Love of Variety in Trade Models with Product Differentiation

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This paper explores the key role of importer's love of variety in applied general equilibrium models featuring product differentiation. The paper compares the Armington-, Krugman-, and Melitz-type trade specifications. Experimental simulations with the model reveal that as love of variety weakens, based on the empirical evidence revealed by Ardelean (2006), the models with homogeneous firms may generate larger welfare gains than the Melitz-type heterogeneous firm model. This stands in marked contrast to the findings of Melitz and Redding (2013), based on the assumption of maximum valuation on increasing variety.

1. Introduction

As regional trade agreements and economic partnership arrangements have proliferated, applied general equilibrium (AGE) analyses have been widely utilized to evaluate their likely impacts, and some model builders have attempted to incorporate theoretical information on intra-industry trade to account for economies of scale and imperfect competition. In conventional AGE models of global trade, the so-called "Armington assumption" has been widely adopted to handle cross-hauling, which is often observed in real data, between developed economies that have similar technologies and factor endowments.[1] Since this can be regarded as an ad hoc approach and shows a tendency to undervalue efficiency gains from trade, some models such as Brown, Deardorff, and Stern (1995), Francois and Roland-Holst (1997), Francois (1998), and Roson (2006) have introduced firm-level product differentiation in their AGE models as presented in the pioneering work by Krugman.

Krugman (1980) focused on two sources of efficiency gains that result from reducing trade barriers: cost reductions brought about by economies of scale, and

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[1] Armington (1969).

increased variety obtained through firm entry. In the steady advance of new trade theory that followed, one of the most successful extensions of his work is that of Melitz (2003). He appended another source of efficiency gains, namely, the reallocations of resources resulting from the endogenous productivity growth among heterogeneous firms.[2] In the AGE research community, Zhai (2008) introduced a Melitz-type trade specification into an AGE model as an alternative to the Armington approach. Then, Balistreri and Rutherford (2013) prepared a comprehensive guide to the treatment of the three approaches by Armington, Krugman, and Melitz. Dixon, Jerie, and Rimmer (2016) proposed a generalized "supermodel" that includes all three types of models as special cases.[3]

In the meantime, there has been a controversy triggered by the seminal work by Arkolakis, Costinot, and Rodriguez-Clare (2012), which concluded that the share of expenditure on domestic goods and an elasticity of imports with respect to variable trade costs (reduced-form trade elasticity) are sufficient statistics for welfare predictions, being independent of the micro-level implications of trade models. In response to their argument, Melitz and Redding (2013) rebutted that calibrating both heterogeneous and homogeneous firm models to the same domestic trade share requires assuming different values of fixed and variable costs.[4] Furthermore, calibrating the two types of models to the same reduced-form trade elasticity involves assuming different elasticities of substitution between varieties. If we consider the Melitz and Krugman models, respectively, as representing the heterogeneous and homogeneous firm models in this discussion, it is quite unrealistic to assume that the preference of economic agents for variety changes across the two models.[5] Then, Melitz and Redding (2013) showed that heterogeneous firm models generate larger welfare gains from reductions in trade costs than homogeneous firm models, applying the same values of behavioral parameters to the models.

Do heterogeneous firm models definitively generate greater welfare gains than homogeneous firm models if we retain the values of preference parameters used

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[2] While Krugman posited many firms, they are all symmetric and therefore effectively homogeneous.

[3] Bekkers and Francois (2018) also presented an alternative way to convert a conventional AGE model of global trade with the Armington-type specification to be the one with the Krugman- or Melitz-type, introducing three shifter parameters that respectively correspond to demand, supply, and trade costs. Akgul, Villoria, and Hertel (2016) have extended the standard GTAP model to incorporate both the Krugman- and Melitz-type monopolistic competition.

[4] A working paper version of Melitz and Redding (2015).

[5] While Dixon et al. (2016) concluded that comparisons between the effects respectively generated by the Melitz- and Armington-type models should be conducted with different substitution elasticities in the two models, their discussion is not subject to this criticism because the preference just related to variety is absent from the Armington-type models.

across these models? To answer this question, the present paper investigates what happens to the economic effects (welfare effects in particular) generated by a set of AGE models with different specifications of product differentiation, when the intensity of importer's love of variety changes. The paper draws inspiration from the work of Ardelean (2006) who found that love of variety (LoV) is likely much weaker than that assumed, both explicitly and implicitly, in many theoretical and applied models. This has important implications for economists using AGE models to inform policy analysis.

In order to verify whether the Chamberlinian monopolistic competition model leads to excessive product diversification, Dixit and Stiglitz (1975) presented a series of independent hypothetical models and threw considerable doubt on the presumption that LoV is as strong as assumed in the Krugman and Melitz models.[6] One of their theoretical models endogenized the elasticity of substitution between varieties supplied from different sources, based on the intuition that an additional variety reduces the distance between varieties filling in the gaps between existing varieties. Another model sought to disentangle LoV from the substitutability between varieties. Although the latter model was excluded from the published version of Dixit and Stiglitz (1977), we follow the latter in order to keep the values of substitution elasticities unchanged in all of the cases considered in this study, as we consider alternative trade specifications.

While Dixit and Stiglitz (1975) introduced product diversity as a multiplicative externality into the constant elasticity of substitution (CES) preference structure, Benassy (1996) introduced more general CES preference structure. To eliminate a potential bias that permeates in the optimality of the market-determined product variety and production levels, he presented a Krugman-type theoretical model, which separates a parameter that controls LoV from the one that controls the market power, i.e., the elasticity of substitution between varieties.[7] Then, Montagna (2001) introduced a CES preference structure a la Benassy in a heterogeneous firm model, which is slightly different from the Melitz-type. She found that, although the monopolistic competition models with homogeneous firms generate the same levels of welfare gains from trade as those obtained by the perfect competition models when there is no positive LoV, the monopolistic competition models with heterogeneous firms may generate negative efficiency effects on welfare and hence welfare gains will be less than those given by the perfect competition models under the same condition.

In the field of empirical international trade, Hummels and Klenow (2005) examined the relationships between the number of traded varieties and the size of exporter country, and found that the number of varieties explains only 60 percent

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[6] A working paper version of Dixit and Stiglitz (1977).

[7] Brown et al. (1995) incorporated a similar formulation into their AGE model known as the "Michigan model."

of the difference in export values across countries. This result implies that the rate of variety growth seems to be less than that predicted by the models with Krugman-type firm-level product differentiation, in which the variety expansion is proportional to country size while the output and price per variety remain constant. Thus, the models with the Krugman-type product differentiation tend to overvalue efficiency gains because there is no terms-of-trade effect. On the other hand, the models with the Armington-type national-level product differentiation, in which importers perceive varieties originating from the same country as perfect substitutes, tend to undervalue efficiency gains by overstating unfavorable terms-of-trade effects because there is no variety adjustment.

Since both terms of trade and efficiency gains are important consequences of trade policy changes, Ardelean (2006) applied the Montagna-type CES preference structure, which generalizes the elasticity of substitution across varieties within a given exporter, to examine whether importer's limited LoV explains the empirical fact revealed by Hummels and Klenow (2005). Using both a cross-section set of 1999 COMTRADE international data and a time-series set of 1991-2004 U.S. Imports of Merchandise data, she found that the observed LoV is between 40 and 60 percent weaker than that assumed in the Krugman model. These results suggest there exists country specific comparative advantages that makes varieties produced in a country more alike, so that consumers perceive within-country varieties as more similar and better substitutes. It is therefore important for a model to (explicitly) incorporate a trade-off between purchasing more varieties or greater quantities per variety. Following Ardelean, we also introduce the Montagna-type preference structure into an AGE model, which flexibly switches over the Armington-, Krugman-, and Melitz-type trade specifications, to explore how trade models with product differentiation behave under different assumptions on the intensity of importer's LoV.

This paper is organized as follows. Section 2 presents a brief overview of the model and explains how we vary the strength of LoV effects. In Section 3, we perform experimental simulations and report on the results that reveal the significant and crucial role of importer's LoV in the three types of trade models with product differentiation. Finally, Section 4 concludes the paper.

2. The Model

The model used in this study is a static AGE model of global trade that incorporates the supermodel inspired by Dixon et al. (2016), which nests the Armington, Krugman, and Melitz models as special cases. The Armington-Krugman-Melitz encompassing (AKME) module handles the international trade part of a full-fledged multi-region multi-sector AGE model, connecting gross outputs supplied in source countries/regions with commodities demanded in destinations. While the model is coded in General Algebraic Modeling System

(GAMS) without linearization, unlike Dixon and his colleagues' original version that was coded in GEMPACK (General Equilibrium Modeling PACKage), its behavior is equivalent to that of Dixon et al. (2016).[8] Detailed descriptions of the AKME module and the full-fledged model can be found in Appendices A and B, respectively.

While the trade specification by Armington (1969) assumed that goods are differentiated by country/region of origin, the monopolistic competition model presented by Krugman (1980) assumes that an importer assesses variety expansion regardless of its source. These imply, as Ardelean (2006) has pointed out, the Armington-type trade specification eliminates the variety expansion channel of larger exporters by fixing the number of varieties so that an exporter grows only through the intensive margin, whereas the Krugman-type predicts that the rate of variety expansion is proportional to the growth in the volume of exports so that an exporter grows only through the extensive margin. Melitz (2003) introduced both channels of export growth respectively through the intensive and extensive margins considering the endogenous productivity changes among heterogeneous firms. As the cut-off level of productivity endogenously shifts by an external shock, the number of surviving firms (extensive margin) and their average sales quantities (intensive margin) change.

In the implementation process of an AGE model, we need to match the theoretical features shown above with the benchmark data. There are two possible approaches as Hertel (2009) has shown. One way is to assume the existence of unobserved (iceberg) trade costs to fill the gap between the observed and calculated trade flows given as a solution by an AGE model with symmetric preference for varieties from different sources in the replication test. This approach requires re-estimation of transportation margins based on a certain assumption. Another way is to include preference weights to capture differentiation among countries/regions, e.g., home bias, just like the Armington-type trade specification.

In the previous studies, Zhai (2008) and Balistreri, Hillberry, and Rutherford (2011) have taken the former approach. Zhai (2008) derived unobserved transportation margins on the international trade flows assuming that the domestic trade incurs no iceberg trade costs.[9] Balistreri et al. (2011) took a strategy to econometrically estimate a set of key parameters using a nonlinear structural estimation procedure. On the other hand, Balistreri and Rutherford (2013) and

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[8] Brooke, Kendrick, and Meeraus (1992) and Harrison and Pearson (1996).

[9] Careful consideration is required to apply this assumption when one is going to handle regions instead of countries in a setting where intra-regional international trade flows are not separated from domestic flows. Assuming that intra-regional trade does not incur iceberg costs, no matter how long the distances of countries grouped in the same region are, might be unrealistic.

Dixon, Jerie, and Rimmer (2018) referred to possibilities of the latter approach.[10] While Balistreri and Rutherford (2013) have explained a part of the calibration processes in both approaches, Dixon et al. (2018) dedicated Chapter 4 of their textbook to explain the whole process of calibration in the latter publication, emphasizing the importance of relaxing theoretical restrictions, and showed that essentially we need only one kind of additional information in order to extend an Armington-type model to be a Melitz-type. It is the information on the Pareto shape parameter for the productivity distribution of firms (γ_i in this study). To calibrate a Krugman-type model, no additional information is required.

The weakness of the models mentioned above is that changes in varieties are fully assessed in the importer's demand aggregator. A typical CES demand aggregator for domestic and imported commodity i from country/region r that assumes sourcing takes place at the border is

$$\sum_j X_{ijs} + C_{is} = \theta_{is} \left\{ \sum_r \delta_{irs} N_{irs} Q_{irs}^{(\sigma_i-1)/\sigma_i} \right\}^{\sigma_i/(\sigma_i-1)}, \tag{1}$$

where

X_{ijs} is the (variety-adjusted) intermediate inputs of composite commodity i by industry j in country/region s,

C_{is} is the (variety-adjusted) final consumption of composite commodity i in country/region s,

Q_{irs} is the average domestic/international trade flow quantity of commodity i per active firm operating on the r-s link,

N_{irs} is the number of domestic/international firms of commodity i active on the r-s link,

$\sigma_i > 1$ is the elasticity of substitution between varieties of commodity i from different sources (firm and country/region),

δ_{irs} is the weight parameter that reflects the preference of country/region s for domestic/imported commodity i with respect to the country/region of origin r, and

θ_{is} is the scaling factor of measuring units.

For simplicity, let equation (1) handle both domestic and inter-regional international trade-links when $r = s$. The number of varieties traded on the r-s link is the number of firms operating on the corresponding trade-link.

Note that both X_{ijs} and C_{is} are measured in variety-adjusted units of intermediate inputs and final consumption, in which extra sources of cost reduction or utility are added by product diversification to the quantities in count units. For instance, 100 cars in 20 different styles bring more customer satisfaction compared to the same count number (100) in 5 styles, if there exists positive preference of customers for variety. In such situation, greater varieties increase

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[10] Although the discussion is limited to the Krugman-type, Francois and Roland-Holst (1997) and Francois (1998) took the latter approach.

possibility for customers to find items which have enough quality to meet their needs and expectations. The variety-adjusted units include this kind of supplemental values induced by the existence of varieties, which are rarely observed in economic data.

The first order condition (FOC) to minimize the costs of producing the composite commodity i that determines the level of Q_{irs} is

$$p_{is}\theta_{is}^{(\sigma_i-1)/\sigma_i}\delta_{irs}\left(\frac{\sum_j X_{ijs}+C_{is}}{Q_{irs}}\right)^{1/\sigma_i} = (1+\tau_{irs})p_{irs}^Q \,, \qquad (2)$$

where

p_{is} is the price index for the (variety-adjusted) composite commodity i inclusive of transportation margin and import tariff,

p_{irs}^Q is the average firm price for domestic/international sales, and

τ_{irs} is the rate of transportation margin plus import tariff.

Notice that equation (2) does not contain N_{irs}, which represents the number of varieties. It implies that the price per variety will not be affected by changes in the number of varieties.

To consider the trade-off that consumers may face between purchasing more varieties or greater quantities per variety with cheaper prices, Ardelean (2006) adopted more general CES preference structure. Following Montagna (2001) and Ardelean (2006), we introduce an additional parameter in order to independently control the influence of LoV. At the same time, we must clearly distinguish two different effects: (a) to what extent, total import values including changes in varieties are differentiated with respect to the country/region of origin, and (b) to what extent, the influence of LoV is accounted for in an importer's demand formation.[11] Then, δ_{irs} in equations (1) and (2) can be defined as

$$\delta_{irs} \equiv \alpha_{irs}N_{irs}^{(\beta_{is}-1)/\sigma_i} \,, \qquad (3)$$

where

$\alpha_{irs} \in [0,1]$ is the demand share parameter which corresponds to the viewpoint (a), and

$\beta_{is} \in [0,1]$ represents the intensity of importer's LoV which corresponds to the viewpoint (b).

β_{is} has suffix s because variety expansion in certain kind of commodity might be differentiated by importers.[12] Note that the value of β_{is} is fixed to zero when the Armington-type trade specification applies, so that LoV plays no role.

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[11] While Ardelean (2006) has shed some light on the intensity of LoV, the import demand still remains symmetric across countries/regions. With such formulation, the model may not reproduce the state given by the benchmark data in the reference run.

[12] It is also possible to add suffix r to consider exporter-specific preference. As Ardelean (2006) has dealt with both cross-importer and importer-specific cases, we do not expand the dimension of the LoV-related parameter in this direction to keep the model relatively tractable.

Substituting (3) into equations (1) and (2), the CES demand aggregator for domestic and imported products from country/region r and the FOC that determines the levels of Q_{irs} are respectively converted to

$$\sum_j X_{ijs} + C_{is}$$
$$= \theta_{is} \left\{ \sum_r \alpha_{irs} N_{irs}^{(\beta_{is}+\sigma_i-1)/\sigma_i} Q_{irs}^{(\sigma_i-1)/\sigma_i} \right\}^{\sigma_i/(\sigma_i-1)}, \tag{4}$$

and

$$p_{is}\theta_{is}^{(\sigma_i-1)/\sigma_i} \alpha_{irs} N_{irs}^{(\beta_{is}-1)/\sigma_i} \left(\frac{\sum_j X_{ijs}+C_{is}}{Q_{irs}}\right)^{1/\sigma_i}$$
$$= (1+\tau_{irs})p_{irs}^Q . \tag{5}$$

Since the volumes of the basic preference weights α_{irs} are adjusted by the scaling factor θ_{is} to pass the replication test in the calibration process, the total sum of the preference weights in the demand aggregator with respect to country/region r is set to unity, i.e., $\sum_r \alpha_{irs} = 1$.

An important point is that the CES weights, $\alpha_{irs} N_{irs}^{(\beta_{is}+\sigma_i-1)/\sigma_i}$, are endogenous. One of the problems of the Armington-type trade specification pointed out in previous studies is that the CES weights are fixed and do not change even in the long-run. This contrasts with the Melitz- and Krugman-types wherein an importer endogenously changes his/her valuation of the commodity based on changes in the number of varieties offered.

While equation (4) is consistent with the setting in the theoretical models by Krugman (1980) and Melitz (2003) at $\beta_{is} = 1$, with which an importer s fully enjoys variety increase, the intensity of LoV weakens to the level an importer s places the same value on one unit increase in the total number of varieties as he/she does on that in the average quantity per variety at $\beta_{is} = 0$. To make the role of β_{is} clear, let us rewrite equation (4) as follows:

$$\sum_j X_{ijs} + C_{is}$$
$$= \theta_{is} \left\{ \sum_r \alpha_{irs} N_{irs}^{\beta_{is}/\sigma_i} (N_{irs}Q_{irs})^{(\sigma_i-1)/\sigma_i} \right\}^{\sigma_i/(\sigma_i-1)} . \tag{6}$$

In equation (6), $N_{irs}Q_{irs}$ is the total quantity of commodity i traded domestically or internationally on the r-s link. For given flow quantities of $N_{irs}Q_{irs}$, increases in N_{irs} have less impact on the variety-adjusted inputs of intermediate goods X_{ijs} and the utility-generating final consumption C_{is} as the value of β_{is} reduces. In this manner, β_{is} stipulates to what extent the aforementioned supplemental values are accounted for in the variety-adjustment process.

Utilizing a cross-section set of 1999 COMTRADE data as well as a time-series set of 1991-2004 U.S. Imports of Merchandise data, Ardelean (2006) estimated that the cross-importer LoV (β_i) equals 0.58 (simple mean) or 0.56 (weighted mean) and the LoV for the United States ($\beta_{i"US"}$) equals 0.41 (simple mean) or 0.40 (weighted mean). Based on these estimated values, we adopt 0.5 as a reference value for β_{is} in the simulation experiments. By allowing β_{is} to deviate from unity, we expect that the Krugman- and Melitz-type models will also avoid predicting excessive

specialization and these revised models should also provide more reasonable simulation results weakening the rate of variety growth.

3. Experimental Design

This section lays out the experimental design used to explore the role of LoV via simulation experiments performed with a relatively simple 3-region 3-sector AGE model that includes the AKME module introduced in the previous section.[13] The numerical model is coded in GAMS software and solved by its PATH solver.[14] The simulations to reveal how trade models with product differentiation behave under different assumptions on the intensity of importer's LoV are categorized into two types. In the first type, we explore the effects of trade liberalization on selected economic indicators switching over the three kinds of trade specification based on the Armington, Krugman, and Melitz models while fixing the value of β_{is} to our preferred value of 0.5. In the second set of simulations, we examine how the results obtained in the earlier simulations change when β_{is} is systematically varied between zero (Armington) and unity (Krugman and Melitz).

The model is calibrated to the Global Trade Analysis Project (GTAP) 9.2 Data Base for 2011.[15] The original 140 countries/regions and 57 commodities/activities are respectively aggregated to a 3x3 model. The countries/regions consist of (r01) the United States of America (US), (r02) China, and (r03) the Rest of the World (RoW). The three sectors are (i01) primary industries, (i02) manufacturing, and (i03) services. The manufacturing sector is assumed to be imperfectly competitive with increasing returns to scale (IRTS), whereas the other two are characterized by constant returns to scale (CRTS). The primary industries sector uses sector specific factors, such as land and natural resources, in addition to capital, labor, and intermediate goods in its production process. The services sector provides a fraction of its output as the international shipping supply.

In the experiments, trade liberalization is expressed as the permanent removal of import tariffs levied on the trade flows of manufactured products. This time, we consider just one kind of trade liberalization scenario: the US unilaterally liberalizes trade in manufactured products imported from China. Even though this scenario sounds unrealistic in the current global-trade-policy environment, we take this simple example involving the world largest two economies to clearly

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[13] This version is a simple implementation of the full-fledged model presented in Appendix B.

[14] Ferris and Munson (1998).

[15] Aguiar, Narayanan, and McDougall (2016). The calibration procedure and benchmark data set used for parameterizing the AKME module are respectively presented in Appendices C and D.

reveal the basic behavior of the model.[16] This liberalization scenario is expressed by setting $\tau^M_{"i02""r02""r01"}$ to zero in the model shown in Appendix B. In the first type of experiment, the values of $\beta_{"i02"s}$ for three countries/regions are all set to 0.5, when the Melitz- and Krugman-type trade specifications apply, based on the estimation results obtained by Ardelean (2006).[17]

In the subsequent set of simulations, the values of $\beta_{"i02"s}$ for all of the three destination countries/regions are simultaneously changed from zero to unity to highlight the effects of changing the intensity of LoV under different trade specifications. The step width of the value changes is set to 0.05, so that we have 21 values of $\beta_{"i02"s}$ between zero and unity. Then, we performed 21 independent simulations for the liberalization scenario to verify how the results obtained by the first experiment change as the intensity of LoV changes. Note that the model must be re-calibrated for every value of $\beta_{"i02"s}$ to render the experiments comparable to one another.[18] If we change the value of $\beta_{"i02"s}$ without re-calibrating the model, the modification itself alters the economic environment and affects the state of the global economy, i.e., it results in a new equilibrium, even when no trade liberalization takes place. Based on this series of experiments, we explore the relationships between the intensity of LoV and levels of welfare gains/losses obtained with the Melitz-type heterogeneous and the Krugman-type homogeneous firm models.

3.1 Effects of trade liberalization under alternative trade specifications

We start by examining the effects of liberalizing trade on selected economic indicators switching over the three types of trade specifications respectively based on the Armington, Krugman, and Melitz models. As noted above, just one simple scenario is considered: unilateral import liberalization by the US for Chinese manufactured products. Importantly, the values of $\beta_{"i02"s}$ for three destination countries/regions are all fixed to 0.5 when the Krugman- and Melitz-type trade specifications apply.

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[16] One could readily alter this scenario to illustrate the impacts of the ongoing "trade war" between these two nations. However, then the tariff shocks would become far more complex.

[17] When the Armington-type trade specification applies, β_{is} for all destination countries/regions are set to zero by definition. Then, the manufacturing sector exhibits CRTS.

[18] Due to the setting in which the total sum of the basic preference weights in the demand aggregator is set to unity, the calibrated values of $\alpha^T_{"i02"rs}$ vary with different values of $\beta_{"i02"s}$ based on equation (C.16) presented in Appendix C. This is the reason why re-calibration is required.

3.1.1 Existing trade barriers

Table 1 shows the average rates of import tariff levied on the trade flows of manufactured products from the source countries/regions (appeared on the left column) to the destinations (appeared on the top row). In general, import tariff rates have already been lowered among countries/regions reflecting the sufficiently advanced globalization processes under the regime of the World Trade Organization. In particular, in this data base (which predates recent tariff hikes by the US), the US sets lower tariff rates (2.967% and 1.123%) on the both imports from China and the RoW than those levied by other countries/regions. In contrast, China sets higher tariff rates (5.739% and 5.449%) on the imports from the US and RoW than those by others. The US and RoW respectively levy relatively heavy duties (2.967% and 5.550%) on the commodity imported from China. Most of this difference is likely due to the composition of products exported from Chine. In the following simulation experiments, the 2.967% tariff shown under the header "US" in Table 1 is removed to reflect unilateral liberalization of manufactured imports.

Table 1. Average rates of import tariff on manufactured products, %.

	US (r01)	China (r02)	RoW (r03)
US (r01)	---	5.739	2.911
China (r02)	2.967	---	5.550
RoW (r03)	1.123	5.449	2.797

Source: GTAP 9.2 Data Base for 2011.

3.1.2 Basic effects

The basic effects of the US import liberalization of Chinese manufactured products, as reflected in the Armington-type specification, are expected to be as follows. Once the market price of the manufactured commodity imported from China declines in the US due to the removal of tariff, the demand for Chinese products increases in the US, thereby boosting the wholesale price (producer price) of the manufactured commodity rises in China. In the US, the increased demand for imports from China partially replaces that for the manufactured substitutes produced domestically, so that the wholesale price drops in the US. Demand for imports from the RoW also shrinks in the US. China increases imports from the RoW to substitute for its comparatively expensive domestic products, so that the direction of change in the wholesale price in the RoW is ambiguous. In many cases, the price tends to decrease from its pre-liberalization level.

Based on these changes in the wholesale price in each country/region, the sign and relative volume of the trade flow on each link can be predicted. The US mainly increases imports from China, so that demand for goods both domestically produced and imported from the RoW diminishes. Meanwhile, the representative producer in the US expands production for exports to both China and the RoW markets, as a substitute to the relatively expensive Chinese products in those

markets. For the same reason, producers in the RoW also increase production for exports to China and other countries within the same region. In light of the increased demand for China's exports, we expect that the country to experience improved terms of trade.

The effects of the US liberalizing trade for Chinese manufactured products on both international and domestic trade-flow quantities as percentage changes in count units (not variety-adjusted), obtained by our numerical model with the Armington-type trade specification, are reported in the upper row of each block in Table 2.[19] The countries/regions on the left of the table (rows) correspond to sources while those across the top (columns) are destinations. Note that the diagonal elements include both domestic and intra-regional transactions (in the case of the RoW region which includes many countries). We now examine how these basic effects are altered or accentuated in the presence of extra adjustment channels as reflected in the Krugman- and Melitz-type trade specifications.

Table 2. Changes in trade-flow quantities of manufactured products, %.

		US (r01)	China (r02)	RoW (r03)
US (r01)	Armington	-0.230	2.671	1.217
	Krugman	-0.224	2.701	1.232
	Melitz	-0.149	1.966	0.901
China (r02)	Armington	9.287	0.054	-1.363
	Krugman	9.375	0.158	-1.275
	Melitz	6.834	0.202	-0.844
RoW (r03)	Armington	-1.427	1.440	0.003
	Krugman	-1.450	1.440	-0.011
	Melitz	-1.058	1.037	-0.017

Note: $\beta_{"i02"s} = 0.5$ for all s when the Krugman- and Melitz-type trade specifications apply.
Source: Calculations by the author.

3.1.3 Extra adjustments in the presence of love of variety

Let us start with the case of the Krugman-type model. Krugman (1980) considered the effects through changes in the number of varieties or firm entries. The middle row of each block in Table 2 shows the effects of the US liberalizing trade for Chinese manufactured products on both international and domestic trade-flow quantities in count units, when the Krugman-type specification is implemented with $\beta_{"i02"s} = 0.5$. In this case, the trade-flow quantities exported from both the US and China, the countries directly affected by the trade liberalization, slightly change in the positive directions from those obtained with the Armington-type. In contrast, the export quantities of RoW change in the negative directions. It is mainly due to the fact that the number of firms increases

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[19] As noted in Section 2, the variety-adjusted units include unobservable extra values induced by the existence of varieties.

in the US and China while firms in the RoW exit, thereby reducing the varieties produced in RoW (the upper row of Table 3).

The removal of protection by the US for China makes it easier for Chinese firms to enter the US market. On the other hand, firms in the US benefit from cheaper intermediate inputs from China, compared to those in the RoW based on the basic effects noted above. In addition, the access to a greater variety of Chinese intermediates enables the US manufacturer to reduce the costs of production through variety adjustments, so that the wholesale price of the US products falls yet further. Hence, the number of firm entries also increases in the US for the purpose of starting business in the non-US markets. Consequently, the less competitive firms established in the RoW tend to leave the business.

Table 3. Changes in overall number of firm entries, %.

	US (r01)	China (r02)	RoW (r03)
Krugman	0.045	0.313	-0.034
Melitz	0.046	0.314	-0.034

Note: $\beta_{"i02"s} = 0.5$ for all s.
Source: Calculations by the author.

With the Melitz-type trade specification, adjustment processes are even more complicated. As the lower row of each block in Table 2 shows, the effects of the US liberalizing trade for Chinese manufactured products on both international and domestic trade-flow quantities in count units, obtained by the Melitz-type specification with $\beta_{"i02"s} = 0.5$, are higher on some routes and lower on others, although the overall number of firm entries does not show much difference from the Krugman-type model (the lower row of Table 3 in comparison with the upper row). However, the endogenous productivity growth among heterogeneous firms introduced by Melitz (2003) leads to two effects. The first is the change in the proportion of active firms, while the second is the change in the average sales quantity per active firm. These two effects always work in opposite directions. Depending on the magnitude of these offsetting effects, the directions of the overall changes in the bilateral trade-flow quantities can be larger or smaller than in the Krugman-type model.

As in the Krugman-type setting, the removal of protection by the US for imports from China in the Melitz-type model makes it easier for Chinese firms to enter the US market. Then, the competition among firms to make sales in the US market escalates so that it becomes difficult for non-Chinese firms to enter. On the other hand, the impediments (cut-off level of productivity) to enter the non-US markets lower for non-Chinese firms because they can set a cheaper sales price compared to the pre-liberalization levels, based on the basic effects discussed previously, and hence some of Chinese firms are pushed out from those markets. The availability of cheaper imported intermediates enables Chinese firms to make greater profits because the manufactured products can now be wholesaled by the representative

producer to firms at lower prices in China. As a result, the hurdle for firms in China to enter the US market falls sharply, as does average productivity. These changes are shown in the upper row of each block in Table 4, which reports the changes in average productivity of firms in each market when the Melitz-type setting applies with $\beta_{"i02"s} = 0.5$. Note that the changes in the average sales quantity per active firm also show the same pattern as the ones in the average or cut-off productivity level (changes in these two perfectly synchronize) while the proportion of active firms operating on each trade-link shows opposite changes. This is because there is a definitive rule in the Melitz-type trade specification that a higher/lower level of the cut-off productivity (also the average productivity) always expands/shrinks the sales quantity per firm and decreases/increases the proportion of active firms.[20]

Table 4. Changes in average productivity and number of active firms (Melitz), %.

		US (r01)	China (r02)	RoW (r03)
US (r01)	Productivity	0.049	-0.474	-0.213
	Number	-0.197	2.451	1.116
China (r02)	Productivity	-1.562	0.028	0.291
	Number	8.529	0.174	-1.132
RoW (r03)	Productivity	0.258	-0.266	-0.004
	Number	-1.312	1.307	-0.014

Note: $\beta_{"i02"s} = 0.5$ for all s.
Source: Calculations by the author.

The effects of the US import liberalization of Chinese manufactured products on the number of active firms (varieties) operating on each trade-link are reported in the lower row of each block in Table 4. Since a change in the number of active firms reflects the effects both on the overall number of firm entries, captured by Table 3, and on the proportion of active firms, the changes in the number of domestic firms in China and that of international firms in the RoW making sales within the region (as well as domestic firms) are not always showing opposite sign to the changes in the productivity level depicted in Table 4. Although the proportion of active firms reduces in the Chinese domestic market, the expansion in the overall number of firm entries in China, because of the removal of protection by the US, surpasses the reduction in the proportion. This also suggests that the sales per firm expands so that relatively large-scale Chinese firms operate in the domestic market.

Finally, the effects on the trade-flow quantities shown in the lower row of each block in Table 2 reflect the changes both in the number of active firms (the overall number of firm entries times the proportion of active firms) and the average sales quantity per active firm. Although it is a rough calculation, adding the numeric values shown in the upper and lower rows of each block in Table 4 corresponding

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[20] The final part of Appendix B shows how this rule can be confirmed.

to the same trade-link generates a value which is close to the one in Table 2, thereby shedding light on the way in which these two competing forces play out.[21]

3.1.4 Welfare effects

Considering the relatively micro-level implications we have explored, let us examine the effects of the US import liberalization of Chinese manufactured products on the national/regional welfare levels. Table 5 shows the Hicksian equivalent variations (EV) in billions U.S. dollars as well as the percentage deviation in aggregate final consumption from its pre-liberalization levels in parentheses. As expected, China gains under all three types of trade specifications respectively related to the Melitz, Krugman, and Armington models, receiving the benefits of trade creation as well as positive terms-of-trade effects amplified by the ensuing sectoral adjustments that reallocate production factors and resources to the most efficient manufacturing sector that exhibits scale economies.[22] On the other hand, the US and RoW tend to be worse off under all specification types because of the negative terms-of-trade shocks. In particular, the terms of trade of the US seriously deteriorate by the removal of import tariff, as suggested by optimal tariff theory. An in-depth discussion on the price of manufactured products will be presented later, in conjunction with Figure 2.

Table 5. Welfare effects, US$ billion (EV) or % (deviations).

		US (r01)	China (r02)	RoW (r03)
Armington	EV	-6.655	11.088	-1.065
	Deviations	-0.042	0.256	-0.005
Krugman	EV	-5.975	16.833	-2.401
	Deviations	-0.037	0.256	-0.005
Melitz	EV	-6.031	16.488	-2.267
	Deviations	-0.038	0.250	-0.005

Note: $\beta_{"i02"s}$ = 0.5 for all s when the Krugman- and Melitz-type trade specifications apply.
Source: Calculations by the author.

Now, let us turn to examining the differences brought about by switching trade specifications. Introduction of the firm-level product differentiation and monopolistic competition to the manufacturing sector in the model, while retaining the same values of substitution elasticities tends to inflate the gains for China, as suggested by Montagna (2001), accumulating efficiency gains generated through the extra adjustment margins in both models presented by Krugman

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[21] For example, the values corresponding to the US exports to China in Table 4 (-0.474 and 2.451) add up to 1.977, which is closer to 1.966 than to 2.671 or 2.701 in Table 2.

[22] The existence of intermediate transactions enables the representative producer in every region to reduce production costs by variety adjustments. Thus, the wholesale price of manufactured products also varies and affects the terms of trade even in the Krugman-type model.

(1980) and Melitz (2003). The main reason is because the welfare effects generated by the Krugman- and Melitz-type models are under the influence of the variety adjustments mentioned in Section 2. This is also evidenced in the claim of Dixon et al. (2016) that the Melitz-type model can be regarded as an Armington-type with high substitution elasticity.

On the other hand, notice that the Krugman-type specification with homogeneous firms provides larger gains than the Melitz-type with heterogeneous firms, unexpectedly, in spite of the fact that one more source of efficiency gains, i.e., the endogenous productivity growth among heterogeneous firms is built into the Melitz-type model. The losses of the US also are larger with the Melitz-type than with the Krugman-type model. These results exhibit a completely different pattern from that suggested by Melitz and Redding (2013) who argue that heterogeneous firm models generate larger welfare gains from reductions in trade costs than homogeneous firm models, if one applies the same values of behavioral parameters to the models. The reason why these happen can be found in the setting of the intensity of LoV. The next section explores this issue in detail by varying the value of $\beta_{"i02"s}$ in these simulations.[23]

3.2 Effects of changing the intensity of love of variety on the simulation results

Let us move to another type of simulation experiment to observe how the impact of unilateral import liberalization by the US, but only for Chinese manufactured products on selected economic indicators changes with different values of $\beta_{"i02"s}$, which controls the intensity of importer's LoV. In this experiment, the value of the parameter is varied from zero to unity simultaneously for the manufacturing sector in all of the three destination countries/regions, with the step width of 0.05. As we discussed in Section 2 using equation (6), the intensive margin represented by sales quantity per firm and the extensive margin by the number of active firms are assessed on the same weight, when $\beta_{"i02"s}$ is set to zero. On the other hand, extra valuation of changes in varieties are added when $\beta_{"i02"s}$ takes a positive value. In most theoretical and applied models, $\beta_{"i02"s}$ is (explicitly or implicitly) set to unity so the models draw maximum possible valuation from the extensive margin. In this case, preferences collapse to the standard LoV and a single parameter effectively governs both the elasticity of substitution and the preference for additional varieties.

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[23] Although Brown et al. (1995), Benassy (1996), and Montagna (2001) have explored the effects obtained with different intensities of LoV, their analyses are limited to some special cases, such as $\beta_{"i02"s} = 0$ and $\beta_{"i02"s} = 1$, so that the relationships between the heterogeneous and homogeneous firm models are not clear in the intermediate range around $\beta_{"i02"s} = 0.5$, which was suggested by Ardelean (2006). Thus, this study tries to elucidate the whole picture of the effects of shifting the value of $\beta_{"i02"s}$ from zero to unity, maximizing the advantage of utilizing numerical simulations.
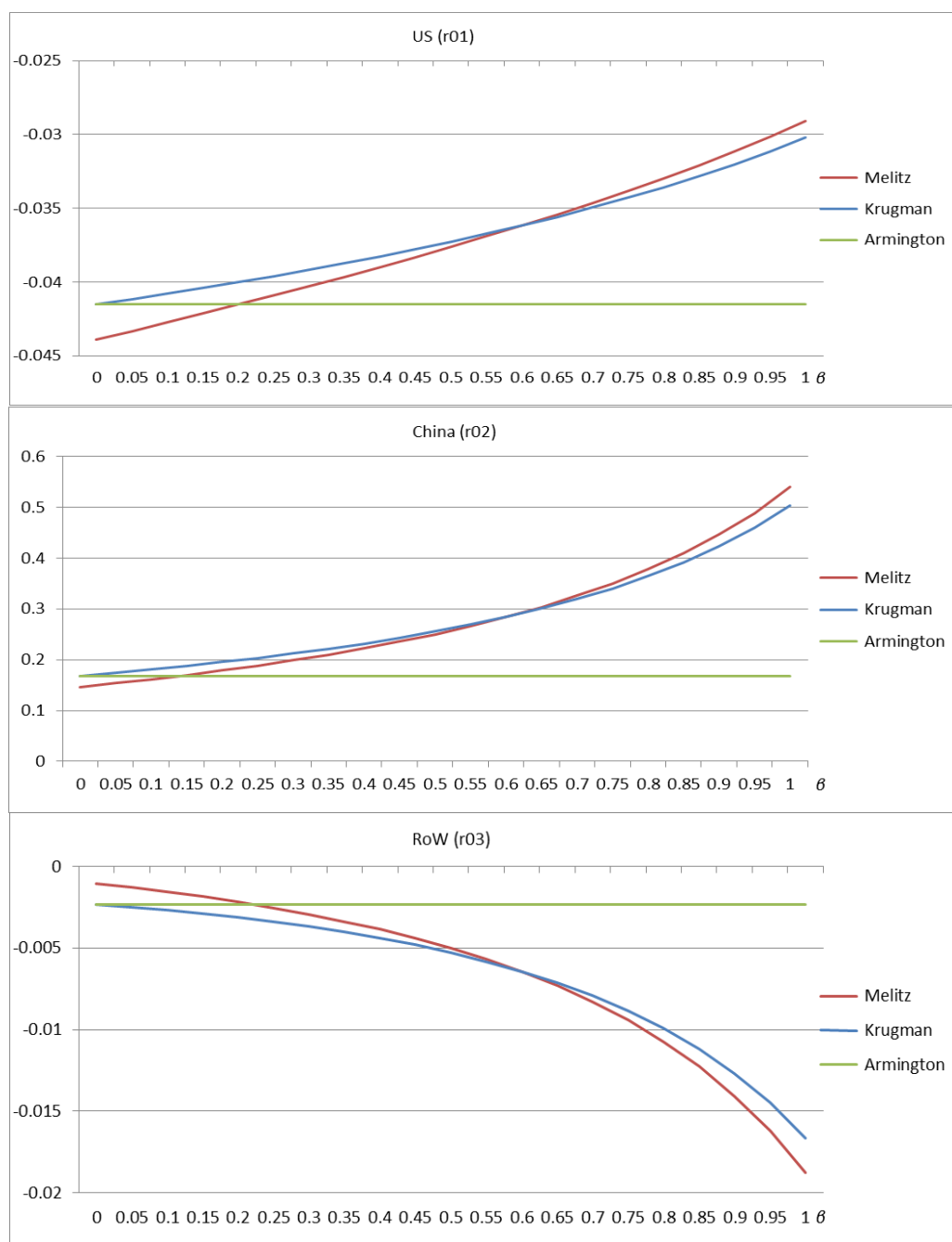
Figure 1. Welfare effects, %.

Note: Deviations in aggregate final consumption from its pre-liberalization levels calculated with different values of $\beta_{\text{"i02"s}}$.

Source: Calculations by the author.
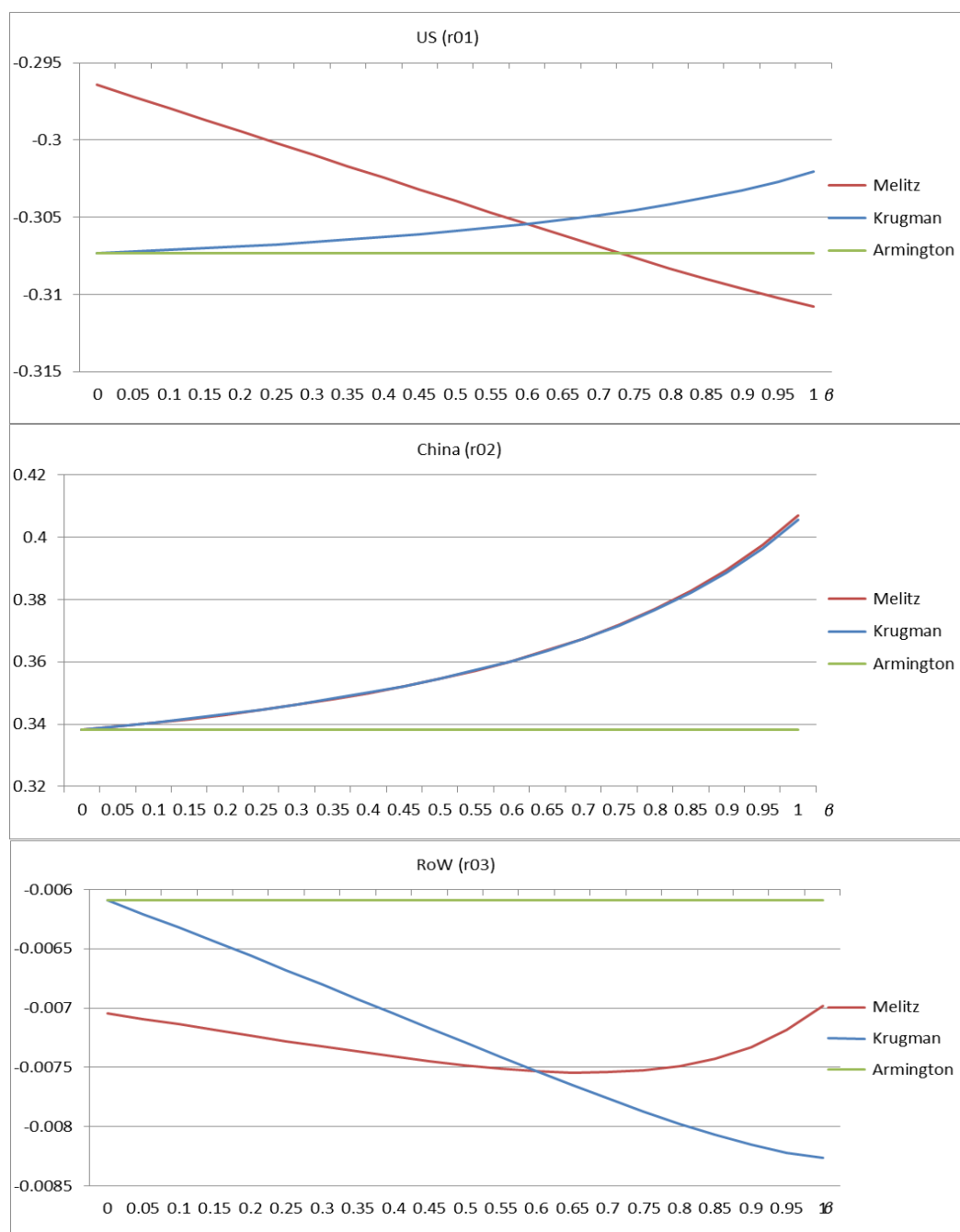
Figure 2. Effects on wholesale price of manufactured products, %.

Note: Deviations in wholesale price of manufactured products from its pre-liberalization levels calculated with different values of $\beta_{"i02"s}$.

Source: Calculations by the author.

Figure 1 shows the effects of the US liberalizing imports of Chinese manufactured products on national/regional welfare in each country/region, including the US, China, and the RoW. The effects are captured as percentage deviations from the levels before the trade liberalization. In each panel in Figure 1, the red, blue, and green lines correspond to the Melitz-, Krugman-, and Armington-type trade specifications, respectively. The green Armington lines are presented for reference only and simply report the volumes associated with the basic effects we have discussed previously in Section 3.1.2. In the panels, welfare changes on the leftmost side, where $\beta_{"i02"s} = 0$, correspond to changes in total consumption quantity in count units.

Before we step into details, let us review how a model generates the effects of an external shock, such as a reduction in trade costs, on the trade-flow quantities in both count and variety-adjusted units, with a choice from the Armington-, Krugman-, and Melitz-type trade specifications. With the Armington-type specification, a model captures the effects as changes in the trade-flow quantities, mainly triggered by improvements or deteriorations in the terms of trade, just led by the intensive margin. In the Armington-type setting, there is no variety adjustment so that efficiency gains from trade tend to be understated. For convenience, let us call this type of effects the "fundamental intensive-margin effects" (FI effects: Table 6, first row).

Second, the Krugman-type specification appends an extra adjustment channel, which enables the trade-flow quantities to grow through the extensive margin. Since this channel works along with positive LoV, the effects on the trade-flow quantities inflate as the value of $\beta_{"i02"s}$ grows. Let us call this type of effects the "fundamental extensive-margin effects" (FE effects: Table 6, second row). The FE effects are caused by the changes in the (overall) number of firm entries in the model, which is fixed to unity when the Armington-type setting applies, and regulate the magnitude of variety adjustments. Assuming a large value for $\beta_{"i02"s}$ may result in overstating these efficiency gains.

Third, the Melitz-type specification appends two extra adjustment channels, which enable trade-flow quantities to grow through both the intensive and extensive margins. As the cut-off level of productivity endogenously shifts by an external shock, the proportion of active firms (extensive margin) and their average sales quantities (intensive margin) change. Since a change in the number of active firms reflects the changes both in the overall number of firm entries and in the proportion of active firms, we call the former type of effects, which work through the proportion of active firms, the "supplemental extensive-margin effects" (SE effects: Table 6, fourth row) to distinguish from the previously introduced FE effects. The latter type, which work through the average sales quantity per active firm, is called the "supplemental intensive-margin effects" (SI effects: Table 6, third

row).[24] The SE effects are elicited by the changes in the market-specific entry rates based on the endogenous productivity growth among heterogeneous firms, which is absent from the Krugman-type trade specification. The SI effects correspond to the terms-of-trade effects based on the changes in the quantities per variety sold at higher/lower prices. The four kinds of quantity-related effects are summarized in Table 6. The volume of the variety adjustments is ambiguous in the Melitz-type setting. Since there is no variety adjustment when $\beta_{"i02"s} = 0$, the magnitude of the variety adjustments when LoV is positive can be approximated by the difference between the levels of effects respectively measured at a point on the red line ($\beta_{"i02"s} > 0$) and that at the leftmost side ($\beta_{"i02"s} = 0$) in each panel.

Finally, the green Armington and blue Krugman lines show the magnitudes and directions of the FI and FE effects, respectively. Since there is no extra valuation on the changes in varieties, the effects calculated under the Krugman- and Armington-type specifications become identical at $\beta_{"i02"s} = 0$, as suggested by Montagna (2001). On the other hand, the differences between the red Melitz and blue Krugman lines equal the summation of the SI and SE effects. These two types of effects offset each other in the Melitz-type model as mentioned in Section 3.1.3, and always emerge as a synthesis.

When the value of $\beta_{"i02"s}$ is small and close to zero, the Melitz-type model tends to generate the lowest welfare levels for countries related to trade liberalization, the US and China (top and middle panels of Figure 1) as studied by Montagna (2001), whereas the highest for third countries, the RoW (bottom panel of Figure 1). In contrast, when the value of $\beta_{"i02"s}$ is large and close to unity, the Melitz-type generates the highest welfare levels for the countries involved in the trade liberalization as Melitz and Redding (2013) have discussed, whereas it generates the lowest welfare outcome for countries outside of the direct involvement (i.e., RoW). Thus, welfare effects predicted by the Melitz-type model are more sensitive to changes in the value of $\beta_{"i02"s}$ compared to those generated by the Krugman-type model. This occurs because, in the countries involved, one of the extra adjustment margins in the Melitz-type model basically yields negative SI effects in a situation when the cut-off productivity is lowered and poorly productive small-scale firms come into operation, while the SE effects, which tend to be much greater than the FE effects captured by the Krugman-type model, are always positive when the proportion of active firms expands. In the top and middle panels of Figure 1, the magnitude of the negative SI effects surpasses that of the favorable SE effects in the interval when the red Melitz line lies below the blue Krugman line, whereas the positive SE effects outweigh when the red line lies above the blue

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[24] When we simply use the term "extensive-margin effects," it includes only the fundamental extensive-margin effects when the Krugman-type trade specification applies, whereas it implies the merger of both fundamental and supplementary effects when the Melitz-type is assumed.

line. In other words, the negative SI effects appear obvious when the changes in varieties have less impact on the positive FE effects with weak LoV.

What determines the values of $\beta^*_{"i02"s}$ that correspond to the intersection of the red Melitz and blue Krugman lines? It is given by the following condition: $\beta^*_{"i02"s} = (\sigma_{"i02"} - 1)/\gamma_{"i02"}$, where $\gamma_{"i02"}$ is the Pareto shape parameter for the productivity distribution of firms such that $\gamma_{"i02"} > \sigma_{"i02"} - 1$.[25] Note that $\beta^*_{"i02"s}$ always stays in the range between zero and unity since $\sigma_{"i02"} > 1$, so that the red Melitz and blue Krugman lines must indeed intersect. As $\sigma_{"i02"}$ and $\gamma_{"i02"}$ have country/region-generic values in this study, the values of $\beta^*_{"i02"s}$ also are common to every country/region.[26] When $\beta_{"i02"s}$ is set to $\beta^*_{"i02"s}$, magnitudes of the SI and SE effects exclusively captured by the Melitz-type model become equivalent and completely cancel out each other. When $0 \leq \beta_{"i02"s} < \beta^*_{"i02"s}$, the magnitude of SI effects fully surpasses that of the SE effects, while the SE effects become dominant with $\beta^*_{"i02"s} < \beta_{"i02"s} \leq 1$.

Thus, homogeneous firm models including not only the Krugman- but also the Armington-types may generate larger welfare gains than the Melitz-type heterogeneous firm model if we assume weaker intensity of LoV. These results, which confirm the findings by Montagna (2001), contradict the claim addressed by Melitz and Redding (2013) that heterogeneous firm models generate larger welfare gains from reductions in trade costs than homogeneous firm models, if we apply the same values of behavioral parameters to the models. The necessary and sufficient condition in the present framework to make the Melitz-type heterogeneous firm models generate greater welfare gains than the Krugman-type (and also the Armington-type) homogeneous firm models is to set the value $\beta_{"i02"s}$, which controls the intensity of importer's LoV, to be greater than $\beta^*_{"i02"s} = (\sigma_{"i02"} - 1)/\gamma_{"i02"}$. Otherwise, the homogeneous firm models may generate larger welfare gains.

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[25] See Appendix E.

[26] Although it is not easy to analytically derive a formula, a possible reason why the red Melitz and green Armington lines intersect with country-specific values of $\beta_{"i02"s}$ is presented in Appendix E.

Table 6. Summary of quantity-related effects.

Effects	Category	Relation	Source	Captured by	Correspondence (Figure 1)
FI	Fundamental	Intensive margin	Basic terms-of-trade effects	Armington	Green line
FE	Fundamental	Extensive margin	Changes in (overall) number of firm entries	Krugman (Melitz)	Difference between blue and green lines
SI	Supplemental	Intensive margin	Terms-of-trade effects based on the changes in quantity per variety	Melitz $(0 \leq \beta_{"i02"s} < \beta^*_{"i02"s})$	Difference between red and blue lines
SE	Supplemental	Extensive margin	Changes in proportion of active firms	Melitz $(\beta^*_{"i02"s} < \beta_{"i02"s} \leq 1)$	Difference between red and blue lines

Source: Author's own construction.

Table 7. Summary of price-related effects.

Effects	Category	Type	Source	Captured by	Correspondence (Quantity-related effects)
FP	Fundamental	Price lifting	Changes in demand	Krugman (Melitz)	FI + FE
FC	Fundamental	Cost reduction	Variety-adjustment process in intermediate transactions	Krugman (Melitz)	FE
SP	Supplemental	Price lifting	Changes in demand	Melitz	SI + SE
SC	Supplemental	Cost reduction	Variety-adjustment process in intermediate transactions	Melitz	SE

Source: Author's own construction.

Similar to the case of the welfare effects, Figure 2 shows the effects of the US liberalizing imports of manufactured products from China on the wholesale price of manufactured products in each country/region. The price effects caused by the changes in LoV can also be divided into price-lifting and cost-reduction effects. The former originates from the changes in demand due to the progress/recession of trade creation/diversion, whereas the latter originate from changes in the degree of variety adjustments enabled by the access to a greater variety of intermediate commodities, which was mentioned by Fujita, Krugman, and Venables (2000, p.242). In particular, the cost-reduction effects of variety adjustments are only generated through intermediate transactions when $\beta_{"i02"s}$ takes a non-zero positive value. These price-lifting and cost-reduction effects of LoV change can be further subdivided into fundamental and supplemental parts as before: the "fundamental price-lifting effects" (FP effects: Table 7, first row) that correspond to the aforementioned FI plus FE effects, the "supplemental price-lifting effects" (SP effects: Table 7, third row) that correspond to the SI plus SE effects, the "fundamental cost-reduction effects" (FC effects: Table 7, second row) generated through the variety-adjustment process in intermediate transactions that correspond to the FE effects, and the "supplemental cost-reduction effects" (SC effects: Table 7, fourth row) generated through the variety-adjustment process in intermediate transactions that correspond to the SE effects. The two kinds of fundamental effects are obvious in the Krugman-type specification, whereas the two kinds of supplemental effects are obvious in the Melitz-type. Table 7 summarizes these price-related effects.

As the value of $\beta_{"i02"s}$ increases, the price tends to rise in China as import demand expands in the US (middle panel of Figure 2). When LoV intensifies, the US seeks to expand imports from China without placing so much weight on China's rising price because China now has the most efficient environment to increase varieties. Since the increase in imported varieties enables the US to reduce production costs through the variety adjustments, the US also expands exports to China in the scale-economy-laden manufacturing sector, thereby enabling China to produce more varieties. Consequently, the ties between the US and China strengthen and promote the formation of a trading bloc separated from the RoW.

This process, by which the US and Chinese economies become more tightly integrated, can be confirmed in particular by the price declines in the US captured by the top panel of Figure 2 when the Melitz-type specification applies. In this case, the SC effects based on the increase in variety of intermediate goods are working substantially to reach the level that fully surpass the SP effects of strong LoV. In contrast, the FC effects are insufficient to stifle the FP effects when the Krugman-type specification applies (also in the top panel of Figure 2). The reason why the price tends to decline in the RoW as well as its welfare worsens is largely attributable to the trade diversion due to being isolated from the trading bloc formed by the US and China (bottom panels of Figures 1 and 2). With the Melitz-

type specification, the wholesale price in the RoW shows that the SP effects of intensive LoV tend to exceed the SC effects of variety adjustments. It can be concluded that the extra adjustment margins in the Melitz-type specification may enhance both the SC effects based on the increase in variety of intermediate goods (variety adjustments) and the SP effects rooted in strong LoV, which often work in opposite directions.

4. Concluding Remarks

Melitz and Redding (2013) showed that, in the presence of the standard Dixit-Stiglitz love-of-variety preferences, heterogeneous firm models generate larger welfare gains from reductions in trade costs than homogeneous firm models, when the same values of behavioral parameters are applied in both types of models. However, the empirical evidence, revealed by Hummels and Klenow (2005) and Ardelean (2006), suggests that the standard preference structure may place too much value on the addition or loss of new varieties. Given the central role of LoV in the Krugman- and Melitz-type models, it is worth exploring how these gains from trade vary across models when LoV is weakened. This paper explores what happens to bilateral trade, prices, and welfare in the presence of unilateral trade liberalization in a 3-region 3-sector AGE model. It accomplishes this comparison by employing an industry module, which flexibly switches over the Armington-, Krugman-, and Melitz-type trade specifications, while at the same time the intensity of importer's LoV can be varied. Taking the case of unilateral import liberalization by the US for Chinese manufactured products, simulation experiments with the model revealed the following points.

1) Welfare effects predicted by the Melitz-type model are more sensitive to the intensity of importer's LoV compared to those generated by the Krugman-type model.
2) The reallocations of resources based on the endogenous productivity changes among heterogeneous firms in the Melitz-type trade specification do not necessarily enhance effectiveness of trade policy beyond the level predicted by the homogeneous firm models when LoV is weaker than that implied by the Dixit-Stiglitz preference.
3) Whether the Melitz-type model generates greater welfare gains than those obtained by the Krugman-type is determined by the relationship between the value of the intensity of LoV and a critical value, which is defined by a combination of the elasticity of substitution between varieties from different sources and the Pareto shape parameter for the productivity distribution of firms. For larger values of the LoV-related parameter, the Melitz-type model generates larger welfare gains, while for smaller values the Krugman-type model prevails.

4) When LoV intensifies in the Krugman- and Melitz-type models, the ties between the countries/regions involved in trade liberalization tend to strengthen and promote the formation of a trading bloc separated from the countries/regions outside of the direct involvement.

The first finding is based on the fact that the effects of trade policy are inflated through the two extra adjustment channels built in the Melitz-type trade specification, namely, the changes in the proportion of active firms and those in the sales quantity per active firms, always work in the opposite directions. As LoV intensifies, the former starts to have more impact on the variety-adjusted units of the utility-generating final consumption.

The second finding disproves the claim addressed by Melitz and Redding (2013) that heterogeneous firm models always generate larger welfare gains from reductions in trade costs than (the Krugman-type) homogeneous firm models, if we apply the same values of behavioral parameters to the models. In this study, the Melitz-type model generated less welfare gains, when the intensity of LoV is set to a relatively realistic value (0.5) based on the empirical evidence revealed by Ardelean (2006).

The third finding is based on the fact that the two kinds of effects, changes in the proportion of active firms and those in the average sales quantity per active firm, which are exclusively captured by the Melitz-type model and always work in opposite directions, become equivalent and completely cancel out one another when $\beta_{is} = (\sigma_i - 1)/\gamma_i$. With $0 \le \beta_{is} < (\sigma_i - 1)/\gamma_i$, the effects related to the latter fully surpasses that of the former, while the effects related to the former become dominant with $(\sigma_i - 1)/\gamma_i < \beta_i \le 1$.

The fourth finding is based on the fact that a country/region that liberalizes trade expands imports from the partner country/region without caring very much about price rise when LoV is strong. It is because the partner country/region has the most efficient environment to increase varieties in the post-liberalization world. Since the increase in imported varieties enables the liberalizing country/region to reduce production costs through the variety adjustments, the liberalizing country/region also expands exports to the partner country/region under the scale economy in order to enable the partner country/region to produce more varieties.

As we have seen in this study, the relatively large impact on the national/regional welfare and other economic indicators predicted by the Melitz- and Krugman-type models under the assumption of extreme LoV is amplified mainly through the intermediate transactions as suggested by Fujita et al. (2000). While the present model is a "sourcing at border" type model, which presumes varieties from different sources are aggregated at the border of every destination country/region, detailed analysis on the process of variety adjustments in intermediate transactions can be done with a "sourcing by agent" type model,

which incorporates direct cross-border linkages between economic agents both on the supply and demand sides. Exploring the role of LoV in the presence of sourcing by agent is an important direction for future work.

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Appendix A. The Armington-Krugman-Melitz Encompassing Module

This appendix provides an explanatory note on the Armington-Krugman-Melitz encompassing (AKME) module used in this study, which bases on the supermodel developed by Dixon, Jerie, and Rimmer (2016). While Dixon and his colleagues' original model is characterized by the dual approach, we take the primal approach in some part to learn the supermodel from a different angle. In addition, we decouple activities of enterprises into two processes, production and sales, in order to implement the AKME module as a part of a full-fledged applied general equilibrium (AGE) model, where a unified production segment of enterprises tends to act as if there is only one representative producer in each industry. Then, the production segment is assumed to be perfectly competitive with constant returns to scale (CRTS) technology whereas the sales segment composed of many agents that exert market power is monopolistically competitive with increasing returns to scale (IRTS). For this reason, we call the production and sales segments in this study "producer" and "firm," respectively.[a1]

Suppose firm o is a member of the overall set of firms established in order to sell commodity i produced by the representative producer in country/region r, i.e., $o \in O(ir)$. Firm d is a member of the set of firms that sell commodity i in the domestic market, i.e., $d \in D(ir)$. Similarly, firm q is a member of the set of exporting firms that sell commodity i on the r-s link, i.e., $q \in Q(irs)$. The sets D and Q are subsets of O, respectively, so that $D \subseteq O$ and $Q \subseteq O$. Then, aggregator functions for domestic and imported products from firms d and q, respectively operating in countries/regions s and r, are assumed as follows:[a2]

$$\tilde{D}_{is} = \left\{ \delta_{is}^D \sum_d \hat{D}_{dis}^{(\sigma_i^T - 1)/\sigma_i^T} \right\}^{\sigma_i^T/(\sigma_i^T - 1)} , \tag{A.1}$$

$$\tilde{Q}_{irs} = \left\{ \delta_{irs}^Q \sum_q \hat{Q}_{qirs}^{(\sigma_i^T - 1)/\sigma_i^T} \right\}^{\sigma_i^T/(\sigma_i^T - 1)} , \tag{A.2}$$

and

$$\sum_j X_{ijs} + C_{is} = \theta_{is}^T \left\{ \tilde{D}_{is}^{(\sigma_i^T - 1)/\sigma_i^T} + \sum_r \tilde{Q}_{irs}^{(\sigma_i^T - 1)/\sigma_i^T} \right\}^{\sigma_i^T/(\sigma_i^T - 1)} , \tag{A.3}$$

where

[a1] This assumption is in line with that placed by Balistreri and Rutherford (2013), in which output of an industrial sector is wholesaled as composite input at the point of export. Thus, in each sector in each country/region, there is a sector-wide market of output for (heterogeneous or homogeneous) firms.

[a2] The hat "^" and tilde "~" symbols respectively indicate the variable is at the firm level and at the aggregate level with respect to firms. The variables without those symbols we will see later are those at the average firm level. The variables with the tilde symbol just disappear once we derive equation (A.4) substituting (A.1) and (A.2) into (A.3).

$\widehat{D}_{dis}$ is the quantity of commodity i sold by domestic firm d operating in country/region s,

$\widehat{Q}_{qirs}$ is the quantity of commodity i exported to country/region s by international firm q operating in country/region r,

$\widetilde{D}_{is}$ is the overall quantity of commodity i sold by domestic firms operating in country/region s,

$\widetilde{Q}_{irs}$ is the overall quantity of commodity i exported to country/region s by international firms operating in country/region r,

X_{ijs} is the (variety-adjusted) intermediate inputs of composite commodity i by industry j in country/region s determined elsewhere in a full-fledged model outside the AKME module,

C_{is} is the (variety-adjusted) final consumption of composite commodity i in country/region s determined elsewhere in a full-fledged model outside the AKME module,

$\sigma_i^T > 1$ is the elasticity of substitution between varieties of commodity i from different sources (firm d, firm q, and country/region r),[a3]

δ_{is}^D is the weight parameter that reflects preference of country/region s for domestically produced commodity i,

δ_{irs}^Q is the weight parameter that reflects preference of country/region s for imported commodity i with respect to the country/region of origin r, and

θ_{is}^T is the scaling factor of measuring units.[a4]

Note that we clearly distinguish $\widetilde{Q}_{iss}$ from $\widetilde{D}_{is}$ because we need to make room for the former to include non-zero international trade flows within a region, which are often observed in a data set obtained with regional aggregation in some part.[a5]

[a3] Notice that the same substitution elasticity σ_i^T is utilized in equations (A.1), (A.2), and (A.3).

[a4] This parameter is needed to pass the replication test that verifies whether an AGE model can reproduce the state captured by the benchmark data when there is no policy change (reference run). For example, think about the case we have a data set which includes expenditures for two kinds of commodity, 1 and 1, and total expenditure 2. If we assume a Cobb-Douglas function to aggregate these two commodities to make a composite good, we need to equate 2 with $1^{0.5} \cdot 1^{0.5}$. In this example, the scaling factor $\theta = 2$ is required in order to satisfy $2 = \theta \cdot 1^{0.5} \cdot 1^{0.5}$.

[a5] The intra-regional trade still is international trade in this study. Therefore, our present setting will not breach the assumption of the original theory developed by Melitz (2003). If one transforms the benchmark data adding intra-regional trade flows to domestic sales or replacing intra-regional trade flows with zero values as he/she would be faithful to the original theory, simulation results may largely be affected by the biases generated in the reconciliation process of the modified data. In the former case, the rates of export duty/subsidy, transportation margin, and import tariff corresponding to the processed intra-regional trade flows might greatly fall from their original levels. In the latter case, simulation results will change depending on the aggregation levels because the size of the

Another important point is that both X_{ijs} and C_{is} are measured in variety-adjusted units of intermediate inputs and final consumption, in which extra sources of cost reduction or utility are added to the quantities in count units by product diversification.[a6] These two variables are determined elsewhere in a full-fledged model, which details are presented in Appendix B, outside the AKME module.

Economic agents in country/region s choose $\widehat{D}_{dis}$ and $\widehat{Q}_{qirs}$ to minimize the total purchase value of commodities subject to (A.1), (A.2), and (A.3). This problem can be expressed as

min $\qquad \sum_d \hat{p}^D_{dis} \widehat{D}_{dis} + \sum_r \sum_q (1 + \tau_{irs}) \hat{p}^Q_{qirs} \widehat{Q}_{qirs}$

s.t. $\qquad \sum_j X_{ijs} + C_{is} = \theta^T_{is} \left\{ \begin{array}{l} \delta^D_{is} \sum_d \widehat{D}^{(\sigma^T_i - 1)/\sigma^T_i}_{dis} \\ + \sum_r \delta^Q_{irs} \sum_q \widehat{Q}^{(\sigma^T_i - 1)/\sigma^T_i}_{qirs} \end{array} \right\}^{\sigma^T_i/(\sigma^T_i - 1)}$, $\qquad$ (A.4)

where

$\hat{p}^D_{dis}$ is the differentiated sales price of commodity i sold by domestic firm d operating in country/region s,

$\hat{p}^Q_{qirs}$ is the differentiated sales price of commodity i exported to country/region s by international firm q operating in country/region r exclusive of transportation margin and import tariff, and

τ_{irs} is the rate of transportation margin plus import tariff.

Equation (A.4) is derived by substituting (A.1) and (A.2) into (A.3). Setting the Lagrange multiplier for (A.4) as p_{is}, we get the following first-order conditions (FOCs) with respect to $\widehat{D}_{dis}$ and $\widehat{Q}_{qirs}$:

$$p_{is} (\theta^T_{is})^{(\sigma^T_i - 1)/\sigma^T_i} \delta^D_{is} \left(\frac{\sum_j X_{ijs} + C_{is}}{\widehat{D}_{dis}} \right)^{1/\sigma^T_i} = \hat{p}^D_{dis} \qquad (A.5)$$

and

$$p_{is} (\theta^T_{is})^{(\sigma^T_i - 1)/\sigma^T_i} \delta^Q_{irs} \left(\frac{\sum_j X_{ijs} + C_{is}}{\widehat{Q}_{qirs}} \right)^{1/\sigma^T_i} = (1 + \tau_{irs}) \hat{p}^Q_{qirs} . \qquad (A.6)$$

Since the value of a Lagrange multiplier can be interpreted as the shadow price at the optimal solution, p_{is} represents the price index for the (variety-adjusted) composite commodity i inclusive of transportation margin and import tariff.

Aggregate total profit of all firms operating in industry i of country/region r can be expressed as

$$\pi_{ir} = \sum_d \hat{\pi}^D_{dir} + \sum_s \sum_q \hat{\pi}^Q_{qirs} - \sum_o p^w_{ir} H_{ir} , \qquad (A.7)$$

---

values subject to be adjusted differs. Anyway, inclusion of plural activities/commodities or intermediate transactions among multi-sectors in an applied study has already been beyond the framework of the Melitz's original theory. Biased fundamentalism may raise another problem and would not lead to a good result.

[a6] For a further discussion on the relationship between the variety-adjusted units and count units, see Dixon, Jerie, and Rimmer (2019).

where

$\hat{\pi}_{dir}^{D}$ is the contribution of firm d to the total profit from its domestic sales in country/region r,

$\hat{\pi}_{qirs}^{Q}$ is the contribution of firm q operating in country/region r to the total profit from its international sales to country/region s,

p_{ir}^{w} is the wholesale price (producer price) of product i, and

H_{ir} is the fixed entry costs, measured in units of gross output (composite input for firms), necessary to establish a firm in country/region r.

Let us explain the relationship between production and sales. Imagine that fixed costs H_{ir} are required to the representative agent of industry i to establish a firm (sales segment).[a7] Then, a successful entrant (firm) checks whether if it is eligible to make sales in a market, drawing productivity from an exogenous distribution. If a firm is capable of bearing additional fixed overhead costs, it starts operating for a domestic or international market. Contrary, a firm that is unable to bear additional fixed overhead costs does not start business and stays inactive. In this environment, the profits from firm sales $\hat{\pi}_{dir}^{D}$ and $\hat{\pi}_{qirs}^{Q}$ can be expressed respectively as

$$\hat{\pi}_{dir}^{D} = \hat{p}_{dir}^{D}\widehat{D}_{dir} - p_{ir}^{w}\widehat{Z}_{dir}^{D} \tag{A.8}$$

and

$$\hat{\pi}_{qirs}^{Q} = \hat{p}_{qirs}^{Q}\widehat{Q}_{qirs} - p_{ir}^{w}\widehat{Z}_{qirs}^{Q} . \tag{A.9}$$

Each firm procures a fraction $\widehat{Z}_{dir}^{D}$ or $\widehat{Z}_{qirs}^{Q}$ of gross output produced by the representative producer of industry i at the wholesale price p_{ir}^{w} as its input, and sells $\widehat{D}_{dir}$ or $\widehat{Q}_{qirs}$ units of commodity i at the differentiated sales price $\hat{p}_{dir}^{D}$ or $\hat{p}_{qirs}^{Q}$. Let us suppose some kind of additional processing is needed to make the wholesaled products salable to customers. Assuming that the fixed overhead costs are measured in units of gross output (composite input for firms), the process of

---

[a7] Since the locations where fixed costs reside have not yet clearly been identified at this moment, we adopt relatively neutral setting in which the fixed costs take the form of foregone gross output in a full-fledged model that includes intermediate transactions. This follows the idea of iceberg trade costs that involve consumption of traded commodities. Assumptions such that specify particular factor/commodity for which fixed costs generate demand, e.g., value-added (Swaminathan and Hertel, 1996; Akgul, Villoria, and Hertel, 2016), services in the destination country (Roson and Oyamada, 2016), and so on, are quite strong, because those specifications tend to accrue additional side effects such as changes in the price of the factor/commodity, followed by substantial efficiency effects that bring substitutions in a certain part of the economy. Our setting also is useful to avoid the potential difficulty one may face in the calibration process of a relatively disaggregated model that the estimated level of fixed costs exceeds the given input/output volume of the corresponding factor/commodity.

finishing wholesaled fractions $\hat{Z}_{dir}^D$ and $\hat{Z}_{qirs}^Q$ as tradables $\widehat{D}_{dir}$ and $\hat{Q}_{qirs}$ can be expressed as follows.[a8]

$$\widehat{D}_{dir} = \hat{\varphi}_{dir}^D \max(\hat{Z}_{dir}^D - F_{ir}^D, 0) \tag{A.10}$$

and

$$\hat{Q}_{qirs} = \hat{\varphi}_{qirs}^Q \max(\hat{Z}_{qirs}^Q - F_{irs}^Q, 0), \tag{A.11}$$

where

  $\hat{\varphi}_{dir}^D$ is the productivity of domestic firm d in country/region r,

  $\hat{\varphi}_{qirs}^Q$ is the productivity of international firm q in country/region r that exports commodity i to country/region s,

  F_{ir}^D is the fixed overhead costs of domestic sales measured in units of gross output (composite input for firms), and

  F_{irs}^Q is the fixed overhead costs of international sales measured in units of gross output (composite input for firms).

Then, equations (A.8) and (A.9) can be rewritten to

$$\hat{\pi}_{dir}^D = \hat{p}_{dir}^D \widehat{D}_{dir} - \frac{p_{ir}^w}{\hat{\varphi}_{dir}^D} \widehat{D}_{dir} - p_{ir}^w F_{ir}^D \tag{A.12}$$

and

$$\hat{\pi}_{qirs}^Q = \hat{p}_{qirs}^Q \hat{Q}_{qirs} - \frac{p_{ir}^w}{\hat{\varphi}_{qirs}^Q} \hat{Q}_{qirs} - p_{ir}^w F_{irs}^Q. \tag{A.13}$$

A domestic firm d in country/region r chooses price and quantity of sales to maximize $\hat{\pi}_{dir}^D$. In a similar manner, an international firm q in country/region r chooses price and quantity of sales in country/region s to maximize $\hat{\pi}_{qirs}^Q$. Then, the domestic sales price $\hat{p}_{dir}^D$ and international sales price exclusive of transportation margin and import tariff $\hat{p}_{qirs}^Q$ are respectively marked up as

$$\hat{p}_{dir}^D = \left(\frac{1}{1+\eta_i}\right) \frac{p_{ir}^w}{\hat{\varphi}_{dir}^D} \tag{A.14}$$

and

$$\hat{p}_{qirs}^Q = \left(\frac{1}{1+\eta_i}\right) \frac{p_{ir}^w}{\hat{\varphi}_{qirs}^Q}, \tag{A.15}$$

[a8] This point differs from the original theory by Melitz (2003), which assumes all of the exporting firms are active in domestic markets. In order to cope with a case when data show most of the products are exported and there is not much left for domestic demand in an industry, which often is the case if we intend to use a highly disaggregated model, we extend the assumption to allow less productive firms to be able to operate in an international market, in reference to the one such placed by Helpman, Melitz, and Yeaple (2004). In many cases, in which domestic sales exceed total exports in the benchmark data, this setting coexists with the Melitz's original assumption. If one wishes to properly handle highly productive export-oriented firms in the present analytical framework, it is necessary to build in the vertical-type or export-platform foreign direct investment based on a well-established (not ad hoc) theory, which hopefully is supported by empirical evidence.

where η_i is related to the elasticity of substitution σ_i^T such that $\eta_i \equiv -1/\sigma_i^T$.

Using (A.5) and (A.14), we can rewrite (A.12) as

$$\begin{aligned}
\hat{\pi}_{dir}^D = &-\eta_i \left(\frac{1}{1+\eta_i}\right)^{1-\sigma_i^T} \left(\frac{p_{ir}^w}{\theta_{ir}^T \hat{\varphi}_{dir}^D}\right)^{1-\sigma_i^T} \left(\delta_{ir}^D \, p_{ir}\right)^{\sigma_i^T} \\
&\times \left(\sum_j X_{ijr} + C_{ir}\right) - p_{ir}^w F_{ir}^D \, .
\end{aligned} \tag{A.16}$$

Similarly, (A.13) can be rewritten using (A.6) and (A.15) to

$$\begin{aligned}
\hat{\pi}_{qirs}^Q = &-\eta_i \left(\frac{1}{1+\eta_i}\right)^{1-\sigma_i^T} \left(\frac{p_{ir}^w}{\theta_{is}^T \hat{\varphi}_{qirs}^Q}\right)^{1-\sigma_i^T} \left(\frac{\delta_{irs}^Q \, p_{is}}{1+\tau_{irs}}\right)^{\sigma_i^T} \\
&\times \left(\sum_j X_{ijs} + C_{is}\right) - p_{ir}^w F_{irs}^Q \, .
\end{aligned} \tag{A.17}$$

Therefore, (A.7) becomes

$$\begin{aligned}
\pi_{ir} = &-\eta_i \left(\frac{1}{1+\eta_i}\right)^{1-\sigma_i^T} \sum_d \left(\frac{p_{ir}^w}{\theta_{ir}^T \hat{\varphi}_{dir}^D}\right)^{1-\sigma_i^T} \left(\delta_{ir}^D \, p_{ir}\right)^{\sigma_i^T} \left(\sum_j X_{ijr} + C_{ir}\right) \\
&-\eta_i \left(\frac{1}{1+\eta_i}\right)^{1-\sigma_i^T} \sum_s \sum_q \left(\frac{p_{ir}^w}{\theta_{is}^T \hat{\varphi}_{qirs}^Q}\right)^{1-\sigma_i^T} \left(\frac{\delta_{irs}^Q \, p_{is}}{1+\tau_{irs}}\right)^{\sigma_i^T} \left(\sum_j X_{ijs} + C_{is}\right) \\
&- p_{ir}^w N_{ir} H_{ir} - \sum_d p_{ir}^w F_{ir}^D - \sum_s \sum_q p_{ir}^w F_{irs}^Q \, ,
\end{aligned} \tag{A.18}$$

where N_{ir} is the overall number of firms once entered industry i in country/region r including inactive firms.

Next, transformation of total gross output Z_{ir}, which is determined elsewhere in a full-fledged model outside the AKME module, can be expressed as

$$\sum_d \frac{\hat{D}_{dir}}{\hat{\varphi}_{dir}^D} + \sum_s \sum_q \frac{\hat{Q}_{qirs}}{\hat{\varphi}_{qirs}^Q} = Z_{ir} - \left(N_{ir} H_{ir} + \sum_d F_{ir}^D + \sum_s \sum_q F_{irs}^Q\right) . \tag{A.19}$$

Equation (A.19) shows that the sector-wide gross output produced by the representative producer is divided and distributed through many firms including exporting agents as their inputs. Then, equation (A.19) replaces the transformation part of gross output into domestic goods and exports in a standard AGE model.

Assuming that the firm-specific productivity is drawn from a Pareto distribution, the relationships between the average productivity of both domestic and international firms, φ_{ir}^D and φ_{irs}^Q, and the cut-off productivity levels required to operate in a market, $\tilde{\varphi}_{ir}^D \in [1, \infty)$ (domestic market) and $\tilde{\varphi}_{irs}^Q \in [1, \infty)$ (international market on the r-s link), can be respectively defined as

$$\varphi_{ir}^D = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{1/(\sigma_i^T - 1)} \tilde{\varphi}_{ir}^D \tag{A.20}$$

and

$$\varphi_{irs}^Q = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{1/(\sigma_i^T - 1)} \tilde{\varphi}_{irs}^Q \, , \tag{A.21}$$

where γ_i is the Pareto shape parameter for the productivity distribution of firms such that $\gamma_i > \sigma_i^T - 1$.[a9]

[a9] For details, see Balistreri and Rutherford (2013).

In addition, the proportion of firms active in a market, $\mu_{ir}^D \in (0,1]$ (domestic market) and $\mu_{irs}^Q \in (0,1]$ (international market on the r - s link), whose productivity is sufficient to meet the cut-off level, are defined as

$$\mu_{ir}^D \equiv \frac{N_{ir}^D}{N_{ir}} = \left(\tilde{\varphi}_{ir}^D\right)^{-\gamma_i} = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\gamma_i/(\sigma_i^T - 1)} \left(\varphi_{ir}^D\right)^{-\gamma_i} \tag{A.22}$$

and

$$\mu_{irs}^Q \equiv \frac{N_{irs}^Q}{N_{ir}} = \left(\tilde{\varphi}_{irs}^Q\right)^{-\gamma_i} = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\gamma_i/(\sigma_i^T - 1)} \left(\varphi_{irs}^Q\right)^{-\gamma_i}, \tag{A.23}$$

where

N_{ir}^D is the number of firms active in the domestic market, and

N_{irs}^Q is the number of international firms active on the r-s link.

Note that the Pareto scale parameter, which defines the minimum possible draw for productivity, is implicitly assumed to be unity in (A.20) through (A.23).[a10] Thus, μ_{ir}^D and μ_{irs}^Q are ensured to remain less than or equal to one.

The cut-off productivity required for a domestic firm in country/region r to be active is determined at the level that satisfies $\hat{\pi}_{dir}^D = 0$. Using (A.16), we obtain

$$\tilde{\varphi}_{ir}^D = \frac{(-\eta_i)^{1/(1-\sigma_i^T)}}{(1+\eta_i)\theta_{ir}^T} \left(\frac{\delta_{ir}^D p_{ir}}{p_{ir}^w}\right)^{\sigma_i^T/(1-\sigma_i^T)} \left(\frac{\sum_j X_{ijr} + C_{ir}}{F_{ir}^D}\right)^{1/(1-\sigma_i^T)}. \tag{A.24}$$

In a similar manner, the cut-off productivity required for an international firm in country/region r to be active on the r-s link is determined at the level that satisfies $\hat{\pi}_{qirs}^Q = 0$. Using (A.17), we obtain

$$\tilde{\varphi}_{irs}^Q = \frac{(-\eta_i)^{1/(1-\sigma_i^T)}}{(1+\eta_i)\theta_{is}^T} \left\{\frac{\delta_{irs}^Q p_{is}}{(1+\tau_{irs})p_{is}^w}\right\}^{\sigma_i^T/(1-\sigma_i^T)} \left(\frac{\sum_j X_{ijs} + C_{is}}{F_{irs}^Q}\right)^{1/(1-\sigma_i^T)}. \tag{A.25}$$

The average productivity level of domestic and international firms can be derived as follows using (A.5), (A.14), (A.20), and (A.24), as well as (A.6), (A.15), (A.21), and (A.25), along with $\eta_i = -1/\sigma_i^T$:

$$\varphi_{ir}^D = \frac{\gamma_i - \sigma_i^T + 1}{\gamma_i(\sigma_i^T - 1)}\left(\frac{D_{ir}}{F_{ir}^D}\right) \tag{A.26}$$

and

$$\varphi_{irs}^Q = \frac{\gamma_i - \sigma_i^T + 1}{\gamma_i(\sigma_i^T - 1)}\left(\frac{Q_{irs}}{F_{irs}^Q}\right). \tag{A.27}$$

Hereafter, the variables with the suffix related to the firm group d or q are all converted to those for the firm at the average level of productivity. In particular, $\hat{D}_{dir}$, $\hat{Q}_{qirs}$, $\hat{p}_{dir}^D$, $\hat{p}_{qirs}^Q$, $\hat{\varphi}_{dir}^D$, and $\hat{\varphi}_{qirs}^Q$ are replaced by D_{ir} (average domestic trade-flow quantity of commodity i per active firm operating in country/region r), Q_{irs} (average international trade-flow quantity of commodity i per active firm operating on the r-s link), p_{ir}^D (differentiated sales price of commodity i for domestic market r), p_{irs}^Q (differentiated sales price of commodity i for

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[a10] Apply $b = 1$ to equation (23.16) in Balistreri and Rutherford (2013, p. 1523).

international market s sold by firms in country/region r), φ_{ir}^D (average productivity level of domestic firms of commodity i active in country/region r), and φ_{irs}^Q (average productivity level of international firms of commodity i active on the r-s link), respectively.

Using φ_{ir}^D, φ_{irs}^Q, N_{ir}^D (number of domestic firms of commodity i active in country/region r), and N_{irs}^Q (number of international firms of commodity i active on the r-s link), equation (A.18) can be converted to

$$
\begin{aligned}
\pi_{ir} = &-\eta_i \left(\tfrac{1}{1+\eta_i}\right)^{1-\sigma_i^T} \left(\tfrac{p_{ir}^w}{\theta_{ir}^T \varphi_{ir}^D}\right)^{1-\sigma_i^T} \left(\delta_{ir}^D p_{ir}\right)^{\sigma_i^T} N_{ir}^D (\textstyle\sum_j X_{ijr} + C_{ir}) \\
&-\eta_i \left(\tfrac{1}{1+\eta_i}\right)^{1-\sigma_i^T} \textstyle\sum_s \left(\tfrac{p_{ir}^w}{\theta_{is}^T \varphi_{irs}^Q}\right)^{1-\sigma_i^T} \left(\tfrac{\delta_{irs}^Q p_{is}}{1+\tau_{irs}}\right)^{\sigma_i^T} N_{irs}^Q (\textstyle\sum_j X_{ijs} + C_{is}) \\
&-p_{ir}^w N_{ir} H_{ir} - p_{ir}^w N_{ir}^D F_{ir}^D - \textstyle\sum_s p_{ir}^w N_{irs}^Q F_{irs}^Q .
\end{aligned}
\tag{A.28}
$$

N_{ir} (overall number of firms of commodity i established in country/region r) is determined at the level that satisfies $\pi_{ir} = 0$.[a11] Using (A.5), (A.6), (A.14), (A.15), and (A.28), as well as replacing $\hat{p}_{dir}^D$ and $\hat{p}_{qirs}^Q$ with p_{ir}^D and p_{irs}^Q, respectively, we obtain

$$
p_{ir}^w \binom{N_{ir} H_{ir} + N_{ir}^D F_{ir}^D}{+ \sum_s N_{irs}^Q F_{irs}^Q} = -\eta_i \binom{p_{ir}^D N_{ir}^D D_{ir}}{+ \sum_s p_{irs}^Q N_{irs}^Q Q_{irs}}.
\tag{A.29}
$$

Equations (A.4) and (A.19) are respectively converted to

$$
\textstyle\sum_j X_{ijs} + C_{is} = \theta_{is}^T \left\{ \begin{array}{l} \delta_{is}^D N_{is}^D D_{is}^{(\sigma_i^T-1)/\sigma_i^T} \\ + \sum_r \delta_{irs}^Q N_{irs}^Q Q_{irs}^{(\sigma_i^T-1)/\sigma_i^T} \end{array} \right\}^{\sigma_i^T/(\sigma_i^T-1)}
\tag{A.30}
$$

and

$$
N_{ir}^D \tfrac{D_{ir}}{\varphi_{ir}^D} + \textstyle\sum_s N_{irs}^Q \tfrac{Q_{irs}}{\varphi_{irs}^Q} = Z_{ir} - \left(N_{ir} H_{ir} + N_{ir}^D F_{ir}^D + \textstyle\sum_s N_{irs}^Q F_{irs}^Q\right),
\tag{A.31}
$$

using

$$
\begin{aligned}
\textstyle\sum_d \hat{D}_{dis}^{(\sigma_i^T-1)/\sigma_i^T} &= N_{is}^D D_{is}^{(\sigma_i^T-1)/\sigma_i^T}, \\
\textstyle\sum_q \hat{Q}_{qirs}^{(\sigma_i^T-1)/\sigma_i^T} &= N_{irs}^Q Q_{irs}^{(\sigma_i^T-1)/\sigma_i^T}, \\
\textstyle\sum_d F_{ir}^D &= N_{ir}^D F_{ir}^D, \\
\textstyle\sum_q F_{irs}^Q &= N_{irs}^Q F_{irs}^Q, \\
\textstyle\sum_d \hat{D}_{dir}/\hat{\varphi}_{dir}^D &= N_{ir}^D D_{ir}/\varphi_{ir}^D,
\end{aligned}
$$

and

$$
\textstyle\sum_q \hat{Q}_{qirs}/\hat{\varphi}_{qirs}^Q = N_{irs}^Q Q_{rs}/\varphi_{irs}^Q .
$$

[a11] Dixon et al. (2016) pointed out that an extra distortion in the form of pure profits/losses exists in the model developed by Zhai (2008). Zhai's version of the Melitz-type trade specification does not consider entry and exit of firms.

Finally, equations (A.5), (A.6), (A.14), (A.15), (A.22), (A.23), (A.26), (A.27), (A.29), (A.30), and (A.31) forms the AKME module. Then, the module switches the Melitz-, Krugman-, and Armington-type trade specifications by applying different choices of equations and parameter settings as follows.

Melitz-type specification: In the Melitz-type specification, the following settings apply, in addition to equations (A.5), (A.6), (A.14), (A.15), (A.22), (A.23), (A.26), (A.27), (A.29), (A.30), and (A.31):

$$N_{ir}^D = \mu_{ir}^D N_{ir} \,,$$
$$N_{irs}^Q = \mu_{irs}^Q N_{ir} \,,$$

and

$$\eta_i = -\frac{1}{\sigma_i^T} \,.$$

Krugman-type specification: In the Krugman-type, the following settings apply, in addition to equations (A.5), (A.6), (A.14), (A.15), (A.29), (A.30), and (A.31):

$$F_{ir}^D = F_{irs}^Q = 0 \,,$$
$$\varphi_{ir}^D = \varphi_{irs}^Q = 1 \,,$$
$$N_{ir} = N_{ir}^D = N_{irs}^Q \qquad (\because \mu_{ir}^D = \mu_{irs}^Q = 1) \,,$$

and

$$\eta_i = -\frac{1}{\sigma_i^T} \,.$$

Armington-type specification: In the Armington-type, the following settings apply, in addition to (A.5), (A.6), (A.14), (A.15), (A.30), and (A.31):

$$H_{ir} = F_{ir}^D = F_{irs}^Q = 0 \,,$$
$$\varphi_{ir}^D = \varphi_{irs}^Q = 1 \,,$$
$$N_{ir} = N_{ir}^D = N_{irs}^Q = 1 \quad (\because \mu_{ir}^D = \mu_{irs}^Q = 1) \,,$$

and

$$\eta_i = 0 \,.$$

Appendix B. General Equilibrium Formulation

This appendix presents a full-fledged multi-region multi-sector applied general equilibrium (AGE) model that includes the Armington-Krugman-Melitz encompassing (AKME) module in a more practical form. Commodities and activities respectively indexed i and j are categorized into three: the primary industries, manufacturing, and services sectors. There are three kinds of primary factors indexed k: capital, labor, and land and natural resources. The primary industries sector is assumed to use sector specific factors, such as land and natural resources, in addition to other primary factors and intermediate goods in its production process. The services sector provides a fraction of its output as the international shipping supply. The manufacturing sector is imperfectly competitive when the Melitz- or the Krugman-type trade specification is adopted, whereas the other two sectors stay perfectly competitive at all times. The primary production factors are assumed to be mobile across sectors whereas immobile among national/regional boundaries.

An important feature of the model is that enterprises in the manufacturing sector are divided into two segments that respectively take charge of production and sales. In the production process, the production segment of enterprises collectively determines the sector-wide input levels of intermediate goods and primary factors, and output volume, based on linearly homogeneous technologies. Then, the product is wholesaled to the sales segment. The sales segment consists of many firms, those who have market power to determine the sales price of the commodity in each market included in the model. The scale economy enters here.

B.1 Production

Composite commodity for intermediate input: First, the representative producer (unified production segment of enterprises) of industry j in country/region r determines the input levels of commodity i for intermediate use X_{ijr} to minimize costs subject to a constant elasticity of substitution (CES) technology. The problem can be expressed as

min $\qquad \sum_i p_{ir} X_{ijr}$

s.t. $\qquad \tilde{X}_{jr} = \theta_{jr}^X \left\{ \sum_i \alpha_{ijr}^X X_{ijr}^{(\sigma_j^X - 1)/\sigma_j^X} \right\}^{\sigma_j^X / (\sigma_j^X - 1)}$, $\qquad\qquad$ (B.1)

where

$\quad p_{ir}$ is the price index for commodity i in country/region r, inclusive of transportation margin and import tariff,

$\quad \tilde{X}_{jr}$ is quantity of the composite intermediate input by industry j in country/region r,

$\quad \sigma_j^X$ is the elasticity of substitution between commodities,

α_{ijr}^X is the demand share parameter that reflects requirements of commodity i to form $\tilde{X}_{jr}$, and

θ_{jr}^X is the scaling factor.

The first-order condition (FOC) for optimization with respect to X_{ijr} is

$$p_{jr}^{\tilde{X}}\left(\theta_{jr}^X\right)^{\left(\sigma_j^X-1\right)/\sigma_j^X} \alpha_{ijr}^X \left(\frac{\tilde{X}_{jr}}{X_{ijr}}\right)^{1/\sigma_j^X} = p_{ir} , \qquad (B.2)$$

where $p_{jr}^{\tilde{X}}$ represents the agent price index for the composite intermediate input by industry j in country/region r.

Value-added: The representative producer of industry j in country/region r also determines the input levels of primary factor V_{kjr} to minimize costs subject to a CES technology. Three kinds of the primary factor, capital, labor, and the one specific to the primary industries, are indexed k. The problem can be expressed as

min $\qquad\qquad\qquad \sum_k w_{kr}V_{kjr}$

s.t. $\qquad\qquad Y_{jr} = \theta_{jr}^Y \left\{\sum_k \alpha_{kjr}^Y V_{kjr}^{\left(\sigma_j^Y-1\right)/\sigma_j^Y}\right\}^{\sigma_j^Y/\left(\sigma_j^Y-1\right)} , \qquad (B.3)$

where

w_{kr} is the rental rate of the primary factor k in country/region r,

Y_{jr} is the value-added by industry j in country/region r,

σ_j^Y is the elasticity of substitution between the primary factors,

α_{kjr}^Y is the demand share parameter that reflects requirements of the primary factor k in production, and

θ_{jr}^Y is the scaling factor.

The FOC for optimization with respect to V_{kjr} is

$$p_{jr}^Y\left(\theta_{jr}^Y\right)^{\left(\sigma_j^Y-1\right)/\sigma_j^Y} \alpha_{kjr}^Y \left(\frac{Y_{jr}}{V_{kjr}}\right)^{1/\sigma_j^Y} = w_{kr} , \qquad (B.4)$$

where p_{jr}^Y represents the price index for the value-added by industry j in country/region r

Gross output: Finally, the representative producer of industry j in country/region r determines the input levels of composite input factors Y_{jr} (value-added) and $\tilde{X}_{jr}$ (composite intermediate input) to minimize costs subject to a CES technology. The problem can be expressed as

min $\qquad\qquad\qquad p_{jr}^{\tilde{X}}\tilde{X}_{jr} + p_{jr}^Y Y_{jr}$

s.t. $\qquad Z_{jr} = \theta_{jr}^Z \left\{\left(1 - \alpha_{jr}^Z\right)\tilde{X}_{jr}^{\left(\sigma_j^Z-1\right)/\sigma_j^Z} + \alpha_{jr}^Z Y_{jr}^{\left(\sigma_j^Z-1\right)/\sigma_j^Z}\right\}^{\sigma_j^Z/\left(\sigma_j^Z-1\right)} , \qquad (B.5)$

where

Z_{jr} is the gross output of industry j in country/region r,

σ_j^Z is the elasticity of substitution between composite input factors,

α_{jr}^Z is the demand share parameter that reflects requirements of value-added Y_{jr} to produce Z_{jr}, and

θ_{jr}^Z is the scaling factor.

The FOCs for optimization with respect to $\tilde{X}_{jr}$ and Y_{jr} respectively are

$$\frac{p_{jr}^Z}{1+\tau_{jr}^Z}\left(\theta_{jr}^Z\right)^{\left(\sigma_j^Z-1\right)/\sigma_j^Z}\left(1-\alpha_{jr}^Z\right)\left(\frac{Z_{jr}}{\tilde{X}_{jr}}\right)^{1/\sigma_j^Z} = p_{jr}^{\tilde{X}} \tag{B.6}$$

and

$$\frac{p_{jr}^Z}{1+\tau_{jr}^Z}\left(\theta_{jr}^Z\right)^{\left(\sigma_j^Z-1\right)/\sigma_j^Z}\alpha_{jr}^Z\left(\frac{Z_{jr}}{Y_{jr}}\right)^{1/\sigma_j^Z} = p_{jr}^Y, \tag{B.7}$$

where

p_{jr}^Z represents the price index for the gross output of industry j in country/region r, and

τ_{jr}^Z is the rate of indirect taxes on production.[b1]

B.2 Final demand

Composite commodity for final consumption: Analogous to the case of intermediate inputs, the representative consumer of country/region r determines the demand levels of commodity i for final consumption C_{ir} to minimize costs subject to a Cobb-Douglas aggregator.[b2] The problem can be expressed as

min $\qquad\qquad\qquad \sum_i p_{ir}\, C_{ir}$

s.t. $\qquad\qquad\qquad \tilde{C}_r = \theta_r^C \prod_i C_{ir}^{\alpha_{ir}^C}, \tag{B.8}$

where

$\tilde{C}_r$ is quantity of the composite final consumption in country/region r,

α_{ir}^C is the demand share parameter that reflects requirements of commodity i to form $\tilde{C}_r$, and

θ_r^C is the scaling factor.

The FOC for optimization with respect to C_{ir} becomes

$$p_r^{\tilde{C}}\alpha_{ir}^C\left(\frac{\tilde{C}_r}{C_{ir}}\right) = p_{ir}, \tag{B.9}$$

where $p_r^{\tilde{C}}$ represents the agent price index for the composite final consumption in country/region r.

[b1] The price indices for the composite intermediate input $p_{jr}^{\tilde{X}}$ and value-added p_{jr}^Y are assumed to be exclusive of indirect taxes, whereas the index for the gross output p_{jr}^Z is tax-inclusive. Thus, the former two indices are discounted by $1+\tau_{jr}^Z$. In the calibration process, the tax-inclusive price index p_{jr}^Z is set to unity.

[b2] Final demand C_{ir} includes fixed capital formation to keep the model simple in this study.

Welfare: Then, the representative consumer of country/region r maximizes the level of composite final consumption $\tilde{C}_r$ subject to a budget constraint, given as the total of factor income and tax revenue transferred from the national/regional authority. In this setting, we presume that the current account remains imbalanced at the same position given by the benchmark data for simplicity.[b3] This problem can be expressed as follows:

$$\text{max} \qquad \tilde{C}_r$$

$$\text{s.t.} \qquad p_r^{\tilde{C}} \tilde{C}_r = \sum_k \sum_j w_{kr} V_{kjr} + T_r + \bar{S}_r^F \,, \tag{B.10}$$

where

$\bar{S}_r^F$ is the foreign savings by country/region r, which is given exogenously, and T_r is the tax revenue, defined as

$$T_r \equiv \left\{ \begin{array}{c} \sum_j \left(\frac{\tau_{jr}^Z}{1+\tau_{jr}^Z}\right) p_{jr}^W Z_{jr} \\ + \sum_i \sum_s \tau_{irs}^E p_{irs}^Q N_{irs}^Q Q_{irs} \\ + \sum_i \sum_s \tau_{isr}^M \left(1 + \tau_{isr}^T\right)\left(1 + \tau_{isr}^E\right) p_{isr}^Q N_{isr}^Q Q_{isr} \end{array} \right\}.$$

Notice that τ_{irs} entered Appendix A is now divided into τ_{irs}^E (rate of export duty/subsidy), τ_{irs}^T (rate of transportation margin), and τ_{irs}^M (rate of import tariff). N_{irs}^Q is set to unity when i is not the manufacturing sector, since the primary industries and services sectors are assumed to be perfectly competitive so that the Armington-type trade specification is applied. The FOC for optimization with respect to $\tilde{C}_r$ is

$$1 = \lambda_r p_r^{\tilde{C}} \,, \tag{B.11}$$

where λ_r corresponds to the total change in the composite consumption given a unit increase of income.

B.3 Other items

Factor market: The factor market clearing condition is

$$\sum_j V_{kjr} = \bar{V}_{kr} \,, \tag{B.12}$$

where $\bar{V}_{kr}$ is the exogenously given factor endowment. Equation (B.12) determines the level of w_{kr}.

Dual relation: A relation between p_{jr}^Z (price index for the gross output) and p_{jr}^W (wholesale price) is added:

$$p_{jr}^Z = p_{jr}^W \,. \tag{B.13}$$

Equation (B.13) determines the volume of Z_{jr}.

[b3] The level of position (foreign savings) is valued by the price of the *numéraire* commodity. Foreign savings $\bar{S}_r^F$ is defined by the total value of imports at cost, insurance, and freight (CIF) prices minus the total value of exports at free on board (FOB) prices that includes inter-regional shipping supply. In the present model, net factor income from abroad does not exist.

International trade (AKME module): The AKME module handles the international trade part that connects gross outputs supplied in source countries/regions with commodities demanded in destinations. Among equations (A.5), (A.6), (A.14), (A.15), (A.22), (A.23), (A.26), (A.27), (A.29), (A.30), and (A.31) shown in Appendix A, (A.5), (A.6), (A.30), and (A.31) require some modifications such as applying

$$\delta_{is}^D \equiv \left(1 - \sum_r \alpha_{irs}^T\right)\left(N_{is}^D\right)^{(\beta_{is}-1)/\sigma_i^T}$$

and

$$\delta_{irs}^Q \equiv \alpha_{irs}^T\left(N_{irs}^Q\right)^{(\beta_{is}-1)/\sigma_i^T}.$$

The set of equations that configure the AKME module are as follows:

$$\sum_j X_{ijs} + C_{is}$$

$$= \theta_{is}^T \left\{ \begin{array}{l} \left(1 - \sum_r \alpha_{irs}^T\right)\left(N_{is}^D\right)^{(\beta_{is}+\sigma_i^T-1)/\sigma_i^T} D_{is}^{(\sigma_i^T-1)/\sigma_i^T} \\ + \sum_r \alpha_{irs}^T\left(N_{irs}^Q\right)^{(\beta_{is}+\sigma_i^T-1)/\sigma_i^T} Q_{irs}^{(\sigma_i^T-1)/\sigma_i^T} \end{array} \right\}^{\sigma_i^T/(\sigma_i^T-1)} , \tag{B.14}$$

$$p_{is}\left(\theta_{is}^T\right)^{(\sigma_i^T-1)/\sigma_i^T}\left(1 - \sum_r \alpha_{irs}^T\right)\left(N_{is}^D\right)^{(\beta_{is}-1)/\sigma_i^T}\left(\frac{\sum_j X_{ijs}+C_{is}}{D_{is}}\right)^{1/\sigma_i^T} \tag{B.15}$$
$$= p_{is}^D ,$$

$$p_{is}\left(\theta_{is}^T\right)^{(\sigma_i^T-1)/\sigma_i^T}\alpha_{irs}^T\left(N_{irs}^Q\right)^{(\beta_{is}-1)/\sigma_i^T}\left(\frac{\sum_j X_{ijs}+C_{is}}{Q_{irs}}\right)^{1/\sigma_i^T} \tag{B.16}$$
$$= \left(1 + \tau_{irs}^M\right)\left(1 + \tau_{irs}^T\right)\left(1 + \tau_{irs}^E\right)p_{irs}^Q ,$$

$$p_{ir}^D = \left(\frac{1}{1+\eta_i}\right)\frac{p_{ir}^w}{\varphi_{ir}^D} , \tag{B.17}$$

$$p_{irs}^Q = \left(\frac{1}{1+\eta_i}\right)\frac{p_{ir}^w}{\varphi_{irs}^Q} , \tag{B.18}$$

$$N_{ir}^D \frac{D_{ir}}{\varphi_{ir}^D} + \sum_s N_{irs}^Q \frac{Q_{irs}}{\varphi_{irs}^Q} + \Omega_{ir} = Z_{ir} - \left(\begin{array}{c} N_{ir}H_{ir} + N_{ir}^D F_{ir}^D \\ + \sum_s N_{irs}^Q F_{irs}^Q \end{array}\right) , \tag{B.19}$$

$$\mu_{ir}^D = \left(\frac{\gamma_i}{\gamma_i-\sigma_i^T+1}\right)^{\gamma_i/(\sigma_i^T-1)}\left(\varphi_{ir}^D\right)^{-\gamma_i} , \tag{B.20}$$

$$\mu_{irs}^Q = \left(\frac{\gamma_i}{\gamma_i-\sigma_i^T+1}\right)^{\gamma_i/(\sigma_i^T-1)}\left(\varphi_{irs}^Q\right)^{-\gamma_i} , \tag{B.21}$$

$$\varphi_{ir}^D = \frac{\gamma_i-\sigma_i^T+1}{\gamma_i(\sigma_i^T-1)}\left(\frac{D_{ir}}{F_{ir}^D}\right) , \tag{B.22}$$

$$\varphi_{irs}^Q = \frac{\gamma_i-\sigma_i^T+1}{\gamma_i(\sigma_i^T-1)}\left(\frac{Q_{irs}}{F_{irs}^Q}\right) , \tag{B.23}$$

and

$$p_{ir}^w\left(\begin{array}{c} N_{ir}H_{ir} + N_{ir}^D F_{ir}^D \\ + \sum_s N_{irs}^Q F_{irs}^Q \end{array}\right) = -\eta_i\left(\begin{array}{c} p_{ir}^D N_{ir}^D D_{ir} \\ + \sum_s p_{irs}^Q N_{irs}^Q Q_{irs} \end{array}\right) , \tag{B.24}$$

where Ω_{ir} is the international transportation supply defined with a national/regional share parameter ω_{ir} as

$$\Omega_{ir} \equiv \frac{\omega_{ir}}{p_{ir}^W} \sum_{i'} \sum_{r'} \sum_s \tau_{i'r's}^T \left(1 + \tau_{i'r's}^E\right) p_{i'r's}^Q N_{i'r's}^Q Q_{i'r's} .$$

Ω_{ir} is included in (B.19) if and only if industry i corresponds to the services sector to satisfy the special treatment concerning international shipping supply by the transportation service sector required in the Global Trade Analysis Project (GTAP) Data Base. Furthermore, the expression in the parenthesis in the right-hand side of equation (B.19) enter if and only if industry i corresponds to the manufacturing sector when we assume the Melitz- and Krugman-type trade specifications. Equations (B.20) through (B.23) are just for the case when industry i is the manufacturing sector. Finally, N_{ir}, N_{ir}^D, N_{irs}^Q, φ_{ir}^D, and φ_{irs}^Q are set to unity while β_{is} and η_i are zero when industry i is not the manufacturing sector.

Finally, the system of a multi-region multi-sector AGE model that includes the AKME module is described by 24 equations consist of (B.1) through (B.24), which respectively determine the levels of $p_{jr}^{\breve{X}}$, X_{ijr}, p_{jr}^Y, V_{kjr}, p_{jr}^Z, $\tilde{X}_{jr}$, Y_{jr}, $p_r^{\breve{C}}$, C_{ir}, λ_r, $\tilde{C}_r$, w_{kr}, Z_{jr}, p_{is}, D_{is}, Q_{irs}, p_{ir}^D, p_{irs}^Q, p_{ir}^W, μ_{ir}^D, μ_{irs}^Q, φ_{ir}^D, φ_{irs}^Q, and N_{ir}.[b4] Since *Walras' Law* holds, one of the market clearing conditions automatically holds. In the simulation experiments with a 3-region 3-sector AGE model, we drop (B.19) with respect to the primary industries in the third country/region, exogenously setting $p_{"i01""r03"}^W$ to unity. This means we treat the primary products made in the third country/region as the *numéraire*.

B.4 The rule on the relationships between the cut-off productivity, the proportion of active firms, and the sales quantity per firm

Differentiating equations (B.21) and (B.23) with respect to φ_{irs}^Q, respectively, we obtain

$$\frac{d\mu_{irs}^Q}{d\varphi_{irs}^Q} = -\gamma_i \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\gamma_i/(\sigma_i^T - 1)} \left(\varphi_{irs}^Q\right)^{-\gamma_i - 1} < 0$$

and

$$\frac{dQ_{irs}}{d\varphi_{irs}^Q} = \frac{\gamma_i(\sigma_i^T - 1)}{\gamma_i - \sigma_i^T + 1} F_{irs}^Q > 0 .$$

[b4] This idea bases on a concept in operations research. A variable in primal relates to a constraint in dual, and *vice versa*. When a model arrives at an optimal solution, the values of Lagrange multipliers are determined by the corresponding constraints. If a constraint is not binding, the value of the corresponding Lagrange multiplier reduces to zero. For the case of equation (B.11), p_{is} is the Lagrange multiplier that can be considered as the shadow price of X_{ijs} and C_{is} in an equilibrium. On the other hand, equations that are not essential for the system but introduced just for convenience in defining some variables, such as equations (B.17), (B.18), (B.20), (B.21), (B.22), and (B.23) are out of the primal-dual relationships in the system.

These relations imply that a higher/lower level of the cut-off productivity (also the average productivity) always reduces/increases the proportion of active firms and expands/shrinks the sales quantity per firm. [b5]

[b5] Analogous relations can be obtained for the case of domestic firms differentiating equations (B.20) and (B.22) with respect to φ_{ir}^{D}.

Appendix C. Parameterization of a Melitz-type Model

This appendix explains the calibration procedure used to parameterize the Armington-Krugman-Melitz encompassing (AKME) module presented in Appendices A and B. Since a Krugman-type model can be parameterized applying an analogous procedure to that will be described here, we just concentrate on explaining the case of a Melitz-type.

C.1 Values or initial levels of key parameters and variables

To parameterize an Armington-type model, it is well known that the following kinds of information are required in advance: $p_{ir}X_{ijr}$ (intermediate input at market price inclusive of transportation costs and import tariff), $p_{ir}C_{ir}$ (final demand at market price inclusive of transportation costs and import tariff), σ_i^T (elasticity of substitution across domestic and international suppliers), τ_{irs} (rate of transportation margin and import tariff), domestic trade flows at market prices, e.g., "VDM" in the Global Trade Analysis Project (GTAP) Data Base, and international trade flows at free on board (FOB) prices or producer prices, e.g., "$VXWD$" or "$VXMD$."[c1] In the present framework, these two types of international trade flows at the different price levels become identical. Let us refer to the data related to the domestic and international trade flow values as "TF_{ir}^D" and "TF_{irs}^Q" here. TF_{ir}^D and TF_{irs}^Q can respectively be regarded as

$$TF_{ir}^D \equiv p_{ir}^D \mu_{ir}^D N_{ir} D_{ir} \tag{C.1}$$

and

$$TF_{irs}^Q \equiv p_{irs}^Q \mu_{irs}^Q N_{ir} Q_{irs} . \tag{C.2}$$

In addition to the information listed above, information on four items γ_i (Pareto shape parameter for the productivity distribution of firms), either of F_{ir}^D (fixed overhead costs of domestic sales) or μ_{ir}^D (proportion of active domestic firms), either of F_{irs}^Q (fixed overhead costs of international sales) or μ_{irs}^Q (proportion of international firms active on the r-s link), and either of H_{ir} (fixed entry costs) or N_{ir} (overall number of firms once established) are basically necessary to include Melitz-type monopolistic competition and heterogeneous firms. Then, D_{ir} (average domestic trade flow quantity of commodity i per active firm operating in country/region r), Q_{irs} (average international trade flow quantity of commodity i per active firm operating on the r-s link), and three of F_{ir}^D, F_{irs}^Q, H_{ir}, μ_{ir}^D, μ_{irs}^Q, and N_{ir} can be derived and calibrated. The value of the Pareto shape parameter γ_i is assumed to be determined based on empirical literatures such as Balistreri, Hillberry, and Rutherford (2011) and Spearot (2016).[c2] In this process, initial levels

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[c1] For details, see Hertel (1997).

[c2] Spearot (2016) presents shape estimates for 39 industries out of the 57 sectors housed in the GTAP Data Base excluding 18 sectors classified as non-tradables or services.

of other endogenous variables, which cannot be observed directly from the given data, p_{ir}^D (average firm price for domestic sales), p_{irs}^Q (average firm price for international sales), φ_{ir}^D (average productivity level of domestic firms), and φ_{irs}^Q (average productivity level of international firms active on the r-s link) also are derived by setting p_{ir}^w (wholesale price of commodity i produced in country/region r) to unity following the usual custom of AGE modeling. After that, the initial levels of p_{is} (trade-cost-inclusive price index for composite units of commodity i sold in country/region s), and the parameter values of α_{irs}^T (demand share parameter) and θ_{is}^T (scaling factor of measuring units) are derived and calibrated utilizing information on β_{is} (importer's marginal valuation of an exporter's variety).[c3]

Equations (B.20) and (B.21) in Appendix B can respectively be rewritten to

$$\varphi_{ir}^D = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{1/(\sigma_i^T - 1)} \left(\mu_{ir}^D\right)^{-1/\gamma_i} \tag{C.3}$$

and

$$\varphi_{irs}^Q = \left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{1/(\sigma_i^T - 1)} \left(\mu_{irs}^Q\right)^{-1/\gamma_i}. \tag{C.4}$$

In the meanwhile, we get the following relations substituting (B.17) and (B.18) in Appendix B into (C.1) and (C.2), respectively:

$$D_{ir} = \frac{(1+\eta_i)\varphi_{ir}^D TF_{ir}^D}{p_{ir}^w \mu_{ir}^D N_{ir}} \tag{C.5}$$

and

$$Q_{irs} = \frac{(1+\eta_i)\varphi_{irs}^Q TF_{irs}^Q}{p_{ir}^w \mu_{irs}^Q N_{ir}}. \tag{C.6}$$

Using (C.3) and (C.5), as well as $\eta_i = -1/\sigma_i^T$, the following relation can be derived:

$$\left(\mu_{ir}^D\right)^{1/\gamma_i} D_{ir} = \left(\frac{\sigma_i^T - 1}{\sigma_i^T}\right)\left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{1/(\sigma_i^T - 1)} \frac{TF_{ir}^D}{p_{ir}^w \mu_{ir}^D N_{ir}}. \tag{C.7}$$

In a similar manner using (C.4) and (C.6) with $\eta_i = -1/\sigma_i^T$, we also get

$$\left(\mu_{irs}^Q\right)^{1/\gamma_i} Q_{irs} = \left(\frac{\sigma_i^T - 1}{\sigma_i^T}\right)\left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{1/(\sigma_i^T - 1)} \frac{TF_{irs}^Q}{p_{ir}^w \mu_{irs}^Q N_{ir}}. \tag{C.8}$$

Respectively substituting (B.22) and (B.23) in Appendix B to (B.20) and (B.21) in Appendix B, we obtain

$$F_{ir}^D = \frac{1}{\sigma_i^T - 1}\left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\sigma_i^T/(1-\sigma_i^T)} \left(\mu_{ir}^D\right)^{1/\gamma_i} D_{ir} \tag{C.9}$$

[c3] If one prefers to be consistent with the theoretical models by Krugman and Melitz, information on β_{is} is not necessary because $\beta_{is} = 1$. Concurrently, the choices of initial levels of the overall number of successful entrants and the proportion of active firms (or parameter values of fixed costs) do not matter for the simulation results. This is the reason why we noted in the beginning of this appendix that only one kind of additional information is required in order to extend an Armington-type model to be a Melitz-type.

and

$$F_{irs}^Q = \frac{1}{\sigma_i^T - 1}\left(\frac{\gamma_i}{\gamma_i - \sigma_i^T + 1}\right)^{\sigma_i^T/(1-\sigma_i^T)}\left(\mu_{irs}^Q\right)^{1/\gamma_i} Q_{irs}\,. \tag{C.10}$$

Then, we can derive the following two relations, plugging (C.7) and (C.8) to (C.9) and (C.10), respectively:

$$p_{ir}^w \mu_{ir}^D N_{ir} F_{ir}^D = \left(\frac{\gamma_i - \sigma_i^T + 1}{\gamma_i \sigma_i^T}\right) TF_{ir}^D \tag{C.11}$$

and

$$p_{ir}^w \mu_{irs}^Q N_{ir} F_{irs}^Q = \left(\frac{\gamma_i - \sigma_i^T + 1}{\gamma_i \sigma_i^T}\right) TF_{irs}^Q\,. \tag{C.12}$$

Finally, the following relation comes up if we manipulate (B.24) in Appendix B using (C.1), (C.2), (C.11), and (C.12):

$$p_{ir}^w N_{ir} H_{ir} = \frac{\sigma_i^T - 1}{\gamma_i \sigma_i^T}\left(TF_{ir}^D + \sum_s TF_{irs}^Q\right)\,. \tag{C.13}$$

This is the final essence of the calibration equations of a Melitz-type model, which shows N_{ir} and H_{ir} are inseparable so that initial values of these variables cannot be estimated independently. Similarly, equations (C.11) and (C.12) also show that μ_{ir}^D and μ_{irs}^Q cannot be estimated independently from F_{ir}^D and F_{irs}^Q, respectively. Thus, values for either of N_{ir} or H_{ir}, either of μ_{ir}^D or F_{ir}^D, and either of μ_{irs}^Q or F_{irs}^Q have to be determined on some kind of special assumptions, in advance to start parameterizing a model.

Following Zhai (2008), we adopt a strategy to make use of the information on μ_{ir}^D and μ_{irs}^Q, instead of F_{ir}^D and F_{irs}^Q. Assuming 60 percent of the entered firms in a country/region make sales in the local domestic market ($\mu_{ir}^D = 0.60$), which is the same value as the one adopted by Zhai (2008), we may derive the initial levels of μ_{irs}^Q based on the following equation if information on the extensive margin is available:

$$\mu_{irs}^Q = \mu_{ir}^D \left\{\frac{(1+\tau_{irs})TF_{irs}^Q}{TF_{ir}^D}\right\}^{\varepsilon_i}, \tag{C.14}$$

where ε_i is the elasticity parameter, for which an estimated value of the extensive margin is applicable.[c4] Zhai (2008) used the empirical findings by Hummels and Klenow (2005) that the extensive margin accounts for 60 percent of the difference in export values across countries/regions ($\varepsilon_i = 0.60$).

How can we determine the initial levels of N_{ir} or parameter values of H_{ir}? As shown in equation (C.13), H_{ir} is calibrated as a parameter accordingly to scale the

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[c4] One problem in this approach is that μ_{irs}^Q cannot be estimated at an appropriate level when the given volume of $(1 + \tau_{irs})TF_{irs}^Q$ takes a value much greater than that of TF_{ir}^D, which can sometimes be observed in real data, because equation (C.14) does not necessarily ensure μ_{irs}^Q to be calculated less than unity. It implies that handling a production sector occupied by export-oriented firms in a highly disaggregated model may cause trouble.

chosen level of N_{ir} so as to make the left-hand side of equation (C.13) meet the sum of the fixed proportions of TF_{ir}^D and $\sum_s TF_{irs}^Q$, which are given by the benchmark data, and *vice versa*. As studied by Dixon, Jerie, and Rimmer (2018), the choice of the initial levels of N_{ir} (overall number of firms established in industry i of country/region r) or parameter values of H_{ir} (fixed entry costs necessary to establish a firm in industry i of country/region r) in the calibration process is perfectly neutral and will not affect the initial levels of endogenous variables and parameter settings elsewhere in a full-fledged model outside the AKME module. Thus, initial levels of N_{ir} (or parameter values of H_{ir}) can be set to any preferred value freely, e.g., $N_{ir} = 1$, as if we derive quantities from the given value data by assuming some of initial prices to be unity.

Furthermore, if we explore more deeply, F_{ir}^D and F_{irs}^Q are calibrated as parameters accordingly to scale the chosen levels of μ_{ir}^D and μ_{irs}^Q, which make the left-hand sides of equations (C.11) and (C.12) meet the fixed proportions of TF_{ir}^D and $\sum_s TF_{irs}^Q$, which are provided by the benchmark data, and *vice versa*. This time, the choice of the initial levels of μ_{ir}^D (proportion of active domestic firms) or parameter values of F_{ir}^D (fixed overhead costs of domestic sales) as well as μ_{irs}^Q (proportion of international firms active on the r-s link) or F_{irs}^Q (fixed overhead costs of international sales) in the calibration process will not affect deviations of the endogenous variables included in an AGE model with the AKME module caused by an exogenous shock given in a counterfactual simulation. Unlike the case of N_{ir} and H_{ir}, the choice of initial levels of μ_{ir}^D and μ_{irs}^Q or parameter values of F_{ir}^D and F_{irs}^Q affects elsewhere in a full-fledged model outside the AKME module. On the other hand, deviations of the endogenous variables from the baseline brought by a certain shock given in a counterfactual simulation will never be affected by the choice. In the ordinary AGE analysis, effects are measured and evaluated by the initial volumes of endogenous variables in the baseline. It implies that just changes in the endogenous variables from the baseline are important and essential. If one stays within this ordinary usage of an AGE model, initial levels of μ_{ir}^D and μ_{irs}^Q or parameter values of F_{ir}^D and F_{irs}^Q will never affect simulation results.

Once the initial levels of N_{ir}, μ_{ir}^D, and μ_{irs}^Q are set, initial levels or parameter values of φ_{ir}^D, φ_{irs}^Q, F_{ir}^D, F_{irs}^Q, and H_{ir} can be calculated first by equations (C.3), (C.4), (C.11), (C.12), and (C.13), respectively, applying $\eta_i = -1/\sigma_i^T$ and $p_{ir}^w = 1$. Then, using the obtained values of φ_{ir}^D and φ_{irs}^Q as well as $\eta_i = -1/\sigma_i^T$ and $p_{ir}^w = 1$, initial values of p_{ir}^D, p_{irs}^Q, D_{ir}, and Q_{irs} can be derived from equations (A.14) and (A.15) in Appendix A, (C.5), and (C.6), respectively. To make the parameterization process simple, we recommend setting the initial levels of N_{ir} to be unity. While the procedure using equation (C.14) to estimate the initial levels of

μ_{irs}^Q essentially have no positive meaning in the present situation, it still is helpful to reasonably choose the levels within the range between zero and unity.

C.2 Parameters in the CES demand aggregator for domestic and imported products

Once p_{ir}^D, p_{irs}^Q, D_{ir}, Q_{irs}, H_{ir}, F_{ir}^D, F_{irs}^Q, φ_{ir}^D, and φ_{irs}^Q are calibrated choosing certain values whatever one likes for N_{ir}, μ_{ir}^D, and μ_{irs}^Q, we can determine the initial levels of p_{is} and parameter values of α_{irs}^T and θ_{is}^T, making use of empirical findings on β_{is} such as presented by Ardelean (2006), if available, based on the following equations:

$$p_{is} = \frac{TF_{is}^D + \sum_r (1+\tau_{irs}) TF_{irs}^Q}{\mu_{is}^D N_{is} D_{is} + \sum_r \mu_{irs}^Q N_{ir} Q_{irs}}, \tag{C.15}$$

$$\alpha_{irs}^T = \frac{(1+\tau_{irs}) p_{irs}^Q \left(\mu_{irs}^Q N_{ir}\right)^{(1-\beta_{is})/\sigma_i^T} Q_{irs}^{1/\sigma_i^T}}{\left\{ \begin{array}{l} p_{is}^D (\mu_{is}^D N_{is})^{(1-\beta_{is})/\sigma_i^T} D_{is}^{1/\sigma_i^T} \\ + \sum_{r'} \left(1+\tau_{ir's}\right) p_{ir's}^Q \left(\mu_{ir's}^Q N_{ir'}\right)^{(1-\beta_{is})/\sigma_i^T} Q_{ir's}^{1/\sigma_i^T} \end{array} \right\}}, \tag{C.16}$$

and

$$\theta_{is}^T = \frac{\sum_j X_{ijs} + C_{is}}{\left\{ \begin{array}{l} (1-\sum_r \alpha_{irs}^T)(\mu_{is}^D N_{is})^{(\beta_{is}+\sigma_i^T-1)/\sigma_i^T} D_{is}^{(\sigma_i^T-1)/\sigma_i^T} \\ + \sum_r \alpha_{irs}^T (\mu_{irs}^Q N_{ir})^{(\beta_{is}+\sigma_i^T-1)/\sigma_i^T} Q_{irs}^{(\sigma_i^T-1)/\sigma_i^T} \end{array} \right\}^{\sigma_i^T/(\sigma_i^T-1)}}, \tag{C.17}$$

where X_{ijs} and C_{is} are respectively calculated from the given information on intermediate input and final demand at market prices inclusive of transportation costs and import tariff using p_{is}. Equations (C.15) through (C.17) can be derived following the usual procedure taken in the calibration process of many AGE models.[c5]

In the procedure presented above, all of the parameter values are just determined, without making any changes in the data set, at the levels that ensure the model to generate an equilibrium solution with values that reproduce the benchmark data in the reference run. For instance, there is no re-estimation of the trade costs. Our approach is on the same basis as the one taken by Zhai (2008), whereas he re-estimates unobserved transportation margins based on the assumption that domestic trade incurs no iceberg trade costs. Unlike our approach, Balistreri et al. (2011) gave the top priority to the measurement of the Pareto shape parameter as well as the unobserved trade frictions that fit to the geographic pattern of trade. Using equations defined by the model based on Melitz (2003) as a series of side constraints and making assumptions on selected structural parameters, they carried out comprehensive econometric estimations to obtain those parameters. Since econometric estimation requires a certain amount

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[c5] For details, study textbooks such as Dervis, de Melo, and Robinson (1982) and Shoven and Whalley (1992).

of data collected from several sources, we adopted a more labor-saving and simpler way, making full use of information such that we are familiar with or relatively easy to have access to. No matter what, Balistreri and his colleagues' work as well as Spearot (2016) that provide important information on the Pareto shape parameter γ_i absolutely helps us in parameterizing a model with the Melitz-type trade specification. Information on the extensive margin also helps us to reasonably (and easily) obtain initial levels of the proportion of active firms, μ_{ir}^D and μ_{irs}^Q.

Appendix D. Benchmark Data for the 3-region 3-sector Model

The benchmark data set for the 3-region 3-sector applied general equilibrium (AGE) model that includes the Armington-Krugman-Melitz encompassing (AKME) module introduced and used in this study consists of input-output (I-O) tables for three countries/regions (Table D.1), trade flow tables at four different price levels (Tables D.2 through D.5), a domestic flow table at producer prices (Table D.6), values of international shipping supply (Table D.7), four types of substitution elasticity σ_j^Z, σ_j^Y, σ_j^X, and σ_i^T (Table D.8), the Pareto shape parameter γ_i, initial values of the overall number of firm entries N_{ir} and proportion of active domestic firms μ_{ir}^D, the extensive margin ε_i (Table D.9), and importer's love of variety (LoV) β_{is}. Although there is essentially no positive meaning to derive μ_{irs}^Q using equation (C.14) with given values of μ_{ir}^D and ε_i, we demonstrate a practice for example.

The former four are obtained from the Global Trade Analysis Project (GTAP) 9.2 Data Base for 2011, and used to construct social accounting matrices (SAMs) for three countries/regions (Table D.10). As noted in Section 3, the original 140 countries/regions and 57 commodities/activities are respectively aggregated to three. The countries/regions consist of (r01) the United States of America (US), (r02) China, and (r03) the Rest of the World (RoW), and the three sectors are (i01) primary industries, (i02) manufacturing, and (i03) services. The primary production factors also are aggregated into three: (k01) capital, (k02) labor, and (k03) land and natural resources. Since the data aggregated by GTAPAgg contains minor rounding errors, which makes I-O tables imbalanced, the discrepancies caused by such errors are all absorbed by the final demand part.

The rest are assumed by the author. Some values of the substitution elasticity are determined based on the information provided by the GTAP Data Base. While the Pareto shape parameter γ_i is determined based on the empirical studies such as done by Balistreri, Hillberry, and Rutherford (2011), the overall number of firm entries N_{ir} is just set to unity. For the proportion of active domestic firms μ_{ir}^D and extensive margin ε_i, we chose the same values as Zhai (2008) assumed. Finally, the values of β_{is} are just selected between zero and unity.

In the tables, AT0x and CT0x also are production sectors. C, E, M, Z, TZ, D, VA0x, FM, HH, WT, IS, and TT respectively denote final demand, exports, imports, gross output, indirect taxes on production, domestic flows, primary factors, producers, the representative consumer, exports/imports, international shipping, and aggregate total.

Table D.1 Input-output tables for each country/region, US$ billion.

r01	i01	i02	i03	C	E-M	Z
i01	55.882	812.360	122.430	80.683	-286.122	785.234
i02	128.149	2785.681	1985.598	3250.819	-619.771	7530.476
i03	180.640	1464.877	5493.851	12700.093	100.859	19940.320
k01	156.821	636.171	3105.004			
k02	109.816	1494.878	7406.350			
k03	133.847					
TZ	20.079	336.508	1827.087			
Z	785.234	7530.476	19940.320			

Source: GTAP 9.2 Data Base for 2011.

r02	i01	i02	i03	C	E-M	Z
i01	164.402	1320.227	193.208	264.355	-457.520	1484.673
i02	313.063	5768.681	1993.069	2050.635	594.842	10720.404
i03	161.887	1348.363	1904.159	4272.193	-14.393	7672.209
k01	152.750	930.922	1446.510			
k02	429.381	915.903	1835.459			
k03	266.553					
TZ	-3.363	436.194	299.805			
Z	1484.673	10720.404	7672.209			

Source: GTAP 9.2 Data Base for 2011.

r03	i01	i02	i03	C	E-M	Z
i01	468.417	3855.589	730.526	1315.392	341.735	6711.659
i02	825.885	12012.565	6955.342	10837.653	-1075.005	29556.440
i03	985.163	5563.099	16816.236	33230.797	689.271	57284.566
k01	1847.043	3677.264	14591.531			
k02	1110.782	2952.415	12703.423			
k03	1274.285					
TZ	200.084	1495.508	5487.508			
Z	6711.659	29556.440	57284.566			

Source: GTAP 9.2 Data Base for 2011.

Table D.2 Trade flows at producer prices, US$ billion.

		r01	r02	r03	E (Exports)
r01	i01	0.000	21.882	92.999	114.881
	i02	0.000	98.460	1195.096	1293.556
	i03	0.000	16.170	416.087	432.256
r02	i01	1.853	0.000	22.012	23.865
	i02	385.313	0.000	1315.345	1700.659
	i03	14.106	0.000	92.424	106.530
r03	i01	372.220	391.192	1742.414	2505.826
	i02	1385.026	902.280	7824.834	10112.140
	i03	358.453	158.146	2309.227	2825.825
M (Imports)	i01	374.073	413.074	1857.426	
	i02	1770.339	1000.741	10335.275	
	i03	372.558	174.315	2817.738	

Source: GTAP 9.2 Data Base for 2011.

Table D.3 Trade flows at FOB prices, US$ billion.

		r01	r02	r03	E (Exports)
r01	i01	0.000	21.883	93.012	114.895
	i02	0.000	98.879	1198.779	1297.658
	i03	0.000	16.170	416.087	432.256
r02	i01	1.902	0.000	22.705	24.607
	i02	410.182	0.000	1358.404	1768.586
	i03	14.106	0.000	92.424	106.530
r03	i01	376.114	400.451	1850.174	2626.738
	i02	1392.963	905.393	7867.003	10165.359
	i03	358.453	158.146	2309.227	2825.825
M (Imports)	i01	378.016	422.334	1965.781	
	i02	1803.146	1004.271	10424.186	
	i03	372.558	174.315	2817.738	

Source: GTAP 9.2 Data Base for 2011.

Table D.4 Trade flows at CIF prices, US$ billion.

		r01	r02	r03	E (Exports)
r01	i01	0.000	26.270	103.953	130.223
	i02	0.000	103.229	1250.752	1353.981
	i03	0.000	16.170	416.087	432.256
r02	i01	2.151	0.000	26.147	28.298
	i02	432.069	0.000	1433.990	1866.059
	i03	14.106	0.000	92.424	106.530
r03	i01	398.430	451.382	1989.712	2839.524
	i02	1452.136	945.160	8158.226	10555.522
	i03	358.453	158.146	2309.227	2825.825
M (Imports)	i01	400.582	477.652	2119.812	
	i02	1884.205	1048.389	10842.968	
	i03	372.558	174.315	2817.738	

Source: GTAP 9.2 Data Base for 2011.

Table D.5 Trade flows at tariff inclusive market prices, US$ billion.

		r01	r02	r03	E (Exports)
r01	i01	0.000	27.018	118.628	145.646
	i02	0.000	109.154	1287.162	1396.316
	i03	0.000	16.170	416.087	432.256
r02	i01	2.167	0.000	29.280	31.447
	i02	444.886	0.000	1513.580	1958.466
	i03	14.106	0.000	92.424	106.530
r03	i01	398.836	454.367	2016.183	2869.386
	i02	1468.441	996.662	8386.403	10851.506
	i03	358.453	158.146	2309.253	2825.851
M (Imports)	i01	401.003	481.385	2164.091	
	i02	1913.326	1105.816	11187.145	
	i03	372.558	174.315	2817.764	

Source: GTAP 9.2 Data Base for 2011.

Table D.6 Domestic flows at producer prices, US$ billion.

	r01	r02	r03
i01	670.353	1460.808	4205.833
i02	6236.920	9019.746	19444.299
i03	19466.902	7512.287	53777.531
D (Domestic)	26374.175	17992.841	774273.663

Source: GTAP 9.2 Data Base for 2011.

Table D.7 International Shipping Supply, US$ billion.

r01	r02	r03
41.161	53.392	681.210

Source: GTAP 9.2 Data Base for 2011.

Table D.8 Substitution elasticity.

	σ_j^Z	σ_j^Y	σ_j^X	σ_i^T
i01	0.85	0.70	0.75	5.00
i02	0.90	1.20	0.80	4.00
i03	0.90	1.50	0.80	2.00

Source: Assumptions by the author.

Table D.9 Other data.

$\gamma_{"i02"}$	$N_{"i02"r}$	$\mu_{"i02"r}^D$	$\varepsilon_{"i02"}$
5.00	1.00	0.60	0.60

Source: Assumptions by the author.

Table D.10 Social accounting matrices for each country/region, US$ billion.

r01	Expenditures	Activities			Commodities			Factors			Institutions		Trade		Total
Receipts:		AT01	AT02	AT03	CT01	CT02	CT03	VA01	VA02	VA03	FM	HH	WT	IS	TT
Activities	AT01				670.353							-0.014	114.895		785.234
	AT02					6236.920						-4.102	1297.658		7530.476
	AT03						19466.902					0.000	432.256	41.161	19940.320
Commodities	CT01	55.582	812.360	122.430								80.683			1071.356
	CT02	128.149	2785.681	1985.598								3250.819			8150.247
	CT03	180.640	1464.877	5493.851								12700.093			19839.460
Factors	VA01	156.821	636.171	3105.004											3897.996
	VA02	109.816	1494.878	7406.350											9011.044
	VA03	133.847													133.847
Institutions	FM							3897.996							3897.996
	HH	20.079	336.508	1827.087	0.422	29.122	0.000		9011.044	133.847	3897.996		708.910	62.464	16027.479
Trade	WT				378.016	1803.146	372.558								2553.720
	IS				22.566	81.059	0.000								103.625
Total	TT	785.234	7530.476	19940.320	1071.356	8150.247	19839.460	3897.996	9011.044	133.847	3897.996	16027.479	2553.720	103.625	

Source: GTAP 9.2 Data Base for 2011.

r02	Expenditures	Activities			Commodities			Factors			Institutions		Trade		Total
Receipts:		AT01	AT02	AT03	CT01	CT02	CT03	VA01	VA02	VA03	FM	HH	WT	IS	TT
Activities	AT01				1460.808							-0.742	24.609		1484.673
	AT02					9019.746						-67.928	1768.586		10720.404
	AT03						7512.287					0.000	106.530	53.392	7672.209
Commodities	CT01	164.402	1320.227	193.208								264.355			1942.193
	CT02	313.063	5768.795	1993.069								2050.635			10125.562
	CT03	161.887	1348.363	1904.159								4272.193			7686.602
Factors	VA01	152.750	930.922	1446.510											2530.182
	VA02	429.381	915.903	1835.459											3180.743
	VA03	266.553													266.553
Institutions	FM							2530.182							2530.182
	HH	-3.363	436.194	299.805	3.733	57.427	0.000		3180.743	266.553	2530.182		-298.802	46.043	6518.514
Trade	WT				422.334	1004.271	174.315								1600.920
	IS				55.318	44.117	0.000								99.436
Total	TT	1484.673	10720.404	7672.209	1942.193	10125.562	7686.602	2530.182	3180.743	266.553	2530.182	6518.514	1600.920	99.436	

Source: GTAP 9.2 Data Base for 2011.

r03	Expenditures	Activities			Commodities			Factors			Institutions		Trade		Total
Receipts:		AT01	AT02	AT03	CT01	CT02	CT03	VA01	VA02	VA03	FM	HH	WT	IS	TT
Activities	AT01				4205.833							-120.913	2626.738		6711.659
	AT02					19444.299						-53.219	10165.359		29556.440
	AT03						53777.531					0.000	2825.825	681.210	57284.566
Commodities	CT01	468.417	3855.589	730.526								1315.392			6369.924
	CT02	825.885	12012.565	6955.342								10837.653			30631.444
	CT03	985.163	5563.099	16816.236								33230.797			56595.295
Factors	VA01	1847.043	3677.264	14591.531											20115.813
	VA02	1110.782	2952.415	12703.423											16766.620
	VA03	1274.285													1274.285
Institutions	FM							20115.837							20115.837
	HH	200.084	1495.508	5487.508	44.279	344.177	0.026		16766.620	1274.285	20115.837		-410.108	-108.507	45209.711
Trade	WT				1965.891	10424.186	2817.738								15207.815
	IS				153.921	418.782	0.000								572.703
Total	TT	6711.659	29556.440	57284.566	6369.924	30631.444	56595.295	20115.837	16766.620	1274.285	20115.837	45209.711	15207.815	572.703	

Source: GTAP 9.2 Data Base for 2011.

Appendix E. Values of β_{is} Corresponding to the Intersections of the Melitz, Krugman, and Armington Lines

This appendix presents a research note on the values of β_{is} that correspond to the intersections of the Melitz, Krugman, and Armington lines depicted in Figures 1 and 2. At the intersections, pairs of the models respectively based on the Melitz-, Krugman-, and Armington-type trade specifications essentially become identical. To make models with different types of trade specifications essentially identical, the following two conditions must be satisfied: (i) the basic preference weights α_{irs}^T that enter the importer's demand aggregator in a model take the same values as those calibrated for another model, and (ii) the influence of endogenous variables that enter the importer's demand aggregator and take different values in each model, such as N_{ir} (overall number of firms of commodity i established in country/region r), μ_{ir}^D (proportion of active domestic firms), and μ_{irs}^Q (proportion of international firms active on the r-s link), is completely neutralized. Our job here is to identify the values of β_{is} that satisfy these two conditions.

E.1 Values of β_{is} that lead models to share the same preference weights α_{irs}^T

Let us identify first the values of β_{is} that lead models to share the same values of α_{irs}^T. Using (B.20) and (B.21) in Appendix B as well as $\eta_i = -1/\sigma_i^T$, equations (B.17) and (B.18) in Appendix B can be rewriting to

$$p_{ir}^D = \left(\frac{\sigma_i^T}{\sigma_i^T-1}\right)\left(\frac{\gamma_i-\sigma_i^T+1}{\gamma_i}\right)^{1/(\sigma_i^T-1)}(\mu_{ir}^D)^{1/\gamma_i}p_{ir}^w \tag{E.1}$$

and

$$p_{irs}^Q = \left(\frac{\sigma_i^T}{\sigma_i^T-1}\right)\left(\frac{\gamma_i-\sigma_i^T+1}{\gamma_i}\right)^{1/(\sigma_i^T-1)}(\mu_{irs}^Q)^{1/\gamma_i}p_{ir}^w . \tag{E.2}$$

Combining (E.1) and (E.2) with (C.7) and (C.8) in Appendix C, respectively, we obtain

$$
\begin{aligned}
&p_{is}^D\left(\mu_{is}^D N_{is}\right)^{(1-\beta_{is})/\sigma_i^T} D_{is}^{1/\sigma_i^T} \\
&= \left(\frac{\sigma_i^T}{\sigma_i^T-1}\right)^{(\sigma_i^T-1)/\sigma_i^T}\left(\frac{\gamma_i-\sigma_i^T+1}{\gamma_i}\right)^{1/\sigma_i^T}(\mu_{is}^D)^{(\sigma_i^T-\beta_{is}\gamma_i-1)/(\gamma_i\sigma_i^T)}N_{is}^{-\beta_{is}/\sigma_i^T} \\
&\quad \times (p_{is}^w)^{(\sigma_i^T-1)/\sigma_i^T}\left(TF_{is}^D\right)^{1/\sigma_i^T}
\end{aligned} \tag{E.3}
$$

and

$$
\begin{aligned}
&p_{irs}^Q\left(\mu_{irs}^Q N_{ir}\right)^{(1-\beta_{is})/\sigma_i^T} Q_{irs}^{1/\sigma_i^T} \\
&= \left(\frac{\sigma_i^T}{\sigma_i^T-1}\right)^{(\sigma_i^T-1)/\sigma_i^T}\left(\frac{\gamma_i-\sigma_i^T+1}{\gamma_i}\right)^{1/\sigma_i^T}(\mu_{irs}^Q)^{(\sigma_i^T-\beta_{is}\gamma_i-1)/(\gamma_i\sigma_i^T)}N_{ir}^{-\beta_{is}/\sigma_i^T} \\
&\quad \times (p_{ir}^w)^{(\sigma_i^T-1)/\sigma_i^T}\left(TF_{irs}^Q\right)^{1/\sigma_i^T} .
\end{aligned} \tag{E.4}
$$

Rewriting (C.16) in Appendix C using (E.3) and (E.4) in addition to setting p_{ir}^w to unity following the usual *cliché*, we get the formula to calibrate the preference weights for the Melitz-type model:

$$\alpha_{irs}^{TM} \equiv \frac{(1+\tau_{irs})\left(\mu_{irs}^Q\right)^{\left(\sigma_i^T-\beta_{is}\gamma_i-1\right)/\left(\gamma_i\sigma_i^T\right)}N_{ir}^{-\beta_{is}/\sigma_i^T}\left(TF_{irs}^Q\right)^{1/\sigma_i^T}}{\left\{\begin{array}{l}\left(\mu_{is}^D\right)^{\left(\sigma_i^T-\beta_{is}\gamma_i-1\right)/\left(\gamma_i\sigma_i^T\right)}N_{is}^{-\beta_{is}/\sigma_i^T}\left(TF_{is}^D\right)^{1/\sigma_i^T}\\ +\sum_{r'}\left(1+\tau_{ir's}\right)\left(\mu_{ir's}^Q\right)^{\left(\sigma_i^T-\beta_{is}\gamma_i-1\right)/\left(\gamma_i\sigma_i^T\right)}N_{ir'}^{-\beta_{is}/\sigma_i^T}\left(TF_{ir's}^Q\right)^{1/\sigma_i^T}\end{array}\right\}}. \qquad (E.5)$$

Applying similar procedures, the formulae to calibrate the preference weights for the Krugman- and Armington-type models can be respectively derived:

$$\alpha_{irs}^{TK} \equiv \frac{(1+\tau_{irs})N_{ir}^{-\beta_{is}/\sigma_i^T}\left(TF_{irs}^Q\right)^{1/\sigma_i^T}}{N_{is}^{-\beta_{is}/\sigma_i^T}\left(TF_{is}^D\right)^{1/\sigma_i^T}+\sum_{r'}\left(1+\tau_{ir's}\right)N_{ir'}^{-\beta_{is}/\sigma_i^T}\left(TF_{ir's}^Q\right)^{1/\sigma_i^T}} \qquad (E.6)$$

and

$$\alpha_{irs}^{TA} \equiv \frac{(1+\tau_{irs})\left(TF_{irs}^Q\right)^{1/\sigma_i^T}}{\left(TF_{is}^D\right)^{1/\sigma_i^T}+\sum_{r'}\left(1+\tau_{ir's}\right)\left(TF_{ir's}^Q\right)^{1/\sigma_i^T}}. \qquad (E.7)$$

For $\mu_{ir}^D \neq 0$, $\mu_{ir}^D \neq 1$, $\mu_{irs}^Q \neq 0$, and $\mu_{irs}^Q \neq 1$, α_{irs}^{TM} becomes equivalent to α_{irs}^{TK} if and only if $\sigma_i^T - \beta_{is}\gamma_i - 1 = 0$. The preference weights α_{irs}^{TM} and α_{irs}^{TK} are calibrated to the same values when β_{is} takes the value that satisfies the following condition:

$$\beta_{is}^* = \frac{\sigma_i^T-1}{\gamma_i}. \qquad (E.8)$$

Given the value of β_{is}^* that satisfies (E.8), the models that respectively assumes the Melitz- and Krugman-type trade specifications are calibrated to have the identical preference weights α_{irs}^T. Note that β_{is}^* always stays in the range between zero and unity, since $\sigma_i^T > 1$ and $\gamma_i > \sigma_i^T - 1$. If σ_i^T and γ_i are set to have the same values for all countries/regions, the values of β_{is}^* also become common to every country/region.

If one sets the initial levels of N_{ir} to be unity as we recommended in Appendix C to make the parameterization process simple, the preference weights α_{irs}^{TK} and α_{irs}^{TA} are calibrated to the same values being independent from the given value of β_{is}. Otherwise, α_{irs}^{TK} and α_{irs}^{TA} become equivalent if and only if $\beta_{is} = 0$ for $N_{ir} \neq 0$ and $N_{ir} \neq 1$. Then, the models that respectively assumes the Krugman- and Armington-type specifications are calibrated to have the identical preference weights α_{irs}^T.

The preference weights α_{irs}^{TM} and α_{irs}^{TA} are calibrated to the same values if and only if $\beta_{is} = \beta_{is}^*$ for $\mu_{ir}^D \neq 0$, $\mu_{ir}^D \neq 1$, $\mu_{irs}^Q \neq 0$, and $\mu_{irs}^Q \neq 1$, in the case when one assumes the initial levels of N_{ir} to be unity in the parameterization process. Then, the models that respectively assumes the Melitz- and Armington-type specifications are calibrated to have the identical preference weights α_{irs}^T. On the other hand, it is not easy to analytically solve the values of β_{is} that equate α_{irs}^{TM} and

α_{irs}^{TA} for $N_{ir} \neq 0$ and $N_{ir} \neq 1$, unlike the previous two cases. Plugging α_{irs}^{TM} in (E.5) to α_{irs}^{TA} in (E.7) and numerically solving with respect to β_{is} probably yields country/region-specific values, as TF_{is}^{D} and TF_{irs}^{Q} may vary for each destination country/region. Consequently, the solution values of β_{is} may not be common to every country/region.

E.2 Values of β_{is} that neutralize the influence of endogenous variables included in the importer's demand aggregator

Let us identify next the values of β_{is} that neutralize the influence of the key variables that enter the importer's demand aggregator and take different values in each model.

Rearranging (B.14) in Appendix B, we obtain

$$
\begin{aligned}
\left(\theta_{is}^{T}\right)^{(1-\sigma_{i}^{T})/\sigma_{i}^{T}} & \\
= \left(1 - \textstyle\sum_{r} \alpha_{irs}^{T}\right) & \left(\mu_{is}^{D} N_{is}\right)^{(\beta_{is}+\sigma_{i}^{T}-1)/\sigma_{i}^{T}} \left(\frac{D_{is}}{\sum_{j} X_{ijs}+C_{is}}\right)^{(\sigma_{i}^{T}-1)/\sigma_{i}^{T}} \\
+ \textstyle\sum_{r} \alpha_{irs}^{T} & \left(\mu_{irs}^{Q} N_{ir}\right)^{(\beta_{is}+\sigma_{i}^{T}-1)/\sigma_{i}^{T}} \left(\frac{Q_{irs}}{\sum_{j} X_{ijs}+C_{is}}\right)^{(\sigma_{i}^{T}-1)/\sigma_{i}^{T}} .
\end{aligned}
$$
(E.9)

Substituting (C.18) and (C.19) in Appendix C to (B.15) and (B.16) to purge p_{is}^{D} and p_{irs}^{Q}, respectively, we get

$$
\begin{aligned}
\left(\frac{D_{is}}{\sum_{j} X_{ijs}+C_{is}}\right)^{1/\sigma_{i}^{T}} & \\
= \left(\frac{\sigma_{i}^{T}-1}{\sigma_{i}^{T}}\right) & \left(\frac{\gamma_{i}}{\gamma_{i}-\sigma_{i}^{T}+1}\right)^{1/(\sigma_{i}^{T}-1)} \left(\theta_{is}^{T}\right)^{(\sigma_{i}^{T}-1)/\sigma_{i}^{T}} \left(1 - \textstyle\sum_{r} \alpha_{irs}^{T}\right) \\
& \times \left(\mu_{is}^{D}\right)^{(\beta_{is}\gamma_{i}-\gamma_{i}-\sigma_{i}^{T})/(\gamma_{i}\sigma_{i}^{T})} N_{is}^{(\beta_{is}-1)/\sigma_{i}^{T}} \left(\frac{p_{is}}{p_{is}^{w}}\right)
\end{aligned}
$$
(E.10)

and

$$
\begin{aligned}
\left(\frac{Q_{irs}}{\sum_{j} X_{ijs}+C_{is}}\right)^{1/\sigma_{i}^{T}} & \\
= \left(\frac{\sigma_{i}^{T}-1}{\sigma_{i}^{T}}\right) & \left(\frac{\gamma_{i}}{\gamma_{i}-\sigma_{i}^{T}+1}\right)^{1/(\sigma_{i}^{T}-1)} \left(\theta_{is}^{T}\right)^{(\sigma_{i}^{T}-1)/\sigma_{i}^{T}} \alpha_{irs}^{T} \\
& \times \left(\mu_{irs}^{Q}\right)^{(\beta_{is}\gamma_{i}-\gamma_{i}-\sigma_{i}^{T})/(\gamma_{i}\sigma_{i}^{T})} N_{ir}^{(\beta_{is}-1)/\sigma_{i}^{T}} \left\{\frac{p_{is}}{(1+\tau_{irs})p_{ir}^{w}}\right\} .
\end{aligned}
$$
(E.11)

Plugging (E.10) and (E.11) to (E.9) to purge D_{is}, Q_{irs}, X_{ijs}, and C_{is}, the following relation for the Melitz-type specification can be derived:

$$
\begin{aligned}
\left(\theta_{is}^{TM}\right)^{1-\sigma_{i}^{T}} & \left(\frac{\sigma_{i}^{T}-1}{\sigma_{i}^{T}}\right)^{1-\sigma_{i}^{T}} \left(\frac{\gamma_{i}-\sigma_{i}^{T}+1}{\gamma_{i}}\right) \\
= \left(1 - \textstyle\sum_{r} \alpha_{irs}^{T}\right)^{\sigma_{i}^{T}} & \left(\mu_{is}^{D}\right)^{(\beta_{is}\gamma_{i}-\sigma_{i}^{T}+1)/\gamma_{i}} N_{is}^{\beta_{is}} \left(\frac{p_{is}}{p_{is}^{w}}\right)^{\sigma_{i}^{T}-1} \\
+ \textstyle\sum_{r} \left(\alpha_{irs}^{T}\right)^{\sigma_{i}^{T}} & \left(\mu_{irs}^{Q}\right)^{(\beta_{is}\gamma_{i}-\sigma_{i}^{T}+1)/\gamma_{i}} N_{ir}^{\beta_{is}} \left\{\frac{p_{is}}{(1+\tau_{irs})p_{ir}^{w}}\right\}^{\sigma_{i}^{T}-1} ,
\end{aligned}
$$
(E.12)

where θ_{is}^{TM} shows the scaling factor is calibrated for the Melitz-type model. Analogously, similar relations respectively for the Krugman- and Armington-type models can be derived:

$$\left(\theta_{is}^{TK}\right)^{1-\sigma_i^T}\left(\frac{\sigma_i^T-1}{\sigma_i^T}\right)^{1-\sigma_i^T}$$

$$= \left(1-\sum_r \alpha_{irs}^T\right)^{\sigma_i^T} N_{is}^{\beta_{is}}\left(\frac{p_{is}}{p_{is}^w}\right)^{\sigma_i^T-1} + \qquad\text{(E.13)}$$

$$\sum_r \left(\alpha_{irs}^T\right)^{\sigma_i^T} N_{ir}^{\beta_{is}}\left\{\frac{p_{is}}{(1+\tau_{irs})p_{ir}^w}\right\}^{\sigma_i^T-1}$$

and

$$\left(\theta_{is}^{TA}\right)^{1-\sigma_i^T}\left(\frac{\sigma_i^T-1}{\sigma_i^T}\right)^{1-\sigma_i^T}$$

$$= \left(1-\sum_r \alpha_{irs}^T\right)^{\sigma_i^T}\left(\frac{p_{is}}{p_{is}^w}\right)^{\sigma_i^T-1} + \sum_r \left(\alpha_{irs}^T\right)^{\sigma_i^T}\left\{\frac{p_{is}}{(1+\tau_{irs})p_{ir}^w}\right\}^{\sigma_i^T-1}, \qquad\text{(E.14)}$$

where θ_{is}^{TK} and θ_{is}^{TA} are the scaling factors respectively calibrated for the Krugman- and Armington-type models.

Considering the fact that the scaling factors θ_{is}^{TM} and θ_{is}^{TK} are calibrated to different levels to absorb differences in p_{is} (price index for the variety-adjusted composite commodity i inclusive of transportation margin and import tariff) respectively enter the Melitz- and Krugman-type models, the necessary and sufficient condition to make (E.12) essentially the same as (E.13) is that $\beta_{is}\gamma_i - \sigma_i^T + 1 = 0$ holds for $\mu_{ir}^D \neq 0$, $\mu_{ir}^D \neq 1$, $\mu_{irs}^Q \neq 0$, and $\mu_{irs}^Q \neq 1$. Thus, β_{is}^*, which was given by (E.8) to set the calibrated values of the preference weights α_{irs}^{TM} and α_{irs}^{TK} to be identical, also works here. With $\beta_{is} = \beta_{is}^*$, the influence of μ_{is}^D and μ_{irs}^Q can be neutralized, and then, N_{ir} that respectively enter the Melitz- and Krugman-type models are calculated to be the same value.

For the pair of the Krugman- and Armington-type models, the necessary and sufficient condition to make (E.13) essentially the same as (E.14) is that $\beta_{is} = 0$ holds for $N_{ir} \neq 0$ and $N_{ir} \neq 1$. Then, $N_{is}D_{is}$ and $N_{ir}Q_{irs}$ in the Krugman-type model will be calculated equivalent to D_{is} and Q_{irs} in the Armington-type.[e1]

Finally, it is not easy again to analytically identify the values of β_{is} that make (E.12) and (E.14) essentially identical, because N_{ir} does not remain constant at unity anymore. Setting $\beta_{is} = \beta_{is}^*$ no longer works here. At least, it can be expected that the values of β_{is} that neutralize the influence of $\left(\mu_{is}^D\right)^{(\beta_{is}\gamma_i-\sigma_i^T+1)/\gamma_i}N_{is}^{\beta_{is}}$ and $\left(\mu_{irs}^Q\right)^{(\beta_{is}\gamma_i-\sigma_i^T+1)/\gamma_i}N_{ir}^{\beta_{is}}$ in (E.12) are the same as those equate α_{irs}^{TM} and α_{irs}^{TA} for $N_{ir} \neq 0$ and $N_{ir} \neq 1$, considering the forms of (E.5) and (E.12). Perhaps those values differ for each country/region.

[e1] N_{ir} is fixed to unity in the Armington-type trade specification.