Additional appendix:
Using Melitz (2003) instead of Krugman (1980)

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Abstract

In this additional appendix, I show that all results can also be derived in the context of a variant of the Arkolakis et al (2008) version of Melitz (2003). It is not intended for publication.

1 Basic model: Two-country case

1.1 Setup

Now, preferences are given by

$$U_j = \left(\sum_{i=1}^{2} \int_0^{n_{ij}} m_{ij} (\upsilon_i)^{\frac{\sigma-1}{\sigma}} \, d\upsilon_i \right)^{\frac{\mu\sigma}{\sigma-1}} Y_j^{1-\mu} \tag{1}$$

where m_{ij} is the quantity of a manufacturing good from country i consumed in country j, Y_j is the quantity of the non-manufacturing good consumed in country j, n_{ij} is the 'number' of manufacturing goods produced in country i available in country j, $\sigma > 1$ is the elasticity of substitution between manufacturing goods, and μ is the share of income spent on manufacturing goods.

Now, manufacturing firms are technologically heterogeneous which is captured by the following two stage production process. In the first stage, firms wishing to enter in country i have to hire f units of labor in country i to draw their productivities $\frac{1}{c}$ from a Pareto distribution with shape parameter $k > \sigma - 1$ and location parameter b

$$F\left(\frac{1}{c}\right) = 1 - (bc)^k \tag{2}$$

where f is a fixed cost of entry. In the second stage, entrants in country i wishing to sell to country j further need to hire $q_{ij}\theta\,(1 + t_{ij})\,c$ units of labor in country i and f_x units of labor in country j to deliver q_{ij} units of output to country j, where θ is an iceberg transport cost, t_{ij} is an iceberg tariff, and f_x is a fixed cost of exporting. As before, the non-manufacturing good technology is one-for-one in labor, non-manufacturing good trade and internal manufacturing trade are free of any barriers, and $\tau_{ij} \equiv 1 + t_{ij}$ for future reference.

As before, the manufacturing goods market is monopolistically competitive whereas the non-manufacturing good market is perfectly competitive. As before, I restrict $\bar{t} \geq t_{ij} \geq 0$, assume that the manufacturing sector is always active in both countries, and assume that the non-manufacturing good sector is always active in all countries.[1]

1.2 Solution for given trade policy

As before, I choose the price of the non-manufacturing good as the numeraire which implies that wages are equal to one in both countries. For given tariffs, it can be shown along the lines of Arkolakis et al (2008) that the model's solution is then determined by the following equilibrium conditions

$$G_1^k L_1^{\frac{k}{\sigma-1}} + G_2^k \left(\theta\tau_{12}\right)^{-k} L_2^{\frac{k}{\sigma-1}} = \kappa \tag{3}$$

$$G_1^k \left(\theta\tau_{21}\right)^{-k} L_1^{\frac{k}{\sigma-1}} + G_2^k L_2^{\frac{k}{\sigma-1}} = \kappa \tag{4}$$

where $G_1 \equiv \rho_1 \left(Me_1 + Me_2 \left(\theta\tau_{21}\right)^{-k}\right)^{-\frac{1}{k}}$ and $G_2 \equiv \rho_2 \left(Me_1 \left(\theta\tau_{12}\right)^{-k} + Me_2\right)^{-\frac{1}{k}}$ are the ideal manufacturing price indices, Me_i are the numbers of manufacturing entrants in country i, $\kappa \equiv \frac{k-\sigma+1}{\sigma-1}\frac{f}{f_x}\left(\frac{\sigma-1}{\sigma}b\right)^{-k}\left(\frac{\sigma f_x}{\mu}\right)^{\frac{k}{\sigma-1}}$, and $\rho_i \equiv \left(\frac{k}{k-\sigma+1}\left(\frac{\sigma-1}{\sigma}b\right)^k\left(\frac{\mu L_i}{\sigma f_x}\right)^{\frac{k-\sigma+1}{\sigma-1}}\right)^{-\frac{1}{k}}$. Equations (3) and (4) can be solved immediately for the equilibrium manufacturing price indices

$$G_1 = \left(\kappa_1 \frac{1-\left(\theta\tau_{12}\right)^{-k}}{1-\left(\theta\tau_{21}\theta\tau_{12}\right)^{-k}}\right)^{\frac{1}{k}} \tag{5}$$

$$G_2 = \left(\kappa_2 \frac{1-\left(\theta\tau_{21}\right)^{-k}}{1-\left(\theta\tau_{21}\theta\tau_{12}\right)^{-k}}\right)^{\frac{1}{k}} \tag{6}$$

where $\kappa_i \equiv \kappa L_i^{\frac{-k}{\sigma-1}}$. If the definitions of the manufacturing price indices are substituted, they can also be solved for the equilibrium numbers of manufacturing entrants

$$Me_1 = \nu\left(\frac{L_1}{1-\left(\theta\tau_{12}\right)^{-k}} - \frac{L_2\left(\theta\tau_{21}\right)^{-k}}{1-\left(\theta\tau_{21}\right)^{-k}}\right) \tag{7}$$

[1] Now, the manufacturing sector is always active in both countries if and only if $\theta \geq \left(\frac{L_1}{L_1+L_2}\right)^{-\frac{1}{k}}$ and $\theta \geq \left(\frac{L_2}{L_1+L_2}\right)^{-\frac{1}{k}}$, and the non-manufacturing sector is always active in both countries if and only if $1-\theta^{-k} \geq \mu\frac{(\sigma-1)(k+1)}{k\sigma-(k-\sigma+1)\mu}$.

$$Me_2 = \nu \left(\frac{L_2}{1 - (\theta\tau_{21})^{-k}} - \frac{L_1 (\theta\tau_{12})^{-k}}{1 - (\theta\tau_{12})^{-k}} \right) \tag{8}$$

where $\nu \equiv \frac{\sigma-1}{k} \frac{\mu}{\sigma f}$. Now, the world number of entrants is constant since $Me_1 + Me_2 = \nu (L_1 + L_2)$. As before, tariffs affect welfare only through the manufacturing price indices since indirect utilities are given by $V_j = \mu^\mu (1-\mu)^{(1-\mu)} L_j G_j^{-\mu}$. Notice that all expressions are very similar to the expressions in the paper. In fact, they become identical as $k \to \sigma - 1$. As a consequence, all lemmas and propositions from the paper can be re-derived in this setup with virtually identical proofs, as I demonstrate below.

1.3 Noncooperative trade policy

Lemma 1 *Suppose that governments choose tariffs simultaneously in an attempt to maximize their citizens' welfare. Then the unique Nash equilibrium is* $(t_{21}, t_{12}) = (\bar{t}, \bar{t})$.

Proof. Follows immediately from equations (5) and (6). ■

Lemma 2 *The set of Pareto-efficient tariff combinations consists of all* (t_{21}, t_{12}) *such that* $(t_{21}, t_{12}) = (\textit{any } t_{21}, 0)$ *or* $(t_{21}, t_{12}) = (0, \textit{ any } t_{12})$.

Proof. A tariff combination (t_{21}, t_{12}) cannot be Pareto efficient if there exist possible Pareto improving tariff changes (dt_{21}, dt_{12}) at (t_{21}, t_{12}). This includes tariff changes (dt_{21}, dt_{12}) such that $dG_2 < 0$ and $dG_1 = 0$. From total differentiation, $dG_1 = \frac{\partial G_1}{\partial t_{21}} dt_{21} + \frac{\partial G_1}{\partial t_{12}} dt_{12}$ and $dG_2 = \frac{\partial G_2}{\partial t_{21}} dt_{21} + \frac{\partial G_2}{\partial t_{12}} dt_{12}$. Therefore, $dG_1 = 0$ if $dt_{21} = -\frac{\partial t_{21}}{\partial G_1} \frac{\partial G_1}{\partial t_{12}} dt_{12}$ so that $dG_2 = \left(\frac{\partial G_2}{\partial t_{12}} - \frac{\partial G_2}{\partial t_{21}} \frac{\partial t_{21}}{\partial G_1} \frac{\partial G_1}{\partial t_{12}} \right) dt_{12}$ along $dG_1 = 0$. Notice that $\frac{\partial G_2}{\partial t_{12}} - \frac{\partial G_2}{\partial t_{21}} \frac{\partial t_{21}}{\partial G_1} \frac{\partial G_1}{\partial t_{12}} > 0$ for all (t_{21}, t_{12}). This is because $\frac{\partial G_1}{\partial t_{21}} = -\frac{(\theta\tau_{21}\theta\tau_{12})^{-(k+1)}\theta\tau_{12}}{1-(\theta\tau_{21}\theta\tau_{12})^{-k}} \theta G_1$, $\frac{\partial G_1}{\partial t_{12}} = \frac{\left(1-(\theta\tau_{21})^{-k}\right)(\theta\tau_{12})^{-(k+1)}}{\left(1-(\theta\tau_{12})^{-k}\right)\left(1-(\theta\tau_{21}\theta\tau_{12})^{-k}\right)} \theta G_1$, $\frac{\partial G_2}{\partial t_{21}} = \frac{\left(1-(\theta\tau_{12})^{-k}\right)(\theta\tau_{21})^{-(k+1)}}{\left(1-(\theta\tau_{21})^{-k}\right)\left(1-(\theta\tau_{21}\theta\tau_{12})^{-k}\right)} \theta G_2$, and $\frac{\partial G_2}{\partial t_{12}} = -\frac{(\theta\tau_{21}\theta\tau_{12})^{-(k+1)}\theta\tau_{21}}{1-(\theta\tau_{21}\theta\tau_{12})^{-k}} \theta G_2$ so that $\frac{\partial G_2}{\partial t_{12}} - \frac{\partial G_2}{\partial t_{21}} \frac{\partial t_{21}}{\partial G_1} \frac{\partial G_1}{\partial t_{12}} = \frac{G_2}{\tau_{12}}$. Hence, there exist Pareto improving tariff changes (dt_{21}, dt_{12}) for all (t_{21}, t_{12}). These (dt_{21}, dt_{12}) are such that $dt_{21} < 0$ and $dt_{12} < 0$ and are thus possible if and only if $t_{21} > 0$ and $t_{12} > 0$. Therefore, only (t_{21}, t_{12}) such that $(t_{21}, t_{12}) = (\text{any } t_{21}, 0)$ or $(t_{21}, t_{12}) = (0, \text{ any } t_{12})$

can be Pareto efficient. It is easy to verify that for none of these (t_{21}, t_{12}) there exists another (t_{21}, t_{12}) which makes one country better off without making the other country worse off. Therefore, they are also indeed Pareto efficient. ■

Proposition 1 *The noncooperative equilibrium is inefficient.*

Proof. Follows immediately from lemmas 1 and 2. ■

1.4 Trade policy under the GATT/WTO: The principle of reciprocity

Similar to before, one can show that, given aggregate manufacturing market clearing, the number of manufacturing entrants in country j can be decomposed as follows:

$$Me_j = \frac{\mu L_j + TB_j}{\frac{k\sigma}{\sigma-1} f} \tag{9}$$

Lemma 3 *Tariff changes leave the number of entrants unchanged in both countries if and only if they are reciprocal.*

Proof. Follows immediately from equation (9) and the definition of reciprocity in the paper.

■

Proposition 2 *Reciprocal trade liberalization (trade protection) monotonically increases (decreases) welfare in both countries.*

Proof. Follows immediately from lemma 3 and the definitions of manufacturing price indices.

■

2 Basic model: Three-country case

2.1 Solution for given trade policy

For given tariffs, it can again be shown along the lines of Arkolakis et al (2008) that the model's solution is determined by the following equilibrium conditions

$$G_1^k L_1^{\frac{k}{\sigma-1}} + G_2^k \left(\theta\tau_{12}\right)^{-k} L_2^{\frac{k}{\sigma-1}} + G_3^k \left(\theta\tau_{13}\right)^{-k} L_3^{\frac{k}{\sigma-1}} = \kappa \tag{10}$$

$$G_1^k \left(\theta\tau_{21}\right)^{-k} L_1^{\frac{k}{\sigma-1}} + G_2^k L_2^{\frac{k}{\sigma-1}} = \kappa \tag{11}$$

$$G_1^k \left(\theta\tau_{31}\right)^{-k} L_1^{\frac{k}{\sigma-1}} + G_3^k L_3^{\frac{k}{\sigma-1}} = \kappa \tag{12}$$

where $G_1 \equiv \rho_1 \left(Me_1 + Me_2 \left(\theta\tau_{21}\right)^{-k} + Me_3 \left(\theta\tau_{31}\right)^{-k}\right)^{-\frac{1}{k}}$, $G_2 \equiv \rho_2 \left(Me_1 \left(\theta\tau_{12}\right)^{-k} + Me_2\right)^{-\frac{1}{k}}$, and $G_3 \equiv \rho_3 \left(Me_3 \left(\theta\tau_{13}\right)^{-k} + Me_3\right)^{-\frac{1}{k}}$.[2] Equations (10) - (12) can be solved immediately for the equilibrium manufacturing price indices

$$G_1 = \left(\kappa_1 \frac{\Phi_1}{\Omega}\right)^{-\frac{1}{k}} \tag{13}$$

$$G_2 = \left(\kappa_2 \frac{\Phi_2}{\Omega}\right)^{-\frac{1}{k}} \tag{14}$$

$$G_3 = \left(\kappa_3 \frac{\Phi_3}{\Omega}\right)^{-\frac{1}{k}} \tag{15}$$

where

$$\Phi_1 \equiv 1 - \left(\theta\tau_{12}\right)^{-k} - \left(\theta\tau_{13}\right)^{-k} \tag{16}$$

$$\Phi_2 \equiv 1 - \left(\theta\tau_{21}\right)^{-k} - \left(\theta\tau_{13}\right)^{-k} \left(\left(\theta\tau_{31}\right)^{-k} - \left(\theta\tau_{21}\right)^{-k}\right) \tag{17}$$

[2] Now, the manufacturing sector is always active in all countries if and only if $\theta \geq \left(\frac{L_1}{L_1+L_2+L_3}\right)^{-\frac{1}{k}}$, $\theta \geq \left(\frac{L_2}{L_1+2L_2}\right)^{-\frac{1}{k}}$, and $\theta \geq \left(\frac{L_3}{L_1+2L_3}\right)^{-\frac{1}{k}}$, and the non-manufacturing sector is always active in all countries if and only if $1 - 2\theta^{-k} \geq \mu \frac{(\sigma-1)(k+1)}{k\sigma-(k-\sigma+1)\mu}$.

$$\Phi_3 \equiv 1 - (\theta\tau_{31})^{-k} - (\theta\tau_{12})^{-k}\left((\theta\tau_{21})^{-k} - (\theta\tau_{31})^{-k}\right) \tag{18}$$

$$\Omega \equiv 1 - (\theta\tau_{21}\theta\tau_{12})^{-k} - (\theta\tau_{31}\theta\tau_{13})^{-k} \tag{19}$$

As before, it is easy to verify that Φ_1, Φ_2, Φ_3, and $\Omega > 0$ given the assumed parameter restrictions. If the definitions of manufacturing price indices are substituted, they can also be solved for the equilibrium numbers of manufacturing firms

$$Me_1 = \nu\left(\frac{L_1}{\Phi_1} - \frac{L_2(\theta\tau_{21})^{-k}}{\Phi_2} - \frac{L_3(\theta\tau_{31})^{-k}}{\Phi_3}\right) \tag{20}$$

$$Me_2 = \nu\left(\frac{L_2\left(1 - (\theta\tau_{31}\theta\tau_{13})^{-k}\right)}{\Phi_2} + \frac{L_3(\theta\tau_{12}\theta\tau_{31})^{-k}}{\Phi_3} - \frac{L_1(\theta\tau_{12})^{-k}}{\Phi_1}\right) \tag{21}$$

$$Me_3 = \nu\left(\frac{L_3\left(1 - (\theta\tau_{21}\theta\tau_{12})^{-k}\right)}{\Phi_3} + \frac{L_2(\theta\tau_{21}\theta\tau_{13})^{-k}}{\Phi_2} - \frac{L_1(\theta\tau_{13})^{-k}}{\Phi_1}\right) \tag{22}$$

As in the two-country case, the world number of manufacturing firms is constant and tariffs affect welfare only through the manufacturing price indices. Notice again that all expressions are very similar to the expressions in the paper. As a consequence, all lemmas and propositions from the paper can be re-derived in this setup with virtually identical proofs, as I demonstrate below.

2.2 Noncooperative trade policy

2.2.1 Three-country version of lemma 1

Suppose that governments choose tariffs simultaneously in an attempt to maximize their citizens welfare. Then the unique Nash equilibrium is $(t_{21}, t_{31}, t_{12}, t_{13}) = \left(\bar{t}, \bar{t}, \bar{t}, \bar{t}\right)$.

Proof. Follows immediately from equations (13) - (15). ■

2.2.2 Three-country version of lemma 2

The set of Pareto-efficient tariff combinations consists of all $(t_{21}, t_{31}, t_{12}, t_{13})$ *such that* $(t_{21}, t_{31}, t_{12}, t_{13}) = (\text{any } t_{21},\ \text{any } t_{31}, 0, 0)$ *or* $(t_{21}, t_{31}, t_{12}, t_{13}) = (0, 0,\ \text{any } t_{12},\ \text{any } t_{13})$.

Proof. A tariff combination $(t_{21}, t_{31}, t_{12}, t_{13})$ cannot be Pareto efficient if there exist possible Pareto improving tariff changes $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$ at $(t_{21}, t_{31}, t_{12}, t_{13})$. This includes tariff changes $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$, $dt_{31} = dt_{13} = 0$, such that $dG_2 < 0$ and $dG_1 = dG_3 = 0$. From total differentiation, $dG_1 = \frac{\partial G_1}{\partial t_{21}} dt_{21} + \frac{\partial G_1}{\partial t_{12}} dt_{12}$, $dG_2 = \frac{\partial G_2}{\partial t_{21}} dt_{21} + \frac{\partial G_2}{\partial t_{12}} dt_{12}$, and $dG_3 = \frac{\partial G_3}{\partial t_{21}} dt_{21} + \frac{\partial G_3}{\partial t_{12}} dt_{12}$. Therefore, $dG_1 = 0$ if $dt_{21} = -\frac{\partial t_{21}}{\partial G_1} \frac{\partial G_1}{\partial t_{12}} dt_{12}$ and $dG_3 = 0$ if $dt_{21} = -\frac{\partial t_{21}}{\partial G_3} \frac{\partial G_3}{\partial t_{12}} dt_{12}$. Notice that these two conditions are identical. This is because $\frac{\partial G_1}{\partial t_{21}} = -\frac{(\theta\tau_{21}\theta\tau_{12})^{-(k+1)}\theta\tau_{12}}{\Omega}\theta G_1$, $\frac{\partial G_1}{\partial t_{12}} = \frac{\Phi_2(\theta\tau_{12})^{-(k+1)}}{\Omega\Phi_1}\theta G_1$, $\frac{\partial G_3}{\partial t_{21}} = \frac{\Phi_1(\theta\tau_{21}\theta\tau_{12})^{-(k+1)}\theta\tau_{12}(\theta\tau_{31})^{-k}}{\Omega\Phi_3}\theta G_3$, and $\frac{\partial G_3}{\partial t_{12}} = -\frac{\Phi_2(\theta\tau_{12})^{-(k+1)}(\theta\tau_{31})^{-k}}{\Omega\Phi_3}\theta G_3$ so that $-\frac{\partial t_{21}}{\partial G_1}\frac{\partial G_1}{\partial t_{12}} = -\frac{\partial t_{21}}{\partial G_3}\frac{\partial G_3}{\partial t_{12}}$. Hence, along $dG_1 = dG_3 = 0$, $dG_2 = \left(\frac{\partial G_2}{\partial t_{12}} - \frac{\partial G_2}{\partial t_{21}}\frac{\partial t_{21}}{\partial G_1}\frac{\partial G_1}{\partial t_{12}}\right) dt_{12}$. Notice that $\frac{\partial G_2}{\partial t_{12}} - \frac{\partial G_2}{\partial t_{21}}\frac{\partial t_{21}}{\partial G_1}\frac{\partial G_1}{\partial t_{12}} > 0$ for all $(t_{21}, t_{31}, t_{12}, t_{13})$. This is because $\frac{\partial G_2}{\partial t_{12}} = -\frac{(\theta\tau_{21}\theta\tau_{12})^{-(k+1)}\theta\tau_{21}}{\Omega}\theta G_2$ and $\frac{\partial G_2}{\partial t_{21}} = \frac{\Phi_1\left(1-(\theta\tau_{31}\theta\tau_{13})^{-k}\right)(\theta\tau_{21})^{-(k+1)}}{\Omega\Phi_2}\theta G_2$ which, together with the derivatives given above, implies that $\frac{\partial G_2}{\partial t_{12}} - \frac{\partial G_2}{\partial t_{21}}\frac{\partial t_{21}}{\partial G_1}\frac{\partial G_1}{\partial t_{12}} = \frac{G_2}{\tau_{12}}$. Hence, there exist Pareto improving tariff changes $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$, $dt_{31} = dt_{13} = 0$, such that $dG_2 < 0$ and $dG_1 = dG_3 = 0$ for all $(t_{21}, t_{31}, t_{12}, t_{13})$. These $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$ are such that $dt_{21} < 0$ and $dt_{12} < 0$ and are thus possible if and only if $t_{21} > 0$ and $t_{12} > 0$. This also includes tariff changes $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$, $dt_{31} = dt_{12} = 0$, such that $dG_2 < 0$ and $dG_1 = dG_3 = 0$. From total differentiation, $dG_1 = \frac{\partial G_1}{\partial t_{21}} dt_{21} + \frac{\partial G_1}{\partial t_{13}} dt_{13}$, $dG_2 = \frac{\partial G_2}{\partial t_{21}} dt_{21} + \frac{\partial G_2}{\partial t_{13}} dt_{13}$, and $dG_3 = \frac{\partial G_3}{\partial t_{21}} dt_{21} + \frac{\partial G_3}{\partial t_{13}} dt_{13}$. Therefore, $dG_1 = 0$ if $dt_{13} = -\frac{\partial t_{13}}{\partial G_1}\frac{\partial G_1}{\partial t_{21}} dt_{21}$ and $dG_3 = 0$ if $dt_{13} = -\frac{\partial t_{13}}{\partial G_3}\frac{\partial G_3}{\partial t_{21}} dt_{21}$. Notice that these two conditions are identical. This is because $\frac{\partial G_1}{\partial t_{13}} = \frac{\Phi_3(\theta\tau_{13})^{-(k+1)}}{\Omega\Phi_1}\theta G_1$ and $\frac{\partial G_3}{\partial t_{13}} = -\frac{(\theta\tau_{31}\theta\tau_{13})^{-(k+1)}\theta\tau_{31}}{\Omega}\theta G_3$ which, together with the derivatives given above, implies that $-\frac{\partial t_{13}}{\partial G_1}\frac{\partial G_1}{\partial t_{21}} = -\frac{\partial t_{13}}{\partial G_3}\frac{\partial G_3}{\partial t_{21}}$. Hence, along $dG_1 = dG_3 = 0$, $dG_2 = \left(\frac{\partial G_2}{\partial t_{21}} - \frac{\partial G_2}{\partial t_{13}}\frac{\partial t_{13}}{\partial G_1}\frac{\partial G_1}{\partial t_{21}}\right) dt_{21}$. Notice that $\frac{\partial G_2}{\partial t_{21}} - \frac{\partial G_2}{\partial t_{13}}\frac{\partial t_{13}}{\partial G_1}\frac{\partial G_1}{\partial t_{21}} > 0$ for all $(t_{21}, t_{31}, t_{12}, t_{13})$. This is because $\frac{\partial G_2}{\partial t_{13}} = -\frac{\Phi_3(\theta\tau_{13})^{-(k+1)}(\theta\tau_{21})^{-k}}{\Omega\Phi_2}\theta G_2$ which, together with the derivatives given above, implies that $\frac{\partial G_2}{\partial t_{21}} - \frac{\partial G_2}{\partial t_{13}}\frac{\partial t_{13}}{\partial G_1}\frac{\partial G_1}{\partial t_{21}} = \frac{\Phi_1(\theta\tau_{21})^{-(k+1)}}{\Phi_2}\theta G_2$. Hence, there exist Pareto improving tariff changes $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$, $dt_{31} = dt_{12} = 0$, such that $dG_2 < 0$ and $dG_1 = dG_3 = 0$ for all $(t_{21}, t_{31}, t_{12}, t_{13})$. These $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$ are such that $dt_{21} < 0$ and $dt_{13} < 0$ and are thus possible if and only if $t_{21} > 0$ and $t_{13} > 0$. Symmetric arguments can be made for tariff changes $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$, $dt_{21} = dt_{12} = 0$, such that $dG_3 < 0$ and $dG_1 = dG_2 = 0$ and tariff changes $(dt_{21}, dt_{31}, dt_{12}, dt_{13})$, $dt_{21} = dt_{13} = 0$, such that $dG_3 < 0$ and $dG_1 = dG_2 = 0$. Therefore, only $(t_{21}, t_{31}, t_{12}, t_{13})$ such that $(t_{21}, t_{31}, t_{12}, t_{13}) = (\text{any } t_{21}, \text{ any } t_{31}, 0, 0)$ or $(t_{21}, t_{31}, t_{12}, t_{13}) = (0, 0, \text{ any } t_{12}, \text{ any } t_{13})$ can be Pareto efficient. It is easy to verify that for none of these $(t_{21}, t_{31}, t_{12}, t_{13})$ there exists another $(t_{21}, t_{31}, t_{12}, t_{13})$ which makes one country better off without making at least one of the other countries worse off. Therefore, they are also indeed Pareto efficient. ■

2.2.3 Three-country version of proposition 1

The noncooperative equilibrium is inefficient.

Proof. Follows immediately from the three-country versions of lemmas 1 and 2 ■

2.3 Trade policy under the GATT/WTO: The principle of nondiscrimination

Similar to before, one can show that, given aggregate manufacturing market clearing, the number of manufacturing entrants in country j can be decomposed as follows:

$$Me_j = \frac{\mu L_j + TB_j}{\frac{k\sigma}{\sigma-1} f} \tag{23}$$

Lemma 4 *Tariff changes leave the number of entrants unchanged in all countries if and only if they are multilaterally reciprocal. Moreover, bilaterally reciprocal trade liberalization (trade protection) between country 1 and country 2 leaves the number of entrants unchanged in country 2 but monotonically increases (decreases) the number of entrants in country 1 at the expense of (to the benefit of) country 3. Similarly, bilaterally reciprocal trade liberalization* *(trade protection) between country 1 and country 3 leaves the number of entrants unchanged in country 3 but monotonically increases (decreases) the number of entrants in country 1 at the expense of (to the benefit of) country 2.*

Proof. The statement that tariff changes leave the number of entrants unchanged in all countries if and only if they are multilaterally reciprocal follows immediately from equation (23) and the definition of multilateral reciprocity in the paper. Similarly, the statement that bilaterally reciprocal trade liberalization between country 1 and country 2 (country 3) leaves the number of entrants unchanged in country 2 (country 3) follows immediately from equation (23) and the definition of bilateral reciprocity in the paper. Finally, the statement that bilaterally reciprocal trade liberalization between country 1 and country 2 (country 3) monotonically increases the number of entrants in country 1 at the expense of country 3 (country 2) follows from the fact that $dMe_1 + dMe_2 + dMe_3 = 0$ together with the observation that $\frac{dMe_3}{dt_{21}} > 0$ if $dt_{31} = dt_{13} = dMe_2 = 0$ ($\frac{dMe_2}{dt_{31}} > 0$ if $dt_{21} = dt_{12} = dMe_3 = 0$) which can be easily established from equation (12) (equation (11)). ■

Proposition 3 *Multilaterally reciprocal trade liberalization (trade protection) monotonically increases (decreases) welfare in all countries. Moreover, bilaterally reciprocal trade liberalization (trade protection) between country 1 and country 2 monotonically increases (decreases) welfare in country 1 and country 2 but monotonically decreases (increases) welfare in country 3. Similarly, bilaterally reciprocal trade liberalization (trade protection) between country 1 and country 3 monotonically increases (decreases) welfare in country 1 and country 3 but monotonically decreases (increases) welfare in country 2.*

Proof. Follows immediately from lemma 4 and the definitions of manufacturing price indices.

■