Global Gains from Reduction of Trade Costs*

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Abstract

We derive a simple equation to calculate the global welfare impact of the simultaneous reduction of trade costs between multiple country-pairs. Interestingly, we find that we obtain the same equation for a broad class of trade models. Moreover, balanced trade is mostly not required for the equation to work, nor does trade elasticity need to be known. The global welfare impact only depends on two sets of statistics: (i) the ratio of bilateral trade flow between each pair of trading partners and global income; and (ii) the percentage change in exporting cost for each pair of trading partners. The class of models includes the many-country, many-good neo-classical-type model, and the Armington-type models such as Eaton and Kortum (2002), Krugman (1980), Melitz (2003) with Pareto distribution of firm productivity, and the extensions of these models to the multi-country and multi-sector case, multi-factor production technology, multi-stage production, the existence of intermediate good and the existence of a non-traded good sector in each country. We then apply the equation to estimate the global welfare impact of the worldwide reduction of international shipping costs in the last five decades.

Keywords: global welfare, trade cost, gains from trade

JEL Classification codes: F10, F12, F13

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1 Introduction

One major theme of international trade economics is the gains from trade. There is a presumption in all trade models that the more integrated is the world, the higher are the gains from trade. Therefore, the lower are trade barriers, the greater global welfare should be. An interesting empirical question is: What is the quantitative effect of the worldwide reduction of trade costs on overall global welfare? For example, what is the elasticity of global welfare with respect to the worldwide reduction of transportation costs? How sensitive is the answer to this question to the trade model being used? Understanding the global welfare impact of such changes is important as a larger pie means that there is more room to make every country better off by proper side payments. Knowing the elasticity of global welfare with respect to transportation costs allows us to evaluate the importance of improvement of transportation technology in the global economy.

In order to estimate gains from trade or reduction of trade costs, we need to assume a trade model. Recently, Arkolakis, Costinot & Rodriguez-Clare (2012) (hereinafter referred to as ACR) show that a country's gains from trade conditional on the import penetration ratio and the trade elasticity are the same regardless of what model is used as long as they belong to the same class of trade models (which we call Armington-type models, following Rodriguez-Clare), which include Armington (1969), Krugman (1980), Melitz (2003) with Pareto distribution of firm productivity, and Eaton and Kortum (2002), among others. Specifically, a country's gains from trade are always given by the same formula and is determined by only two sufficient statistics: (i) the share of expenditure on domestic goods, which is equal to one minus the import penetration ratio; and (ii) the elasticity of imports with respect to the variable trade cost. This is no doubt a significant discovery. It helps us to better understand the properties of these Armington-type models. However, there are some limitations to their equation. First, it no longer holds when trade is unbalanced. Second, it no longer holds when extended to multi-sector setting.¹ Third, the estimated trade elasticity may be sensitive to the trade model used. For example, Simonovska and Waugh (2012) find that trade models that incorporate micro-level margins lead to lower measured trade elasticities and hence larger gains from trade, relative to models without these margins. Consequently, the gains from trade predicted from ACR's formula differ from model to model, e.g. the gains from trade calculated based on the Armington model are less than those based on Eaton-Kortum (2002), while those based on Krugman (1980) are less than those based on Melitz (2003).

Besides evaluating the gains from trade (or from reduction of trade costs) for an individual country, we often are interested in estimating the gains from reduction of trade costs for the world as a whole. Can we come up with a simple user-friendly formula to calculate the global welfare impact of the simultaneous reduction of trade costs for multiple pairs of trading partners? How sensitive is the answer to the assumption of the trade model? For example, does the existence

¹ See, for example, Balistreri, Hillberry and Rutherford (2011).

of intermediate goods or offshoring matter? We find a striking answer to these questions. We find that, for a very broad class of models and settings, the percentage change in global welfare resulting from the simultaneous reduction of trade costs for multiple country-pairs is given by the same simple formula. There is no need for trade to be balanced in any country in most cases. Specifically, we find that the percentage change in global welfare is simply given by the sales-share-weighted average of percentage changes in exporting costs for all pairs of trading partners, namely, given by the expression $-\sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij}$, where X_{ij} is the value of exports from country i to country j , Y^w is the total GDP of the world, and $\hat{\tau}_{ij} \equiv \frac{d\tau_{ij}}{\tau_{ij}}$ is the percentage change in the cost of exporting from i to j . Hence, the global welfare impact only depends on two sets of statistics: (i) the ratio of the bilateral trade flow between each pair of trading partners and global income; and (ii) the percentage change in exporting cost between each pair of trading partners. In fact, the expression is just equal to the total saving in trade costs keeping trade flows unchanged, divided by global income.

Note that the global gains from trade costs reduction solely arises from the “direct effect” of the saving in trade costs which would otherwise have been wasted. The “indirect effects” such as the changes in relative prices between countries, in trade balances, in the number of potential entrants, and in the extensive margins of trade in the countries, totally offset each other. In other words, the general equilibrium adjustments of these variables have no effect on overall global welfare. Under both perfect and imperfect competition, the equation is independent of changes in relative prices because of the conservation of physical quantities of goods and it is independent of changes in trade imbalances because they sum to zero. Under imperfect competition, (i) it is independent of the number of potential entrants (i.e. entries and exits of firms) because of the proportionality between total profit and total revenue in each country (based on our assumption A1); (ii) it is independent of the adjustments of extensive margins of trade because of the CES import demand system (based on our assumption A2). Therefore, in the end only the direct effect remains. Most interestingly, the formula applies to a very broad class of models and settings, which include the many-country, many-good neo-classical-type model, and the Armington-type models such as Eaton and Kortum (2002), Krugman (1980), Melitz (2003) with Pareto distribution of firm productivity, and the extensions of these models to the multi-sector case, multi-factor production technology, multi-stage production, the existence of tradable intermediate goods (as in Alvarez and Lucas, 2007) and the existence of a non-traded good sector in each country. Our work is inspired by that of ACR. Yet, our result not only applies to a considerably broader set of models and settings than theirs but also does not require the estimation of trade elasticity nor require trade to be balanced. We apply our equation to estimate the global welfare impact of the worldwide reduction of international shipping time in the last five decades, and the estimate is in the range [2.98%, 8.81%].

There are a couple of reasons why our equation applies more broadly than does ACR’s.² There

² ACR’s equation can be adapted to evaluate the welfare impact of changes in trade costs on an individual country.

are effects that affect the welfare of individual countries that do not affect the welfare of the world as a whole, as trade costs are reduced. There are two important effects of this kind. First, the changes in trade balances sum to zero for the world as a whole but the change in trade balance for an individual country can be non-zero. This explains why our equation can allow for trade imbalances whereas ACR cannot. Second, in the multi-sectoral setting, the number of potential entrants in each sector changes because of the intersectoral resource allocation effect. The welfare impact of the potential entrants effects on country i originating from different sectors of the same country i do not offset each other. However, the global welfare impact of the potential entrants effects originating from different sectors of the same country i offset each other. This explains why our equation applies to multi-sectoral setting whereas ACR's does not.

One may argue that the class of models to which our equation applies is not broad enough, given the restrictive nature of the models that it includes. However, if one accepts that the case of perfect competition is an important benchmark for analyzing the global macroeconomy, then our equation is not so restrictive. Under perfect competition, the restrictive assumptions (called A1 and A2) that we need for the equation to work for the imperfect competition models are not required. Therefore, our equation is indeed quite general once one accepts perfect competition as an important benchmark for analyzing the global macroeconomy. In fact, one can cite numerous important papers analyzing the macroeconomy that assume perfect competition as the market structure. In our opinion, the reason for analyzing the imperfect competition models is to understand how much deviation from perfect competition we can allow for our equation to work. We find that when restrictions A1 and A2 (which are R2 and R3 in ACR) are imposed on the imperfect competition models, they behave in similar ways as the perfect competition model. It turns out that most of the trade models that are widely used in recent years satisfy these restrictions. Perhaps it is not coincident that these imperfect competition models have been widely used, as they are simpler and more user-friendly, which in turn is because they are closer to perfect competition. By imposing restrictions A1 and A2, we confine the models to be sufficiently close to perfect competition so that they become the cousins of the perfect competition model.

In fact, one can say similar things about ACR. Their equation applies to the perfect competition model with relative few restrictions. It only needs balanced trade (R1) and CES import demand (R3). However, under monopolistic competition, they need R2 as well so as to confine the model to behave like the perfect competition model.

One class of models that this paper does not include is the imperfect competition models with endogenously variable markups. Such models can capture the pro-competitive gains from trade which models with constant markups cannot. However, there is mixed empirical evidence on the size of the pro-competitive gains from trade. Indeed, pro-competitive effects are sometimes negative so that variable markups reduce the gains from trade (see, for example, Arkolakis, Costinot, Donaldson

and Rodriguez-Clare, 2012). In fact, Edmond, Midrigan and Xu (2012) conclude that the size of the gains from trade depends a great deal on the underlying micro-details. Therefore, there is no presumption that our equation will bias the estimate upward or downward by not including this class of model.

The message that the details of firms' responses are of secondary importance to the estimation of the welfare impact of trade costs reduction for an individual country is explained in Atkeson and Burstein (2010). Under the symmetry, i.e. the relative wage is one, they find that though changes in trade costs can have a substantial impact on heterogeneous firms' exit, export, and process innovation decisions, the impact of these changes on a country's welfare largely offset each other. In other words, the welfare impact of trade cost reduction calculated from the trade models based on monopolistic competition, such as Melitz (2003) with Pareto distribution of firm productivity, mainly stems from the direct effect of the reduction in trade costs. As Atkeson and Burstein (2010) analyze the welfare of an individual country, the mechanism in their model is closer in spirit to ACR's (which can be adapted to calculate the welfare effect of changes in trade costs of an individual country) than to ours.

The structure of this paper is as follow. In section 2, we give a definition to the concept of the percentage change in global welfare and derive, based on the neo-classical assumptions, a simple equation to calculate this change as a consequence of the reduction of trade costs. It will be seen that the effects of changes in relative prices of goods between countries offset each other from the global welfare point of view. In section 3, we switch our attention to the Armington-type models, and lay down the basic setup and assumptions. In section 4, under assumptions A1 and A2, we prove that the change in global welfare is given by the same equation as derived under the neo-classical type model. In section 5, we prove that the above equation continues to hold in a number of extensions of the basic Armington-type models, e.g. multi-sector, multi-factor, multiple stages of production, the existence of intermediate good, and existence of a non-traded good sector. Section 6 summarizes the results in the previous sections. Section 7 presents an empirical application of the model. The last section concludes.

2 A first cut at the problem

Suppose in the world economy there are n countries that are capable of producing m goods, which are all tradable. In this section, we first present a justification for the use of an equation that we shall use as a measure of percentage change in global welfare. Then we derive a formula based on a neo-classical model with perfect competition to calculate the change in global welfare resulting from reduction of trade costs.

2.1 Definition of percentage change in global welfare

We want to define a measure of percentage change in global welfare resulting from **small changes** (infinitesimal ones in the formal analysis) in trade costs. We would like to have a concept of change of global welfare such that an increase in global welfare signifies an enlargement of the global pie so that *potentially* every country can be better off by some proper income transfers between countries. Note that income is transferable but utility is not transferable. Therefore, the sum of utility of all countries is not a good measure of global welfare based on this concept.

As the world consists of a number of sovereign countries, each of which only cares about its own welfare, we have to define the improvement in global welfare based on the concept of Pareto improvement. More specifically, the improvement to global welfare resulting from a shock (such as reduction of trade costs) should be measured by how much potential Pareto improvement is afforded to the world after the change. Thus, we define the percentage increase in global welfare (after trade costs reduction) as the maximum potential equiproportional increase in welfare of all countries after some proper lump sum transfers of income between countries. It measures the potential amount of Pareto improvement to the countries of the world as a whole. Note that this amount can be negative. The above concept of the change in global welfare is consistent with that of Kaldor and Hicks (see, for example, Friedman 1998).³ Consistent with Kaldor-Hicks' concept of efficiency, an outcome is more efficient if those that are made better off could in principle compensate those that are made worse off, so that a Pareto improving outcome can potentially result. This concept of Pareto improvement does not require compensation actually be paid, but merely that the possibility for compensation exists.

Define E_i , P_i and U_i as the expenditure, exact price index and welfare of country i , respectively. The utility function (or welfare function) of country i , given by $U_i(\mathbf{q}_i)$ (where $\mathbf{q}_i = (q_i^1, q_i^2, \dots, q_i^m)$ is the vector of quantities of goods consumed) is assumed to be homogeneous of degree one in $\mathbf{q}_i$. Consequently, we can define an exact price index P_i , which stands for the cost a consumer has to pay to obtain one unit of utility. Therefore, the total utility of all consumers in country i (i.e. welfare of country i) is given by $U_i = E_i/P_i$ for all i . After the reduction of trade costs, the vector of price-cum-welfare of the countries changes from $(P_1, \dots, P_n; U_1, \dots, U_n)$ to $(P_1 + dP_1, \dots, P_n + dP_n; U_1 + dU_1, \dots, U_n + dU_n)$. Let μ be the potential equiproportional increase in welfare of all countries after trade costs reduction. Then,

$$\sum_{i=1}^n (P_i + dP_i) (U_i + dU_i) = \sum_{i=1}^n (P_i + dP_i) (\mu + 1) U_i$$

The LHS is the total expenditure before lump-sum transfers while the RHS is the total global expenditure after lump-sum transfers that leads to an equiproportional increase in welfare for all

³Because we are considering small changes, the use of the Kaldor-Hicks compensation criterion does not carry with it some of the shortcomings cited by its critics.

countries equal to μ . Re-arranging the above equation, we have

$$\begin{aligned}
\mu + 1 &= \frac{\sum_{i=1}^n (P_i + dP_i) (U_i + dU_i)}{\sum_{i=1}^n (P_i + dP_i) U_i} \\
\Rightarrow \mu &= \frac{\sum_{i=1}^n (P_i + dP_i) (dU_i)}{\sum_{i=1}^n (P_i + dP_i) U_i} \\
&= \frac{\sum_{i=1}^n P_i (dU_i)}{\sum_{i=1}^n P_i U_i} + O(\epsilon^2) \\
&= \sum_i \frac{P_i U_i}{\sum_k P_k U_k} \cdot \frac{dU_i}{U_i} \\
&= \sum_{i=1}^n s_i \hat{U}_i
\end{aligned}$$

where $O(\epsilon^2)$ denotes second order terms, which can be dropped, as we are considering only infinitesimal changes; $s_i \equiv \frac{E_i}{Y^w}$, $\hat{U}_i \equiv \frac{dU_i}{U_i}$, $E_i = P_i U_i$ and $Y^w \equiv \sum_k P_k U_k$ is the GDP of the world.⁴ Hereinafter, $\hat{x} \equiv \frac{dx}{x}$, which we call the percentage change of x .

Thus, $\sum_{i=1}^n s_i \hat{U}_i$ (or the expenditure-share-weighted average percentage change of welfare of all countries) is the percentage change in global welfare. This makes sense as the importance of a country as reflected in its size should be reflected in the calculation of the change in global welfare. Note that we do not have to define what is global welfare. We only need to define what is the percentage change in global welfare. Note also that utility is cardinal, not ordinal, in this model. To get an intuitive sense of what μ means, note that the welfare impact of a percentage change in global welfare of μ is equivalent to having all consumers in the world potentially increasing their consumption of each good by a fraction of μ , if the same sets of goods are produced, traded and consumed by each country before and after the shock.⁵ This expression for the percentage change in global welfare has been used in the literature, such as in Hsieh and Ossa (2011). However, as far as we are aware, we are the first to present a justification for its use.⁶

2.2 A neo-classical-type model

Consider a many-country, many-good, many-factor trade model under perfect competition, and allow for the possibility of incomplete specialization in each sector in each country.⁷ For lack of a better name, we shall call it a neo-classical-type model. It includes the multi-country, multi-good,

⁴The third line follows from the second line as all second order terms are dropped when we only consider small dP_i and dU_i . See the appendix for a more detailed proof.

⁵This is because we assume that the utility function of each country is homogeneous of degree one in quantities of all goods consumed in that country. Therefore, the percentage change in global welfare is homogeneous of degree one in the percentage change of quantities of all goods consumed in the world as a whole.

⁶Note also that though our formal analysis is based on infinitesimal changes, the equation should be a sufficiently good approximation as long as all percentage changes of P_i and U_i are less than, say, ten percent as a rule of thumb. Therefore, the equation should be applicable to many yearly changes.

⁷We would like to thank Gene Grossman for suggesting a two-country two-good version of this model to us.

Ricardian and multi-factor factor-proportions models. Suppose in the world economy there are n countries that are capable of producing m goods, which are all tradable. Let $\Omega_{ij} \subseteq \Omega = \{1, \dots, m\}$ denote the set of goods exported from country i to country j . Therefore, the price $p_j(\omega)$ faced by consumers of good ω in country j satisfies

$$p_j(\omega) = p_i(\omega) \tau_{ij} \text{ for } \omega \in \Omega_{ij}$$

where τ_{ij} is an iceberg trade cost such that τ_{ij} units are shipped from the source country i for one unit to arrive at the destination country j (assume that $\tau_{ii} = 1$).⁸ We can call $p_i(\omega)$ the F.O.B. price and $p_j(\omega)$ the C.I.F. price of good ω .

E_j denotes the expenditure in country j , while $\mathbb{E}_j[p_j(1), \dots, p_j(m), U_j]$ stands for the expenditure function (therefore, by definition $E_j = \mathbb{E}_j$ always), $U_j[q_j(1), \dots, q_j(m)]$ denotes the welfare of country j (where $q_j(\omega)$ denotes the consumption of good ω in country j), and the GDP function $R_j = [p_j(1), \dots, p_j(m); \mathbf{D}_j]$ (where $\mathbf{D}_j$ is the vector of factor endowments, which are assumed to be fixed) denotes the total sales revenue of firms in country j , which is also equal to total output Y_j , or the GDP of country j . The net export of country j is equal to $X_j^{net} \equiv R_j[p_j(1), \dots, p_j(m); \mathbf{D}_j] - \mathbb{E}_j[p_j(1), \dots, p_j(m), U_j]$, which implies that

$$dX_j^{net} = \sum_{\omega \in \Omega} \left[\frac{\partial R_j}{\partial p_j(\omega)} - \frac{\partial \mathbb{E}_j}{\partial p_j(\omega)} \right] dp_j(\omega) - \frac{\partial \mathbb{E}_j}{\partial U_j} dU_j \quad (1)$$

The question is: what are the effects of τ_{ij} on U_k for $i, j, k \in \{1, \dots, n\}$? The answer to this question will guide us to calculate $\sum_{i=1}^n s_i \widehat{U}_i$ resulting from changes in τ_{ij} for $i, j \in \{1, \dots, n\}$.

Assumptions:

1. There is perfect competition in all goods markets.
2. Utility $U_j[q_j(1), \dots, q_j(m)]$ is homogeneous of degree one in $\{q_j(1), \dots, q_j(m)\}$ and satisfies the usual assumptions of a well-behaved utility function.
3. Define $y_j(\omega)$ as the total output of good ω in country j . The production function $y_j(\omega) = \mathcal{F}_j[\mathbf{D}_j(\omega)]$ is homogeneous of degree one in $\mathbf{D}_j(\omega)$, which is the vector of factors employed in the production of good ω in country j , and it satisfies the usual assumptions of a well-behaved production function.
4. The extensive margins of trade are fixed, which means that the set $\Omega_{ij} \forall i, j$ remain the same before and after the change in trade costs.

Steps in deriving $\sum_{i=1}^n s_i \widehat{U}_i$:

⁸The amount $\tau_{ij} - 1$ can be called the “wastage due to shipping”, but it should also include the ad-valorem trade cost equivalent of any administrative delay or other non-tariff barriers.

1. τ_{ij} affects $p_i(\omega)$ and $p_j(\omega)$ for good $\omega \in \Omega_{ij}$, i.e.

$$\widehat{p}_j(\omega) = \widehat{p}_i(\omega) + \widehat{\tau}_{ij}. \quad (2)$$

2. $p_i(\omega)$ affects R_i . By envelope theorem, we have $\frac{\partial R_i}{\partial p_i(\omega)} = y_i(\omega)$, which is the total production of good ω in country i .

3. $p_j(\omega)$ affects $\mathbb{E}_j$. By envelope theorem, we have $\frac{\partial \mathbb{E}_j}{\partial p_j(\omega)} = q_j(\omega)$, which is the total consumption of good ω in country j .

4. **Conservation of physical quantities of goods.** Note that $y_i(\omega) = \sum_{i=1}^n y_{ij}(\omega)$ where $y_{ij}(\omega)$ denotes the quantity of good ω produced in i that is exported to country j . Thus, $y_{ij}(\omega) > 0$ if i is an exporter of good ω to j and $y_{ij}(\omega) = 0$ if i is not an exporter of good ω to j . Consequently, $y_{ij}(\omega) > 0 \Rightarrow y_{ji}(\omega) = 0$.

Note also that $q_j(\omega) = \sum_{i=1}^n q_{ij}(\omega)$ where $q_{ij}(\omega)$ denotes the quantity of good ω consumed in j that is imported from country i . Thus, $q_{ij}(\omega) > 0$ if i is an exporter of good ω to j and $q_{ij}(\omega) = 0$ if i is not an exporter of good ω to j . Consequently, $q_{ij}(\omega) > 0 \Rightarrow q_{ji}(\omega) = 0$.

Therefore, if i exports good ω to j (i.e. $\omega \in \Omega_{ij}$), then $y_{ij}(\omega) > 0$ and $q_{ij}(\omega) > 0$. Moreover, the quantity of ω shipped out of i to j has to be equal to the quantity of ω shipped into j from i plus the wastage due to shipping. That is,

$$\begin{aligned} \tau_{ij} q_{ij}(\omega) &\equiv y_{ij}(\omega) \quad \text{for } \omega \in \Omega_{ij} \\ \Rightarrow p_j(\omega) q_{ij}(\omega) &\equiv p_i(\omega) y_{ij}(\omega) \quad \text{for } \omega \in \Omega_{ij} \end{aligned} \quad (3)$$

The LHS represents the total value of j 's import of good ω from i , while the RHS represents the total value of i 's export of good ω to j .

5. U_j and $p_j(\omega)$ affect $\mathbb{E}_j$, as shown in (1), which in turn is related to dX_j^{net} and the effect of $p_j(\omega)$ on R_j . That is,

$$\begin{aligned} \frac{\partial \mathbb{E}_j}{\partial U_j} dU_j &= \sum_{\omega \in \Omega} \left[\frac{\partial R_j}{\partial p_j(\omega)} - \frac{\partial \mathbb{E}_j}{\partial p_j(\omega)} \right] dp_j(\omega) - dX_j^{net} \quad \text{by (1)} \\ &= \sum_{\omega \in \Omega} \left[\sum_{i=1}^n y_{ji}(\omega) - \sum_{i=1}^n q_{ij}(\omega) \right] dp_j(\omega) - dX_j^{net} \quad \text{by envelope theorem (steps 2 and 3)} \\ &= \sum_{\omega \in \Omega} \sum_{i=1}^n p_j(\omega) y_{ji}(\omega) \widehat{p}_j(\omega) - \sum_{\omega \in \Omega} \sum_{i=1}^n p_j(\omega) q_{ij}(\omega) [\widehat{p}_i(\omega) + \widehat{\tau}_{ij}] - dX_j^{net} \quad \text{by (2)} \end{aligned} \quad (4)$$

6. Consider the expenditure function $\mathbb{E}_j[p_j(1), \dots, p_j(m), U_j]$ and the indirect utility function $U_j = V_j[p_j(1), \dots, p_j(m), E_j]$. By definition of the two functions, we have the identity

$$\mathbb{E}_j(p_j(1), \dots, p_j(m), V_j[p_j(1), \dots, p_j(m), E_j]) \equiv E_j.$$

Totally differentiating this identity, we get

$$\begin{aligned} \frac{\partial \mathbb{E}_j [p_j(1), \dots, p_j(m), U_j]}{\partial U_j} \cdot \frac{\partial V_j [p_j(1), \dots, p_j(m), E_j]}{\partial E_j} &= 1 \\ \implies \frac{\partial \mathbb{E}_j}{\partial U_j} &= \frac{1}{\frac{\partial V_j}{\partial E_j}}. \end{aligned} \quad (5)$$

7. If utility $U_j [q_j(1), \dots, q_j(m)]$ is homogeneous of degree one in $\{q_j(1), \dots, q_j(m)\}$, then the indirect utility function $V_j [p_j(1), \dots, p_j(m), E_j] = E_j \cdot \tilde{V}_j [p_j(1), \dots, p_j(m)]$, which implies that

$$\frac{\partial V_j}{\partial E_j} = \tilde{V}_j = \frac{V_j}{E_j}.$$

Substituting this into (5), we get

$$\frac{\partial \mathbb{E}_j}{\partial U_j} = \frac{E_j}{V_j} = \frac{E_j}{U_j}$$

Combining this equation with (4), we have the expenditure-weighted percentage in welfare of country j given by

$$\begin{aligned} E_j \hat{U}_j &= \frac{\partial \mathbb{E}_j}{\partial U_j} dU_j = \sum_{i=1}^n \sum_{\omega \in \Omega} p_j(\omega) y_{ji}(\omega) \hat{p}_j(\omega) - \sum_{i=1}^n \sum_{\omega \in \Omega} p_j(\omega) q_{ij}(\omega) \hat{p}_i(\omega) \\ &\quad - \sum_{i=1}^n \sum_{\omega \in \Omega} p_j(\omega) q_{ij}(\omega) \hat{\tau}_{ij} - dX_j^{net} \end{aligned} \quad (6)$$

The first term reflects the increase in welfare of j resulting from increases in F.O.B. prices of j the exporter, while the second term is the decrease in welfare of j resulting from increases in F.O.B. prices of j the importer, keeping the trade costs unchanged. The sum of the first and the second term can be positive or negative. It reflects the “relative price effects” of the reduction of trade costs. The third term is the direct gains from saving in trade costs, which we call “direct price effect”. The last term reflects the increase in welfare of j as expenditure increases relative to income.

Summing $E_j \hat{U}_j$ over j , we have the expenditure-weighted average percentage change in welfare given by:

$$\begin{aligned} \sum_{j=1}^n E_j \hat{U}_j &= \sum_{i,j,\omega} p_j(\omega) y_{ji}(\omega) \hat{p}_j(\omega) - \sum_{i,j,\omega} p_j(\omega) q_{ij}(\omega) [\hat{p}_i(\omega) + \hat{\tau}_{ij}] - \sum_{j=1}^n dX_j^{net} \\ &= \sum_{i,j,\omega} p_j(\omega) y_{ji}(\omega) \hat{p}_j(\omega) - \sum_{i,j,\omega} p_j(\omega) q_{ij}(\omega) \hat{p}_i(\omega) - \sum_{i,j,\omega} p_j(\omega) q_{ij}(\omega) \hat{\tau}_{ij} \\ &= \sum_{i,j,\omega} p_i(\omega) y_{ij}(\omega) \hat{p}_i(\omega) - \sum_{i,j,\omega} p_j(\omega) q_{ij}(\omega) \hat{p}_i(\omega) - \sum_{i,j,\omega} p_j(\omega) q_{ij}(\omega) \hat{\tau}_{ij} \\ &= - \sum_{i,j,\omega} p_j(\omega) q_{ij}(\omega) \hat{\tau}_{ij} \\ &= - \sum_{j=1}^n \sum_{i=1}^n X_{ij} \hat{\tau}_{ij} \end{aligned}$$

where the operator $\sum_{i,j,\omega} \equiv \sum_{i=1}^n \sum_{j=1}^n \sum_{\omega \in \Omega}$. The second line follows from $\sum_{i=1}^n dX_i^{net} = 0$, which is implied from $\sum_{i=1}^n X_i^{net} = 0$; the third line stems from interchanging i and j in the first term on the previous line; the fourth line follows from equation (3); the last line stems from the definition of the total value of exports from country i to country j , i.e., $X_{ij} = \sum_{\omega \in \Omega} p_j(\omega) q_{ij}(\omega)$. The cancellation of the first and second terms on the second line of the above derivation signifies that the effects of changes in relative prices offset each other from the global welfare point of view. It is the result of the fact that the quantity of ω shipped out of i to j has to be equal to the quantity of ω shipped into j from i plus the wastage due to shipping.⁹

The last equality of the above derivation is equivalent to

$$\sum_{i=1}^n s_i \hat{U}_i = - \sum_{i=1}^n \sum_{j=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} \quad (7)$$

where $s_i \equiv \frac{E_i}{Y^w}$ is the expenditure share of country i in the world and $Y^w = \sum_{k=1}^n E_k = \sum_{k=1}^n Y_k =$ GDP of the world.

Note that the RHS of (7) is equal to the total saving in trade costs, controlling for the volumes of exports, divided by global GDP.¹⁰ This is the direct effect, and, interestingly, the only effect. The indirect effects, such as those due to the changes in relative prices between countries and in trade balances of different countries, offset each other from the global welfare point of view. The key to obtaining the simple result in (7) is the conservation of physical quantities of goods, trade imbalances summing up to zero, and envelope theorem. One important feature of this model is that it allows for incomplete specialization (for each country and each good, the source of supply can be from all countries simultaneously).

However, there are a number of limitations to the model: 1. there is a fixed number of goods being produced and consumed in the world; 2. the extensive margins of trade are fixed; 3. market structure is perfect competition; 4. although the model can possibly be modified to accommodate monopolistic competition under some special assumptions such as constant markup and homogeneous firms (e.g. Krugman, 1980), it is hard to address the case of heterogeneous firms, such as in Melitz (2003), even with special assumptions such as constant markup and Pareto distribution of firm productivity, as the effects of the changes in firms' entries or exits and firms' export decisions are hard to account for in this framework. Can we generalize our result to other frameworks?

An alternative to the neo-classical-type model, which is best suited to analyze the situation

⁹Controlling for the trade cost of a good, an increase in the F.O.B. price (i.e. $p_i(\omega)$ if country i is the exporter of good ω) increases the welfare of the exporter but reduces that of the importer. However, because the F.O.B. value of export of the good by the exporter is equal to the F.O.B. value of import by the importer, the effect on the exporter and that on the importer cancel each other from the global welfare point of view.

¹⁰The total exporting costs for exporting from i to j is equal to $[\sum_{\omega} p_i(\omega) q_{ij}(\omega)] (\tau_{ij} - 1)$. Therefore, the total saving in exporting costs from i to j , controlling for the volumes of exports, is equal to $[\sum_{\omega} p_i(\omega) q_{ij}(\omega)] d\tau_{ij} = \left[\frac{\sum_{\omega} p_i(\omega) q_{ij}(\omega)}{\tau_{ij}} \right] d\tau_{ij} = X_{ij} \hat{\tau}_{ij}$.

with incomplete specialization under perfect competition, is the Armington-type models, which feature complete specialization. In the following sections, we shall show that the main result in this section, namely that the indirect effects from different countries completely offset each other, can be applied to the Armington-type models when certain restrictions are imposed. Our interpretation is that when these restrictions are imposed, the imperfect competition models become cousins of the perfect competition model, and so they behave in similar ways.

3 The Armington-type models: the setup

In sections 4, 5 and ??, we shall show that the same result as in section 2 can be obtained in the Armington-type models, provided that we impose certain restrictions on the model, which are explained below. The Armington-type models are characterized by complete specialization, in the sense that for each country and each good consumed, there is only one source of supply. The use of the Armington-type models allows us to address two limitations of the neo-classical-type model we use in section 2: (i) the extensive margins of trade are fixed and (ii) the difficulty in the modeling of monopolistic competition, especially with heterogeneous firms. It will be seen however that the Armington-type models have at least one limitation that the neo-classical models do not have: assumption of complete specialization. Therefore, the model in section 2 and those in sections 4, 5 and ?? can be regarded as complementary with each other. The fact that the main result in section 2 applies to all these models implies that whether there is complete or incomplete specialization probably does not matter.¹¹

In this section, we change the setting of the previous section to: 1. existence of a continuum of goods instead of discrete goods;¹² 2. CES preferences; 3. if the market structure is perfect competition, then we only need to assume that there is complete specialization; 3. if the market structure is monopolistic competition, then we need to impose some or all of a set of restrictions called A1 and A2 (which implies complete specialization), which will be described in section 4.2 below. Our A1 and A2 are the same as R2 and R3 respectively in ACR. It will be seen that (7) holds in the Armington-type models under these restrictions. The fact that the monopolistic competition models require more restrictions than the perfect competition model reflects the fact that all the monopolistic competition models satisfying A1 and A2 are cousins of the perfect competition model. These assumptions confine them to be sufficiently close to the perfect competition model so that they are more tractable and “well-behaved”. Hence, their user-friendliness stems from their

¹¹In order to make the (endogenous) extensive margins of trade inconsequential, we need to assume CES preferences in the Armington-type models. In the neo-classical type model, on the other hand, we assume general preferences but fixed extensive margins of trade. Therefore, we need either CES preferences or fixed extensive margins of trade in both types of models.

¹²The case of discrete goods is actually covered though the formal analysis is based on a continuum of goods.

proximity to perfect competition. It is therefore not coincidence that they are widely used. We first introduce the basic elements of the Armington-type model, which are by and large adopted from ACR. We first consider a world economy consisting of n countries indexed by $i = 1, \dots, n$, with a single factor of input, labor, which is inelastically supplied and immobile across countries. There is a continuum of goods indexed by $\omega \in \Omega = [0, N]$ that can potentially be made available to consumers. We use L_i and w_i to denote the total endowment of labor and the wage level in country i respectively.

3.1 Tastes, Technology and Market Structure

Preferences: In each country j , the representative consumer chooses her consumption bundle to maximize her utility subject to the budget constraint. Her utility is given by the Dixit-Stiglitz function:

$$U_j = \left[\sum_{i=1}^n \int_{\omega \in \Omega} q_{ij}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \quad (8)$$

where $q_{ij}(\omega)$ denotes the consumption of variety ω that is exported from country i to country j ; $\sigma > 1$ is the elasticity of substitution.¹³ Consequently, we have

$$P_j = \left[\sum_{i=1}^n \int_{\omega \in \Omega} p_{ij}(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$$

where P_j is the exact price index in country j and $p_{ij}(\omega)$ is the price of variety ω that is exported from country i to country j .

Technology: For every good $\omega \in \Omega$, there is a blueprint that can be acquired by one or many firms depending on the market structure (to be described below). If a firm from country i produces $\mathbf{q} \equiv \{q_{ij}(\omega)\}$ units of good ω to be sold to country j , its cost function is given by

$$C_i(w_i, \mathbf{q}, \omega) = \sum_{j=1}^n [\tau_{ij} w_i a_i(\omega) q_{ij}(\omega) + \xi_{ij} w_i \cdot \mathbf{1}(q_{ij}(\omega) > 0)]$$

and $\mathbf{1}(q_{ij}(\omega) > 0)$ is an indicator function, w_i is the wage in country i , $\tau_{ij} w_i a_i(\omega)$ denotes the constant marginal cost inclusive of trade cost, and $\xi_{ij} w_i$ denotes the fixed cost of exporting from i to j , where $\xi_{ij} \geq 0 \forall i, j$ is exogenous. Note that we treat a country- i firm serving market i as exporting from i to i . We assume that ξ_{ii} can be non-zero. The exogenously given iceberg trade cost $\tau_{ij} \geq 1 \forall i, j$ means that τ_{ij} units of a good is shipped for one unit to arrive at the destination. We assume that $\tau_{ii} = 0 \forall i$. The exogenous unit labor requirement parameter $a_i(\omega)$ reflects the heterogeneity of productivities across blueprints.¹⁴

Market Structure: We consider two market structures in each country: (i) perfect competition and (ii) monopolistic competition (with either restricted or free entry). Under both market

¹³If $i = j$, then the domestically produced good ω is consumed.

¹⁴In fact, equation (7) will continue to be valid even if we adopt more general assumptions on the technology such

structures, there is a large number of firms in each country, and all goods-markets and labor markets clear. Under perfect competition, firms have free access to all blueprints, and there are no fixed entry costs, production costs or exporting costs.

Under monopolistic competition with restricted entry, we assume that in country i there is an exogenous number of firms $N_i < N$ each freely obtains monopoly power by freely acquiring a blueprint. The assignment of blueprints to firms is random. Under monopolistic competition with free entry, a firm from country i needs to hire F_i units of labor to develop a blueprint, which confers it with monopoly power. The measure of potential number of goods N_i produced in country i is endogenously determined by the zero profit condition. In equilibrium, the entry cost, $w_i F_i$, is equal to the expected profit of each firm.

3.2 Restrictions

Besides the above structure, we also require the model to satisfy some more restrictions.

For monopolistic competition models, we need two macro-level restrictions for each country: A1 and A2, which will be explained below.

For perfect competition models, we need to have complete specialization. Complete specialization is implied by A2. Besides this, no other restrictions are needed. Therefore the two restrictions are more than sufficient for perfect competition models to work.

In the following, we describe these restrictions in detail.

1. **Aggregate profit is a constant share of total revenue.** Let Π_j denote country j 's aggregate profit gross of entry cost. Total revenue is given by $R_j = \sum_{i=1}^n X_{ji}$, where X_{ji} denotes the total value of exports from j to i . The first macro-level restriction is

A1 *For any country j , Π_j/R_j is constant.*

Under monopolistic competition with homogeneous firms, with and without free entry, and CES preferences, A1 necessarily holds.

2. Import demand is CES. Formally, this macro-level restriction is stated as

A2 *The import demand system is such that for any importer j and any pair of exporters $i \neq j$*

as

$$\begin{aligned} c_{ij}(w_i, t_j, \omega) &\equiv \tau_{ij} \cdot w_i \cdot a_{ij}(\omega) \cdot t_j^{\frac{1}{1-\sigma}} \\ f_{ij}(w_i, t_j, \omega) &\equiv \xi_{ij} \cdot w_i \cdot b_{ij}(\omega) \cdot m_{ij}(t_j) \end{aligned}$$

similar to that of ACR. Please refer to ACR (2012) for detail. We make simpler assumptions here so as to highlight our intuition more clearly.

and $k \neq j$, $\varepsilon_j^{ik} \equiv \frac{\partial \ln(X_{ij}/X_{jj})}{\partial \ln \tau_{kj}} = \varepsilon < 0$ if $i = k$ and zero otherwise.

The elasticity ε_j^{ik} is the percentage change in the relative imports from country i in country j associated with a small change in the marginal exporting cost from country k to j , holding wages (w_i) and the measure of goods that can be produced (N_i) in each country i fixed. Under perfect competition, A2 implies complete specialization in the sense that for all i and $k \neq i$, and for all j , the measure of goods in $\Omega_{ij} \cap \Omega_{kj}$ must be equal to zero, where Ω_{ij} is the set of goods exported from i to j . Complete specialization is a sufficient condition under perfect competition for our result to hold. Under monopolistic competition, A2 implies that the measure of firms that are indifferent to selling in a particular market must be equal to zero.

4 One-sector Armington-type models

The welfare of country j is given by $U_j = E_j/P_j$, where P_j denotes the exact price index faced by the representative consumer in country j . As explained in section 2.1, the percentage change in global welfare is given by $\sum_{j=1}^n s_j \widehat{U}_j$.

We will show below that (7) continues to hold. In the rest of this section, we only outline the proofs of this result, while relegating the detailed proofs to the appendix.

4.1 One-sector model under perfect competition

Under perfect competition, we only need to assume complete specialization, which is implied from A2 (as explained in ACR). In the appendix, we prove the following proposition.

Proposition 1 *Suppose that the market structure is perfect competition. Under complete specialization, the change in global welfare associated with small changes in trade costs is given by equation (7).*

Here is a sketch of the proof:

Step 1: First, $\widehat{U}_j = \widehat{E}_j - \widehat{P}_j$. Second, $E_j = Y_j - X_j^{net} \implies E_j \widehat{E}_j = Y_j \widehat{Y}_j - dX_j^{net} \implies$

$$\widehat{E}_j = \frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j}$$

Therefore, the change in real income of country j is given by:

$$\widehat{U}_j = \frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j} - \widehat{P}_j$$

Step 2: Under complete specialization, as each good consumed in a country is solely supplied by a single country (domestic or foreign), the percentage change in its price just depends on that of the unit cost (that of the wage of the producing country) and that of the trade cost. Other than that, the extensive margin effect, called the “specialization effect” in Wilson (1980), which reflects a change in the pattern of specialization, does not affect the price index.¹⁵ Therefore, *the change in the consumer price index is given by:*

$$\hat{P}_j = \sum_{i=1}^n \lambda_{ij} (\hat{w}_i + \hat{\tau}_{ij})$$

where $\lambda_{ij} = \frac{X_{ij}}{E_j}$ is country j 's share of expenditure on goods originating from country i and consumed in country j .

Step 3: From steps 1 and 2, we have

$$\hat{U}_j = \sum_{i=1}^n \left(\frac{X_{ji}}{E_j} \hat{w}_j - \frac{X_{ij}}{E_j} \hat{w}_i \right) - \sum_{i=1}^n \frac{X_{ij}}{E_j} \hat{\tau}_{ij} - \frac{dX_j^{net}}{E_j} \quad (9)$$

The term $\sum_{i=1}^n \left(\frac{X_{ji}}{E_j} \hat{w}_j - \frac{X_{ij}}{E_j} \hat{w}_i \right)$ captures the change in purchasing power induced by the general equilibrium adjustments in relative wages, which we refer to as “relative price effect”.¹⁶ The term $\frac{dX_j^{net}}{E_j}$ captures the reduction in expenditure due to trade imbalance, which we refer to as “trade imbalance effect”. The term $\sum_{i=1}^n \frac{X_{ij}}{E_j} \hat{\tau}_{ij}$ captures the direct effect of changes in trade costs (saving in trade costs), which we refer to as “direct price effect”. Note the similarity between (9) and (6).

Based on (9), we calculate:

$$\begin{aligned} \sum_{j=1}^n s_j \hat{U}_j &= \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ji}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} - \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} \\ &= \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} \\ &= - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} \end{aligned}$$

where the second line stems from $\sum_{j=1}^n dX_j^{net} = 0$, which is implied from $\sum_{j=1}^n X_j^{net} \equiv 0$, and from interchanging i and j in the first term on RHS of line one. As a result, we have Proposition 1.

From the perspective of global welfare, the relative price effects completely offset each other simply because of the conservation of physical quantities of goods — the quantity of ω shipped out of i to j has to be equal to the quantity of ω shipped into j from i plus the wastage due to shipping. The trade imbalance effects completely offset each other as $\sum_{j=1}^n X_j^{net} = 0$. Like in the

¹⁵The specialization effect works through a change in the pattern of specialization. This term is attributed to Wilson (1980). For example, the set of goods produced by Home only (or Foreign only) will change during trade liberalization, leading to welfare effect on each country. (This happens in, say, Dornbusch-Fisher-Samuelson (1977)). Complete specialization can avoid discontinuity in the effect of specialization on welfare under a small change in trade cost.

¹⁶ $\hat{w}_j$ and $\hat{w}_i$ reflect the changes in F.O.B. prices of goods exported from j and i respectively. Thus, this effect is similar to that explained in section 3.2 underneath (6).

neo-classical-type model presented in section 2, these relationships play a crucial role in obtaining equation (7).

Examples of models to which this proposition applies are Dornbusch-Fisher-Samuelson (1977), Anderson (1979) and Eaton and Kortum (2002).

4.2 One-sector model under monopolistic competition

In the appendix, we prove the following proposition:

Proposition 2 *Suppose that the market structure is monopolistic competition. Under assumptions A1 and A2, the change in global welfare associated with small changes in trade costs is given by equation (7).*

The following is an outline of the proof.

Step 1: *As in the last subsection, the change in real income in country j is given by $\hat{U}_j = \frac{Y_j}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j} - \hat{P}_j$.*

Step 2: Totally differentiating the price index equation given in subsection 3.1 yields an expression for the change in consumer price index, given by:

$$\hat{P}_j = \sum_{i=1}^n \frac{\lambda_{ij}}{1 - \sigma - \gamma_j} \left\{ \left[1 - \sigma - \frac{\sigma}{\sigma - 1} \gamma_{ij} \right] \hat{w}_i + \frac{\gamma_{ij}}{\sigma - 1} \hat{E}_j + (1 - \sigma - \gamma_{ij}) \hat{\tau}_{ij} + \hat{N}_i \right\}$$

where γ_{ij} is the elasticity of extensive margin with respect to the variable cost, and $\gamma_j = \sum_{i=1}^n \lambda_{ij} \gamma_{ij}$.

Step 3: A2 implies that $\gamma_{ij} = 1 - \sigma - \varepsilon$ (which is a constant) for all i , which, together with steps 1 and 2, implies that the percentage change in welfare of country j is given by:¹⁷

$$\hat{U}_j = \left(\frac{1}{\sigma - 1} + \frac{1}{\varepsilon} + 1 \right) \left(\sum_{i=1}^n \frac{X_{ji}}{E_j} \hat{w}_j - \sum_{i=1}^n \frac{X_{ij}}{E_j} \hat{w}_i - \frac{dX_j^{net}}{E_j} \right) + \sum_{i=1}^n \frac{X_{ij}}{E_j} \frac{\hat{N}_i}{\varepsilon} - \sum_{i=1}^n \frac{X_{ij}}{E_j} \hat{\tau}_{ij} \quad (10)$$

where $\varepsilon < 0$ is the elasticity of trade as defined in A2; it is assumed that $|\varepsilon| \geq \sigma - 1 > 0$. The first term now captures the relative price effect, the trade imbalance effect and the extensive margin effect (explained below). When firms are homogeneous, $\varepsilon = 1 - \sigma$. The difference between homogeneous firms and heterogeneous firms is that, under heterogeneous firms, there is one more effect: $\left(\frac{1}{\sigma - 1} + \frac{1}{\varepsilon} \right) \left(\sum_{i=1}^n \frac{X_{ji}}{E_j} \hat{w}_j - \sum_{i=1}^n \frac{X_{ij}}{E_j} \hat{w}_i - \frac{dX_j^{net}}{E_j} \right)$.¹⁸ It reflects the effect of the change in the

¹⁷The fact that γ_{ij} is a constant is important in obtaining the final result.

¹⁸In Krugman's (1980) monopolistic competition model, $\varepsilon = 1 - \sigma$. Based on Melitz's (2003) model with Pareto distribution of firm productivity, $\varepsilon \neq 1 - \sigma$, yet the effect of the change in the productivity cutoff for exporting on welfare, compared with the monopolistic competition models with homogeneous firms, are very small. This is because the trade elasticity $|\varepsilon|$ now denotes the shape parameter of Pareto distribution of firm productivity. According to

productivity cutoff for exporting on welfare, which we call the “extensive margin effect”. This is the outcome of two counteracting forces. A higher productivity cutoff for exporting leads to a higher average productivity for exporters and hence a higher welfare for the destination country. On the other hand, it lowers the probability of exporting and therefore reduces the destination country’s welfare. The net effect of these two forces on welfare of the destination j is equal to $\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon}\right) \left(\sum_{i=1}^n \frac{X_{ji}}{E_j} \hat{w}_j - \sum_{i=1}^n \frac{X_{ij}}{E_j} \hat{w}_i - \frac{dX_j^{net}}{E_j}\right)$. Comparing (10) with (9), there is still one more indirect effect, namely that of changes in number of potential entrants, which captures the entry and/or exit of firms due to changes in trade costs. Hereinafter, we shall refer to this effect as the “potential entrants effect”.

Step 4: From A1, we can infer that the number of potential entrants N_i in each country i is constant either because it is exogenously determined under restrictive entry or it is unchanged in equilibrium under free entry with a fixed overhead cost in each period. Therefore, in equilibrium, $\hat{N}_i = 0$. Hence, the “potential entrants effect” for an individual country is zero, which implies that it does not affect the welfare of an individual country.¹⁹

Step 5: We calculate $\sum_{j=1}^n s_j \hat{U}_j$ based on (10). Like in perfect competition in this section and in section 2, the relative price effects of different countries completely offset each other because $\sum_{j=1}^n \sum_{i=1}^n X_{ji} \hat{w}_j = \sum_{j=1}^n \sum_{i=1}^n X_{ij} \hat{w}_i$ which is due to conservation of physical quantities of goods. The trade imbalance effect completely offset each other because $\sum_{j=1}^n X_j^{net} \equiv 0$. The extensive margin effects completely offset each other due to the CES import demand system, as ε is constant.

Combining the results in the five steps, we conclude that *the change in global welfare is given by (7)*. From the global welfare point of view, the relative price effects and the trade imbalance effect completely offset each other, as explained in the case of perfect competition. Moreover, the extensive margin effects completely offset each other because of the CES import demand system (A2). Therefore, only the direct price effect remains to be relevant for determining the global welfare impact of trade cost reduction. Hence, we have Proposition 2.

Examples of models to which this proposition applies are Krugman (1980), Melitz (2003) with Pareto distribution of firm productivity, and Arkolakis (2010).

The proofs for the one-sector perfect competition model and monopolistic competition model form the basis of the proofs in the extensions discussed in sections 5 and ?? below.

Axtell (2001), $\frac{-\varepsilon}{\sigma-1}$ is close to one. Hence, the effect of the change in the productivity cutoff for exporting on welfare, given by $\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon}\right) \left[\sum_{i=1}^n \frac{X_{ji}}{E_j} \hat{w}_j - \sum_{i=1}^n \frac{X_{ij}}{E_j} \hat{w}_i - \frac{dX_j^{net}}{E_j}\right]$, is close to zero. Consequently, consistent with Atkeson and Burstein (2010), small changes in trade barriers usually have similar aggregate effects on welfare for each individual country for models with and without firm heterogeneity.

¹⁹However, the potential entrants effect for an individual country will not be zero under the multi-sector extension, as we shall see in section 5.1.

5 Extensions of the basic Armington-type model

In this section, we consider a number of extensions of the basic Armington-type models in the last section to the cases with multiple sectors and multiple factors, and the existence of tradable intermediate goods. We conclude that Propositions 1 and 2 continue to hold under these settings. In other words, the structure of the trade model does not affect the property that the change in global welfare only depends on the direct effect of the reduction of trade costs. The proofs in these cases are fundamentally similar to those explained in the last section. Because of the proofs are long, we only outline the intuition below while relegating the detailed proof to the appendix.

5.1 Multiple Sectors

The virtue of extending to the multiple sector setting is that we can allow for different trade costs in different sectors, which is an important empirical fact. Suppose that the set of goods $\omega \in \Omega$ is separated into groups denoted by Ω^s where $s = 1, \dots, S$, and Ω^s is referred to as sector s . Consumers in country j have their preferences represented by the following utility function:²⁰

$$U_j = \prod_{s=1}^S [U_j(s)]^{\eta^s}$$

$$\text{where } U_j(s) = \left[\sum_{i=1}^n \int_{\omega \in \Omega} q_{ij}^s(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}},$$

$0 \leq \eta^s \leq 1$ denotes the (constant) share of expenditure on goods in sector s in any country, $q_{ij}^s(\omega)$ denotes the consumption of variety ω in sector s in country j of goods originating from country i . Now, we assume that our macro-level restrictions apply to the sectoral level variables, namely, total profit of sector s of country j , Π_j^s ; total revenue of sector s of country j , R_j^s ; total value of sector s 's goods exported from country i to country j , X_{ij}^s . A1 and A2 are now modified to:

AM1: For any country j and any sector s , Π_j^s/R_j^s is constant.

AM2: The bilateral value of exports from country i to country j in sector s , X_{ij}^s , satisfies:

$$\frac{\partial \ln(X_{ij}^s/X_{jj}^s)}{\partial \ln \tau_{kj}^{s'}} = \varepsilon \text{ if } s' = s \text{ and } k = i$$

$$\frac{\partial \ln(X_{ij}^s/X_{jj}^s)}{\partial \ln \tau_{kj}^{s'}} = 0 \text{ otherwise}$$

Furthermore, when we refer to restricted entry under monopolistic competition in country j , we assume that there is an exogenous number of firms, N_j^s , each of which freely receives monopoly power as a result of freely acquiring ownership of a blueprint in sector s . Under monopolistic

²⁰ Assuming CES preferences across sectors instead of Cobb-Douglas preferences does not affect our result stated in Proposition 3 below.

competition with free entry, a firm in any sector in country i needs to employ F_i units of labor to develop a blueprint, which gives it monopoly power. Thus, the entry cost is $w_i F_i$.²¹ We prove the following proposition in the appendix.

Proposition 3 *If (i) there is complete specialization for models under perfect competition, or (ii) AM1 and AM2 hold for models under monopolistic competition, then the change in global welfare is given by*

$$\sum_{j=1}^n s_j \widehat{U}_j = -\sum_{j=1}^n \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ij}^s}{Y^w} \widehat{\tau}_{ij}^s.$$

Therefore, if we assume that $\tau_{ij}^s = \tau_{ij}$ for any $s = 1, \dots, S$, the change in global welfare again reduces to (7).

Here we outline the intuition of Proposition 3 by comparing the multi-sector models with the one-sector models. Under perfect competition, the proof of Proposition 3 concerning each sector is very similar to that of the proof of Proposition 1, and so will not be elaborated here. Under monopolistic competition, the change of welfare in country j is given by

$$\widehat{U}_j = \left(\frac{1}{\sigma - 1} + \frac{1}{\varepsilon} + 1 \right) \left(\sum_{i=1}^n \sum_{s=1}^S \frac{X_{ji}^s}{E_j} \widehat{w}_j - \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ij}^s}{E_j} \widehat{w}_i - \frac{dX_j^{net}}{E_j} \right) - \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ij}^s}{E_j} \left(\widehat{\tau}_{ij}^s + \frac{\widehat{N}_i^s}{\varepsilon} \right) \quad (11)$$

It is instructive to compare this equation with (10) in the one-sector monopolistic competition model. One important difference between the two equations is that the potential entrants effect on individual country's welfare captured by $\widehat{N}_i^s$ here is not zero anymore under free entry with a fixed overhead cost in each period.²² In other words, $\widehat{N}_i^s \neq 0$ under free entry, as resources reallocate across sectors as trade costs change. For example, Fan, Lai and Qi (2012) describe the “inter-sectoral resource allocation” (IRA) effect in the face of trade liberalization (same as the potential entrants effect in this paper) in a multi-sectoral model with intra-sectoral firm heterogeneity. In general, the change in number of potential entrants in a sector may have a positive or negative welfare effect on domestic and foreign countries. From the global welfare point of view, the potential entrants effects from different sectors of the same country completely offset each other, as shown below. As before, the relative price effects and trade imbalance effects from different countries offset each other. This leaves the direct price effect as the only relevant effect on global welfare.

The mechanism is as follows. An increase in the number of potential entrants in a country increases the consumer welfare in other countries as the variety of goods available for the latter increases. Therefore, a more positive $\widehat{N}_i^s$ tends to increase $\widehat{U}_j$ (note that $\varepsilon < 0$). We calculate global welfare impact, $\sum_{j=1}^n \frac{E_j}{Y^w} \widehat{U}_j$, based on the equation for $\widehat{U}_j$ above. We focus on the term

²¹ Our results continue to hold if we assume the entry costs are different across sectors.

²² Under restrictive entry, N_i^s is exogenous; therefore the potential entrants effect on individual country's welfare is zero.

$\sum_{i=1}^n \sum_{s=1}^S \sum_{j=1}^n \frac{X_{ij}^s}{Y^w} \frac{\widehat{N}_i^s}{\varepsilon}$, the potential entrants effect, in the resulting expression. The global welfare impact of an increase in number of potential entrants in sector s of country i is equal to $\left(\sum_{j=1}^n X_{ij}^s\right) \cdot \widehat{N}_i^s / Y^w = \left(R_i^s \cdot \widehat{N}_i^s\right) / Y^w$. Therefore, the total global welfare effect of changes in the number of potential entrants in all sectors of country i is equal to $\sum_{s=1}^S \left(R_i^s \cdot \widehat{N}_i^s\right) / Y^w$, which is equal to $\sum_{s=1}^S R_i^s \left(\widehat{R}_i^s - \widehat{w}_i\right) / Y^w$, as $\widehat{R}_i^s = \widehat{N}_i^s + \widehat{w}_i$ due to AM1 and the free entry condition.²³ Total income $w_i L_i$ equals total revenue $\sum_{s=1}^S R_i^s$, which implies that $\widehat{w}_i = \left(\sum_{s=1}^S R_i^s \cdot \widehat{R}_i^s\right) / \sum_{s=1}^S R_i^s$, which in turn implies that $\sum_{s=1}^S R_i^s \left(\widehat{R}_i^s - \widehat{w}_i\right) = 0$.²⁴ Hence, $\sum_{s=1}^S \sum_{j=1}^n \frac{X_{ij}^s}{Y^w} \frac{\widehat{N}_i^s}{\varepsilon} = 0$, meaning that the global welfare impact of the potential entrants effects originating from different sectors of the same country i offset each other.

Note that the multi-sector model cannot collapse into a single-sector model because of the intersectoral resource allocation (IRA) effect. The IRA effect explains why ACR's equation works for a single-sector model but not in a multi-sector model, as they need the welfare impact of the potential entrants effects on country i originating from different sectors of the same country i to offset each other, which is not true. For us, the IRA effect does not invalidate our equation because all we need is for the global welfare impact of the potential entrants effects originating from different sectors of the same country i to offset each other, which is true.

Examples of models to which this equation applies are: multi-sector extensions of Melitz (2003) with Pareto distribution of firm productivity, Hsieh and Ossa (2011), multi-sector extensions of Eaton-Kortum (2002), Chor (2010), Donaldson (2010), Costinot, Donaldson and Komunjer (2012).

5.2 Multiple Factors and Sectors

In the previous sections, the only factor input is labor. Here we consider multiple factor inputs. We assume that the factor endowment in country i is given by L_{ki} , where $k = 1, \dots, K$ denote indexes of factors. Suppose that goods $\omega \in \Omega$ are divided into groups denoted by Ω^s , where $s = 1, \dots, S$, and Ω^s is referred to as sector s . The representative consumer in country j has preferences given by the following utility function:²⁵

$$U_j = \prod_{s=1}^S [U_j(s)]^{\eta^s}$$

$$\text{where } U_j(s) = \left[\sum_{i=1}^n \int_{\omega \in \Omega_i^s} q_{ij}^s(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}},$$

²³AM1 and free entry condition implies that $\varsigma R_i^s = \Pi_i^s = N_i^s w_i F_i$, which in turn implies that $\widehat{R}_i^s = \widehat{N}_i^s + \widehat{w}_i$.

²⁴This means that the global welfare impact of the change in number of potential entrants in each individual country induced by trade liberalization in multiple countries is equal to zero.

²⁵Assuming CES preferences across sectors instead of Cobb-Douglas preferences does not affect our result stated in Proposition 4 below.

$0 \leq \eta^s \leq 1$ denotes the (constant) share of consumption expenditure in any country on goods in sector s ; $q_{ij}^s(\omega)$ denotes the consumption of variety ω in sector s exported from country i to country j . Note that $\sum_{s=1}^S \eta^s = 1$. The production function of a firm in sector s of country i is given by $f_i^s(l_1, \dots, l_K; \omega) = A_i(\omega) \prod_{k=1}^K (l_k)^{\beta_k(s)}$, where $\beta_k(s)$ is the cost share of factor k in sector s so that $\sum_{k=1}^K \beta_k(s) = 1$ for all s ; l_k is the input of factor k ; $A_i(\omega)$ denotes the firm's productivity. To be consistent with the one-sector model, the cost function for producing quantities $\mathbf{q} \equiv \{q_{ij}^s(\omega)\}$ is given by

$$C_i^s(v_i^s, \mathbf{q}, \omega) = \sum_{j=1}^n [\tau_{ij}^s v_i^s a_i(\omega) q_{ij}^s(\omega) + \xi_{ij} v_i^s \cdot \mathbf{1}(q_{ij}^s(\omega) > 0)]$$

where $v_i^s = \prod_{k=1}^K \left(\frac{w_{ki}}{\beta_k(s)} \right)^{\beta_k(s)}$ is the aggregate factor cost in sector s of country i ; and $A_i(\omega) \equiv 1/a_i(\omega)$. The environment of the perfect competition model and monopolistic competition model with restricted entry are the same as in subsection 5.1. Under monopolistic competition with free entry, each firm from country i needs to pay $v_i^s F_i$ to acquire a blueprint. We prove the following proposition in the appendix.

Proposition 4 *If (i) there is complete specialization for models under perfect competition, or (ii) AM1 and AM2 hold for models under monopolistic competition, then the change in global welfare is given by*

$$\sum_{j=1}^n s_j \widehat{U}_j = - \sum_{j=1}^n \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ij}^s}{Y^w} \widehat{\tau_{ij}^s}.$$

Therefore, if we assume that $\tau_{ij}^s = \tau_{ij}$ for any $s = 1, \dots, S$, the change in global welfare again reduces to (7).

The analogue of (11) is

$$\widehat{U}_j = \left(\frac{1}{\sigma - 1} + \frac{1}{\varepsilon} + 1 \right) \left(\sum_{i=1}^n \sum_{s=1}^S \frac{X_{ji}^s}{E_j} \widehat{v}_j^s - \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ij}^s}{E_j} \widehat{v}_i^s - \frac{dX_j^{net}}{E_j} \right) - \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ij}^s}{E_j} \left(\widehat{\tau_{ij}^s} + \frac{\widehat{N}_i^s}{\varepsilon} \right) \quad (12)$$

Compared with the single-factor model in the last subsection, the relevant factor cost is aggregate factor cost v_i^s instead of wage w_i . Like the relative price effects, these relative aggregate factor cost effects offset each other from the global welfare point of view as a result of conservation of physical quantities of goods. Moreover, the potential entrants effects and trade imbalance effects from different countries offset each other. Thus, only the direct effect remains.

Examples of models to which this equation applies are: Bernard, Redding and Schott (2007), Burstein and Vogel (2010) and Heckscher-Ohlin models with complete specialization such as Dornbusch-Fisher-Samuelson (1980).

5.3 Multi-stage Production

In this extension we allow some goods to be used only as intermediate inputs into the production of other goods. We assume that each country produces a single nontraded final good. The final good is produced in three sequential stages. The final good is assembled from a continuum of stage-2 outputs indexed by $\omega \in \Omega$. The production of stage-2 output of variety ω (which shall be called “stage-2 ω ”) requires the input of stage-1 output for ω (which shall be called “stage-1 ω ”) and labor. The production of stage-1 ω requires only labor. All stage-1 and stage-2 outputs are tradable, and all countries possess the technologies of production for all stages. The market structure for all goods is assumed to be perfect competition. The production function in the first stage in country i is given by

$$y_{1i}(\omega) = A_{1i}(\omega) l_{1i}(\omega) \quad \text{where } \omega \in \Omega$$

where $y_{1i}(\omega)$ is the output of stage-1 ω , $A_{1i}(\omega) \equiv 1/a_{1i}(\omega)$ is country i 's labor productivity associated with the production of stage-1 ω , and $l_{1i}(\omega)$ is country i 's labor input in the production of stage-1 ω . Stage-1 ω and labor are combined in a nested Cobb-Douglas production function at the second stage to produce stage-2 ω :

$$y_{2i}(\omega) = x_{1i}(\omega)^\theta [A_{2i}(\omega) l_{2i}(\omega)]^{1-\theta} \quad \text{where } \omega \in \Omega$$

where $y_{2i}(\omega)$ is the output of stage-2 ω ; $A_{2i}(\omega) \equiv 1/a_{2i}(\omega) \implies [A_{2i}(\omega)]^{1-\theta} \equiv [a_{2i}(\omega)]^{\theta-1}$, which is country i 's total factor productivity associated with the production of stage-2 ω ; $l_{2i}(\omega)$ is country i 's labor input in the production of stage-2 ω ; $x_{1i}(\omega)$ is country i 's use of stage-1 ω for stage-2 production, and the constant θ represents the cost share of the intermediate input $x_{1i}(\omega)$. In the final stage, stage-2 outputs are assembled into the nontraded final good using a constant elasticity of substitution (CES) technology:

$$Y_i = \left[\int_{\omega \in \Omega} x_{2i}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}},$$

where $x_{2i}(\omega)$ is country i 's use of stage-2 ω and σ is the elasticity of substitution between the inputs in this stage. The utility function is given by $U_j \equiv Y_j$. The consumer price index in country j , which can be derived from the utility function, is therefore given by

$$P_j = \left[\sum_{i=1}^n \int_{\omega \in \Omega} p_{ij}(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$$

where $p_{ij}(\omega)$ is the price of stage-2 ω exported from i to j .

We prove the following proposition in the appendix.

Proposition 5 *When there is multi-stage production under perfect competition with complete specialization, equation (7) holds.*

Define $\lambda_{mij} \equiv X_{mij}/E_j$ as the expenditure share of country j on imported stage-2 good from country i , whose production uses the stage-1 good imported from country m . It can be shown in the appendix that

$$\hat{U}_j = \frac{X_j^{net}}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j} - \sum_{i=1}^n \sum_{m=1}^n \lambda_{mij} [\theta (\hat{w}_m - \hat{w}_i + \hat{\tau}_{mi}) + \hat{w}_i - \hat{w}_j + \hat{\tau}_{ij}] \quad (42)$$

Note that $\theta \sum_{m=1}^n X_{ijm} + \sum_{m=1}^n X_{mij} = X_{ij}$, which implies $\theta \sum_{m=1}^n s_m \lambda_{ijm} + \sum_{m=1}^n s_j \lambda_{mij} = s_j \lambda_{ij}$ which further implies $\sum_{j=1}^n \sum_{i=1}^n \left(\theta \sum_{m=1}^n s_m \lambda_{ijm} + \sum_{m=1}^n s_j \lambda_{mij} \right) = \sum_{j=1}^n \sum_{i=1}^n s_j \lambda_{ij}$. Moreover, $\sum_{j=1}^n \sum_{i=1}^n \sum_{m=1}^n s_j \lambda_{mij} (\hat{w}_m - \hat{w}_i + \hat{\tau}_{mi}) = \sum_{j=1}^n \sum_{i=1}^n \sum_{m=1}^n s_m \lambda_{ijm} (\hat{w}_i - \hat{w}_j + \hat{\tau}_{ij})$. Therefore, as we calculate $\sum_{j=1}^n s_j \hat{U}_j$, the term corresponding to the last term in (42), $\sum_{j=1}^n s_j \sum_{i=1}^n \sum_{m=1}^n \lambda_{mij} [\theta (\hat{w}_m - \hat{w}_i + \hat{\tau}_{mi}) + \hat{w}_i - \hat{w}_j + \hat{\tau}_{ij}]$, collapses to $-\sum_{j=1}^n \sum_{i=1}^n s_j \lambda_{ij} (\hat{w}_i - \hat{w}_j + \hat{\tau}_{ij})$. Following a similar procedure as for the one-sector perfect competition model in subsection 4.1, we obtain (7). A detailed proof is given in the Appendix.

When there are many stages of production, the effect of a small change in trade cost in each stage will accumulate to affect the consumer price index, and this direct effect in each stage is only related to the trade value and trade cost in that stage. Again, the indirect effects offset each other from the global welfare point of view, just like in subsection 4.1. As a result, the change in global welfare resulting from small changes in trade costs is only affected by the cumulative trade value over all stages between each and every pair of trading partners and changes in trade costs between each and every pair of trading partners. It is noteworthy that this result applies to a model with more than three stages, though we only discuss the three-stage example here for simplicity of exposition.

Examples of models to which this result applies is the one-factor version of the models in Yi (2003) and Yi (2010).

5.4 Existence of a non-traded good sector

In this subsection, we assume that there are two sectors: sector H produces a homogeneous good, and it is a non-tradable; sector D produces a set of differentiated products, and they are all tradable.²⁶ There is perfect competition in sector H , where production is characterized by constant returns to scale. In the tradable-good sector, there are two possible market structures: perfect competition and monopolistic competition (with either restricted or free entry). Under monopolistic competition with restricted entry, we assume that there is an exogenous number of firms, N_i , in the differentiated good sector of country i . Under monopolistic competition with free entry, a firm from

²⁶The result continues to hold if the non-tradable good sector produces differentiated goods, as long as there is perfect competition there.

country i needs to hire F_i units of labor to develop a blueprint, which confers it with monopoly power, just as in the basic model. The utility function for the representative consumer in country j is given by

$$U_j = H_j^b D_j^{1-b}$$

$$\text{with } D_j = \left[\sum_{i=1}^n \int_{\omega \in \Omega_i} q_{ij}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}$$

where H_j is the consumption of homogeneous good in i , $1-b$ is the constant share of expenditure on tradable goods, $q_{ij}(\omega)$ is j 's consumption of tradable variety ω that is imported from i . Now, X_{ij} denotes the total value of imports from i to j in the tradable-good sector. Π_j and R_j still denote country j 's aggregate profit gross of entry cost and total revenue. We make the following two assumptions:

AH1: For any country j , Π_j/R_j is constant.

AH2: In the tradable-good sector, the import demand system is such that for any importer j and any pair of exporters $i \neq j$ and $k \neq j$, $\varepsilon_j^{ik} = \frac{\partial \ln(X_{ij}/X_{jj})}{\partial \ln \tau_{kj}} = \varepsilon < 0$ if $i = k$ and zero otherwise.

We prove the following proposition in the appendix.

Proposition 6 *If (i) there is complete specialization and perfect competition in the tradable-good sector, or (ii) AH1, AH2 and $X_j^{net} = 0 \forall j$ under monopolistic competition in the tradable-good sector, then equation (7) holds.*

The proof of the perfect competition case is straightforward. Under monopolistic competition, it can be shown that

$$\sum_{j=1}^n s_j \hat{U}_j = - \sum_{j=1}^n b \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \frac{X_j^{net}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij}$$

In Krugman's (1980) monopolistic competition model, $\varepsilon = 1 - \sigma$. Thus, equation (7) holds. For Melitz's (2003) model with Pareto distribution of firm productivity, $\varepsilon \neq 1 - \sigma$. Therefore, theoretically, we need $X_j^{net} = 0 \forall j$ (i.e. balanced trade for all countries) for (7) to hold. The reason is that the extensive margin effect is not zero anymore when some trade balances are non-zero. Note, however, that $|\varepsilon|$ is the shape parameter of the Pareto distribution of firm productivity. According to Axtell (2001), the distribution of firm productivity is Pareto with a very fat tail. This observation has been confirmed by other studies. This corresponds to $\frac{-\varepsilon}{\sigma-1}$ being empirically very close to one. Therefore, there is a presumption that the term $\sum_{j=1}^n b \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \frac{X_j^{net}}{Y^w} \hat{w}_j$ is empirically close to zero. Hence, we can conclude that balanced trade is theoretically necessary but empirically not important for (7) to hold.

5.5 Existence of Intermediate Good

For this case, we return to a one-sector model. We focus on the case of perfect competition. We now assume that a good ω can either be consumed as final good or be used as input in the production of a unique intermediate good. The utility in country j continues to be given by (8). The production function of the unique intermediate good has the same form as (8). Therefore, the output of intermediate good is equal to $\left[\sum_{i=1}^n \int_{\omega \in \Omega} q_{ij}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}$, where $q_{ij}(\omega)$ represents j 's employment of good ω that is imported from i for production of the intermediate good. Thus, P_j now represents both the consumer price index in country j and the price of the unique intermediate good in this country. There is only one factor input, labor. We assume that the production function of any good ω is Cobb-Douglas with labor cost share β and intermediate good share $1 - \beta$. Therefore, for country i , the marginal cost for producing good ω is equal to $\tau_{ij} w_i^\beta P_i^{1-\beta} a_i(\omega)$. To simplify exposition, we let $\delta_i \equiv w_i^\beta P_i^{1-\beta}$, which can be regarded as aggregate factor cost. Based on this setting, we prove the following proposition in the appendix.

Proposition 7 *When there are intermediate goods in the production process, then under perfect competition and complete specialization, equation (7) holds.*

As discussed in the previous sections, we know that the expenditure on the final goods is given by $E_j = Y_j - X_j^{net}$, where $X_j^{net} = \sum_{i=1}^n X_{ji} - \sum_{i=1}^n X_{ij}$ is net exports and $Y_j = w_j L_j$ is GDP of country j (as GDP is equal to total factor income). To take into account the fact that all goods $\omega \in \Omega$ can either be consumed as final goods or used as input in the production of intermediate good, we can write total expenditure by country j , $\widetilde{E}_j$, as the sum of the expenditures for final and intermediate goods. In other words, $\widetilde{E}_j = E_j + (1 - \beta) R_j$ where $R_j = \sum_{i=1}^n X_{ji}$ denotes total output of intermediate and final goods. In addition, $Y_j = \beta R_j$ since the expenditure share on labor in production of intermediate and final goods is β .²⁷ Therefore, total expenditure satisfies:

$$\widetilde{E}_j = E_j + \frac{(1 - \beta)}{\beta} (E_j + X_j^{net}) = \frac{1}{\beta} [E_j + (1 - \beta) X_j^{net}]$$

The intuition for Proposition 7 is as follows. Under perfect competition,

$$\begin{aligned} \widehat{U}_j &= \frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j} - \widehat{P}_j \\ &= \frac{X_j^{net}}{E_j} \widehat{\delta}_j + \frac{E_j + (1 - \beta) X_j^{net}}{\beta E_j} (\widehat{\delta}_j - \widehat{P}_j) - \frac{dX_j^{net}}{E_j} \\ &= \frac{X_j^{net}}{E_j} \widehat{\delta}_j - \sum_{i=1}^n \frac{X_{ij}}{E_j} (\widehat{\delta}_i - \widehat{\delta}_j + \widehat{\tau}_{ij}) - \frac{dX_j^{net}}{E_j} \\ &= \sum_{i=1}^n \left(\frac{X_{ji}}{E_j} \widehat{\delta}_j - \frac{X_{ij}}{E_j} \widehat{\delta}_i \right) - \frac{dX_j^{net}}{E_j} - \sum_{i=1}^n \frac{X_{ij}}{E_j} \widehat{\tau}_{ij} \end{aligned} \quad (13)$$

²⁷ Now, the total revenue of country j , R_j , is not equal to its GDP, Y_j .

where the second line stems from $Y_j = E_j + X_j^{net}$ and $\hat{\delta}_j = \beta \hat{w}_j + (1 - \beta) \hat{P}_j$; the third line arises from $\hat{P}_j = \sum_{i=1}^n \frac{X_{ij}}{E_j} (\hat{\delta}_i + \hat{\tau}_{ij})$; the last line follows from $\sum_{i=1}^n X_{ij} + X_j^{net} = \sum_{i=1}^n X_{ji}$. Compared with equation (9), $\hat{w}_i$ is replaced by $\hat{\delta}_i = \beta \hat{w}_i + (1 - \beta) \hat{P}_i$. As a result, the first term in the last line of equation (13), $\sum_{i=1}^n \left(\frac{X_{ji}}{E_j} \hat{\delta}_j - \frac{X_{ij}}{E_j} \hat{\delta}_i \right)$, which captures the “relative price effect”, reflects the changes in unit costs of the goods produced by country j relative to the changes in the unit costs of the goods produced by country i . It turns out that the expenditure-share-weighted sum of these terms over all countries completely offset each other from the global welfare point of view as a result of the conservation of physical quantities of goods. In addition, the second term in the last line of equation (13), $\frac{dX_j^{net}}{E_j}$, captures the “trade imbalance effect”. The expenditure-share-weighted sum of this term over all countries completely offset each other from the global welfare point of view due to $\sum_{j=1}^n X_j^{net} \equiv 0$.

In contrast, ACR (2012) show that their equation does not hold in this setting even under perfect competition.

Examples of models to which this equation applies are Eaton and Kortum (2002), Dekle, Eaton and Kortum (2007, 2008), Alvarez and Lucas (2007).

6 Summary

Here is a summary of the results.

1. For the neo-classical-type model: **Under perfect competition**, fixed extensive margins of trade and allowing for incomplete specialization $\implies$ all indirect effects completely offset each other $\implies$ (7) holds.
2. For the Armington-type models: 1. **Under perfect competition**, CES preferences and complete specialization (which is implied from A2) $\implies$ all indirect effects completely offset each other $\implies$ (7) holds. 2. **Under monopolistic competition without the existence of a non-traded good**, CES preferences and A1 and A2 $\implies$ all indirect effects completely offset each other $\implies$ (7) holds. 3. **Under monopolistic competition with the existence of a non-traded good**, CES preferences and A1 and A2 $\implies$ (7) holds under balanced trade, which is needed theoretically, but not important empirically.

From the above summary, we can conclude that (7) works for perfect competition models with and without complete specialization. Moreover, under perfect competition, the equation works without the restrictions A1 and A2 that we impose on the imperfect competition models. Under monopolistic competition, we need various degrees of restriction for the equation to work. In fact, perfect competition should be treated as the benchmark, as it is the most natural assumption to make in analyzing the macroeconomy. The reason for analyzing the imperfect competition models

is to understand how much deviation from perfect competition we can allow for our equation to work. It turns out that most of the trade models that are widely used in recent years satisfy our restrictions A1 and A2. Perhaps it is not coincident that these imperfect competition models have been widely used, as they are simpler and more user-friendly, which in turn is because they are closer to perfect competition. By imposing restrictions A1 and A2, we confine the models to be sufficiently close to perfect competition so that they become the cousins of the perfect competition model.

One class of models that this paper does not include is the imperfect competition models with endogenously variable markups. Such models can capture the pro-competitive gains from trade which models with constant markup cannot. However, there is mixed empirical evidence on the size of the pro-competitive gains from trade. Indeed, pro-competitive effects are sometimes negative so that variable markups reduce the gains from trade (see, for example, Arkolakis, Costinot, Donaldson and Rodriguez-Clare, 2012). In fact, Edmond, Midrigan and Xu (2012) conclude that the size of the gains from trade depends a great deal on the underlying micro-details. Therefore, there is no presumption that our equation will bias the estimate upward or downward by not including this class of model.

7 Empirical Application

In this section, we apply equation (7) to estimate the change in global welfare due to the reduction of trade costs throughout the world in the last five decades. Hummels (2007) and Hummels and Schaur (2012) find that there were declines in the costs of air freight and overland transport, but rises in the ocean freight rates in the post-WWII period. Consequently, there were structural changes in the composition of the modes of international shipping and declines in the costs of distant transport. They estimate the time costs in shipping and interpret it as trade costs. They show that each day of shipping time is equivalent to an ad-valorem trade cost of 0.6 to 2.3 percent. We adopt their estimate and follow their method by assuming that average shipping time was 40 days for international trade in 1960. At that time, almost all international shipments were through ocean freight. We also assume that there was gradual reduction of ocean shipping time and a gradual substitution towards air freight since 1960. The average international shipping time in 2010 was 20 days and air-shipped trade rose from (approximately) 0% to 50% from 1960 to 2010.²⁸ Thus, the average shipping days dropped from 40 to $0.5 * 20$ (by sea) + $0.5 * 1$ (by air) = 10.5 days during the period 1960-2010. As we assume the cost reduction process to be gradual (i.e. the

²⁸These numbers are based on U.S. trade statistics. Given that the shipping industry has been very competitive, we think it is reasonable to assume that these numbers also apply to all other countries of the world. A sharp speeding up of ocean transport followed from the introduction of containerization in the late 1960s and 1970s, and we assume that the annual rate of reduction of trade cost is constant during this period.

rate of reduction is constant throughout the fifty years), the number of shipping days dropped by $(40 - 10.5)/50 = 0.59$ per year during the period 1960-2010, which is equivalent to a reduction of ad-valorem trade cost by $[0.354\%, 1.357\%]$ per year. Based on the data of the share of trade in GDP from World Development Indicator (WDI) published by the World Bank, we calculate from equation (7) the cumulative global welfare gains in the last five decades from the saving in shipping time to be $[2.98\%, 8.81\%]$.²⁹ Note that we obtain these estimates by calculating the annual percentage increase in global welfare each year from 1960 through 2009, and then calculate the cumulative welfare gains from these fifty numbers.³⁰ The yearly changes in trade costs were sufficiently small for our equation to be valid, as our equation only applies to small percentage changes.^{31, 32}

In another empirical application, we consider a counterfactual experiment of a one-percent reduction in all bilateral trade costs in the year 2010. This reduction can be due to technological improvements or other exogenous changes. Based on our theory, we only need to know the share of total trade value in world GDP in order to calculate the impact on global welfare. The data shows that global trade volume was equal to 22.8% of world GDP in the year 2010. It follows from (7) that the elasticity of global welfare with respect to trade cost is equal to 0.228%.

8 Conclusion

Our theoretical analysis conveys two messages. First, ACR (2012) find that the gains from trade for a country based on a broad class of trade models conditional on the import penetration ratio and trade elasticity are the same regardless of the trade model used. The class of models include the Armington model, Eaton and Kortum (2002), Krugman (1980), Melitz (2003) with Pareto distribution of firm productivity. However, when one extends these models to multi-sector settings, the result no longer holds. In this paper, we prove that a broad class of models and settings yield the same global gains from reduction of trade costs conditional on the set of trade flows and set of changes in trade costs. The set of trade models and settings to which the equation is applicable is

²⁹These estimates seem to be quite small. However, they are roughly in line with the finding of, say, Eaton and Kortum (2002). From Table IX there, we can calculate the GDP-share-weighted average of the welfare gains of the nineteen OECD countries from moving from autarky to the trade situation in 1990 to be 1.72%.

³⁰Let μ_t be the percentage global welfare gain in year t . The cumulative percentage increase in global welfare is equal to $\left[\prod_{t=1960}^{2009} (1 + \mu_t) \right] - 1$.

³¹Any change in trade costs less than 10% can be regarded as small enough for our equation to hold with sufficient accuracy.

³²If we had a panel data of pairwise shipping time for all trading partners, or a panel of detailed data on freight rates for all importers, we could carry out a more accurate calculation of global welfare gains due to savings in shipping costs or other types of trade costs. Unfortunately, these data are not readily available at present. Therefore, we leave it for future research.

considerably broader than that of ACR. In addition, unlike ACR, whether or not trade is balanced is not important in our paper. Moreover, unlike ACR, our equation does not require estimation of trade elasticity, which is hard to estimate.

The second message is that the global welfare impact of trade cost reduction only depends on two sets of sufficient statistics: (i) the ratio of the bilateral trade volume between each and every pair of trading partners and global income; and (ii) the change in exporting cost for each and every pair of trading partners. Under both perfect competition and imperfect competition, the equation is independent of indirect effects such as changes in relative prices of goods because of the conservation of physical quantities of goods. It is independent of trade imbalances because they sum up to zero in the world. Under imperfect competition, it is independent of the adjustments in the numbers of potential entrants because of the proportionality between total profit and total revenue in each country (based on our assumption A1); and it is independent of the adjustments of extensive margins of trade because of the CES import demand system (based on our assumption A2). Therefore, in the end only the direct effect remains.

One may argue that the class of models to which our equation applies is not that broad, given the restrictive nature of assumptions A1 and A2. However, if one accepts that the assumption of perfect competition is an important benchmark for analyzing the global macroeconomy, then our equation is not so restrictive. Under perfect competition, the restrictions A1 and A2 that we impose on the imperfect competition models are not necessary. Therefore, our equation is indeed quite general once one accepts perfect competition as an important benchmark for analyzing the global macroeconomy. In fact, one can cite numerous important papers analyzing the macroeconomy that assume perfect competition as the market structure. The imperfect competition models to which our equation applies can in fact be considered cousins of the perfect competition model. One obvious deviation from this class of models is the imperfect competition models with endogenous variable markups. However, there is no presumption that the gains from trade or trade cost reduction is biased one way or the other when variable markups are introduced.

Our framework can also be applied to analyze the worldwide effects of other shocks, such as endowment change or innovation originating from one country. It is noteworthy that an individual country's gains from reduction of trade costs conditional on a set of bilateral trade flows and a set of changes in bilateral trade costs is in general not robust to the trade model used. In other words, while the global size of gains is independent of the indirect effects, the global distribution of gains is not. It would be interesting to calculate the distribution of the global gains from some important episodes of worldwide trade cost reduction (e.g. Uruguay round of GATT) using different trade models, and compare the results of different models and estimates based on other methods such as computable general equilibrium model. This is left for future research.

Appendix

(Note that some of these appendixes can be put online in the interest of space once the paper is accepted for publication)

A Proof for subsection 2.1

$$\begin{aligned}
& \frac{\sum_{i=1}^n (P_i + dP_i) (dU_i)}{\sum_{i=1}^n (P_i + dP_i) U_i} - \frac{\sum_{i=1}^n P_i (dU_i)}{\sum_{i=1}^n P_i U_i} \\
&= \frac{[\sum_{i=1}^n (P_i + dP_i) (dU_i)] [\sum_{i=1}^n P_i U_i] - [\sum_{i=1}^n P_i (dU_i)] [\sum_{i=1}^n (P_i + dP_i) U_i]}{[\sum_{i=1}^n (P_i + dP_i) U_i] [\sum_{i=1}^n P_i U_i]} \\
&= \frac{[\sum_{i=1}^n P_i (dU_i)] [\sum_{i=1}^n P_i U_i] - [\sum_{i=1}^n P_i (dU_i)] [\sum_{i=1}^n P_i U_i]}{[\sum_{i=1}^n (P_i + dP_i) U_i] [\sum_{i=1}^n P_i U_i]} + O(\epsilon^2) \\
&= 0
\end{aligned}$$

where the last line stems from ignoring $O(\epsilon^2) \equiv \frac{\sum_{i=1}^n \sum_{j=1}^n dP_i \cdot P_j \cdot (dU_i U_j - U_i dU_j)}{[\sum_{i=1}^n (P_i + dP_i) U_i] [\sum_{j=1}^n P_j U_j]}$, which is a residual that contains all terms of order higher than the first.

The following sections are proofs of the propositions.

For any importing country j , we denote by $G_j(a_1, \dots, a_n)$ the share of goods $\omega \in \Omega$ such that $a_i(\omega) \leq a_i$ for all i , and by $g_j(a_1, \dots, a_n)$ the corresponding density function.

B Proof of Proposition 1 (One-sector perfect competition)

Similarly to ACR (2012), we define the following variables:

$$c_{ij} = w_i \tau_{ij} \tag{14}$$

$$g_{ij}(a_i, c_{1j}, \dots, c_{nj}) = \int_{a_1 > \frac{a_i c_{ij}}{c_{1j}}} \dots \int_{a_{i-1} > \frac{a_i c_{ij}}{c_{i-1j}}} \int_{a_{i+1} > \frac{a_i c_{ij}}{c_{i+1j}}} \dots \int_{a_n > \frac{a_i c_{ij}}{c_{nj}}} g_j(\mathbf{a}) d\mathbf{a}_{-i} \tag{15}$$

where $\mathbf{a} \equiv (a_1, \dots, a_n)$ while $\mathbf{a}_{-i}$ denotes a vector formed by removing the i -th component from vector $\mathbf{a}$. The variable $c_{ij}a_i$ captures the unit cost of goods exported from country i to country j , and $g_{ij}(a_i, c_{1j}, \dots, c_{nj})$ is the conditional probability density function that country i is the cheapest source of supply in country j . We prove Proposition 1 in the following steps.

Step 1: The change in the welfare of country j is given by:

$$\widehat{U}_j = \frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j} - \widehat{P}_j \tag{16}$$

Proof: By definition, $\hat{U}_j = \hat{E}_j - \hat{P}_j$. Since the total profit of firms $\Pi_j = 0$ under perfect competition, we have $Y_j = w_j L_j$. Meanwhile, $E_j = Y_j - X_j^{net}$, which implies that $\hat{E}_j = \frac{Y_j}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j}$, which immediately implies equation (16).

Step 2: The change in the consumer price index is given by:

$$\hat{P}_j = \sum_{i=1}^n \lambda_{ij} \hat{c}_{ij} = \sum_{i=1}^n \lambda_{ij} (\hat{w}_i + \hat{\tau}_{ij}). \quad (17)$$

Proof: By Lemma 1 in ACR, we know that, due to complete specialization, the consumer price index can be written as:

$$P_j = \left[\sum_{i=1}^n \int_0^\infty (c_{ij} a_i)^{1-\sigma} N g_{ij}(a_i, c_{1j}, \dots, c_{nj}) da_i \right]^{\frac{1}{1-\sigma}}. \quad (18)$$

Totally differentiating this expression, we obtain:

$$\hat{P}_j = \frac{1}{1-\sigma} \sum_{i=1}^n \lambda_{ij} \left[(1-\sigma) \hat{c}_{ij} + \sum_{k=1}^n \gamma_{ij}^k \hat{c}_{kj} \right] \quad (19)$$

where

$$\lambda_{ij} = \frac{\int_0^\infty (c_{ij} a_i)^{1-\sigma} g_{ij}(a_i, c_{1j}, \dots, c_{nj}) da_i}{\sum_{k=1}^n \int_0^\infty (c_{kj} a_k)^{1-\sigma} g_{kj}(a_k, c_{1j}, \dots, c_{nj}) da_k}$$

$$\gamma_{ij}^k = \frac{\partial \ln \left(\int_0^\infty a_i^{1-\sigma} g_{ij}(a_i, c_{1j}, \dots, c_{nj}) da_i \right)}{\partial \ln c_{kj}}$$

where γ_{ij}^k is the extensive margin elasticity. By equation (15), the extensive margin elasticities satisfy $\gamma_{ij}^i = -\sum_{k \neq i} \gamma_{ij}^k$. Thus, we can rewrite equation (19) as:

$$\hat{P}_j = \frac{1}{1-\sigma} \sum_{i=1}^n \lambda_{ij} \left[(1-\sigma) \hat{c}_{ij} + \sum_{k \neq i} \gamma_{ij}^k (\hat{c}_{kj} - \hat{c}_{ij}) \right]$$

The extensive margin elasticities also satisfy $\lambda_{ij} \gamma_{ij}^k = \lambda_{kj} \gamma_{kj}^i$ according to equation (15), which implies that

$$\sum_{i=1}^n \sum_{k \neq i} \lambda_{ij} \gamma_{ij}^k (\hat{c}_{kj} - \hat{c}_{ij}) = 0.$$

Combining the previous two equations, we obtain equation (17).

Step 3: The change in global welfare is given by (7):

Proof: By equations (16) and (17), the percentage change in the welfare of country j is given by:

$$\begin{aligned} \hat{U}_j &= \frac{Y_j}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j} - \sum_{i=1}^n \frac{X_{ij}}{E_j} (\hat{w}_i + \hat{\tau}_{ij}) \\ &= \sum_{i=1}^n \left(\frac{X_{ji}}{E_j} \hat{w}_j - \frac{X_{ij}}{E_j} \hat{w}_i \right) - \frac{dX_j^{net}}{E_j} - \sum_{i=1}^n \frac{X_{ij}}{E_j} \hat{\tau}_{ij} \end{aligned} \quad (20)$$

where the last equation stems from $Y_j = \sum_{i=1}^n X_{ji}$. From (20), we obtain:

$$\begin{aligned}\sum_{j=1}^n s_j \hat{U}_j &= \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ji}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i - \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} \\ &= \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} \\ &= -\sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij}\end{aligned}$$

where the second line comes from $\sum_{j=1}^n dX_j^{net} = 0$, which is implied from $\sum_{j=1}^n X_j^{net} \equiv 0$, and from interchanging i and j in the first term in line one.

C Proof of Proposition 2 (One-sector monopolistic competition)

We use the following additional notation:

$$a_{ij}^* \equiv \sigma^{\frac{\sigma}{1-\sigma}} (\sigma - 1) \left(\frac{P_j}{w_i \tau_{ij}} \right) \left(\frac{\xi_{ij} w_i}{E_j} \right)^{\frac{1}{1-\sigma}} \quad (21)$$

$$p_{ij}(a) \equiv \left(\frac{\sigma}{\sigma - 1} \right) a w_i \tau_{ij} \quad (22)$$

$$g_{ij}(a) \equiv \int_0^{+\infty} g_j(\mathbf{a}_{-i}, a_i = a) d\mathbf{a}_{-i} \quad (23)$$

Note that $1/a_{ij}^*$ captures the productivity cutoff for exporting in Melitz (2003); $p_{ij}(a)$ denotes the price of a good exported from country i to country j with unit labor requirement a , and $g_{ij}(a)$ is the conditional density function of goods in Ω_{ij} with unit labor requirements a . Proposition 2 is proved in the following steps.

Step 1: *The change in welfare is given by (16).*

Proof: By definition, $\hat{U}_j = \hat{E}_j - \hat{P}_j$. Under free entry in country j , $Y_j = w_j L_j$ since net profits are zero. Meanwhile, $E_j = Y_j - X_j^{net}$, which implies that $\hat{E}_j = \frac{Y_j}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j}$, which immediately implies equation (16). Under restricted entry in country j , $Y_j = w_j L_j + \Pi_j$. By A1, we have $\Pi_j = \zeta R_j = \zeta Y_j$ with $0 < \zeta < 1$. Thus, $Y_j = \frac{1}{1-\zeta} w_j L_j$, which implies that $\hat{Y}_j = \hat{w}_j$, which in turn implies $\hat{E}_j = \frac{Y_j}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j}$. This again implies equation (16).

Step 2: *The change in the consumer price index is given by:*

$$\hat{P}_j = \sum_{i=1}^n \frac{\lambda_{ij}}{1 - \sigma - \gamma_j} \left[\left(1 - \sigma - \frac{\sigma}{\sigma - 1} \gamma_{ij} \right) \hat{w}_i + \frac{\gamma_{ij}}{\sigma - 1} \hat{E}_j + (1 - \sigma - \gamma_{ij}) \hat{\tau}_{ij} + \hat{N}_i \right] \quad (24)$$

where γ_{ij} is given by equation (27) below, and $\gamma_j = \sum_{i=1}^n \lambda_{ij} \gamma_{ij}$.

Proof: By Lemma 2 in ACR, we know that, under assumption A2, the consumer price index can be written as:

$$P_j = \left[\sum_{i=1}^n N_i \int_0^{a_{ij}^*} [p_{ij}(a)]^{1-\sigma} g_{ij}(a) da \right]^{\frac{1}{1-\sigma}}. \quad (25)$$

Totally differentiating this expression, we obtain

$$\widehat{P}_j = \sum_{i=1}^n \frac{\lambda_{ij}}{1-\sigma} \left[(1-\sigma) (\widehat{w}_i + \widehat{\tau}_{ij}) + \widehat{N}_i + \gamma_{ij} \widehat{a}_{ij}^* \right] \quad (26)$$

where

$$\gamma_{ij} = \frac{\left[p_{ij}(a_{ij}^*) \right]^{1-\sigma} a_{ij}^* g_{ij}(a_{ij}^*)}{\int_0^{a_{ij}^*} [p_{ij}(a)]^{1-\sigma} g_{ij}(a) da} \quad (27)$$

with γ_{ij} being the counterpart of the extensive margin elasticities under perfect competition. By definition of a_{ij}^* , we know that

$$\widehat{a}_{ij}^* = \widehat{P}_j - \widehat{\tau}_{ij} - \widehat{w}_i - \frac{1}{\sigma-1} (\widehat{w}_i - \widehat{E}_j). \quad (28)$$

Combining equations (26) and (28), we get equation (24).

Step 3: *The change in welfare is given by:*

$$\widehat{U}_j = \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \sum_{i=1}^n \left(\frac{X_{ji}}{E_j} \widehat{w}_j - \frac{X_{ij}}{E_j} \widehat{w}_i \right) - \frac{dX_j^{net}}{E_j} + \sum_{i=1}^n \frac{X_{ij}}{E_j} \frac{\widehat{N}_i}{\varepsilon} - \sum_{i=1}^n \frac{X_{ij}}{E_j} \widehat{\tau}_{ij} \quad (29)$$

Proof: By Lemma 2 in ACR, the total value of exports from country i to country j equals

$$X_{ij} = \frac{N_i \int_0^{a_{ij}^*} [p_{ij}(a)]^{1-\sigma} g_{ij}(a) da}{\sum_{k=1}^n N_k \int_0^{a_{kj}^*} [p_{kj}(a)]^{1-\sigma} g_{kj}(a) da} Y_j.$$

Totally differentiating this expression yields:

$$\widehat{X}_{ij} - \widehat{X}_{jj} = (1-\sigma) (\widehat{w}_i - \widehat{w}_j + \widehat{\tau}_{ij}) + \gamma_{ij} \widehat{a}_{ij}^* - \gamma_{jj} \widehat{a}_{jj}^* + \widehat{N}_i - \widehat{N}_j.$$

From equation (28), we get

$$\widehat{a}_{ij}^* = \widehat{a}_{jj}^* - \widehat{\tau}_{ij} - \left(\frac{1}{\sigma-1} + 1 \right) (\widehat{w}_i - \widehat{w}_j).$$

The last two equations imply:

$$\widehat{X}_{ij} - \widehat{X}_{jj} = \left[1 - \sigma - \left(\frac{1}{\sigma-1} + 1 \right) \gamma_{ij} \right] (\widehat{w}_i - \widehat{w}_j) + (1 - \sigma - \gamma_{ij}) \widehat{\tau}_{ij} + (\gamma_{ij} - \gamma_{jj}) \widehat{a}_{jj}^* + \widehat{N}_i - \widehat{N}_j$$

This implies that, for any $i, k \neq j$,

$$\frac{\partial \ln(X_{ij}/X_{jj})}{\partial \ln \tau_{kj}} = \varepsilon_j^{ik} = \begin{cases} 1 - \sigma - \gamma_{ij} + (\gamma_{ij} - \gamma_{jj}) \frac{\partial \ln a_{jj}^*}{\partial \ln \tau_{ij}} & \text{for } k = i \\ (\gamma_{ij} - \gamma_{jj}) \frac{\partial \ln a_{jj}^*}{\partial \ln \tau_{kj}}, & \text{for } k \neq i \end{cases}.$$

Since $\frac{\partial \ln a_{jj}^*}{\partial \ln \tau_{kj}} > 0$, the above equation together with A2 imply that the first line is equal to ε and the second line is equal to zero. This further implies that $\gamma_{ij} = 1 - \sigma - \varepsilon$ for all i . Substituting $\gamma_{ij} = 1 - \sigma - \varepsilon$ into equation (24), we have

$$\widehat{P}_j = \sum_{i=1}^n \lambda_{ij} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \widehat{w}_i + \widehat{\tau}_{ij} + \frac{\widehat{N}_i}{\varepsilon} \right] - \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \widehat{E}_j. \quad (30)$$

This, together with $\widehat{U}_j = \widehat{E}_j - \widehat{P}_j$ and $\widehat{E}_j = \frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j}$ as explained in Step 1, imply that

$$\begin{aligned}\widehat{U}_j &= \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \left(\frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j} \right) - \sum_{i=1}^n \lambda_{ij} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \widehat{w}_i + \widehat{\tau}_{ij} + \frac{\widehat{N}_i}{\varepsilon} \right] \\ &= \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \left(\sum_{i=1}^n \frac{X_{ji}}{E_j} \widehat{w}_j - \sum_{i=1}^n \frac{X_{ij}}{E_j} \widehat{w}_i - \frac{dX_j^{net}}{E_j} \right) + \sum_{i=1}^n \frac{X_{ij}}{E_j} \frac{\widehat{N}_i}{\varepsilon} - \sum_{i=1}^n \frac{X_{ij}}{E_j} \widehat{\tau}_{ij}\end{aligned}$$

where the last equation stems from $Y_j = \sum_{i=1}^n X_{ji}$ and $\lambda_{ij} = \frac{X_{ij}}{E_j}$.

Step 4: *The change in the number of potential entrants satisfies $\widehat{N}_i = 0$.*

Proof: Under restricted entry in country i , we have $\widehat{N}_i = 0$. Under free entry, the zero profit condition implies that $\Pi_j = N_j w_j F_j$. Since $\Pi_j = \zeta Y_j = \zeta w_j L_j$ by A1, we therefore have $\widehat{\Pi}_j = \widehat{w}_j$, which implies $\widehat{N}_j = 0$ for all j .

Step 5: *The change in global welfare is given by (7):*

Proof: Equation (29), together with $s_j = \frac{E_j}{Y^w}$ and $\widehat{N}_i = 0$, imply that

$$\begin{aligned}\sum_{j=1}^n s_j \widehat{U}_j &= \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \sum_{j=1}^n \left(\sum_{i=1}^n \frac{X_{ji}}{Y^w} \widehat{w}_j - \sum_{i=1}^n \frac{X_{ij}}{Y^w} \widehat{w}_i - \frac{dX_j^{net}}{Y^w} \right) - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \widehat{\tau}_{ij} \\ &= - \sum_{i=1}^n \frac{X_{ij}}{Y^w} \widehat{\tau}_{ij}\end{aligned}$$

where the second line stems from $\sum_{j=1}^n X_j^{net} \equiv 0$ and $\sum_{j=1}^n \sum_{i=1}^n \frac{X_{ji}}{Y^w} \widehat{w}_j = \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \widehat{w}_i$.

D Proof of Proposition 3 (Multi-sector)

We proceed with the proof in two steps. The consumer price index is given by

$$P_j = \prod_{s=1}^S [P_j(s)]^{\eta^s} \quad (31)$$

where $P_j(s)$ denotes the aggregate price index for sector s .

Step 1: *The change in global welfare is given by:*

$$\sum_{j=1}^n s_j \widehat{U}_j = \sum_{j=1}^n \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ji}^s}{Y^w} \widehat{w}_j + \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{j=1}^n \sum_{s=1}^S \frac{\eta^s E_j}{Y^w} \widehat{P}_j(s). \quad (32)$$

Proof: Totally differentiating the consumer price index (31), we get

$$\widehat{P}_j = \sum_{s=1}^S \eta^s \widehat{P}_j(s).$$

Similar to step 1 of the proofs in Propositions 1 and 2, we have $\widehat{U}_j = \frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j} - \widehat{P}_j$ under both perfect competition and monopolistic competition. Then, combining the fact that $\sum_{s=1}^S \eta^s = 1$ and the last equation, we have

$$\widehat{U}_j = \frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j} - \sum_{s=1}^S \eta^s \widehat{P}_j(s)$$

Therefore,

$$\sum_{j=1}^n s_j \hat{U}_j = \sum_{j=1}^n \frac{Y_j}{Y^w} \hat{w}_j - \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{j=1}^n \sum_{s=1}^S \frac{\eta^s E_j}{Y^w} \hat{P}_j(s)$$

which implies (32), since $Y_j = \sum_{i=1}^n \sum_{s=1}^S X_{ji}^s$.

Step 2: The change in global welfare is given by:

$$\sum_{j=1}^n s_j \hat{U}_j = - \sum_{j=1}^n \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ij}^s}{Y^w} \hat{\tau}_{ij}^s. \quad (33)$$

Proof: Here, we will show that equation (33) holds under both perfect competition and monopolistic competition.

Under Perfect competition:

Based on the same derivation as in the proof of Proposition 1, equation (17) continues to hold for each of the sectors. In other words, the change in the aggregate price index $P_j(s)$ in sector s is given by

$$\hat{P}_j(s) = \sum_{i=1}^n \lambda_{ij}^s (\hat{w}_i + \hat{\tau}_{ij}^s)$$

where $\lambda_{ij}^s \equiv X_{ij}^s / (\eta^s E_j)$ is the penetration ratio of country i 's exports in sector s of country j . Substituting this expression into equation (32), we obtain

$$\begin{aligned} \sum_{j=1}^n s_j \hat{U}_j &= \sum_{i,j,s} \frac{X_{ji}^s}{Y^w} \hat{w}_j + \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} (\hat{w}_i + \hat{\tau}_{ij}^s) \\ &= - \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \hat{\tau}_{ij}^s, \quad \text{which is (33)} \end{aligned}$$

where the second line stems from $\sum_{j=1}^n X_j^{net} \equiv 0$ and $\sum_{i,j,s} \frac{X_{ji}^s}{Y^w} \hat{w}_j = \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \hat{w}_i$, where $\sum_{i,j,s} \equiv \sum_{i=1}^n \sum_{j=1}^n \sum_{s=1}^S$

Under Monopolistic competition:

Based on the same derivation as in the proof of Proposition 2, equation (30) continues to hold from the perspective of the sector under assumption AM2. Hence, the aggregate price index in sector s satisfies:

$$\hat{P}_j(s) = \sum_{i=1}^n \lambda_{ij}^s \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \hat{w}_i + \hat{\tau}_{ij}^s + \frac{\hat{N}_i^s}{\varepsilon} \right] - \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \hat{E}_j$$

where N_i^s is the expected mass of potential entrants in sector s in country i . Substituting this

expression into (32), we have:

$$\begin{aligned}
\sum_{j=1}^n s_j \widehat{U}_j &= \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \sum_{j=1}^n \left(\frac{Y_j}{Y^w} \widehat{w}_j - \frac{dX_j^{net}}{Y^w} \right) - \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \widehat{w}_i + \widehat{\tau}_{ij}^s + \frac{\widehat{N}_i^s}{\varepsilon} \right] \\
&= \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \sum_{j=1}^n \left(\sum_{i=1}^n \sum_{s=1}^S \frac{X_{ji}^s}{Y^w} \widehat{w}_j - \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ij}^s}{Y^w} \widehat{w}_i - \frac{dX_j^{net}}{Y^w} \right) - \sum_{j,i,s} \frac{X_{ij}^s}{Y^w} \left(\widehat{\tau}_{ij}^s + \frac{\widehat{N}_i^s}{\varepsilon} \right) \\
&= - \sum_{j,i,s} \frac{X_{ij}^s}{Y^w} \left(\widehat{\tau}_{ij}^s + \frac{\widehat{N}_i^s}{\varepsilon} \right) \tag{34}
\end{aligned}$$

where the second line stems from $Y_j = \sum_{i=1}^n \sum_{s=1}^S X_{ji}^s$; the third line follows from $\sum_{j=1}^n X_j^{net} \equiv 0$ and $\sum_{i,j,s} \frac{X_{ji}^s}{Y^w} \widehat{w}_j = \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \widehat{w}_i$.

In addition, under monopolistic competition with restricted entry, N_i^s is exogenous, i.e., $\widehat{N}_i^s = 0$. Under free entry, $\zeta R_j^s = \Pi_j^s = N_j^s w_j F_j$ for all s and j , by AM1 and the free entry condition. Therefore, $\widehat{R}_j^s = \widehat{N}_j^s + \widehat{w}_j$. Zero net profits implies that total labor income is equal to total income, $w_j L_j = \sum_{s=1}^S R_j^s$, which implies that $\widehat{w}_j = \sum_{s=1}^S \frac{R_j^s}{\sum_{s=1}^S R_j^s} \widehat{R}_j^s = \sum_{s=1}^S \frac{R_j^s}{\sum_{s=1}^S R_j^s} (\widehat{N}_j^s + \widehat{w}_j)$, which in turn implies that $\sum_{s=1}^S R_j^s \widehat{N}_j^s = 0$. Hence, in both the unrestricted entry and restricted entry cases, we have $\sum_{s=1}^S R_i^s \widehat{N}_i^s = 0$. This means that

$$\sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \widehat{N}_i^s = \frac{\sum_{i=1}^n \sum_{s=1}^S R_i^s \widehat{N}_i^s}{Y^w} = 0$$

Combining the above expression with equation (34), we have:

$$\sum_{j=1}^n s_j \widehat{U}_j = - \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \widehat{\tau}_{ij}^s$$

E Proof of Proposition 4 (Multi-factor and multi-sector)

$v_i^s = \prod_{k=1}^K \left(\frac{w_{ki}}{\beta_k(s)} \right)^{\beta_k(s)}$ implies $\widehat{v}_i^s = \sum_{k=1}^K \beta_k(s) \widehat{w}_{ki}$. The consumer price index in country j is given by

$$P_j = \prod_{s=1}^S [P_j(s)]^{\eta^s} \tag{35}$$

In the following proof, we proceed in three steps.

Step 1: The change in GDP is given by

$$\widehat{Y}_j = \frac{\sum_{i=1}^n \sum_{s=1}^S X_{ji}^s \widehat{v}_j^s}{Y_j} \tag{36}$$

Proof: The production function, the exporting cost function, and the entry cost function in each sector are all Cobb-Douglas. As a result, the total expenditure on factor k in sector s is a fraction $\beta_k(s)$ of the total expenditure on all factors in sector s . Under perfect competition and

monopolistic competition with free entry, the total expenditure on all factors in country j in sector s is the revenue of country j in this sector $R_j^s = \sum_{i=1}^n X_{ji}^s$. Hence the total expenditure on factor k in sector s in country j is $\beta_k(s) \sum_{i=1}^n X_{ji}^s$. Therefore, the total expenditure on factor k in country j is $\sum_{s=1}^S \beta_k(s) \sum_{i=1}^n X_{ji}^s$, which equals $w_{kj} L_{kj}$ by factor market clearing condition. Under monopolistic competition with restricted entry, the total expenditure on all factors in country j is a fraction $1 - \zeta$ of the total revenue of country j in this sector, since the profits of firms are a fraction ζ of the total revenue in this sector by assumption AM1. Hence, the total expenditure on factor k in sector s in country j is $(1 - \zeta) \beta_k(s) \sum_{i=1}^n X_{ji}^s$. Therefore, the total expenditure on factor k in country j is $(1 - \zeta) \sum_{s=1}^S \beta_k(s) \sum_{i=1}^n X_{ji}^s$, which equals $w_{kj} L_{kj}$ by the factor market clearing condition.

Under perfect competition and monopolistic competition with free entry, we have $Y_j = \sum_{k=1}^K w_{kj} L_{kj}$, which implies:

$$\begin{aligned} \hat{Y}_j &= \sum_{k=1}^K \frac{w_{kj} L_{kj}}{\sum_{k=1}^K w_{kj} L_{kj}} \hat{w}_{kj} = \sum_{k=1}^K \frac{\sum_{s=1}^S \beta_k(s) \sum_{i=1}^n X_{ji}^s}{Y_j} \hat{w}_{kj} \\ &= \frac{\sum_{i=1}^n \sum_{s=1}^S \sum_{k=1}^K \beta_k(s) X_{ji}^s \hat{w}_{kj}}{Y_j} = \frac{\sum_{i=1}^n \sum_{s=1}^S X_{ji}^s \left(\sum_{k=1}^K \beta_k(s) \hat{w}_{kj} \right)}{Y_j} \\ &= \frac{\sum_{i=1}^n \sum_{s=1}^S X_{ji}^s \hat{v}_j^s}{Y_j} \end{aligned}$$

where the last line follows from $\hat{v}_j^s = \sum_{k=1}^K \beta_k(s) \hat{w}_{kj}$.

Similarly, under monopolistic competition with restricted entry, we have $Y_j = \frac{1}{1-\zeta} \sum_{k=1}^K w_{kj} L_{kj}$ by assumption AM1. Totally differentiating this equation yields:

$$\begin{aligned} \hat{Y}_j &= \sum_{k=1}^K \frac{w_{kj} L_{kj}}{\sum_{k=1}^K w_{kj} L_{kj}} \hat{w}_{kj} = \sum_{k=1}^K \frac{(1 - \zeta) \sum_{s=1}^S \beta_k(s) \sum_{i=1}^n X_{ji}^s}{(1 - \zeta) Y_j} \hat{w}_{kj} \\ &= \frac{\sum_{i=1}^n \sum_{s=1}^S \sum_{k=1}^K \beta_k(s) X_{ji}^s \hat{w}_{kj}}{Y_j} = \frac{\sum_{i=1}^n \sum_{s=1}^S X_{ji}^s \hat{v}_j^s}{Y_j} \end{aligned}$$

Step 2: The change in global welfare is given by (33).

Proof: We will show that this step holds under perfect competition and under monopolistic competition, separately. Totally differentiating (35) yields

$$\hat{P}_j = \sum_{s=1}^S \eta^s \hat{P}_j(s) \quad (37)$$

Under Perfect Competition:

Based on same derivation as in Proof of Proposition 1, equation (17) continues to hold from the perspective of a single sector by replacing wage with aggregate factor cost. In other words, the change in the aggregate price index $P_j(s)$ in sector s is given by:

$$\hat{P}_j(s) = \sum_{i=1}^n \lambda_{ij}^s (\hat{v}_i^s + \hat{\tau}_{ij}^s) \quad (38)$$

where $\lambda_{ij}^s = X_{ij}^s / \eta^s E_i$. Therefore, the percentage change in global welfare is given by:

$$\begin{aligned}
\sum_{j=1}^n s_j \hat{U}_j &= \sum_{j=1}^n s_j \left(\frac{Y_j}{E_j} \hat{Y}_j - \frac{dX_j^{net}}{E_j} - \hat{P}_j \right) \\
&= \sum_{j=1}^n \frac{Y_j}{Y^w} \hat{Y}_j - \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{j=1}^n \sum_{s=1}^S \frac{\eta^s E_i}{Y^w} \hat{P}_j(s) \\
&= \sum_{i,j,s} \frac{X_{ji}^s}{Y^w} \hat{v}_j^s - \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} (\hat{v}_i^s + \hat{\tau}_{ij}^s) \\
&= - \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \hat{\tau}_{ij}^s
\end{aligned}$$

where the second line stems from equation (36), (37), (38) and $s_j = \frac{E_j}{Y^w}$; the third line follows from $\sum_{j=1}^n X_j^{net} \equiv 0$ and $\sum_{i,j,s} \frac{X_{ji}^s}{Y^w} \hat{v}_j^s = \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \hat{v}_i^s$. The last line of the above equations is (33).

Under Monopolistic Competition:

Based on the similar derivation as the first three steps in the Proof of Proposition 2, we obtain the aggregate price index in sector s :

$$\hat{P}_j(s) = \sum_{i=1}^n \lambda_{ij}^s \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \hat{v}_i^s + \hat{\tau}_{ij}^s + \frac{\hat{N}_i^s}{\varepsilon} \right] - \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \hat{E}_j \quad (39)$$

which is analogous to (30), with $\hat{v}_i^s$ replacing $\hat{w}_i$. Hence,

$$\begin{aligned}
\sum_{j=1}^n s_j \hat{U}_j &= \sum_{j=1}^n s_j \left[\hat{E}_j - \sum_{s=1}^S \eta^s \hat{P}_j(s) \right] \\
&= \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \sum_{j=1}^n \left(\frac{Y_j}{Y^w} \hat{Y}_j - \frac{dX_j^{net}}{Y^w} \right) - \sum_{j,i,s} \frac{X_{ij}^s}{Y^w} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \hat{v}_i^s + \hat{\tau}_{ij}^s + \frac{\hat{N}_i^s}{\varepsilon} \right] \\
&= \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \sum_{j=1}^n \left(\sum_{i=1}^n \sum_{s=1}^S \frac{X_{ji}^s}{Y^w} \hat{v}_j^s - \frac{dX_j^{net}}{Y^w} \right) - \sum_{j,i,s} \frac{X_{ij}^s}{Y^w} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \hat{v}_i^s + \hat{\tau}_{ij}^s + \frac{\hat{N}_i^s}{\varepsilon} \right] \\
&= - \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \left(\hat{\tau}_{ij}^s + \frac{\hat{N}_i^s}{\varepsilon} \right) \quad (40)
\end{aligned}$$

The first line follows from equation (37); the second line stems from (39), $s_j = \frac{E_j}{Y^w}$ and $\hat{E}_j = \frac{Y_j}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j}$; the third line stems from equation (36); the fourth line comes from $\sum_{j=1}^n X_j^{net} \equiv 0$ and $\sum_{i,j,s} \frac{X_{ji}^s}{Y^w} \hat{v}_j^s = \sum_{i,j,s} \frac{X_{ij}^s}{Y^w} \hat{v}_i^s$.

Under monopolistic competition with restricted entry, N_i^s is exogenous, i.e., $\hat{N}_i^s = 0$, which, together with (40), implies (33). Under free entry, $\zeta R_j^s = \Pi_j^s = N_j^s v_j^s F_j$ for any s, j by AM1 and free entry condition. Therefore, $\hat{R}_j^s = \hat{N}_j^s + \hat{v}_j^s$. By definition, $Y_j = \sum_{s=1}^S R_j^s$, which implies that $\hat{Y}_j = \sum_{s=1}^S \frac{R_j^s}{Y_j} \hat{R}_j^s = \sum_{s=1}^S \frac{R_j^s}{Y_j} (\hat{N}_j^s + \hat{v}_j^s) = \sum_{i=1}^n \sum_{s=1}^S \frac{X_{ji}^s}{Y_j} \hat{v}_j^s + \sum_{s=1}^S \frac{R_j^s}{Y_j} \hat{N}_j^s$, which in turn implies that $\sum_{s=1}^S R_i^s \hat{N}_i^s = 0$ according to equation (36). Therefore,

$$\frac{\sum_{i,j,s} X_{ij}^s \hat{N}_i^s}{Y^w} = \frac{\sum_{i=1}^n \sum_{s=1}^S R_i^s \hat{N}_i^s}{Y^w} = 0 \quad (41)$$

Combining (40) and (41), we obtain equation (33) under monopolistic competition with free entry.

F Proof of Proposition 5 (Multi-stage Production)

We proceed to prove this proposition in two steps.

Step 1: *The change in welfare is given by*

$$\hat{U}_j = \frac{X_j^{net}}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j} - \sum_{i=1}^n \sum_{m=1}^n \lambda_{mij} [\theta (\hat{w}_m - \hat{w}_i) + \hat{w}_i - \hat{w}_j + \theta \hat{\tau}_{mi} + \hat{\tau}_{ij}] \quad (42)$$

where $\lambda_{mij} \equiv \frac{X_{mij}}{E_j}$ denotes the expenditure share of country j on imported stage-2 good from country i , whose production use the stage-1 good from country m .

Proof: Based on similar derivation as in the proof of Proposition 1, we can show that equation (17) continues to hold. However, the marginal cost now is related to where the first-stage production happens. Totally differentiating the aggregate price index given in section 5.3, we have

$$\hat{P}_j = \sum_{i=1}^n \sum_{m=1}^n \lambda_{mij} \hat{c}_{mij} = \sum_{i=1}^n \sum_{m=1}^n \lambda_{mij} [\theta \hat{w}_m + \theta \hat{\tau}_{mi} + (1 - \theta) \hat{w}_i + \hat{\tau}_{ij}] \quad (43)$$

where $c_{mij} = \left(\frac{w_m \tau_{mi} a_{1m}}{\theta} \right)^\theta \left(\frac{w_i a_{2i}}{1 - \theta} \right)^{1 - \theta} \tau_{ij}$ denotes the competitive price of a good imported into country j from country i after stage-2 production, whose production use the stage-1 good from country m . Under perfect competition, $Y_j = w_j L_j$ and $X_j^{net} = Y_j - E_j$, which imply $\hat{U}_j = \hat{E}_j - \hat{P}_j = \frac{X_j^{net}}{E_j} \hat{w}_j - \frac{dX_j^{net}}{E_j} + \hat{w}_j - \hat{P}_j$. Substituting (43) into this equation, and invoking $\sum_{i=1}^n \sum_{m=1}^n \lambda_{mij} = 1$, we get equation (42).

Step 2: *The change in global welfare is given by (7).*

Proof: $X_{ij} \equiv \lambda_{ij} E_j$ now consists of two parts: (i) imports of stage-1 goods from country i to country j for producing stage-2 good; this value equals $\theta \sum_{m=1}^n X_{ijm} \equiv \theta \sum_{m=1}^n \lambda_{ijm} E_m$ since for each dollar of country m 's imports of stage-2 goods from country j , there are θ dollars of imports of stage-1 goods from country i to country j ; (ii) imports of stage-2 goods from i to j for producing final good; this value is equal to $\sum_{m=1}^n X_{mij} \equiv \sum_{m=1}^n \lambda_{mij} E_j$. Hence,

$$\begin{aligned} X_{ij} &= \sum_{m=1}^n X_{mij} + \theta \sum_{m=1}^n X_{ijm} \\ \Leftrightarrow \lambda_{ij} E_j &= \sum_{m=1}^n \lambda_{mij} E_j + \theta \sum_{m=1}^n \lambda_{ijm} E_m \\ \Leftrightarrow s_j \lambda_{ij} &= \sum_{m=1}^n s_j \lambda_{mij} + \theta \sum_{m=1}^n s_m \lambda_{ijm} \end{aligned} \quad (44)$$

Thus, from (42), we have

$$\begin{aligned}
\sum_{j=1}^n s_j \hat{U}_j &= \sum_{j=1}^n \frac{X_j^{net}}{Y^w} \hat{w}_j - \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{j=1}^n \sum_{i=1}^n \sum_{m=1}^n s_j \lambda_{mij} [\theta (\hat{w}_m - \hat{w}_i) + \hat{w}_i - \hat{w}_j + \theta \hat{\tau}_{mi} + \hat{\tau}_{ij}] \\
&= \sum_{j=1}^n \frac{X_j^{net}}{Y^w} \hat{w}_j - \theta \sum_{j=1}^n \sum_{i=1}^n \sum_{m=1}^n s_j \lambda_{mij} (\hat{w}_m - \hat{w}_i + \hat{\tau}_{mi}) - \sum_{j=1}^n \sum_{i=1}^n \sum_{m=1}^n s_j \lambda_{mij} (\hat{w}_i - \hat{w}_j + \hat{\tau}_{ij}) \\
&= \sum_{j=1}^n \frac{X_j^{net}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \left(\theta \sum_{m=1}^n s_m \lambda_{ijm} + \sum_{m=1}^n s_j \lambda_{mij} \right) (\hat{w}_i - \hat{w}_j + \hat{\tau}_{ij}) \\
&= \sum_{j=1}^n \frac{X_j^{net}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n s_j \lambda_{ij} (\hat{w}_i - \hat{w}_j + \hat{\tau}_{ij}) \\
&= \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ji}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} \\
&= - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij}
\end{aligned}$$

where the second line comes from $\sum_{j=1}^n X_j^{net} \equiv 0$; the third line arises from switching m to i , i to j , j to m in the second term of line two; the fourth line follows from equation (44); the fifth line is from $s_j = \frac{E_j}{Y^w}$, $\lambda_{ij} = \frac{X_{ij}}{E_j}$, and $\sum_{i=1}^n X_{ij} + X_j^{net} = \sum_{i=1}^n X_{ji}$; the last line comes from interchanging i and j in the first term of the second last line. Hence, equation (7) holds.

The following appendices are not for publication. They are for the perusal of the referee only.

G Proof of Proposition 6 (Existence of a non-traded-good sector)

The consumer price index is given by

$$P_j = w_j^b P_j(D)^{1-b}$$

where $P_j(D)$ denotes the price index of differentiated goods. Totally differentiating this expression, we have $\hat{P}_j = b\hat{w}_j + (1-b)\hat{P}_j(D)$. In the following, we present the proofs under perfect competition and monopolistic competition separately.

Under Perfect Competition:

Based on the same derivation as in the proof of Proposition 1, equation (17) continues to hold in the differentiated-good sector, i.e.,

$$\hat{P}_j(D) = \sum_{i=1}^n \frac{\lambda_{ij}}{1-b} (\hat{w}_i + \hat{\tau}_{ij}) \quad (45)$$

where $\lambda_{ij} = \frac{X_{ij}}{E_j}$. Thus, the change in real income is given by:

$$\begin{aligned}\hat{U}_j &= \hat{E}_j - b\hat{w}_j - (1-b)\hat{P}_j(D) \\ &= \frac{X_j^{net}}{E_j}\hat{w}_j - \frac{dX_j^{net}}{E_j} - \sum_{i=1}^n \lambda_{ij}(\hat{w}_i - \hat{w}_j + \hat{\tau}_{ij})\end{aligned}$$

where the last line stems from equation (45) and $\sum_{i=1}^n \lambda_{ij} = 1 - b$. Hence, the change in global welfare is given by:

$$\begin{aligned}\sum_{j=1}^n s_j \hat{U}_j &= \sum_{j=1}^n \frac{X_j^{net}}{Y^w} \hat{w}_j - \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} (\hat{w}_i - \hat{w}_j + \hat{\tau}_{ij}) \\ &= \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ji}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} \\ &= -\sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij}\end{aligned}$$

where the second line comes from $\sum_{j=1}^n X_j^{net} \equiv 0$ and $\sum_{i=1}^n X_{ij} + X_j^{net} = \sum_{i=1}^n X_{ji}$; the last line comes from interchanging i and j in the first term of the second last line. Hence, equation (7) holds under perfect competition.

Under Monopolistic competition:

Like in perfect competition,

$$\hat{U}_j = \hat{E}_j - b\hat{w}_j - (1-b)\hat{P}_j(D) \quad (46)$$

Like in step 1 of the proof in Proposition 2, $E_j = Y_j - X_j^{net}$ and $\hat{E}_j = \frac{Y_j}{E_j}\hat{w}_j - \frac{dX_j^{net}}{E_j}$ imply that $\hat{E}_j = \frac{X_j^{net}}{E_j}\hat{w}_j + \hat{w}_j - \frac{dX_j^{net}}{E_j}$. Based on the same derivation as in the proof of Proposition 2, equation (30) continues to hold in the differentiated-good sector, i.e.,

$$\hat{P}_j(D) = \sum_{i=1}^n \frac{\lambda_{ij}}{1-b} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \hat{w}_i + \hat{\tau}_{ij} + \frac{\hat{N}_i}{\varepsilon} \right] - \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \hat{E}_j \quad (47)$$

Under monopolistic competition with restricted entry, N_i is exogenous, which implies that $\hat{N}_i = 0$. Under free entry, $\Pi_j = N_j w_j F_j$. By AH1, we have $N_j w_j F_j = \Pi_j = \zeta R_j = \zeta w_j L_j$. This implies

that $\hat{N}_i = 0$. Equations (46) and (47), together with $\hat{N}_i = 0$ and $s_j = \frac{E_j}{Y^w}$, imply that:

$$\begin{aligned}
& \sum_{j=1}^n s_j \hat{U}_j \\
&= \sum_{j=1}^n \left(\frac{1-b}{\sigma-1} + \frac{1-b}{\varepsilon} + 1 \right) \frac{E_j}{Y^w} \hat{E}_j - \sum_{j=1}^n \frac{bE_j}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \hat{w}_i + \hat{\tau}_{ij} \right] \\
&= \sum_{j=1}^n \left(\frac{1-b}{\sigma-1} + \frac{1-b}{\varepsilon} + 1 \right) \left(\frac{X_j^{net}}{Y^w} \hat{w}_j + \frac{E_j}{Y^w} \hat{w}_j \right) - \sum_{j=1}^n \frac{bE_j}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \hat{w}_i + \hat{\tau}_{ij} \right] \\
&= \sum_{j=1}^n \left(\frac{1-b}{\sigma-1} + \frac{1-b}{\varepsilon} + 1 \right) \frac{X_j^{net}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \left[\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) (\hat{w}_i - \hat{w}_j) + \hat{\tau}_{ij} \right] \\
&= -b \sum_{j=1}^n \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \frac{X_j^{net}}{Y^w} \hat{w}_j + \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} + 1 \right) \left(\sum_{j=1}^n \sum_{i=1}^n \frac{X_{ji}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{w}_i \right) - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij} \\
&= -b \sum_{j=1}^n \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \frac{X_j^{net}}{Y^w} \hat{w}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \hat{\tau}_{ij}
\end{aligned}$$

where the third line follows from $\hat{E}_j = \frac{X_j^{net}}{E_j} \hat{w}_j + \hat{w}_j - \frac{dX_j^{net}}{E_j}$ and $\sum_{j=1}^n X_j^{net} \equiv 0$; the fourth line follows from $(1-b)E_j = \sum_{i=1}^n X_{ij}$; the fifth line follows from $\sum_{i=1}^n X_{ij} + X_j^{net} = \sum_{i=1}^n X_{ji}$; the last line follows from interchanging i and j in the first term inside the third set of parentheses in the fifth line. When $X_j^{net} = 0$ for all j , equation (7) holds.

From the fifth line, we can see that the total effect is decomposed into the extensive margin effects, the relative wage effects and the direct effects. The sixth line shows that the relative wage effects offset each other, but the extensive margin effects do not add up to zero.³³ The intuition is that the effect of X_j^{net} on the extensive margin is through the tradable goods sector only, as $(1-b)E_j = \sum_{i=1}^n X_{ij}$. As a result, the extensive margin effect is equal to $(1-b) \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \sum_{j=1}^n \frac{X_j^{net}}{Y^w} \hat{w}_j$ instead of $\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \sum_{j=1}^n \frac{X_j^{net}}{Y^w} \hat{w}_j$.

H Proof of Proposition 7 (Existence of Intermediate Good)

Based on same derivation as in the proof of Proposition 1, equation (17) continues to hold, i.e.,

$$\hat{P}_j = \sum_{i=1}^n \lambda_{ij} \left[\hat{\delta}_i + \hat{\tau}_{ij} \right] \quad (48)$$

³³The extensive margin effect is given by $-\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} (\hat{w}_i - \hat{E}_j)$, which can be simplified to $-b \left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \sum_{j=1}^n \frac{X_j^{net}}{Y^w} \hat{w}_j$. Intuitively, $-\left(\frac{1}{\sigma-1} + \frac{1}{\varepsilon} \right) \sum_{i=1}^n \lambda_{ij} (\hat{w}_i - \hat{E}_j)$ captures the effect of changes in the export cutoffs on the welfare of country j . Please refer to step 3 in subsection 4.2 for more detailed explanation.

where $\widehat{\delta}_i = \beta \widehat{w}_i + (1 - \beta) \widehat{P}_i$ replaces $\widehat{w}_i$ in the equation for the one-sector model without intermediate goods and $\lambda_{ij} = X_{ij}/\widetilde{E}_j$. Thus, the change in the welfare of country j is given by:

$$\begin{aligned}
\widehat{U}_j &= \frac{Y_j}{E_j} \widehat{w}_j - \frac{dX_j^{net}}{E_j} - \widehat{P}_j \\
&= \frac{X_j^{net}}{E_j} \widehat{w}_j + \widehat{w}_j - \widehat{P}_j - \frac{dX_j^{net}}{E_j} \\
&= \frac{X_j^{net}}{E_j} \frac{1}{\beta} \left[\widehat{\delta}_j - (1 - \beta) \widehat{P}_j \right] + \frac{1}{\beta} \left(\widehat{\delta}_j - \widehat{P}_j \right) - \frac{dX_j^{net}}{E_j} \\
&= \frac{X_j^{net}}{E_j} \widehat{\delta}_j + \frac{E_j + (1 - \beta) X_j^{net}}{\beta E_j} \left(\widehat{\delta}_j - \widehat{P}_j \right) - \frac{dX_j^{net}}{E_j}
\end{aligned} \tag{49}$$

(49), (48), $\lambda_{ij} = X_{ij}/\widetilde{E}_j$, $\widetilde{E}_j = \frac{1}{\beta} \left[E_j + (1 - \beta) X_j^{net} \right]$ and $\sum_{i=1}^n \lambda_{ij} = 1$, together imply:

$$\begin{aligned}
\widehat{U}_j &= \frac{X_j^{net}}{E_j} \widehat{\delta}_j - \sum_{i=1}^n \frac{X_{ij}}{E_j} \left[\widehat{\delta}_i - \widehat{\delta}_j + \widehat{\tau}_{ij} \right] - \frac{dX_j^{net}}{E_j} \\
&= \sum_{i=1}^n \left[\frac{X_{ji}}{E_j} \widehat{\delta}_j - \frac{X_{ij}}{E_j} \widehat{\delta}_i \right] - \frac{dX_j^{net}}{E_j} - \sum_{i=1}^n \frac{X_{ij}}{E_j} \widehat{\tau}_{ij}
\end{aligned} \tag{50}$$

where the second line follows from $\sum_{i=1}^n X_{ij} + X_j^{net} = \sum_{i=1}^n X_{ji}$. Equation (50), together with $s_j = \frac{E_j}{Y^w}$, imply that the percentage change in global welfare is given by:

$$\begin{aligned}
\sum_{j=1}^n s_j \widehat{U}_j &= \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ji}}{Y^w} \widehat{\delta}_j - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \widehat{\delta}_i - \sum_{j=1}^n \frac{dX_j^{net}}{Y^w} - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \widehat{\tau}_{ij} \\
&= - \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \widehat{\tau}_{ij}
\end{aligned}$$

where the second line comes from $\sum_{j=1}^n X_j^{net} \equiv 0$ and $\sum_{j=1}^n \sum_{i=1}^n \frac{X_{ji}}{Y^w} \widehat{\delta}_j = \sum_{j=1}^n \sum_{i=1}^n \frac{X_{ij}}{Y^w} \widehat{\delta}_i$.

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