameter α is small.

Intuitively, the introduction of a small export subsidy generates a lower average price and a greater level of variety in the home market, which leads to a gain in consumer surplus. This gain overwhelms the subsidy expense when selection effects are strong; however, when selection effects are weak, it is possible that the subsidy expense dominates in the home-country welfare calculation. We note, though, that the introduction of an export subsidy does generate a gain for the home country in the weak-selection case when α is small. This finding resonates with our examination of the entry-externality effect above, since we argue there that entry is socially inadequate to begin with (i.e., under free trade) when α is small.

To see this tradeoff more clearly, consider the extreme case in which the transportation cost approaches infinity ($\tau \to \infty$). In this limiting case, the home country can be interpreted in terms of our closed-economy analysis, and (34) is reducible to the idea of Proposition 4 that additional entry is desirable if and only if $\alpha < 2 \cdot \lim_{\tau \to \infty} c_D^{FT}$. Thus, if there are too few entrants without government intervention, then additional entry generates a positive externality, and policies that encourage entry are attractive.[24]

We may also compare Proposition 6 with Venables' (1985) findings. For the homogeneous-firms Cournot model, he shows that the introduction of a small home export subsidy harms the foreign country but benefits the home country, at least when demand is linear. Our finding above likewise shows that the unilateral benefit of a small export subsidy is more qualified than that for a small import tariff, but in the heterogeneous-firms model that we analyze here the key considerations that determine the unilateral benefit of a small export subsidy are related to parameters that describe the significance of the selection effect and the externality associated with entry. Our findings thus suggest that strategic export subsidy policies may be more effective in some sectors than others. Sectors characterized by low transportation costs and high productivity dispersion (i.e., strong-selection characteristics) would seem natural candidates for small strategic subsidies according to Proposition 6.

Proposition 6 offers a partial perspective on the WTO's prohibition of export subsidies. To the extent that governments use trade agreements to limit the scope in the long run for beggar-thy-neighbor policies, Proposition 6 suggests that restrictions on export subsidies could be attractive once governments have achieved through preceding negotiations an outcome that is sufficiently close to global free trade. In this context, an interesting feature of the analysis provided here is that the appeal of restrictions is greater under conditions that may be descriptive of the current trading environment - namely, low transportation costs and high productivity dispersion - since a country has unilateral incentive to introduce a small export subsidy when these conditions prevail. A more complete evaluation of the treatment of export subsidies in this model, however, requires a characterization of the efficiency frontier, a topic we consider below.[25]

4.3 Introduction of a Small Import and Export Tariff

We now consider a different unilateral path from global free trade and allow that the home government simultaneously increases its import and export tariffs. The broad idea is to propose a simultaneous increase in home tariffs so as to maintain home consumer surplus while also generating tariff revenue. Bagwell and Staiger (2012b) explore such an intervention and define the tariffs so as to maintain the local price in the home country. For the linear Cournot delocation model, they show that the intervening country gains from the

[24] Under infinite transportation cost, trade policy doesn't affect welfare. But the sign is maintained as the transportation cost goes to infinity, in that $\frac{dU^l}{d\tilde{t}^l}$ approaches zero from below when $\alpha < 2 \cdot c_D^{FT}$.

[25] See Bagwell and Staiger (2012b) for a characterization of efficient trade policies in the Venables (1985) model. They draw on this characterization to evaluate the treatment of export subsidies in the WTO.

introduction of a small policy intervention of this kind. In the setting that we consider here, however, consumer surplus is influenced by price and variety effects, suggesting that perhaps the argument does not extend.

In fact, however, we can utilize the structure of the Melitz-Ottaviano model to deliver clear findings. As (24) indicates, the price and variety influences on consumer welfare are all channeled through the critical cut-off cost level for domestic sales in the home market. Thus, the candidate intervention in the framework that we consider here is one in which the home country raises its import and export tariffs so as to maintain its critical cut-off cost level for domestic sales.

To formally explore this idea, let us consider the tariffs for any country l that serve to fix c_D^l. We suppose again that all tariffs are initially set at free trade. Using (15), we then find that the introduction of slight changes in country l's tariffs that preserve c_D^l must satisfy

$$\frac{\partial \tilde{t}^l}{\partial t^l} \mid_{t^h=\tilde{t}^h=t^l=\tilde{t}^l=0, \bar{c}_D^l} = -\frac{\frac{\partial c_D^l}{\partial t^l}}{\frac{\partial c_D^l}{\partial \tilde{t}^l}} \mid_{t^h=\tilde{t}^h=t^l=\tilde{t}^l=0, \bar{c}_D^l} = \tau^{-k} > 0. \tag{36}$$

Intuitively, and as Proposition 1 confirms, a higher import tariff lowers c_D^l whereas a higher export tariff raises c_D^l. The particular positive relationship that maintains c_l^D then takes an especially simple form starting from global free trade. Since $TR^l = t^l \cdot IMP^l + \tilde{t}^l \cdot EXP^l$, we have that

$$\frac{dTR^l}{dt^l} \mid_{t^l=\tilde{t}^l=0} = IMP^l > 0 \text{ and } \frac{dTR^l}{d\tilde{t}^l} \mid_{t^l=\tilde{t}^l=0} = EXP^l > 0,$$

and so the proposed tariff changes are also sure to raise country l's tariff revenue. Referring to (24) and (27), we may now conclude that the proposed tariff changes leave country l's consumer surplus unaltered, raise country l's tariff revenue, and thus generate a gain in country l's welfare.[26]

Further utilizing the structure of the Melitz-Ottaviano model, we also find that the welfare of country h must fall when country l departs from global free trade and introduces this policy variation. To see why, we use (15) and show that the introduction of slight

[26] It is now clear that the home country's gain from the proposed tariff changes does not require that the foreign country also adopt a policy of free trade. On the other hand, if the home country's initial tariffs were to differ from free trade, then the home country would gain from the proposed tariff change if and only if the change raises home-country tariff revenue. This tariff-revenue condition holds when the home country starts at free trade but need not hold otherwise.

changes in country l's tariffs that preserve c_D^h must satisfy

$$\frac{\partial \tilde{t}^l}{\partial t^l} \mid_{t^h=\tilde{t}^h=t^l=\tilde{t}^l=0,\bar{c}_D^h} = -\frac{\frac{\partial c_D^h}{\partial t^l}}{\frac{\partial c_D^h}{\partial \tilde{t}^l}} \mid_{t^h=\tilde{t}^h=t^l=\tilde{t}^l=0,\bar{c}_D^h} = \tau^k > 0, \tag{37}$$

where $\tau^k > \tau^{-k}$ under our assumptions. Thus, for a given increase in t^l, the increase in $\tilde{t}^l$ that maintains c_D^l is not sufficiently great to maintain c_D^h. Since Proposition 1 implies that c_D^h is decreasing in $\tilde{t}^l$, we conclude that the proposed tariff variation for country l causes an increase in c_D^h. Using (24), it is straightforward to show that a country's consumer surplus is decreasing in its critical cut-off cost level for domestic sales.[27] Since country h has a policy of free trade, country l's policy change has no impact on country h's tariff revenue. We thus conclude from (27) that country h is harmed by the proposed tariff variation for country l.

The following proposition summarizes our findings:

Proposition 7 *(Small import and export tariffs) For countries l and h with $l, h \in \{H, F\}$ and $l \neq h$, if both countries initially adopt a policy of free trade, then the introduction of a small import tariff and a small export tariff by country l that satisfies (36) is sure to increase country l's welfare and lower country h's welfare.*

A notable feature of Proposition 7 is that the welfare implications hold for all trade costs, demand and dispersion parameters. Proposition 7 is related to Bagwell and Staiger's (2012b) finding for the linear Cournot delocation model; however, a novel feature of Proposition 7 is that it also addresses the externality associated with the described intervention. In particular, Proposition 7 indicates that this unilateral policy intervention, too, imposes a cost on the trading partner, provided that policies are initially placed at global free trade.

5 Efficient and Nash Trade Policies

In this section, we offer characterizations of efficient and Nash trade policies.

5.1 Efficient Symmetric Trade Policies

In this model, efficient trade policies maximize the sum of the two countries' welfare functions.[28] An initial point, confirmed as Lemma 16 in the Appendix, is that total welfare depends on individual tariffs, $\{t^H, \tilde{t}^H, t^F, \tilde{t}^F\}$, only through total tariffs, $\{T^H \equiv t^H + \tilde{t}^F, T^F \equiv t^F + \tilde{t}^H\}$.

[27] See Lemma 15 in the Appendix.

[28] Total welfare is the appropriate criterion for efficiency, since countries have sufficient trade-policy instruments to achieve lump-sum transfers. One country can achieve a lump-sum transfer to the other country, if the former (latter) country lowers (raises) its export (import) tariff in a way that maintains the total tariff.

Efficient tariff policies are thus defined as those which solve

$$\max_{\{T^H, T^F\}} U^H + U^F = \max_{\{t^H, \tilde{t}^H, t^F, \tilde{t}^F\}} U^H + U^F$$

The *efficient symmetric total tariff,* T^*, then maximizes $U^H + U^F$ over the set of symmetric total tariffs, $T = T^H = T^F$. Note that T^* can be achieved using a continuum of possible *efficient symmetric tariffs*, defined as tariffs $\{t^H, \tilde{t}^H, t^F, \tilde{t}^F\}$ that maximize $U^H + U^F$ over the set of tariffs that are symmetric in the sense that $t^H + \tilde{t}^F = \tilde{t}^H + t^F$.

At this point, we turn our focus to the specific question of whether global free trade constitutes a set of efficient symmetric tariffs. Our result follows:

Proposition 8 *(Free trade and efficiency) If both countries initially adopt a policy of free trade, then the introduction of a small and symmetric increase in the total tariff* $T = T^H = T^F$ *raises joint welfare if and only if* $\alpha > 2 \cdot c_D^{FT}$*, lowers joint welfare if and only if* $\alpha < 2 \cdot c_D^{FT}$*, and has no first-order effect on joint welfare if and only if* $\alpha = 2 \cdot c_D^{FT}$*.*

This proposition indicates the global free trade is not in general an efficient trade policy, even within the restricted class of symmetric trade policies. The result resonates well with Proposition 4, which suggests that additional entry generates a negative externality for the economy when $\alpha > 2 \cdot c_D^{FT}$. Starting at global free trade, or any other symmetric trade policy for which $T^H = T^F = 0$, a trade agreement can generate higher welfare for its members if the agreement calls for a slight increase in the total tariff when $\alpha > 2 \cdot c_D^{FT}$, and a symmetric decrease (i.e., a subsidy) in the total tariff when $\alpha < 2 \cdot c_D^{FT}$. Finally, if $\alpha = 2 \cdot c_D^{FT}$, then a trade agreement cannot induce a first-order gain to its members with a small symmetric movement in trade policies.[29]

To consider the implications of this finding for trade-agreement design, let us consider a strong-selection environment so that $\tau^k < 2(k + 2)$. In this setting, and starting at global free trade, Proposition 6 indicates that a unilateral export subsidy is attractive to the intervening country. Therefore, if $\alpha = 2 \cdot c_D^{FT}$, then an efficiency-enhancing trade agreement would restrict small departures from global free trade in any form, even though each country has a unilateral incentive to depart from global free trade with a small import tariff or a small export subsidy.[30] The case of $\alpha = 2 \cdot c_D^{FT}$ generates results analogous to those

[29] Our policy analysis here contrasts interestingly with the second-best analysis of Nocco, Ottaviano and Salto (2014). As described previously, they consider per unit (i.e., specific) production subsidies that are provided on every produced unit within a closed-economy setting. By contrast, we consider ad valorem policies that are provided only on traded units within an open-economy setting. The critical cut-off cost level is impacted by a subsidy or tariff in the policy analysis that we examine.

[30] Proposition 8 is stated in the context of small changes in the symmetric total tariff, but the proposition takes the same form when small unilateral tariff changes are considered.

found by Bagwell and Staiger (2012b) under global free trade, since they show that any small movement from global free trade reduces efficiency in the linear Cournot delocation model. Other cases are possible here, however. Regarding the treatment of export subsidies, the unilateral incentive for a country to impose a small export subsidy would be beneficial (detrimental) for efficiency if $\alpha < 2 \cdot c_D^{FT}$ ($\alpha > 2 \cdot c_D^{FT}$). Thus, conditional on starting at global free trade and for the strong-selection environment, the model is consistent with effective and efficiency-enhancing restrictions on the use of export subsidies in a trade agreement if $\alpha \geq 2 \cdot c_D^{FT}$.[31] When $\alpha > 2 \cdot c_D^{FT}$, however, the model does not provide a rationale for restrictions on the introduction of small import tariffs.

5.2 Nash Trade Policies

We now characterize symmetric Nash equilibria, where a *symmetric Nash equilibrium* is a set of tariffs, $\{t^H, \tilde{t}^H, t^F, \tilde{t}^F\}$, that forms a Nash equilibrium in the full strategy set and is also symmetric in the sense that $t^H = t^F$ and $\widetilde{t}^H = \widetilde{t}^F$. For a symmetric Nash equilibrium, we denote the *symmetric Nash tariffs* as a pair $(t^N, \widetilde{t}^N)$, where $t^N \equiv t^H = t^F$ is the symmetric Nash import tariff and $\widetilde{t}^N \equiv \widetilde{t}^H = \widetilde{t}^F$ is the symmetric Nash export tariff, and we represent the associated *symmetric Nash total tariff* as $T^N \equiv t^N + \widetilde{t}^N$.

To analyze Nash trade policies, we must allow that tariffs are non-zero, which means in turn that we require a characterization of the manner in which tariffs affect trade values and, through this channel, tariff revenues. We provide such a characterization below. In the next subsection, we then build on this analysis to compare efficient symmetric and symmetric Nash tariffs. In this and the next subsection, our maintained assumption regarding entry takes the form that a positive number of firms enters in each country whether the total tariff is T^* or T^N. To ensure that the efficient symmetric and symmetric Nash tariffs are consistent with the assumptions used in Section 2, we also assume that these tariffs are interior (i.e., $T^* > -1$ and $T^N > -1$), which ensures in turn that the respective tariffs must satisfy first-order conditions.

We show in the Appendix (in the proof of Proposition 9 to follow) that the import value for country l, IMP^l, decreases as country l's import tariff increases and that a higher export tariff for country l similarly leads to an increased import value, IMP^l. If we further assume that the initial policies are symmetric, then we can draw additional implications that are

[31] Similarly, in the weak-selection environment where $\tau^k \geq 2(k+2)$, a unilateral export subsidy is attractive to the intervening country if $\alpha < (1 + \frac{\tau^k}{\tau^k - 2(k+2)})c_D^{FT}$, where the term in the parenthesis exceeds 2. Conditional on starting at global free trade and for the weak-selection environment, the model is consistent with effective and efficiency-enhancing restrictions on the use of export subsidies in a trade agreement if $(1 + \frac{\tau^k}{\tau^k - 2(k+2)})c_D^{FT} > \alpha \geq 2 \cdot c_D^{FT}$.

useful for our analysis of symmetric Nash equilibria. In particular, we find that:

Proposition 9 *(Tariffs and trade values) If trade policies are symmetric in that $T^H = T^F$, then $\frac{dIMP^l}{dt^l} = \frac{dEXP^l}{d\tilde{t}^l} < 0$, $\frac{dIMP^l}{d\tilde{t}^l} = \frac{dEXP^l}{dt^l} > 0$ and $\frac{dIMP^l}{dt^l} + \frac{dEXP^l}{dt^l} < 0$.*

Note that the final inequality in Proposition 9 indicates that overall trade volume rises under symmetry when country l cuts its import tariff, since IMP^l rises by more than EXP^l falls. The notion of symmetry in Proposition 9 concerns only total tariffs, because trade volumes depend on individual tariffs only through total tariffs. Of course, if individual trade policies were symmetric, in that $t^H = t^F$ and $\tilde{t}^H = \tilde{t}^F$, then the symmetry of total tariffs, $T^H = T^F$, would follow, and so Proposition 9 would apply.

Using Proposition 9, we may now establish an interesting relationship between the import and export policies in any symmetric Nash equilibrium:

Proposition 10 *(Symmetric Nash tariffs) Assume that a symmetric Nash equilibrium exists. Then $t^N > \tilde{t}^N$.*

Proposition 10 shows that the symmetric Nash import tariff is more trade-restrictive than the symmetric Nash export tariff. For example, if both policies are positive, as Proposition 7 suggests could be the case, then the Nash import tariff is the higher of the two taxes.

For the linear Cournot delocation model, Bagwell and Staiger (2012b) establish this ranking as well. The key insight in both frameworks is that an import tariff both generates tariff revenue and lowers the domestic price whereas an export tariff provides additional tariff revenue but at the cost of raising the domestic price.

5.3 Liberalization Paths

We next explore the relationship between efficient symmetric and symmetric Nash tariffs. An understanding of this relationship provides insight into the liberalization paths that are consistent with the model. Our first proposition of this kind establishes conditions under which efficient symmetric trade policies entail a total tariff that is positive but below that in a symmetric Nash equilibrium:

Proposition 11 *(Nash and efficient tariffs) Assume $\alpha > 2 \cdot c_D^{FT}$ and that there exists a unique symmetric Nash equilibrium and a unique efficient symmetric total tariff. If $T^N > 0$, then $T^N > T^* > 0$.*

In models of trade agreements in which governments have political-economic preferences, a common finding is that Nash tariffs exceed efficient tariffs in total, where the total efficient tariff is positive when governments attach a greater welfare weight to profit in import-competing sectors.[32] Proposition 11 establishes conditions under which a similar ranking occurs in the Melitz-Ottaviano model, even though the model has a zero-expected-profit condition. As Proposition 8 suggests, the assumption that $\alpha > 2 \cdot c_D^{FT}$ is used in establishing that the efficient symmetric tariff policy is characterized by a positive total tariff. In the Appendix, we use Proposition 9 and show further that the total tariff then must be higher in the symmetric Nash equilibrium than under efficient symmetric tariff policies. Bagwell and Staiger (2012b) provide a related result for the linear Cournot delocation model, but an important difference is that $T^* = 0$ in that model.

When policies are initially placed at a symmetric Nash equilibrium, what combinations of symmetric and small policy adjustments would enhance efficiency and thus generate mutual gains for both countries? We answer this question in our next proposition:

Proposition 12 *(Liberalization paths) Starting at a symmetric Nash equilibrium, if countries agree to exchange small reductions in (i) import tariffs, (ii) export tariffs, or (iii) import and export tariffs, then the welfare of each country increases.*

The proof of Proposition 12 uses a standard envelope argument and is provided in the Appendix. The key idea is that, starting at a Nash equilibrium, a small change in a country's tariff has no first-order effect on its own welfare, and so the implication of such a change for efficiency is dictated by the impact of the change on the welfare of its trading partner. In this context, Proposition 12 establishes that two countries that begin with Nash trade policies are sure to achieve mutual gains if they form a trade agreement that facilitates small reductions in their import and/or export tariffs. As Bagwell and Staiger (2012b) show, a related finding arises also in the linear Cournot delocation model.[33]

Proposition 12 provides an interpretation for why early GATT rounds emphasized negotiated reductions in import tariffs but not reductions in export subsidies. This finding is of special interest when viewed in combination with Proposition 6. Starting at global free trade, Proposition 6 establishes that the introduction of a small export subsidy by the home country always hurts foreign welfare but can raise home welfare. As suggested above, to the

[32] See, e.g., Bagwell and Staiger (2001) and Grossman and Helpman (1995).

[33] As in the linear Cournot delocation model studied by Bagwell and Staiger (2012b), an interesting feature of Proposition 12 is that countries can achieve mutual gains by exchanging small reductions in export tariffs, even though a reduction in one country's export tariff generates a terms-of-trade *loss* for its trading partner. Specifically, if the home country were to lower its export tariff, then the average price in the foreign country would rise, and so the average world price for foreign imports thus would increase. In line with the explanation provided by Bagwell and Staiger (2012b), the foreign country nevertheless gains, since it would suffer an even greater terms-of-trade loss were it to engineer a rise in the average price in its country by decreasing its own import tariff.

extent that governments use trade agreements to limit the scope in the long run for beggar-thy-neighbor policies, Proposition 6 suggests that restrictions on export subsidies could be attractive once governments have achieved through preceding negotiations an outcome that is sufficiently close to global free trade. At the same time, we note from Proposition 8 that global free trade is not generally efficient in the Melitz-Ottaviano model; thus, a simultaneous ban on export subsidies and import tariffs receives less support in this model than in the linear Cournot delocation model considered by Bagwell and Staiger (2012b).

5.4 Numerical Illustration

We consider now a simple numerical illustration. Consider the following parameters: $\alpha = 2$, $c_M = 1$, $k = 1.1$, $f_e = 0.1$, $\tau = 1.1$ and $\gamma = 1 = \eta$. Under this specification, at global free trade, we find that $c_D^{FT} = 0.885 < 1 = \alpha/2$ and that the consumption of the numeraire good satisfies $q_0^* = 0.332 > 0$. For this specification, we find that the efficient symmetric trade policies satisfy $T = T^H = T^F = .03$. Thus, consistent with Propositions 8 and 11, this example satisfies $\alpha > 2 \cdot c_D^{FT}$ and the efficient symmetric trade policies call for a positive total tariff. The symmetric Nash equilibrium for this example entails the following tariffs: $t^N = 8.25$ and $\tilde{t}^N = 7.75$. Thus, as Proposition 10 indicates, the symmetric Nash import tariff exceeds the symmetric Nash export tariff. In line with Proposition 11, the total tariff in the symmetric Nash equilibrium also exceeds that under efficient symmetric tariffs.

An interesting feature of this example is that the Nash export tariff is positive. This feature may be surprising given the optimal export subsidy result in Proposition 6, but it can be readily interpreted in light of the complementary relationship between import and export tariffs identified in Proposition 7. Intuitively, when the home country has a positive import tariff in place, as it does here, it has an enhanced incentive to use an export tariff, since the resulting expansion in the foreign country's export value (see Proposition 9) then generates import tariff revenue for the home country.[34] Bagwell and Staiger (2012b) show generally that the Nash import and export tariffs are both positive in the Cournot delocation model and interpret their finding in terms of this complementary relationship between import and export tariffs. Our numerical example confirms the possibility of a similar effect in the Melitz-Ottaviano model.

[34] Indeed, using Proposition 9, it is readily confirmed that, starting at global free trade, import and export tariffs exert a complementary relationship on tariff revenue: $\frac{d^2TR^l}{dt^l d\tilde{t}^l} = \frac{dIMP^l}{d\tilde{t}^l} + \frac{dEXP^l}{dt^l} > 0$ at global free trade.

6 Conclusion

We analyze trade policy in a symmetric, two-country version of the Melitz-Ottaviano (2008) model. Our characterizations are influenced by three driving forces corresponding to the selection effect, the firm-delocation effect, and the entry-externality effect. Starting at global free trade, we show that a country gains from the introduction of (1) a small import tariff; (2) a small export subsidy, if transportation costs are low and the dispersion of productivities is high; and (3) an appropriately combined small increase in its import and export tariffs. The welfare of its trading partner, however, falls in each of these three cases. We also offer characterizations of efficient and Nash trade policies. We find that global free trade is generally not efficient, even within the class of symmetric trade policies; and we establish that the import tariff exceeds the export tariff in a symmetric Nash equilibrium. We also provide conditions under which efficient symmetric trade policies entail a total tariff that is positive but below that in a symmetric Nash equilibrium; and we show that, starting at the symmetric Nash equilibrium, countries can mutually gain by exchanging small reductions in import tariffs, export tariffs or combinations thereof. Finally, a numerical examination illustrates the possibility that the Nash import and export tariffs both may be positive.

7 Appendix

Lemma 13 $\frac{\partial c_D^l}{\partial t^l} = \frac{\partial c_D^l}{\partial \tilde{t}^h} < 0$ *and* $\frac{\partial c_D^l}{\partial t^h} = \frac{\partial c_D^l}{\partial \tilde{t}^l} > 0$

Proof: Using (15) and (16), calculations reveal that

$$\begin{aligned} \frac{\partial c_D^l}{\partial t^l} &= \frac{\partial c_D^l}{\partial \tilde{t}^h} = -\frac{(k+1)}{(k+2)}\frac{\rho^l\rho^h}{(1-\rho^l\rho^h)}\frac{c_D^l}{1+t^l+\tilde{t}^h} < 0 \\ \frac{\partial c_D^h}{\partial t^l} &= \frac{\partial c_D^h}{\partial \tilde{t}^h} = \frac{(k+1)}{(k+2)}\frac{(1-\rho^h)\rho^l}{(1-\rho^l)(1-\rho^l\rho^h)}\frac{c_D^h}{1+t^l+\tilde{t}^h} > 0 \end{aligned} \tag{38}$$

where the inequalities follow given our maintained assumptions that $1+t^l+\tilde{t}^h > 0$ and $0 < \rho^l < 1$. ■

Lemma 14 $\frac{\partial c_X^l}{\partial t^l} = \frac{\partial c_X^l}{\partial \tilde{t}^h} > 0$ *and* $\frac{\partial c_X^l}{\partial t^h} = \frac{\partial c_X^l}{\partial \tilde{t}^l} < 0$

Proof: Using (15), Lemma 13 and (16), calculations reveal that

$$\frac{\partial c_X^l}{\partial t^l} = \frac{\partial c_X^l}{\partial \tilde{t}^h} = \frac{(k+1)}{(k+2)}\frac{(1-\rho^h)\rho^l}{(1-\rho^l)(1-\rho^l\rho^h)}\frac{c_D^h(\frac{\rho^h}{\tau})^{\frac{1}{k+1}}}{1+t^l+\tilde{t}^h} > 0$$

$$\frac{\partial c_X^l}{\partial t^h} = \frac{\partial c_X^l}{\partial \tilde{t}^l} = -\left(\frac{c_D^h(\frac{\rho^h}{\tau})^{\frac{1}{k+1}}}{1+t^h+\tilde{t}^l}\right)\left(\frac{(k+1)}{(k+2)}\frac{\rho^l\rho^h}{(1-\rho^l\rho^h)}+1\right) < 0$$

where the inequalities follow given our maintained assumptions that $1 + t^l + \tilde{t}^h > 0$ and $0 < \rho^l < 1$. ■

Proof of Proposition 1 (Selection effect): See proof of Lemma 13.■

Proof of Proposition 2 (Firm-delocation effect): Our first step is to establish that $\frac{dN^l}{dt^l} = \frac{dN^l}{d\tilde{t}^h} > 0 > \frac{dN^h}{dt^l} = \frac{dN^h}{d\tilde{t}^h}$. Clearly, $\frac{dN^l}{dt^l} = \frac{dN^l}{d\tilde{t}^h}$ and $\frac{dN^h}{dt^l} = \frac{dN^h}{d\tilde{t}^h}$. We thus suppose that t^l increases and focus on the first term in each expression. Using (18) and Lemma 13, we obtain

$$\frac{dN^l}{dt^l} = \frac{dN^l}{dc_D^l}\frac{\partial c_D^l}{\partial t^l} = -\frac{2\alpha\gamma(k+1)}{\eta(c_D^l)^2}\frac{\partial c_D^l}{\partial t^l} > 0. \tag{39}$$

Using (18) and Lemma 13, we obtain

$$\frac{dN^h}{dt^l} = \frac{dN^h}{dc_D^h}\frac{\partial c_D^h}{\partial t^l} = -\frac{2\alpha\gamma(k+1)}{\eta(c_D^h)^2}\frac{\partial c_D^h}{\partial t^l} < 0. \tag{40}$$

Our second step is to establish $\frac{dN_E^l}{dt^l} = \frac{dN_E^l}{d\tilde{t}^h} > 0 > \frac{dN_E^h}{dt^l} = \frac{dN_E^h}{d\tilde{t}^h}$. Clearly, $\frac{dN_E^l}{dt^l} = \frac{dN_E^l}{d\tilde{t}^h}$ and $\frac{dN_E^h}{dt^l} = \frac{dN_E^h}{d\tilde{t}^h}$. We thus suppose that t^l increases and focus on the first term in each expression. Then $\rho^l \Downarrow$, $c_D^l \Downarrow$, $c_D^h \Uparrow$, $c_X^h \Downarrow$ by (16), Lemma 13 and Lemma 14. Recalling $\xi^l \equiv \rho^l(1+t^l+\tilde{t}^h)$, we can also easily derive that $\xi^l \Downarrow$.

By $\xi^l \Downarrow$, $c_D^l \Downarrow$, $c_D^h \Uparrow$, the number of entrants in country h decreases: $N_E^h \Downarrow$. To see this, we use (39) and (40) and refer to (20):

$$N_E^h = \frac{(c_M)^k}{1-\xi^l\xi^h} \Downarrow \cdot \left[\frac{N^h}{(c_D^h)^k} \Downarrow - \frac{\xi^h N^l}{(c_D^l)^k} \Uparrow\right] \Downarrow,$$

where the bracketed expression is positive since $N_E^h > 0$. Thus, $N_E^h \Downarrow$.

Referring to (19), we now use (39), $N_E^h \Downarrow$, $c_D^l \Downarrow$ and $c_X^h \Downarrow$ to find that

$$N^l \Uparrow = G\left(c_D^l \Downarrow\right) \cdot N_E^l + G\left(c_X^h \Downarrow\right) \cdot N_E^h \Downarrow .$$

It follows that that $N_E^l \Uparrow$.■

Proof of Proposition 3 (Metzler paradox): As captured in (17), there is one-to-one relation between the average price and the critical cutoff cost level for domestic sales:

$$\bar{p}^l = \frac{2k+1}{2k+2} \cdot c_D^l.$$

By Lemma 13, we have

$$\begin{aligned}\frac{d\bar{p}^l}{dt^l} &= \frac{2k+1}{2k+2}\frac{\partial c_D^l}{\partial t^l} < 0 \\ \frac{d\bar{p}^l}{dt^h} &= \frac{2k+1}{2k+2}\frac{\partial c_D^l}{\partial t^h} > 0.\end{aligned}$$

To complete the proof, we note that $\frac{d\bar{p}^l}{dt^l} = \frac{d\bar{p}^l}{d\tilde{t}^h}$ and $\frac{d\bar{p}^l}{dt^h} = \frac{d\bar{p}^l}{d\tilde{t}^l}$.■

Lemma 15 *Consumer Surplus decreases with the critical cutoff cost level for domestic sales:* $\frac{dCS^l}{dc_D^l} < 0$.

Proof: Using (24), we find that find that

$$\frac{dCS^l}{dc_D^l} = \frac{2(1+k)c_D^l - (3+2k)\alpha}{2(2+k)\eta} < 0 \tag{41}$$

where the inequality follows from $\alpha > c_D^l$ (or equivalently from $N^l > 0$).■

Proof of Proposition 4 (Entry-externality effect): We begin by confirming that $\overline{CS}$, VE, N_E and $\bar{\pi}$ can all be regarded as functions of c_D. Following (31) and using $q_D(c) = (c_D - c)/(2\gamma)$, the expected consumer surplus at a single variety, $\overline{CS}$, can be calculated by integration as

$$\overline{CS} = \frac{\gamma}{2}\int_0^{C_D} (q_D(c))^2 dG(c) = \frac{(c_M)^{-k}(c_D)^{k+2}}{4\gamma(k+1)(k+2)}. \tag{42}$$

Referring to (19) and setting $N_E^h \equiv 0$ while replacing N_E^l with N_E, N^l with N and c_D^l with c_D, we have that

$$N_E = \frac{N}{G(c_D)} = \frac{2(1+k)\gamma(c_M)^k}{\eta}\frac{(\alpha - c_D)}{(c_D)^{k+1}}, \tag{43}$$

where we use (18) to express N in terms of c_D after similar variable replacements. The variety effect, VE, is derived as the difference between consumer surplus and the sum of consumer surplus at single varieties. Using the expression for consumer surplus in (24) and that for N_E in (43), and after making similar variable replacements, we get

$$VE = CS - N_E \cdot \overline{CS} = \frac{(\alpha - c_D)^2}{2\eta}, \tag{44}$$

where we also use (42). Finally, referring to (13) after setting $c_X^l = 0$ and after also replacing $\overline{\pi}^l$ with $\overline{\pi}$ and $\pi_D^l(c)$ with $\pi_D(c) = (c_D - c)^2/(4\gamma)$, respectively, we get that

$$\overline{\pi} = \frac{(c_M)^{-k}(c_D)^{k+2}}{2\gamma(k+1)(k+2)}. \tag{45}$$

With these derivations in place, we define

$$EXT \equiv \overline{CS} + \frac{dVE}{dN_E} + N_E\frac{d\overline{CS}}{dN_E} + N_E\frac{d\overline{\pi}}{dN_E}$$

and proceed next to sign each term in this expression. From (42), it is evident that

$$\overline{CS} = \frac{(c_M)^{-k}(c_D)^{k+2}}{4\gamma(k+1)(k+2)} > 0$$

Using the implicit function theorem, and employing (43) while using $\alpha > c_D$ (i.e., $N > 0$), we obtain

$$\frac{dc_D}{dN_E} = (\frac{dN_E}{dc_D})^{-1} = -(\frac{2(1+k)\gamma(c_M)^k(\alpha(1+k) - kc_D)}{\eta(c_D)^{k+2}})^{-1} < 0. \tag{46}$$

Combining (46) with (42), (44) and (45), we find

$$\frac{dVE}{dN_E} = \frac{dVE}{dc_D}\frac{dc_D}{dN_E} = -\frac{(\alpha - c_D)}{\eta}\frac{dc_D}{dN_E} > 0$$

$$\frac{d\overline{CS}}{dN_E} = \frac{d\overline{CS}}{dc_D}\frac{dc_D}{dN_E} = \frac{(c_M)^{-k}(c_D)^{k+1}}{4\gamma(k+1)}\frac{dc_D}{dN_E} < 0$$

$$\frac{d\overline{\pi}}{dN_E} = \frac{d\overline{\pi}}{dc_D}\frac{dc_D}{dN_E} = \frac{(c_M)^{-k}(c_D)^{k+1}}{2\gamma(k+1)}\frac{dc_D}{dN_E} < 0.$$

We have thus now signed each term in EXT.

We now proceed to sign EXT. To this end, we observe from (44) that

$$\frac{dCS}{dN_E} = \overline{CS} + \frac{dVE}{dN_E} + N_E\frac{d\overline{CS}}{dN_E},$$

and so we can write

$$EXT = \frac{dCS}{dN_E} + N_E\frac{d\overline{\pi}}{dN_E} = (\frac{dCS}{dc_D} + N_E\frac{d\overline{\pi}}{dc_D})\frac{dc_D}{dN_E}.$$

It now follows from (46) that

$$sign\{EXT\} = -sign\{\frac{dCS}{dc_D} + N_E\frac{d\bar{\pi}}{dc_D}\}.$$

Using (41) after replacing CS^l with CS and c_D^l with c_D, respectively, and using (43) and (45), we find that $N_E\frac{\partial\bar{\pi}}{\partial c_D} = (\alpha - c_D)/\eta$ and thus

$$\frac{dCS}{dc_D} + N_E\frac{d\bar{\pi}}{dc_D} = \frac{\alpha - 2c_D}{2\eta(k+2)},$$

whence

$$sign\{EXT\} = -sign\{\alpha - 2c_D\}$$

We thus have that $EXT < 0$ if and only if $\alpha - 2c_D > 0$. Finally, to relate this derivation to the statement of Proposition 4, we may fix c_D at the market-equilibrium level determined by the free-entry condition: $c_D = c_D^m$ ■

Proof of Proposition 5 (Small import tariff): We consider first the incentive for country l to impose a small import tariff, given an initial situation of global free trade. Using (27), we find that

$$\frac{dU^l}{dt^l} = \frac{d}{dt^l}[CS^l + t^l \cdot IMP^l + \tilde{t}^l \cdot EXP^l]. \tag{47}$$

Thus, given an initial situation of global free trade, we have that

$$\begin{aligned}\frac{dU^l}{dt^l} \mid_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} &= \frac{dCS^h}{dt^h} + IMP^h \mid_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} \\ &= \frac{dCS^l}{dc_D^l}\frac{\partial c_D^l}{\partial t^l} + IMP^h \mid_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} > 0,\end{aligned}$$

where the inequality follows from Lemma 13, Lemma 15 and $IMP^h > 0$ (by $N_E^H > 0$). Thus, country l gains from the introduction of a small import tariff, starting at global free trade.

Next, we consider the effect on country h when country l departs from global free trade and introduces a small import tariff. Using (27), the externality of an increase in country l's import tariff is given by

$$\frac{dU^h}{dt^l} = \frac{d}{dt^l}[CS^h + t^h \cdot IMP^h + \tilde{t}^h \cdot EXP^h]. \tag{48}$$

Starting from global free trade, we then have that

$$\frac{dU^h}{dt^l} \quad |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} = \frac{dCS^h}{dt^l} |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0}$$
$$= \frac{dCS^h}{dc_D^h}\frac{\partial c_D^h}{\partial t^l} |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} < 0$$

where the inequality follows from Lemma 13 and Lemma 15. Thus, starting at global free trade, country h is harmed when country l introduces a small import tariff.■

Proof of Proposition 6 (Small export subsidy): We being with part 2 of the proposition and show that, starting at global free trade, country h suffers a welfare loss when country l introduces a small export subsidy. Using (27), we find that the externality of an increase in country l's export tariff is given by

$$\frac{dU^h}{d\tilde{t}^l} = \frac{d}{d\tilde{t}^l}[CS^h + t^h \cdot IMP^h + \tilde{t}^h \cdot EXP^h]. \tag{49}$$

Starting from global free trade, we then have that

$$\frac{dU^h}{d\tilde{t}^l} \quad |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} = \frac{dCS^h}{d\tilde{t}^l} |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0}$$
$$= \frac{dCS^h}{dc_D^h}\frac{\partial c_D^h}{\partial \tilde{t}^l} |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} > 0$$

where the inequality follows from Lemma 13 and Lemma 15. Thus, starting at global free trade, country h gains when country l introduces a small export tariff. Equivalently, from this starting point, country h loses when country l introduces a small export subsidy.

We turn now to part 1 of the proposition and determine conditions under which country l gains from breaking from global free trade and introducing a small export subsidy. Using (27), we find that

$$\frac{dU^l}{d\tilde{t}^l} = \frac{d}{d\tilde{t}^l}[CS^l + t^l \cdot IMP^l + \tilde{t}^l \cdot EXP^l]. \tag{50}$$

Thus, given an initial situation of global free trade, we have that

$$\frac{dU^l}{d\tilde{t}^l} \quad |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} = \frac{dCS^l}{d\tilde{t}^l} + EXP^l |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0}$$
$$= \frac{dCS^l}{dc_D^l}\frac{\partial c_D^l}{\partial \tilde{t}^l} + EXP^l |_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0},$$

where the first term is negative under Lemma 13 and Lemma 15 while the second term is positive: $EXP^l > 0$ (by $N_E^L > 0$). Thus, it is not immediately clear whether country l gains from the introduction of a small export subsidy, even when starting at global free trade.

To go further, we use (18), (20), (26), (38) and (41) to get

$$\frac{dU^l}{d\tilde{t}^l} \mid_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0} = \frac{dCS^l}{d\tilde{t}^l} + EXP^l \mid_{t^l=\tilde{t}^l=t^h=\tilde{t}^h=0}$$
$$= \frac{(1+k)\, c_D^{FT}}{2\,(2+k)^2\,\eta\,(\tau^{2k}-1)} [\alpha\left(\tau^k - 2k - 4\right) + 2c_D^{FT}\left(2+k-\tau^k\right)]$$

where $c_D^{FT} = c_D^l \mid_{t^h=\tilde{t}^h=t^f=\tilde{t}^f=0}$. The sign of the optimal unilateral export policy is thus determined by the expression in the brackets. Country l thus gains from the introduction of a small export subsidy if and only if

$$\alpha\left(\tau^k - 2(k+2)\right) < c_D^{FT}\left(2\tau^k - 2(k+2)\right). \tag{51}$$

Suppose first that $\tau^k \geq 2(k+2)$ or equivalently that $\tau \geq (4+2k)^{\frac{1}{k}}$. If $\tau^k = 2(k+2)$, then the LHS of (51) is zero and the RHS of (51) is positive, whence the introduction of a small export subsidy benefits country l. If $\tau^k > 2(k+2)$, then the LHS and RHS of (51) are both positive, and we may confirm that (51) holds, and thus the introduction of a small export subsidy benefits country l, if and only if

$$\alpha < \left(1 + \frac{\tau^k}{\tau^k - 2(k+2)}\right) c_D^{FT},$$

which is simply inequality (34) in the statement of Proposition 6. We have thus now established that the introduction of a small export subsidy benefits country l in the weak selection effect defined in part 1b of Proposition 6.

Suppose second that $\tau^k < 2(k+2)$ or equivalently that $\tau < (4+2k)^{\frac{1}{k}}$. A first subcase is that $k+2 \leq \tau^k < 2(k+2)$. In this subcase, the LHS of (51) is negative whereas the RHS is non-negative; thus, (51) holds in this subcase. A second subcase is that $\tau^k < k+2 < 2(k+2)$. Both the LHS and RHS of (51) are then negative, so that (51) holds if and only if

$$\alpha > \left(1 + \frac{\tau^k}{\tau^k - 2(k+2)}\right) c_D^{FT}.$$

This inequality is sure to hold for the subcase under consideration, given $\alpha > c_D^{FT}$. Thus, in the strong selection setting where $\tau < [4+2k]^{\frac{1}{k}}$, as considered in part 1a of Proposition 6, the introduction of a small export subsidy benefits country l.■

Lemma 16 *Total utility depends on individual tariffs,* $\left\{t^H, \tilde{t}^H, t^F, \tilde{t}^F\right\}$*, only through total tariffs,* $\left\{T^H = t^H + \tilde{t}^F, T^F = t^F + \tilde{t}^H\right\}$.

Proof: Recall from (27) that $U^l = 1 + t^l IMP^l + \tilde{t}^l EXP^l + \frac{(\alpha - c_D^l)}{2\eta}[\alpha - c_D^l \frac{k+1}{k+2}]$. Thus,

$$\begin{aligned} U^l + U^h &= 2 + \frac{(\alpha - c_D^l)}{2\eta}[\alpha - c_D^l \frac{k+1}{k+2}] + \frac{(\alpha - c_D^h)}{2\eta}[\alpha - c_D^h \frac{k+1}{k+2}] \\ &\quad + t^l IMP^l + \tilde{t}^l EXP^l + t^h IMP^h + \tilde{t}^h EXP^h. \end{aligned}$$

From here, we may use $IMP^l = EXP^h$, which may be verified using (25) and (26), to rewrite total utility as

$$\begin{aligned} U^l + U^h &= 2 + \frac{(\alpha - c_D^l)}{2\eta}[\alpha - c_D^l \frac{k+1}{k+2}] + \frac{(\alpha - c_D^h)}{2\eta}[\alpha - c_D^h \frac{k+1}{k+2}] \\ &\quad + (t^l + \tilde{t}^h) IMP^l + (\tilde{t}^l + t^h) EXP^l. \end{aligned} \tag{52}$$

We may now use (15), (16), (21), (25) and (26) to verify that $U^l + U^h$ depends only on total tariffs, T^l and T^h.■

Proof of Proposition 8 (Free trade and efficiency): Using Lemma 16, for symmetric total tariffs, $T \equiv T^l = T^h$, we may define the symmetric total utility function, $S(T) \equiv U^l + U^h$. Using the expression for total utility in (52), and that trade values depend on individual tariffs only through total tariffs, we may now compute $S'(T)$ as follows:

$$\begin{aligned} S'(T) &= 2\left(\frac{2\,(1+k)\,c_D^l - (3+2k)\,\alpha}{2\,(2+k)\,\eta}\right)\left(\frac{\partial c_D^l}{\partial t^l} + \frac{\partial c_D^l}{\partial t^h}\right) \\ &\quad + 2IMP^l + 2T(\frac{dIMP^l}{dt^l} + \frac{dEXP^l}{dt^l}), \end{aligned} \tag{53}$$

where we use that $c_D^l = c_D^h$, $\frac{\partial c_D^l}{\partial t^l} = \frac{\partial c_D^h}{\partial t^h}$, $\frac{\partial c_D^l}{\partial t^h} = \frac{\partial c_D^h}{\partial t^l}$, $IMP^l = EXP^h = EXP^l = IMP^h$, $T = T^l = T^h$, $\frac{dIMP^l}{dt^l} = \frac{dEXP^l}{dt^h}$ and $\frac{dIMP^l}{dt^h} = \frac{dEXP^l}{dt^l}$ under symmetric total tariffs. (As we note in the proof of Lemma 16, $IMP^l = EXP^h$, which may be verified using (25) and (26). Given symmetry, we also know that $EXP^h = EXP^l$.) At global free trade, we thus have

$$S'(0) = 2\left(\frac{2\,(1+k)\,c_D^{FT} - (3+2k)\,\alpha}{2\,(2+k)\,\eta}\right)\left(\frac{\partial c_D^l}{\partial t^l} + \frac{\partial c_D^l}{\partial t^h}\right) + 2IMP^l\,|_{T^l = T^h = 0} \tag{54}$$

To evaluate this expression, we use (16), (21), (25) and (38) to find that, at free trade,

$$\begin{aligned} \frac{\partial c_D^l}{\partial t^l} + \frac{\partial c_D^l}{\partial t^h} &= \frac{(k+1)}{(k+2)} \frac{\tau^{-k}(1-\tau^{-k})c_D^{FT}}{(1-\tau^{-2k})} \\ IMP^l &= \frac{(k+1)}{(k+2)} \frac{\tau^{-k}(1-\tau^{-k})(\alpha - c_D^{FT})c_D^{FT}}{\eta(1-\tau^{-2k})} \end{aligned}$$

and so, after gathering terms and simplifying,

$$S'(0) = \left(\frac{(k+1)}{(k+2)^2} \frac{\tau^{-k}(1-\tau^{-k})c_D^{FT}}{(1-\tau^{-2k})\,\eta} \right) \left(\alpha - 2c_D^{FT}\right),$$

which completes the proof. ■

Proof of Proposition 9 (Tariffs and trade values): Using (15), (16), (21), (25) and (26), we note that ρ^l, c_D^l, N_E^l and thus IMP^l and EXP^l depend on tariffs only through the total tariffs. As noted in the proof of Lemma 16, we may use (25) and (26) to verify that $IMP^l = EXP^h$. We thus have that, at symmetric trade policies,

$$\frac{dIMP^l}{dt^l} = \frac{dEXP^h}{dt^l} = \frac{dEXP^h}{d\tilde{t}^h} = \frac{dEXP^l}{d\tilde{t}^l}, \tag{55}$$

where the first equality follows from $IMP^l = EXP^h$ (at any policies), the second equality follows from the observation that EXP^h depends only on the total tariff, and the final equality holds since we start with symmetric total tariffs. Likewise, we have that, at symmetric total tariffs,

$$\frac{dIMP^l}{d\tilde{t}^l} = \frac{dEXP^h}{d\tilde{t}^l} = \frac{dEXP^h}{dt^h} = \frac{dEXP^l}{dt^l}. \tag{56}$$

Our next task is to sign the derivatives. Referring to (25), we find that

$$\frac{dIMP^l}{dt^l} = \frac{1}{2\gamma(k+2)(c_M)^k}[N_E^h \rho^l \frac{d(c_D^l)^{k+2}}{dt^l} + N_E^h (c_D^l)^{k+2} \frac{\partial \rho^l}{\partial t^l} + \rho^l (c_D^l)^{k+2} \frac{dN_E^h}{dt^l}] < 0 \tag{57}$$

where the inequality follows from Lemma 13, (16) and Proposition 2. Likewise, we find that

$$\frac{dIMP^l}{d\tilde{t}^l} = \frac{\rho^l}{2\gamma(k+2)(c_M)^k}[N_E^h \frac{d(c_D^l)^{k+2}}{d\tilde{t}^l} + (c_D^l)^{k+2} \frac{dN_E^h}{d\tilde{t}^l}] > 0, \tag{58}$$

where the inequality follows from Lemma 13 and Proposition 2. We note that the signs of $\frac{dIMP^l}{dt^l}$ and $\frac{dIMP^l}{d\tilde{t}^l}$ are not reliant upon the assumption of symmetric trade policies.

Our remaining task is to show that

$$(\frac{dIMP^l}{dt^l} + \frac{dEXP^l}{dt^l})|_{T^l=T^h} < 0. \tag{59}$$

To establish this inequality, we recall from (56) that $\frac{dEXP^l}{dt^l} = \frac{dIMP^l}{d\hat{t}^l}$ at symmetric total tariffs. Using (57) and (58), along with (16), (21) and (38), and after simplification, we find that

$$(\frac{dIMP^l}{dt^l} + \frac{dEXP^l}{dt^l})|_{T^l=T^h} = [\frac{(k+1)^2\rho^l c_D^l}{\eta(k+2)(1+\xi^l)}(\alpha \cdot g_1 + c_D^l \cdot g_2)]|_{T^l=T^h}, \tag{60}$$

where

$$g_1 \equiv \frac{k\rho^l}{(k+1)(1+\xi^l)} + \frac{\rho^l}{(k+2)(1+\rho^l)(1+T^l)} - \frac{1}{(1+T^l)} \tag{61}$$

and

$$g_2 \equiv \frac{k\rho^l}{(k+2)(1+\rho^l)(1+T^l)} - \frac{k\rho^l}{(k+1)(1+\xi^l)} - \frac{\rho^l}{(1+\rho^l)(1+T^l)} + \frac{1}{(1+T^l)}. \tag{62}$$

We note that

$$g_1 + g_2 = \frac{-\rho^l}{(1+\rho^l)(1+T^l)(k+2)} < 0. \tag{63}$$

Since our maintained assumption of positive entry implies that $\alpha > c_D^l$, we conclude from (60) and (63) that $(\frac{dIMP^l}{dt^l} + \frac{dEXP^l}{dt^l})|_{T^l=T^h} < 0$ if $g_1 < 0$.

To show that $g_1 < 0$, we treat g_1 as a function of τ with T^l held fixed, $g_1 = g_1(\tau; T^l)$, and observe that

$$\frac{dg_1}{d\tau} = \frac{\partial\rho^l}{\partial\tau}\left(\frac{k}{(k+1)(1+\xi^l)^2} + \frac{1}{(1+T^l)(k+2)(1+\rho^l)^2}\right) < 0, \tag{64}$$

where the inequality follows using (16). We also find that

$$\lim_{\tau\to 1} g_1 = \frac{1}{1+T^l}\left(\frac{k}{(k+1)(1+(1+T^l)^k)} + \frac{1}{(k+2)(1+(1+T^l)^{k+1})} - 1\right). \tag{65}$$

We now note that

$$\frac{k}{(k+1)(1+(1+T^l)^k)} + \frac{1}{(k+2)(1+(1+T^l)^{k+1})} < \frac{k}{k+1} + \frac{1}{k+2} < 1,$$

and so we observe from (65) that $\lim_{\tau\to 1} g_1 < 0$. Combing this observation with (64), we conclude that $g_1(\tau; T^l) < 0$ for all $\tau > 1$ and $T^l = T^h > -1$. Hence, we have established (59), which completes the proof. ■

Proof of Proposition 10 (Symmetric Nash tariffs): Assume the existence of a symmetric Nash equilibrium. For country l, the first-order conditions for a Nash equilibrium are given by $\frac{dU^l}{dt^l} = 0 = \frac{dU^l}{d\tilde{t}^l}$. Using (47) and (50), we may write these first-order conditions as

$$t^N = -\frac{(\frac{dCS^l}{dt^l} + IMP^l + \tilde{t}^N \cdot \frac{dEXP^l}{dt^l})}{\frac{dIMP^l}{dt^l}} \tag{66}$$

and

$$\tilde{t}^N = -\frac{(\frac{dCS^l}{d\tilde{t}^l} + EXP^l + t^N \cdot \frac{dIMP^l}{d\tilde{t}^l})}{\frac{dEXP^l}{d\tilde{t}^l}}, \tag{67}$$

where both expressions are evaluated at the symmetric Nash policies, $\frac{dIMP^l}{dt^l} < 0$ follows from (57) and $\frac{dEXP^l}{d\tilde{t}^l} = \frac{dIMP^l}{dt^l} < 0$ then follows under symmetry from (55).

Given that the expressions in (66) and (67) thus share a common denominator, and using also that $\frac{dEXP^l}{dt^l} = \frac{dIMP^l}{d\tilde{t}^l}$ by (56) and that $IMP^l = EXP^l$ (as argued using symmetry in the proof of Proposition 8), we may subtract (67) from (66) to get

$$t^N - \tilde{t}^N = \frac{[\frac{dCS^l}{d\tilde{t}^l} - \frac{dCS^l}{dt^l} + (t^N - \tilde{t}^N) \cdot \frac{dIMP^l}{d\tilde{t}^l}]}{\frac{dIMP^l}{dt^l}},$$

which may be re-arranged to give

$$t^N - \tilde{t}^N = \frac{\frac{dCS^l}{dt^l} - \frac{dCS^l}{d\tilde{t}^l}}{\frac{dIMP^l}{d\tilde{t}^l} - \frac{dIMP^l}{dt^l}} > 0, \tag{68}$$

where the inequality follows from Lemma 15, Lemma 13 and Proposition 9. ■

Proof of Proposition 11 **(Nash and efficient tariffs):** Assume $\alpha > 2 \cdot c_D^{FT}$ and that there exists a unique symmetric Nash equilibrium with an associated total tariff $T^N > 0$. Assume also that there exists a unique efficient symmetric total tariff, T^*.

We set $S'(T^*) = 0$ and use (41) and (53) to re-write the first-order condition as

$$T^* = F_S(T^*), \tag{69}$$

where

$$F_S(T) = -\frac{[(\frac{dCS^l}{dc_D^l})(\frac{\partial c_D^l}{\partial t^l} + \frac{\partial c_D^l}{\partial t^h}) + IMP^l]}{\frac{dIMP^l}{dt^l} + \frac{dEXP^l}{dt^l}} \tag{70}$$

and where each term on the RHS depends only on the total tariffs, T^l and T^h, and is evaluated at $T^l = T^h = T$. We recall from (59) in the proof of Proposition 9 that $\frac{dIMP^l}{dt^l} + \frac{dEXP^l}{dt^l} < 0$

when $T^l = T^h$.

Likewise, we may use $T^N \equiv t^N + \widetilde{t}^N$ and add the first-order conditions (66) and (67) to obtain that

$$T^N = F_N(T^N), \tag{71}$$

where

$$F_N(T) = -\frac{[(\frac{dCS^l}{dc_D^l})(\frac{\partial c_D^l}{\partial t^l} + \frac{\partial c_D^l}{\partial t^h}) + 2 \cdot IMP^l]}{\frac{dIMP^l}{dt^l} + \frac{dEXP^l}{dt^l}} \tag{72}$$

and where each term on the RHS depends only on the total tariffs, T^l and T^h, and is evaluated at $T^l = T^h = T$. To derive (71) and (72), we use $\frac{dEXP^l}{d\widetilde{t}^l} = \frac{dIMP^l}{dt^l}$ (under symmetry by (55)), $\frac{dEXP^l}{dt^l} = \frac{dIMP^l}{d\widetilde{t}^l}$ (under symmetry by (56)), $IMP^l = EXP^l$ (as argued using symmetry in the proof of Proposition 8) and $\frac{\partial c_D^l}{\partial \widetilde{t}^l} = \frac{\partial c_D^l}{\partial t^h}$ (by Lemma 13).

The proof now proceeds in two steps. The first step is to show that

$$[(\frac{dCS^l}{dc_D^l})(\frac{\partial c_D^l}{\partial t^l} + \frac{\partial c_D^l}{\partial t^h}) + IMP^l]|_{T^l = T^h = 0} > 0. \tag{73}$$

To establish this inequality, we use (41) when evaluated at $T^l = T^h = 0$, and we refer to the proof of Proposition 8 for expressions for $\frac{\partial c_D^l}{\partial t^l} + \frac{\partial c_D^l}{\partial t^h}$ and IMP^l under free trade. We then obtain that

$$[(\frac{dCS^l}{dc_D^l})(\frac{\partial c_D^l}{\partial t^l} + \frac{\partial c_D^l}{\partial t^h}) + IMP^l]|_{T^l = T^h = 0} = \frac{(k+1)\tau^{-k}(1-\tau^{-k})c_D^{FT}(\alpha - 2c_D^{FT})}{2(k+2)^2(1-\tau^{-2k})\eta} > 0,$$

where the inequality follows under the assumption that $\alpha > 2c_D^{FT}$.

The second step of the proof utilizes the implications of (59) and (73). Using (59), (70) and (73), we see that $F_S(0) > 0$. Referring also to (72), we observe that $F_N(T) > F_S(T)$ for $T > -1$ such that $IMP^l > 0$. By assumption, there exists a unique symmetric Nash equilibrium with $T^N > 0$ satisfying (71). Given $IMP^l > 0$ at T^N, we may conclude from (59) that $IMP^l > 0$ at any $T^l = T^h = T \in [0, T^N]$. It follows that there exists $T^* \in (0, T^N)$ satisfying (69). By assumption, the $T^* \in (0, T^N)$ so defined uniquely satisfies (69). ■

Proof of Proposition 12 **(Liberalization paths):** Fix a symmetric Nash equilibrium. Drawing on (47) and (50), we may write country l's first-order conditions for a Nash equilibrium as follows:

$$\begin{aligned} \frac{dU^l}{dt^l} &= \frac{d}{dt^l}[CS^l + t^l \cdot IMP^l + \widetilde{t}^l \cdot EXP^l] = 0 \\ \frac{dU^l}{d\widetilde{t}^l} &= \frac{d}{d\widetilde{t}^l}[CS^l + t^l \cdot IMP^l + \widetilde{t}^l \cdot EXP^l] = 0. \end{aligned} \tag{74}$$

Thus, starting at a symmetric Nash equilibrium, country l experiences no first-order effect from small changes in its own policies. Consider now the externalities experienced by country l from small changes in the export and import tariffs of country h:

$$\begin{aligned} \frac{dU^l}{d\tilde{t}^h} &= \frac{d}{d\tilde{t}^h}[CS^l + t^l \cdot IMP^l + \tilde{t}^l \cdot EXP^l] \\ \frac{dU^l}{dt^h} &= \frac{d}{dt^h}[CS^l + t^l \cdot IMP^l + \tilde{t}^l \cdot EXP^l]. \end{aligned} \tag{75}$$

We now sign the externality effect at the symmetric and interior Nash equilibrium. We begin by observing that

$$\begin{aligned} \frac{dCS^l}{dt^l} &= \frac{dCS^l}{d\tilde{t}^h}, \ \frac{dIMP^l}{dt^l} = \frac{dIMP^l}{d\tilde{t}^h}, \ \frac{dEXP^l}{dt^l} = \frac{dEXP^l}{d\tilde{t}^h} \\ \frac{dCS^l}{d\tilde{t}^l} &= \frac{dCS^l}{dt^h}, \ \frac{dIMP^l}{d\tilde{t}^l} = \frac{dIMP^l}{dt^h}, \ \frac{dEXP^l}{d\tilde{t}^l} = \frac{dEXP^l}{dt^h} \end{aligned} \tag{76}$$

where in each case the associated economic variable depends only on the total tariff. Using (74) and (76), we may now re-write (75) as

$$\begin{aligned} \frac{dU^l}{d\tilde{t}^h} &= \frac{d}{d\tilde{t}^h}[CS^l + t^l \cdot IMP^l + \tilde{t}^l \cdot EXP^l] = -IMP^l < 0 \\ \frac{dU^l}{dt^h} &= \frac{d}{dt^h}[CS^l + t^l \cdot IMP^l + \tilde{t}^l \cdot EXP^l] = -EXP^l < 0. \end{aligned} \tag{77}$$

Using (74) and (77), we have the following conclusion: starting at a symmetric Nash equilibrium, country l's welfare is sure to increase when small tariff reductions in country l are exchanged for small tariff reductions in country h. ■

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