Comparison of Welfare Gains in the Armington, Krugman and Melitz Models: insights based on a structural gravity approach*

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Abstract: How large are the estimated gains from trade from a reduction in trade costs in the heterogeneous firms Melitz model compared with the Armington and Krugman models? Surprisingly little is known beyond the one-sector model. This paper analyzes this question using a global trade model that contains ten regions and various numbers of sectors (1-9). Following Arkolakis *et al*. (2012), the analysis holds the trade response constant across the model comparisons based on a structural gravity estimate. We evaluate numerous important model features and scenarios, almost none of which has been examined across the three market structures with a common trade response. In response to global reductions in iceberg trade costs, in all models except the simplest one-sector model, the welfare gains are largest in Melitz and smallest in Armington; and the Krugman model captures between 75 and 95 percent of the additional gains above the Armington model that are estimated by the Melitz model. These results are symmetric with respect to increases in trade costs, with the Melitz model producing the largest losses in absolute value. However, for individual regions, there are numerous cases where the welfare gains are largest in Armington and smallest in Melitz. We construct a multi-sector Feenstra ratio to measure the Dixit-Stiglitz variety externality and calculate changes in the terms-of-trade. These provide intuitive explanations of the general pattern of results and the unexpected welfare rankings. We find that our regions typically gain from *unilateral* increases in tariffs in our Armington model but lose with monopolistic competition models. We conclude that, despite the general pattern for the world, for individual regions, the welfare ranking of the market structures is model, data, parameter and scenario dependent. The results highlight the need for data and structural considerations in policy analysis.

Keywords: welfare gains from the new trade theory, structural gravity, heterogeneous firms, monopolistic competition, multi-sector Feenstra ratio.

JEL classification: F12, F18

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1. Introduction

An important question for both theory and policy is: how large are the estimated gains from trade in the heterogeneous firms model of Melitz (2003) compared with the homogeneous firms, monopolistic competition model of Krugman (1980) and the perfectly competitive model of Armington (1969)? In their well-known paper, "New Theories, Same Old Gains," Arkolakis, Costinot and Rodriguez-Clare (2012) showed the surprising result that in their stylized one-sector model,[1] the welfare gains were identical. Key to their result was that they adjusted the trade elasticities and proportional change in the domestic trade shares (what we call the trade response in this paper) in the Armington, Krugman and Melitz models so that they were all consistent with a structural gravity estimate.

In this paper, we contribute to the literature on the comparison of the welfare gains of market structures by introducing a wide range of modeling variations, policies and realistic data that are important in both theory and policy applications. Further, grounding model comparison estimates on gravity in multi-sector, comparative static models has not previously been attempted. We extend the logic of grounding the estimates on gravity to multi-sector comparative static models.

We show that the above result of Arkolakis *et al*. (2012) is fragile. The first challenge to the result above was by Balistreri, Hillberry and Rutherford (2010). Although Balistreri *et al*. (2010) did not hold the trade response constant, they found that with a labor-leisure choice in the Arkolakis *et al*. (2012) one-sector model and a positive (negative) elasticity of labor supply with respect to the real wage, the Melitz model produced larger (smaller) welfare gains than the Armington model.[2] Arkolakis *et al*. (2012) showed analytically that if there is a unique aggregate intermediate good, the gains are larger in the monopolistic competition models. Further, they showed that multiple sectors break the welfare equivalence (with ambiguous impacts). Costinot and Rodriguez-Clare (2014) used numerical methods in multi-region, multi-sector models. Based on their results for the average for the world, they also found that the welfare gains are larger in the monopolistic competition models with a single aggregate intermediate good; there were, however, several unexplained exceptions for individual regions in their results. They also found that multiple sectors break the welfare equivalence. Melitz and Redding (2015) introduced a finite upper bound on the Pareto distribution of productivity in a model otherwise identical to the stylized model of Arkolakis *et al*. (2012). They showed that, compared with the Krugman model,

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[1] They assumed one sector, one factor of production; no labor-leisure choice; balanced trade in all regions; no initial tariffs, iceberg trade costs, no intermediates and a global change in iceberg trade costs.
[2] See also Adao, Arkolakis and Esposito (2017).

there are larger welfare gains in the heterogeneous firms model from reductions in trade costs and smaller welfare losses from increases in trade costs.[3]

Beyond the above results, surprisingly little is known regarding the relative welfare impacts in the Armington, Krugman and Melitz models.[4] Costinot and Rodriguez-Clare (2014) attempted a comprehensive numerical treatment of these issues. But they have only shown results in the Melitz or Krugman framework for the limited cases mentioned above. Costinot and Rodriguez-Clare assess the impact of relaxing many of the simplifying assumptions, but only in their Armington model. We show that the impact of a model assumption in the Armington model does not generalize to the Krugman or Melitz models and may even have an opposite impact in the Krugman or Melitz model, i.e., even the sign of the impact may be opposite.[5]

Based on contradictory results in autarchy and comparative static results, Costinot and Rodriguez-Clare (2014, 231) indicate that we cannot generalize from autarchy exercises to trade policy exercises and that the comparative static exercises are "richer." [6] Consequently, in this paper, all exercises are comparative static without moving to autarchy.

We first replicate the Arkolakis *et al*. (2012) equivalence result from a global ten percent reduction in iceberg trade costs, in their one-sector model. We then progressively introduce model features to incorporate real features of the data. The following results are new results in the welfare comparison literature that is grounded on gravity. We start with labor-leisure choice in a one-sector model and show that the result of Balistreri *et al*. (2010) remains valid when we hold the trade response constant based on a gravity estimate. The solution of multi-sector Melitz style models with intermediate demand shares based on real data has heretofore eluded researchers. [7] We allow our sectors to demand intermediates in different proportions and also are the first to examine the impact of the elasticity of

[3] See Balistreri and Tarr (2018, section 2.2 and table 1) for a more detailed review of known results of the literature.
[4] Jafari and Britz (2017) assess the Transatlantic Trade and Investment Partnership (TTIP) and find that the Melitz model produces considerably larger welfare gains than the Armington model. They do not, however, hold, the trade response constant across the market structures. Dixon, Jerie and Rimmer (2018) develop a 10 region, 57 sector model with 56 Armington sectors and one Melitz sector to assess a unilateral tariff increase in the one Melitz sector by the North American region.
[5] For example, in the cases of China and the United States in table 4 below show that even the sign of the impact of a modeling variation in the Armington model may be opposite of the sign of the impact in the Krugman or Melitz models.
[6] In an Armington model, Costinot and Rodriguez-Clare (2014) find opposite results regarding the impact of multiple sectors between their autarchy exercise and a forty percent tariff increase. They conclude that "one should be careful when extrapolating from the autarky exercises …to richer comparative static exercises. Models that point towards larger gains from trade liberalization from one counterfactual scenario may very well lead to smaller gains from trade liberalization for another."
[7] Costinot and Rodriguez-Clare (2014), Balistreri, Hillberry and Rutherford (2011) and Jafari and Britz (2017) incorporated intermediates in a multi-sector model, but they assumed an aggregate intermediate good. So all their sectors use intermediates in the same proportion in that model. Further, they did not test for sensitivity of the results to the elasticity of substitution for intermediates.

demand for intermediates on the welfare impacts. We find that intermediate demand based on data as opposed to a single aggregate and a lower elasticity of substitution both make a significant difference: the former increases the relative gains of the monopolistic competition models and the latter reduces them. We investigate variations in primary factor assumptions: single primary factor; three primary factors with and without a specific factor and labor-leisure choice.[8] To analyze tariff policies, we expand our model to nine sectors and evaluate the impact of global free trade in the three market structures. We evaluate global free trade with and without initial uniform tariffs.[9]

We use this model to investigate unilateral *increases* in tariffs without retaliation by individual regions. With the tariff changes and elasticities we assume, we find welfare *gains* from terms-of-trade gains in the Armington model. But due to variety losses that typically dominate the terms-of-trade gains in monopolistic competition, we typically estimate welfare *losses* in the monopolistic competition models

To summarize our results across these many model variants, define *M*, *K* and *A* as the change in welfare in the Melitz, Krugman and Armington models, respectively. If we consider the global welfare gains from the global reduction in iceberg or tariff costs, in all model variants beyond the simple one-sector model without intermediates, we find that the Melitz structure produces the largest welfare gains and the Armington model produces the least welfare gains, hereafter, $M > K > A$. Further, this result is symmetric; in response to *increases* in global trade costs, the absolute value of the global *losses* is greatest under Melitz and least under Armington: $|M| > |K| > |A|$. We find that the Krugman model captures between 75 and 95 percent of the increase in the welfare gains above the Armington model, depending on the model variant and data. This suggests that although the selection effect of the Melitz model adds to the welfare gains above the Krugman model, the variety effect of the Krugman model is quantitatively more important in explaining differences above the Armington model from global policy changes.

There are numerous cases for specific regions of a reversed welfare ranking than the welfare ranking for the average for the world, i.e., we have $|M| < |K| < |A|$ for one or more of our ten regions in many of our scenarios**.** These results show that for individual regions the welfare ranking of the Armington, Krugman and Melitz market structures is model, data, parameter and scenario dependent. We

[8] Costinot and Rodriguez-Clare (2014, 200-223) evaluated the impact two factors of production, but only in their autarchy exercises and with common cost shares across countries for the two factors. They report that there are virtually no Heckscher-Ohlin effects in their Armington model, but they do not report results in the monopolistic competition models with multiple primary factors of production.

[9] In the Melitz and Krugman models, Costinot and Rodriguez-Clare (2014, section 4.3) assumed zero initial tariffs so did not consider and changes in tariffs from existing tariff structures, like global free trade. Further, they assumed uniform tariffs in the monopolistic competition models when they assessed 40 percent tariff changes. They assessed the impact of heterogeneous tariffs, but only in an Armington model without intermediates.

cannot conclude that one of these market structures will always produce larger or smaller welfare gains without additional restrictions on the model. In this context, we find that numerical models are useful for policy analysis.

Like Costinot and Rodriguez-Clare (2014), our results are numerical. We choose units such that initial prices are unity. We take advantage of the calibrated share form of CES technologies and preferences developed by Rutherford (2002). Analogous to the popular "exact hat" approach, e.g., Dekle *et al*. (2008), we recover the proportional changes in our variables, including prices, quantities, numbers of firms and average productivities, as the equilibrium solution to the numerical problem.[10] Our data is from the GTAP 9 dataset.

We develop a multi-sector extension of the Feenstra ratio, which provides a comprehensive measure of the variety impact on welfare. We find that the multi-sector Feenstra ratio and the percentage change in the terms-of-trade are instrumental to understanding the reasons for the welfare impacts.

We elaborate the equations of the models in section 2. In section 3, we discuss how we calibrate the trade response based on a structural gravity estimate and define our multi-sector Feenstra ratio. The key model results are in section 4. In section 5, we assess the sensitivity of the results to the structural gravity estimate, to unilateral tariff increases and to increases in global trade costs.

2. Equations of the Models

2.1 Notation

2.1.1 Sets: R is the set of all regions, indexed by r or s. I is the set of all goods and services, indexed by i or j with subsets $K \subseteq I$ as the set of Krugman sectors and the subset $M \subseteq I$ as the set of Melitz style sectors. We reserve the index k for Krugman sectors and the index m for Melitz sectors. F is the set of factors, indexed by f, with the subset $\tilde{F} \subseteq F$ as the set of sector-specific factors.

2.1.2 Variables:

D_r Scalar index of full consumption in region r, equal to one in the benchmark equilibrium;

Y_{ir} Scalar indices for domestic output of sector i in region r, equal to one in the benchmark equilibrium;[11]

S_{ir} Scalar indices for supply of good or service i in region r, equal to one in the benchmark equilibrium;

e_r Unit expenditure index (true cost of living index);

[10] We have verified that our results in our Krugman and Melitz models are invariant with respect to the initial values of the numbers of firms, subject to consistency with the theory of the models. In our Melitz model, we have found that our welfare results are unchanged (up to the fifth decimal point in percentage change in welfare) in response to a change in the initial values of the average productivities.

[11] Under monopolistic competition, domestic output is a composite input used by firms to cover both fixed and variable costs.

c_{ir} Price of domestic output (price of composite inputs for monopolistically competitive firms used for both fixed and variable costs);

P_{ir} Price of goods and services (Dixit-Stiglitz price in monopolistic competition);

w_{fr} Price of mobile primary factor *f* in region r;

$\tilde{w}_{fir}$ Price of specific primary factor *f* in the sector *i* in region r;

n_{ir} Number of active firms for $i \in K$; number of firms that enter for $i \in M$;

N_{mrs} Number of Melitz firms in sector m of region *r* selling in region *s*, $m \in M$;

p_{krs} Gross firm-level price of Krugman firms from region *r* selling in region *s*, $k \in K$;

q_{krs} Firm level quantity for Krugman firms from region *r* selling in region *s*, $k \in K$;

$\tilde{p}_{mrs}$ Gross firm-level price of Melitz representative firms from region *r* selling in region *s*, $m \in M$;

$\tilde{q}_{mrs}$ Firm-level quantity of Melitz representative firms from region *r* selling in region *s*, $m \in M$;

$\tilde{\varphi}_{mrs}$ Firm-level productivity of Melitz representative firms from region *r* selling in region s; $m \in M$;

RA_r Nominal income of region r (measured in units of the numeraire).

2.13 Instruments

τ_{irs} Iceberg trade costs on exports of sector *i* from region *r* to region s;

t_{irs} Tariff rates in sector *i* on imports into region *s* from region r.

2.14 Parameters

$d0_r$ Benchmark value of full consumption;[12]

$y0_{ir}$ Benchmark value of gross output of sector i;

$s0_{ir}$ Benchmark value of domestic and imported supply;

$\alpha0_{jir}$ Benchmark share of intermediate input *j* in gross output of sector *i* in region *r*;

β_{fir} Benchmark share of primary factor f in value-added of sector *i* in region *r*;

μ_r Benchmark share of leisure in full consumption;

θ_{ir} Benchmark share of *i* in total consumption of goods and services;

σ^A Elasticity of substitution in Armington sectors between goods from different regions;

[12]Includes the imputed value of leisure if there is a labor-leisure choice.

σ^K Dixit-Stiglitz elasticity of substitution between firm varieties in Krugman sectors;

σ^M Dixit-Stiglitz elasticity of substitution between firm varieties in Melitz sectors;

λ_{irs}^A Preference weight in Armington aggregation of regional varieties from region *r* in region *s*;

λ_{krs}^K Preference weight in Krugman aggregation of firm varieties from region *r* in region *s*, $k \in K$;

λ_{mrs}^M Preference weight in Melitz aggregation of firm varieties from region *r* in region *s*, $m \in M$;

σ^L Elasticity of substitution between leisure and consumption of goods and services;

σ^T Elasticity of substitution between intermediates and between intermediates and value-added;

f_{kr}^K Fixed costs of Krugman firms in sector *k* of region *r*, $k \in K$;

f_{mrs}^M Fixed costs of Melitz firms in sector *m* of region *r* operating in region *s*, $m \in M$;

f_{mr}^E Sunk entry costs of Melitz firms in sector *m* of region *r*, $m \in M$;

a Pareto shape parameter;

b Pareto lower support;

δ Annual probability of firm death;

$\bar{F}_{fr}$ Endowment of mobile factor *f* in region *r*;

$\overline{SF}_{fir}$ Endowment of specific factor *f* in sector *i* of region *r*;

$\overline{BOP}_r$ Benchmark capital account surplus.

2.2 Representing technologies and preferences using duality

2.2.1 Preferences. With the option to include a labor-leisure choice, the unit expenditure function is given by

$$e_r = \left[\mu_r w_{Lr}^{1-\sigma^L} + (1-\mu_r) \left(\prod_{i \in I} P_{ir}^{\theta_{ir}} \right)^{1-\sigma^L} \right]^{1/(1-\sigma^L)} \qquad r \in R. \tag{1}$$

If $\mu_r = 0$ labor supply is perfectly inelastic; then the unit expenditure function reduces to only the Cobb-Douglas preference nest over goods and services.

2.2.2 Technology. The production technology in the dual is given by one of the following formulations.[13] We always assume that value-added inputs combine in a Cobb-Douglas nest, but we

[13] See Balistreri and Tarr (2018) for the characterization of the three intermediate demand structures in the primal, along with the labor-leisure choice model and its calibration based on estimates of compensated and uncompensated labor supply.

employ multiple treatments of intermediates. If we assume that intermediates and a value-added composite substitute with an elasticity of substitution $\sigma^T \neq 1$, we have the cost function of equation (2a).

$$c_{ir} = \left[\sum_{j\in I} \alpha_{jir} P_{jr}^{1-\sigma^T} + (1-\sum_{j\in I} \alpha_{jir}) \left(\prod_{f\notin \tilde{F}} (w_{fr})^{\beta_{fir}} \prod_{f\in \tilde{F}} (\tilde{w}_{fr})^{\beta_{fir}} \right)^{1-\sigma^T} \right]^{1/(1-\sigma^T)} \quad i\in I,\, r\in R. \qquad (2a)$$

If there are no intermediates, then the α_{jir} parameters are all zero and we only have the Cobb-Douglas nest of primary factors. If $\sigma^T = 1$, we have the cost function of Cobb-Douglas technology in equation (2b).

$$c_{ir} = \prod_{j\in I} P_{jr}^{\alpha_{jir}} \prod_{f\notin \tilde{F}} (w_{fr})^{(1-\Sigma_j \alpha_{jir})\beta_{fir}} \prod_{f\in \tilde{F}} (\tilde{w}_{fr})^{(1-\Sigma_j \alpha_{jir})\beta_{fir}} \qquad i\in I,\, r\in R. \qquad (2b)$$

If we adopt the single-composite intermediate treatment, then the price of intermediates is the unit expenditure function and the cost function is shown by equation (2c).

$$c_{ir} = e_r^{\Sigma_j \alpha_{jir}} \prod_{f\notin \tilde{F}} (w_{fr})^{(1-\Sigma_j \alpha_{jir})\beta_{fir}} \prod_{f\in \tilde{F}} (\tilde{w}_{fr})^{(1-\Sigma_j \alpha_{jir})\beta_{fir}} \qquad i\in I,\, r\in R. \qquad (2c)$$

In the case when we do not have any intermediates, the α share parameters in the above equations would all be zero.

2.2.3 Prices. The next set of equations indicates the dual price of the good or service in region s. For the Armington structure, we have a simple CES aggregation of regional varieties:

$$P_{is} = \left[\sum_{r\in R} \lambda_{irs}^A (1+t_{irs}) \tau_{irs} c_{ir}^{1-\sigma^A} \right]^{1/(1-\sigma^A)} \qquad i\in I,\, s\in R. \qquad (3a)$$

If we assume a monopolistic competition structure, the dual price is either a Dixit-Stiglitz aggregation of Krugman firm-level varieties, as:

$$P_{ks} = \left[\sum_{r\in R} \lambda_{krs}^K n_{kr} p_{krs}^{1-\sigma^K} \right]^{1/\left(1-\sigma^K\right)} \qquad k\in K,\, s\in R; \qquad (3b)$$

or of Melitz representative firm varieties as:

$$P_{ms} = \left[\sum_{r\in R} \lambda_{mrs}^M N_{mrs} \tilde{p}_{mrs}^{1-\sigma^M} \right]^{1/\left(1-\sigma^M\right)} \qquad m\in M,\, s\in R. \qquad (3c)$$

2.2 Market Clearance

We choose notation that makes explicit that we solve for percentage changes in variables. In the case of the supply of output in each sector in region *r* (from both domestic and imported sources) we write the supply of output of sector *i* in region *r* as $s0_{ir} S_{ir}$; this is its value in the benchmark times a scalar multiple that has a value of one in the benchmark. Then the endogenous supply variable for which we solve, S_{ir} , is the proportional change in the supply. Similarly, we define output and consumption by $y0_{ir}Y_{ir}$ and $d0_r D_r$, respectively, so that the variables (times 100) for which we solve are the percentage changes in output and consumption.

We first establish the market clearance conditions for supply and demand of goods and services available for domestic use. The demand for goods and services is derived by applying Shepard's Lemma to the above defined consumption and production technologies. The market clearance conditions of supply and demand are given by:

$$s0_{ir}S_{ir} = d0_r D_r \frac{\partial e_r}{\partial P_{ir}} + \sum_{j\in I} y0_{jr}Y_{jr}\frac{\partial c_{jr}}{\partial P_{ir}} \quad i\in I,\, r\in R. \tag{4}$$

Next, we establish market clearance for the production of good *i* in region r and all of its uses in all markets. Under Armington the associated price is simply marginal cost, c_{ir} , so market clearance is given by:

$$y0_{ir}Y_{ir} = \sum_{s\in R}\tau_{irs}s0_{is}S_{is}\frac{\partial P_{is}}{\partial[(1+t_{irs})\tau_{irs}c_{ir}]} \quad i\in I,\, r\in R, \tag{5a}$$

where P_{is} is given by (3a) above.

For the monopolistic competition models, we must account for the use of output for fixed costs as well as variable costs. Under Krugman we have

$$y0_{kr}Y_{kr} = n_{kr}\left(f_{kr}^{K} + \sum_{s\in R} q_{krs}\right) \qquad k\in K,\, r\in R; \tag{5b}$$

and under Melitz we have:

$$y0_{mr}Y_{mr} = \delta f_{mr}^{E} n_{mr} + \sum_{s\in R} N_{mrs}\left(f_{mrs}^{M} + \frac{\tilde{q}_{mrs}}{\tilde{\varphi}_{mrs}}\right) \quad m\in M,\, r\in R. \tag{5c}$$

For sector-specific primary factors, the market clearance condition is:

$$\overline{SF}_{fir} = y0_{ir}Y_{ir}\frac{\partial c_{jr}}{\partial \tilde{w}_{fir}} \qquad f\in\tilde{F}, i\in I, r\in R. \tag{6}$$

For non-labor primary mobile factors of production, we account for demand across different sectors:

$$\bar{F}_{fr} = \sum_{i\in I} y0_{ir}Y_{ir}\frac{\partial c_{jr}}{\partial w_{fr}} + d0_r D_r \frac{\partial e_r}{\partial w_{fr}} \quad f\in F,\ f\notin\bar{F},\, r\in R. \tag{7}$$

Leisure demand is given by the final term on the right-hand side, which is non-zero only if the factor is labor and we have chosen a non-zero elasticity of labor supply.

Real Consumption and Welfare. In most of our model variations, intermediates are modeled as in either equation (2a) or (2b); then the quantity associated with real consumption is fully exhausted in final demand, giving us

$$d0_r D_r = \frac{RA_r}{e_r} \qquad r \in R, \tag{8a}$$

where the change in $\frac{RA_r}{e_r}$ is the Hicksian equivalent variation.

In the one model where we assume a single composite intermediate input as in equation (2c), however, some of the consumption good is used in production. In that special case, market clearance of supply and demand of the consumption good is:

$$d0_r D_r = \frac{RA_r}{e_r} + \sum_{j \in I} y0_{jr} Y_{jr} \frac{\partial c_{jr}}{\partial e_r} \qquad r \in R, \tag{8b}$$

and Hicksian equivalent variation remains the change in $\frac{RA_r}{e_r}$.

2.3 Krugman specific equations

Consistent with the Dixit-Stiglitz aggregation, demand for a variety produced by an individual firm in region *r* and sold in region *s* is:

$$q_{krs} = \lambda_{krs}^K s0_{ks} S_{ks} \left(\frac{P_{ks}}{p_{krs}} \right)^{\sigma^K} \qquad k \in K,\ r \in R,\ s \in R. \tag{9}$$

Faced with this demand, the price that maximizes profit for the individual firm includes a markup above marginal costs:

$$p_{krs} = \frac{(1+t_{krs})\tau_{krs} c_{kr}}{1 - 1/\sigma^K} \qquad k \in K,\ r \in R,\ s \in R. \tag{10}$$

Free entry leads to zero profits, so accumulated quasi-rents across all markets just cover fixed costs:

$$\sum_{s \in R} \frac{p_{krs} q_{krs}}{\sigma^K (1+t_{krs})} = f_{kr}^K c_{kr} \qquad k \in K,\ r \in R. \tag{11}$$

Associated with the zero-profit condition is n_{kr}, the number of firms entered in sector k of region r.

2.4 Melitz specific equations

The Melitz equilibrium is defined by a representative firm (variety) on each bilateral trade link. Demand for the representative firm is given by:

$$\tilde{q}_{mrs} = \lambda_{mrs}^{M} s0_{ms} S_{ms} \left(\frac{P_{ms}}{\tilde{p}_{mrs}} \right)^{\sigma^M} \qquad m \in M,\, r \in R,\, s \in R; \tag{12}$$

Optimal pricing leads to:

$$\tilde{p}_{mrs} = \frac{(1+t_{mrs})\tau_{mrs} c_{mr}}{\tilde{\varphi}_{mrs}(1-1/\sigma^M)} \qquad m \in M,\, r \in R,\, s \in R. \tag{13}$$

We need a condition that determines selection into each bilateral market. The marginal firm will earn zero profits. With a Pareto distribution and shape parameter *a,* the zero cutoff profit condition maps to the representative firm's profit by:

$$\frac{\tilde{p}_{mrs}\tilde{q}_{mrs}}{(1+t_{mrs})} \frac{a+1-\sigma^M}{a\sigma^M} = f_{mrs}^{M} c_{mr} \qquad m \in M,\, r \in R,\, s \in R. \tag{14}$$

We need a condition that determines how many firms enter (take a productivity draw). Equilibrium requires that a potential entrant have zero expected profits from potentially multiple markets; then expected profits across multiple markets just equal the annualized sunk costs of establishing a variety. With δ as the rate of firm death, this requires that:

$$\sum_{s \in R} \left(\frac{N_{mrs}}{n_{mr}} \right) \frac{\tilde{p}_{mrs}\tilde{q}_{mrs}(\sigma^M - 1)}{(1+t_{mrs})a\sigma^M} = \delta f_{mr}^{E} c_{mr} \qquad m \in M,\, r \in R. \tag{15}$$

Finally, the productivity of the representative firm is:

$$\tilde{\varphi}_{mrs} = b \left(\frac{N_{mrs}}{n_{mr}} \right)^{-1/a} \left(\frac{a+1-\sigma^M}{a} \right)^{1/(1-\sigma^M)} \qquad m \in M,\, r \in R,\, s \in R. \tag{16}$$

2.5 Income balance and numeraire

The model is based on relative prices (the model is homogeneous of degree zero in nominal prices). We define the numeraire as the price of a unit of utility in the United States, i.e., $e_{USA} \equiv 1$. All prices are relative to this numeraire.

In terms of units of the numeraire, we must have nominal income equal expenditures of the representative agent in region *r*. Income equals the value of factor endowments plus any tariff revenue plus the value of any capital account surplus. Note that the model includes a constant balance of trade constraint measured in international transfer units.

$$\begin{aligned} RA_r = & \sum_{f \notin \tilde{F}} w_{fr} \bar{F}_{fr} + \sum_{f \in \tilde{F}} \sum_{i} \tilde{w}_{fr} \overline{SF}_{fir} + \sum_{i \notin K \cup M} \sum_{s \in R} t_{isr} c_{is} s0_{ir} S_{ir} \frac{\partial P_{ir}}{\partial [(1+t_{irs})\tau_{irs} c_{ir}]} \\ & + \sum_{k \in K} \sum_{s \in R} t_{ksr} M_{ks} p_{ksr} q_{ksr} / (1+t_{ksr}) + \sum_{m \in M} \sum_{s \in R} t_{msr} N_{ksr} \tilde{p}_{msr} \tilde{q}_{msr} / (1+t_{msr}) + e_{\text{usa}} \overline{BOP}_r \end{aligned} \qquad r \in R. \tag{17}$$

3. The Trade Response, Multi-Sector Feenstra Ratio and Terms-of-Trade Change

In general, the monopolistic competition model can produce larger gains than the Armington model due to: (i) more varieties; (ii) lower markups over marginal costs that lead to rationalization gains; and (iii) with heterogeneous firms, an increase in average firm productivity from the selection effect. But in a multi-sector, multi-region model, there are also (iv) terms-of-trade effects. Terms-of-trade effects can impact differences in welfare results across regions and market structures, with ambiguous impacts for particular regions between the market structures. Given that the unit costs of fixed and variable costs are the same in our model, under monopolistic competition the output per firm is fixed; so rationalization gains are ruled out as an explanation of our results. In order facilitate interpretation of the variety and terms-of-trade effects, we have developed: a multi-sector version of the Feenstra ratio and the proportional change in the terms-of-trade. Along with the welfare results, we report the values of both of these, for all ten regions of the model.

We begin this section with how we hold the trade response constant. We discuss our multi-sector extension of the Feenstra ratio in section 3.2. We refer the reader to Balistreri and Tarr (2018) for the relatively straightforward definition of the terms-of-trade.

3.1 Calibration of the Trade Response

Arkolakis, Costinot and Rodriguez-Clare (2012) they have shown that the changes in the trade flows are very important to the welfare calculation. Costinot and Rodriguez-Clare (2014, p. 198) note that while the micro-foundations of gravity models encompass a large number of market structures, they share the same macro-level predictions regarding the change in bilateral trade flows as a function of bilateral trade costs. They mention that the focus of their work is to investigate the quantitative implications of this basic macro prediction. Costinot and Rodriguez-Clare have successfully investigated the implications of this macro-level prediction of gravity in their autarky and simple one-sector models. In multi-sector, comparative static models, however, they have not matched the changes in the trade flows. We extend their logic by matching both the initial trade flow data (which they have matched) and the changes in the trade flows (the trade responses) across the Armington, Krugman and Melitz market structures. We start by elaborating the Costinot and Rodriguez-Clare calibration procedure and explain how we extend their logic.

As in Costinot and Rodriguez-Clare, define X_{rs} equal to the total value of expenditures by country *s* on imports from country *r*, and λ_{rs} as country *r*'s share of the expenditure of country *s* in the initial equilibrium, i.e.,

$$\lambda_{rs} = \frac{X_{rs}}{\sum_{r \in R} X_{rs}} \tag{18}$$

where *R* is the set of all regions. Analogously, λ'_{rs} is country *r*'s share of the expenditure of country *s* in the counterfactual equilibrium. $\hat{\lambda}_{rs}$ is the proportional change in country *r*'s share of the expenditure of country *s* between the equilibria is defined by:

$$\hat{\lambda}_{rs} \equiv \frac{\lambda'_{rs}}{\lambda_{rs}} \tag{19}$$

In this paper, we refer to the variable $\hat{\lambda}_{rs}$ as the trade response.

3.1.1 Autarky. In the special case of autarky, $\lambda'_{rr} = 1$. Provided that the researcher calibrates the initial equilibrium of all models to be consistent with the trade flow data, we have that the changes in the domestic trade responses will be equal across the model structures, i.e.:

$$\hat{\lambda}_{rr} \equiv \frac{1}{\lambda_{rr}} = \hat{\lambda}^{A}_{rr} = \hat{\lambda}^{K}_{rr} = \hat{\lambda}^{M}_{rr}, \tag{20}$$

where the superscripts *A*, *K* and *M* refer to the Armington, Krugman or Melitz models, respectively. In addition, in the special case of a movement to autarky, the equality of the changes in the domestic trade responses will hold even at the sector level in multi-sector models, and it will hold independent of the elasticities chosen in the model. Since Costinot and Rodriguez-Clare (2014) matched the trade flows of the data in the initial equilibrium of the Armington, Krugman and Melitz models, from equation (20), they also match the domestic trade responses in the case of autarky.

3.1.2 Comparative Statics (without autarky). For the one sector model, Costinot and Rodriguez-Clare (2014, 209-211) derive the elasticity relationship:

$$\varepsilon = (1+\eta)(\sigma - 1) \tag{21}$$

where ε is the trade elasticity from gravity, σ is the Dixit-Stiglitz elasticity θ is the Pareto distribution shape parameter $\theta > \sigma - 1$; and $\eta = \frac{\theta}{\sigma - 1}\left(1 + \frac{1-\sigma}{\theta}\right) > 0$ in Melitz, equal 0 otherwise.

In their multi-sector models, Costinot and Rodriguez-Clare (2014, p. 213) assume that their reduced-form assumption on price indices in the one-sector model holds sector by sector, which, along some additional assumptions, yields their sector level elasticity relationship as:

$$\varepsilon_s = (1+\eta_s)(\sigma_s - 1) \tag{22}$$

where the *s* subscript denotes the sector. They take ε_s from Caliendo and Parro (2010), except for services, where they take a value of 5. They take $\eta_s = 0.65$ for all *s* under Melitz, equal to 0 otherwise. They then solve for σ_s from (22) and calibrate the model such that the *initial* trade flows are consistent with these elasticities. When they conduct counterfactual exercises, however, Costinot and Rodriguez-Clare do not attempt to match the changes in the trade flows in multi-sector, comparative static models. But equation (22) is an approximation, as it does not have the firm theoretical basis of equation (21).[14] We show in this paper, that in the one-sector, comparative static model, application of equation (21) results in precisely matched *changes* in trade flows in the Armington, Krugman and Melitz models. In multi-sector, comparative static models, however, if we use the elasticities from equation (22), there are unequal changes in trade flows across the models.[15]

For our calibration, we numerically calculate the trade responses and adjust the trade elasticities such that both the initial trade flows and the changes in the trade flows (the trade responses) are equal across the market structures.[16] We let λ_W indicate the share of global expenditures that are spent on goods that are produced in their respective home region: :

$$\lambda_W = \frac{\sum_{r \in R} X_{rr}}{\sum_{r \in R} \sum_{s \in R} X_{rs}}$$

Analogous to the above, define λ'_W as the domestic trade share in the in the counterfactual equilibrium and $\hat{\lambda}_W \equiv \frac{\lambda'_W}{\lambda_W}$. We take the trade response from the Melitz model based and adjust elasticities in the

[14] Melitz and Redding (2015) showed that the "existence of a single constant trade elasticity and its sufficiency property for welfare are highly sensitive to small departures from those Arkolakis, Costinot and Rodriguez-Clare parameter restrictions."

[15] In our applications, we choose $\varepsilon = \theta = 4.58$ for all sectors *s*. Then equations (21) and (22) imply a value of 5.58 for σ^K, the Dixit-Stiglitz elasticity in the Krugman model (for all sectors and regions). In our simpler one sector models, consistent with equation (21) above, we find that $\sigma^K = 5.58$ exactly equilibrates the trade responses. In the multi-sector models, however, with iceberg trade costs, we get values of σ^K **b**etween 5.59 and 5.65. When we conduct comparative static tariff exercises, we calibrate values of σ^K between 5.81 and 5.88. The Armington elasticities are typically larger than the Krugman elasticities.

[1616] As Rutherford (2002) has explained, the data on the initial trade flows may be calibrated to be consistent with any set of CES elasticities. Thus, calibrating elasticities to match changes in trade flows does not constrain the calibration of the model to also match the initial trade flows.

Krugman and Armington model such that $\hat{\lambda}_W$ is the same in the Krugman and Armington models. The selection effect magnifies the trade response in the Melitz model, but this effect is absent in the Krugman model. To obtain the same trade response, consistent with equations (21) and (22), we find that we must impose larger Dixit-Stiglitz elasticities in the Krugman model. This means that the value of an additional variety will be greater in the Melitz model compared to the Krugman model. This fact is important in the interpretation of results.[17] Since the Krugman model has entry of firms, to achieve the same trade response in the Armington model as in the Krugman model, we typically must choose the Armington elasticities of substitution to be larger than the Dixit-Stiglitz elasticities of our multi-sector Krugman models.

For the Pareto distribution shape parameter, we choose the value 4.58 from the structural estimation of Balistreri, Hillberry and Rutherford (2011). Arkolakis *et al*. (2012) have shown that in their one sector Melitz model, the Pareto shape parameter is equal to the trade elasticity. For the value of the Dixit-Stiglitz trade elasticity in the Melitz model, we take the value of 5.0 that Hillberry and Hummels (2014, p.1240) report as the median estimate from cross section and panel estimates. For transparency, we take $\varepsilon = \theta = 4.58,\ \sigma^M = 5.0$ for all sectors, regions and model variations of the Melitz structure in this paper. For the Krugman model, we adjust the Dixit-Stiglitz elasticities of substitution. In our Armington models, we adjust σ^A, the Armington elasticities of substitution between goods and services from different regions. In our nine-sector Krugman and Melitz models, we have four CRTS and five monopolistically competitive sectors; then we adjust the Dixit-Stiglitz and Armington elasticities by the same multiple. In all of our models and scenarios of this paper, we adjust the elasticities σ^K and σ^A such that $\hat{\lambda}_W^A = \hat{\lambda}_W^K = \hat{\lambda}_W^M$ where the superscripts A, K and M refer to the Armington, Krugman and Melitz models, respectively. The values of σ^K and σ^A that equilibrate the trade responses are reported in the tables of results.

[17] In an effort to keep the love of variety effect constant in the Krugman and Melitz models, we could impose the same Dixit-Stiglitz elasticities of substitution in the Melitz and Krugman models and attempt to adjust the Pareto shape parameter in the Melitz model. The problem with this calibration strategy is that it requires a value of the Pareto shape parameter, a, very close to $\sigma^M - 1$, where σ^M is the Dixit-Stiglitz elasticity of substitution in the Melitz model. At $a \le \sigma^M - 1$ it is well known that the Melitz equilibrium is ill defined. As a matter of computation, the Melitz models fail to solve reliability as the value of the Pareto shape parameter approaches $\sigma^M - 1$ from above.

3.2 A Multi-Sector Feenstra Ratio for Interpreting Welfare Results

Feenstra (1994; 2010) derived a ratio that precisely measures the welfare impact of the variety externality in a one-sector monopolistic competition model. His measure shows that the welfare impact of the set of additional varieties depends not only on the Dixit-Stiglitz elasticity of substitution but also on the expenditure share on the new varieties. Suppressing subscripts for region *r*, the ratio of Feenstra (2010, Theorem 2) is (with rearranging):

$$FN = \left[\frac{\lambda_{t-1}(G)}{\lambda_t(G)}\right]^{1/(\sigma-1)} = \frac{e_{t-1}}{e_t} P^{SV}(\mathbf{p}_t, \mathbf{p}_{t-1}, \mathbf{q}_t, \mathbf{q}_{t-1}, G) \tag{20}$$

where e_t is the unit expenditure function in period t; $\mathbf{p}_t$ and $\mathbf{q}_t$ are the vectors of prices and quantities in period t; G_t is the set of goods and services available in period *t* at prices $\mathbf{p}_t$; $G = G_t \cap G_{t-1}$ is the set of goods available in both periods *t* and *t-1; $P^{SV}(\mathbf{p}_t, \mathbf{p}_{t-1}, \mathbf{q}_t, \mathbf{q}_{t-1}, G)$* is the Sato-Vartia index that shows the ratio of the unit expenditure function in the two periods if the sets of available goods in the two periods are identical; and $\lambda_t(G)$ is the period *t* expenditure share on goods in the common set G relative to period *t* total expenditure. Feenstra's theorem tells us that the proportional change in the unit expenditure function is the product of: (i) a measure of the change in the prices charged by firms on goods common to the two periods (the Sato-Vartia index); and (ii) a ratio that is a measure of the value of the variety gain--the Feenstra ratio. The methodology requires distinguishing changes in the price charged by firms on goods available in both periods from the variety externality. A larger number of new goods in period *t* will tend to lower $\lambda_t(G)$. A value of 1.01 for our Feenstra ratio means that the cost of a unit of utility declined by one percent due to new varieties.

In a multi-sector, multi-region model, we define the Feenstra ratio for region *s* as:

$$FN_s = \sum_i \omega_{is} FN_{is} \qquad s \in R \tag{21}$$

where ω_{is} is the economy-wide expenditure share (absorption share) on goods or services of sector i in region *s*; and FN_{is} is the Feenstra ratio for sector *i* in region *s* defined as:

$$FN_{is} = \frac{P_{is}(0)}{P_{is}(1)} P_{is}^{SV} \qquad i \in I,\ s \in R \tag{22}$$

where $P_{is}(t)$ is the Dixit-Stiglitz price index of sector *i* in region *s* defined in section 2, with *t*= 0,1 for initial and counterfactual equilibria, and P_{is}^{SV} is the Sato-Vartia index of goods and services common to the initial and counterfactual equilibria of sector *i* in region *s*. Since we have multi-level CES preferences, Sato (1976, footnote 11) has shown that the Sato-Vartia index (Vartia I) remains an "ideal" index of firm level prices at the sector level. Since the Dixit-Stiglitz index is the unit cost of goods in sector *i* taking variety into account, our index FN_{is} is precise at the sector level. If we have a one-sector model without intermediates (we only have private consumption as final demand in this model) , equation (21) reduces to equation (20), and our measure is that of Feenstra (2010). Given the existence of intermediates in our model, the absorption weighted aggregation across sectors is an approximation; but we present this multi-sector variety measure for more than 40 scenarios in this paper and find that changes in the Feenstra ratios and terms-of-trade together are able to explain virtually all the relative welfare results across the models. They are especially useful in explaining the reversed welfare rankings.

4. Model Results

We begin with the simplest single sector model and progressively introduce model features to capture aspects of the data. In our one-sector and four-sector models, we examine a ten percent reduction in iceberg trade costs. For our tariff policy scenarios, we employ a more realistic nine-sector model. All our models contain ten regions and an untruncated Pareto distribution in the Melitz model. To be consistent with the literature, we rebalance the GTAP data so that all final demand is consumption demand. We report Hicksian equivalent variation as a percent of the benchmark value of real consumption.

4.1 Welfare Equivalence in the Model with One Sector, One Factor and No Intermediates

First, we consider the simplest model of Arkolakis, Costinot and Rodriguez-Clare (2012), i.e., one-sector, one primary factor of production, no intermediate inputs, trade costs are iceberg, balanced trade and no labor-leisure choice. Our simulations (see Balistreri and Tarr, 2018, table 2) replicate the result of Arkolakis *et al.* (2012) that the alternative market structures generate identical welfare impacts. Further, we make an additional calculation of the change in welfare based only on the domestic expenditure share trade response and the trade elasticity. We show that the welfare estimate from our general equilibrium model in section 2 is identical to this very simple calculation. These are precisely the points made by Arkolakis *et al.* (2012).

We also consider initial trade imbalances based on the data. We find (Balistreri and Tarr, 2018, table 2) that, in this class of one sector models, we retain the welfare equivalence across the three market structures when rounded to a single decimal point of percentage change, i.e., the trade imbalances in this one-sector model are insufficient to separate the welfare results across the Armington, Krugman or Melitz market structures.

We note that the domestic expenditure shares λ_{rr} change as a result of the incorporation of the benchmark trade imbalances. In all the subsequent simulations in this paper, we assume trade imbalances based on the data and that the observed current-account imbalances are held fixed in units of the numeraire, see equation (17).

4.2 Breaking the Equivalence: Labor-Leisure Choice, Intermediate Goods and Multiple Sectors

In table 1, we show results of our simulations where we introduce three model features that break the equivalence of the welfare results between the market structures: (i) labor-leisure choice; (ii) intermediates in a single sector (without labor-leisure choice); and (iii) multiple sectors with intermediates (without labor-leisure choice). We again consider a ten percent reduction in iceberg trade costs and retain the single primary mobile factor assumption. In our Krugman and Melitz multi-sector models in these scenarios, all the sectors are monopolistically competitive. The values of the elasticities in the Armington, Krugman and Melitz models are shown at the top of table 1, columns 1-9. Notice that these elasticities are adjusted to hold the trade response constant.

4.2.1 Labor-Leisure Choice (One Sector Model).

In the models with labor-leisure choice, to facilitate comparison across the model structures, we continue to report Hicksian equivalent variation as a percent of consumption of goods and services in the benchmark equilibrium.[18] We see that labor-leisure choice breaks the equivalence. For all regions, we have that $M > K > A$. In multiple cases, however, the difference between the Krugman and Melitz model results is only in the second decimal.

We assume an elasticity of substitution between leisure and consumption of 2, which yields a positive elasticity of labor supply. The larger gains in the monopolistic competition models are explained by the fact that the decline in trade costs increases real wages, which makes more labor available for production. This leads to more varieties and an increase in welfare due to the Dixit-Stiglitz externality. Although they did not hold the trade response constant, this was the argument of Balistreri *et al*. (2010). This intuition is verified by noting that all Feenstra ratios in columns 3 and 5 of table 1 exceed unity.

In order to hold the trade response constant, we must select a higher value of the Dixit-Stiglitz elasticity in the Krugman model—5.0 for Melitz and 5.58 for Krugman in this case. Then an additional variety is valued more highly in the Melitz model. We see that the values of the Feenstra ratios in the

[18] That is, we do not include the imputed value of leisure in the denominator.

Melitz model are greater than or equal to the values of the Feenstra ratios the Krugman model for all regions in the model other than the United States. For the United States, the larger welfare gains in the Melitz model over Krugman, may be explained by the reported lower terms-of-trade loss or by productivity effects in Melitz.

4.2.2 Intermediates (One Sector).

To isolate the impact of intermediates, we hold labor supply fixed. We assume Cobb-Douglas production in the single primary factor (labor) and the intermediate good.

In all regions of the model, we see that $M > K > A$ (table 1, columns 4-6). As shown by the Feenstra ratios greater than one in all cases, the monopolistic competition models provide larger gains than Armington due to variety gains. Except for the United States (where terms-of-trade effects are better in Melitz), the Feenstra ratios show there are larger variety gains in the Melitz model compared with the Krugman model.

4.2.3 Multiple Sectors with Intermediates.

In columns 7-9 of table 1, we present welfare results with a four-sector model, labor as a single primary factor of production and Cobb-Douglas demand for intermediates and labor. For the average welfare impact for the world and for seven of the ten regions, we again have the ranking $M > K > A$. Additional varieties contribute to larger welfare results of the monopolistic competition models over Armington for most of the regions and the average for the world. Since an additional variety is valued more highly in the Melitz model than the Krugman model, for six of our regions, the Feenstra ratios show a larger welfare gain from varieties in the Melitz model than the Krugman model.

With the introduction of multiple sectors, however, we have a reversal of the welfare ranking in the case of the Low-Income region, i.e., we have $M < K < A$. The terms-of-trade values show that the larger welfare gains for the Low-Income region in the Armington model derive from larger terms-of-trade gains than in the monopolistic competition cases (columns 12, 13 and 15 of table 1 continued). So, a smaller terms-of-trade gain in the monopolistic competition models outweighs their variety gains, leading to larger welfare gains in the Armington model for the Low-Income region.

For three regions, we have the reversed welfare ranking of $M < K$: the Low-Income region; Middle-Income region; and Australia-New Zealand (in the second decimal). In all three of these regions (and only these three regions), we see that the Feenstra ratios show lower variety gains in the Melitz model than the Krugman model. In these three regions, the lower Feenstra ratios in the Melitz case show that, compared with the Krugman model, either expenditure shares shifted to sectors with fewer increases in varieties or there was a smaller increase in varieties in the Melitz model.

The fact that not all regions follow the pattern of the average for the world is consistent with the results of Costinot and Rodriguez-Clare (2014, table 4.3). In their ten-region, sixteen-sector model with intermediates, they conduct comparative static exercises of forty percent tariff increases. They find that on average, losses are largest under Melitz and smallest under Armington; but they find reversed welfare rankings between Krugman and Armington in three of their regions (Eastern Europe, North America and Rest of World) and reversed welfare results for Krugman versus Melitz in the case of their Pacific Ocean region. They use the Dixit-Stiglitz elasticities to explain the results for the average for the world, but they do not explain the cases where they find reversed relative welfare rankings.[19] Our Feenstra ratio and terms-of-trade values, however, facilitate understanding these reversed welfare rankings.

4.2.4 Relative Gains over Armington: Krugman compared to Melitz

In all model variations in tables 1-4, we reduce trade costs. For the average for the world, we find that $M > K > A$. Regarding the larger global welfare gains of the monopolistic competition models, we ask how much of an additional welfare gain does the Melitz model provide over the Krugman model? Alternatively, are the Krugman model's welfare gains closer to the Armington or Melitz style models?

To measure this, we define K_A = the ratio of the global welfare gains in the Krugman model to the global welfare gains in the Armington model; and M_A = the ratio of the global welfare gains in the Melitz model to the global welfare gains in the Armington model. We define the Krugman model's share of the larger welfare gains in the Melitz model over the Armington as: $R_{K/M} = \left[\frac{K_A - 1}{M_A - 1}\right]$. In the case of labor-leisure choice in table 1, for the average for the world, the $R_{K/M}$ ratio is .87; with intermediates in a single sector model, we have $R_{K/M} = .82$.; and in the case of four-sectors in table 1, the ratio is .76. Thus, in the model variations of table 1, regarding the gains to the world, a Krugman model would capture the majority of the gains of the Melitz model above the Armington model.

4.3 Impact of Intermediate Demand based on Real Data and of a Lower Elasticity of Substitution for Intermediate Inputs

The solution of multi-sector Melitz style models with intermediate demand shares based on real data has heretofore eluded researchers.[20] In this subsection, we employ a four-sector, ten-region model and evaluate a ten percent global reduction in iceberg trade costs. We present results in table 2 for the impact of three structures of intermediate demand (i) for comparison with earlier modeling efforts, a

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[19] There are also reversed welfare rankings in the autarchy exercises of the 34-region model of Costinot and Rodriguez-Clare (2014, table 4.1, p. 206). They define the gains from international trade as the absolute value of the welfare change of moving to autarchy. They find that on average for the world: $M > K > A$. But they find four regions (Australia, Greece, Romania and the Russian Federation) with the reversed welfare ranking $M < K < A$.

[20] Balistreri, Hillberry and Rutherford (2011), Jafari and Britz (2017) and Costinot and Rodriguez-Clare (2014) used a single aggregate intermediate good. Costinot and Rodriguez-Clare (2014, p. 219) acknowledge that it would have been better to use the data on the intermediate shares; but they did not find a solution with the actual data in the monopolistic competition cases.

single aggregate intermediate good (columns 1-3); (ii) Cobb-Douglas demand for intermediates based on data on intermediate shares (columns 4-6); and (iii) CES demand for intermediates based on data on intermediate shares, with elasticity of substitution equal to 0.5 (columns 7-9). We assume a single primary factor, zero tariffs, no labor-leisure choice, but we incorporate trade imbalances and intermediate shares from the data. In the Krugman and Melitz models, all four sectors are monopolistically competitive. Table 2 shows several interesting results.

First, allowing intermediate demand to be disaggregated based on data increases the gains in the monopolistic competition models relative to the Armington model. With disaggregated intermediates, firms can optimize among intermediates based on their input shares and relative costs. With Cobb-Douglas demand for intermediates and a single aggregate intermediate good, equivalent variation in the Krugman (Melitz) model is 138 (147) percent of the equivalent variation in the Armington case; and these ratios rise to 155 (172) percent with intermediate shares based on data.

Second, with the lower elasticity of substitution, the quantitative differences between the welfare gains in the perfect competition model and the monopolistic competition models is significantly reduced. With CES demand and an elasticity of substitution for intermediates of 0.5, equivalent variation in the Krugman (Melitz) model falls to 120 (124) percent of the equivalent variation in the Armington case. With the lower elasticity of substitution, firms are less able to substitute goods from sectors whose Dixit-Stiglitz variety adjusted price falls the most; thus, the monopolistic competition models benefit less from the variety increases.

Third, in all three intermediate model structures, regarding the average for the world (and for seven of our ten regions), we have non-equivalence of the welfare results with $M > K > A$. We can see that the Feenstra ratios exceed unity in all 30 cases in table 2, verifying that all regions in all three scenarios experience variety gains.

Fourth, in multi-sector, multi-region models, terms-of-trade effects can overcome variety gains and result in reversed welfare rankings for some regions, with larger gains in the Armington model compared to either or both of the monopolistic competition models, i.e., we can have $A > K \text{ or } A > M$. For the Low-Income region, we have $A > K > M$ with all three intermediate demand structures; for the Middle-Income region and Australia-New Zealand, we have $A > K > M$ in the case of the low elasticity of substitution of 0.5 and for the Middle-Income region, we have $A > M$ in the case of Cobb-Douglas demand for intermediates with real data. Our terms-of-trade parameter reveals that, for these three regions, the change in the terms-of-trade is better in the Armington model than in both monopolistic competition models for all three intermediate demand structures. Although our Feenstra ratio parameter shows that these regions gain from variety, a relatively better terms-of-trade impact in the Armington model dominates the variety gains of the monopolistic competition models.

Fifth, a smaller variety gain can contribute to a reversed ranking of $K > M$. For the three regions Lower-Income, Middle-Income and Australia-New Zealand, with both intermediate demand structures based on real data, we have $K > M$. In these cases, the Feenstra ratio shows a lower variety gain in the Melitz model than the Krugman model. Since an additional variety is valued more highly in the Melitz model, the larger Feenstra ratio in the Krugman model in these cases shows the importance of considering expenditure shares or a smaller increase in bilateral varieties.

Sixth, the Krugman model captures the majority of the world's welfare gains above the Armington model. Using the results or the average welfare change for the world, the values of the parameter $R_{K/M}$ for the Krugman model's share of the larger welfare gains in the Melitz model over the Armington model are: .80 for Cobb-Douglas demand with a single aggregate intermediate; .76 for Cobb-Douglas demand with data on intermediate shares; and .84 for CES demand with data on intermediate shares.

Finally, table 2 provides examples that show that the qualitative impact of a modeling assumption in the Armington model does not imply that the same modeling assumption will have the same qualitative impact in the Krugman or Melitz models. Consider the impact of a Cobb-Douglas intermediate structure with real data compared to Cobb-Douglas demand with an aggregate intermediate good. There are nine cases in table 2 where the *sign* of the impact in the Armington model has the opposite sign of the impact in either the Krugman or Melitz model.[21] Take China in particular. If we compare the estimated welfare gains for China using the Armington or Krugman models, we see that they are smaller with the real data in the Armington model (in columns 1 and 4, we have: 3.5% – 3.6% < 0); but they are larger with the Krugman model (columns 2 and 5 yield: 9.7% - 7.8% > 0).

4.4 Multiple Primary Factors, Sector Specific Factors and Labor-Leisure Choice

Heretofore, we have assumed a single primary factor of production. In this section, we investigate the impact of allowing primary factors of production to include labor, capital and a resource factor which may be sector specific. Demand for primary factors is Cobb-Douglas. We also consider a case with labor-leisure choice. All scenarios assume: four sectors (which are all either Krugman or Melitz sectors in the monopolistic competition versions); CES demand for intermediates based on the data on intermediate shares by sector, and an elasticity of substitution equal to 0.5; we have both initial trade imbalances and initial tariffs. We take primary factor share intensities from the GTAP data. We simulate a global ten percent reduction in iceberg trade costs.

[21] See the cases of Canada, China, Japan, Low-Income and Middle-Income.

Regarding the results for the average, we see that we have $M > K > A$ in all model variants of table 3. The values of our parameter $R_{K/M}$ in the four sets of scenarios are: .83; .83; .83; .82. Again, we observe that, for these global changes in iceberg costs, the Krugman model captures the majority of the welfare gains above the Armington model.

We do not find, however, that additional factors of production have a significant impact on the welfare results. We produce estimates for the welfare gains with a single primary factor in columns 1-3 and with three primary factors columns 4-6. Holding market structure constant, the maximum welfare difference for any of the ten regions is a single decimal point of percentage welfare change. This extends the Costinot and Rodriguez-Clare result to the Krugman and Melitz models of very little welfare impact of multiple factors of production compared to a single factor.[22]

On the other hand, labor-leisure choice plays a very important role in producing larger estimated welfare gains in the monopolistic competition models, and it widens the difference in estimates with the Armington model. Comparing the average for the world with and without labor-leisure (columns 7-9 with columns 10-12), we see that the ratio of estimate gains in Krugman (Melitz) to Armington K_A (M_A) increase from 1.16 (1.20) to 1.26 (1.32). This result is consistent with the earlier result we saw in table 1, where with labor-leisure choice the availability of more resources led to more varieties and more gains in the monopolistic competition models.

Further, labor-leisure choice eliminates the reversed welfare ranking for the individual regions. *Without* labor-leisure choice, columns 1-9 show that we have a reversed welfare ranking for the regions Australia-New Zealand, Low-Income and Middle-Income, i.e., $A > K > M$. With labor-leisure choice, however, we have $M > K > A$ for Australia-New Zealand and the Low-Income regions; and we have approximate indifference for the Middle-Income region.

4.5. Tariff Versus Iceberg Trade Costs Reduction in a Nine-sector, Ten Region Model

To evaluate global free trade, we employ a more realistic model with nine-sectors, four of which are always modeled as perfectly competitive Armington sectors, and five of which are modeled as monopolistically competitive when we evaluate the Krugman and Melitz models.[23] We incorporate initial

[22] See Bernard, Redding and Schott (2007), however, for an approach that embeds heterogeneous firms in a comparative advantage model. They consider a reduction in trade costs and find complex interactions at the sector level between inter-sectoral comparative advantage impacts and intra-sectoral reallocations toward high productivity firms.

[23] We aggregate the 57 sectors of the GTAP database into the following sectors (the first four of which are always perfectly competitive sectors in this subsection): (i) agriculture; (ii) natural resources extraction; (iii) utilities; (iv) all

tariffs based on the data and we have initial trade imbalances. We also evaluate the impact of uniform tariffs. For sensitivity purposes with the earlier simulations, we evaluate and compare a reduction in iceberg trade costs in this model. Other model assumptions and the results are shown in table 4.

4.5.1 Global Free Trade in Tariffs

We evaluate a movement to global free trade in three model variants: (i) initial tariffs based on the data; (ii) initial uniform tariffs in each country, where the uniform tariff rate equalizes the revenue for initial tariffs based on the data; and (iii) initial tariffs based on the data with labor-leisure choice. Regarding the results for the average for the world and for all regions other than China, we again have the ranking of welfare results as $M > K > A$. The values of our parameter $R_{K/M}$ for the relative importance of the Krugman model to the Melitz model are: (i) .95 for initial tariffs based on data; (ii) .83 for initial uniform tariffs; and (iii) .90 for initial tariffs with labor-leisure choice.

We note that the variety gains of the monopolistic competition models are relatively more important when we start with uniform tariffs. With uniform tariffs, the gains to the world of global free trade in the Krugman (Melitz) models are 406 (467) percent of the gains in the Armington model. This compares to 166 (169) percent without uniform tariffs. Since uniform tariffs eliminate tariff peaks, the Harberger distortion costs of the tariffs (that increase with the square of the tariff) are smaller with uniform tariffs. Further, labor-leisure choice again increases the relative gains of the monopolistic competition models (columns 7-9 compared to 13-15).

In the cases of the Low-Income region and Middle-Income region (with data based initial tariffs), we observe a sign change in the welfare results between Armington model and the monopolistic competition models. These regions experience an estimated welfare loss from global free trade in the Armington model, but not in the monopolistic competition models. The difference is quite dramatic in the case on the Low-Income region with initial uniform tariffs (columns 10-12). Our terms-of-trade parameter shows that the negative terms-of-trade effect under Armington becomes positive under Krugman and Melitz. Interestingly, under Krugman, the Feenstra ratio shows a *loss* of the variety externality under Krugman (column 20 of table 4 continued). In these models with monopolistic competition, we retain four of the nine sectors as Armington sectors; thus, it is possible for regions to shift expenditures away from monopolistically competitive sectors toward perfectly competitive sectors. Any such shift would entail a loss of the variety externality. Under Melitz, however, the variety externality for the Low-Income region is positive (column 21 of table 4 continued).

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other services, not included elsewhere; (v) food; (vi) textiles; (vii) refined resource products; (viii) other manufacturing, not elsewhere classified; and (ix) business services.

In the case of China (with global free trade and initial data-based tariffs) we see a sign change in the welfare results; China *gains* under Armington but *loses* under Krugman and Melitz. Note that the terms-of-trade in the monopolistic competition models is better than in the Armington model. On the other hand, due to an expenditure shift toward Armington sectors, China experiences a loss of the variety externality in these partially monopolistic competitive models (see table 4 continued, columns 14, 16, 24 and 26), and the variety loss evidently dominates.

Then why does Krugman provide more welfare gains than Melitz in the case of China in these model variants? Our reports show that it is neither terms-of-trade effects nor the variety externality that explain this welfare ranking reversal. Productivity effects are a possible explanation. In our Melitz model, productivity is impacted by both intersectoral shifts in resources as well as intra-sectoral shifts among heterogeneous firms. In the case of China, we calculate a shift in resources toward the Armington sectors in these scenarios.[24]

4.5.2 Iceberg Trade Cost Reduction in the Nine-Sector Model

In multi-sector models, it is natural to classify some sectors as perfectly competitive and others as imperfectly competitive. We find that this classification can change the ranking of the welfare results across the Armington, Krugman and Melitz models for particular regions.

We compare the impact of a ten percent reduction in iceberg trade costs in the four-sector models (columns 7-9 of table 3) with the nine-sector models (columns 1-3 of table 4). The only differences between the models in these scenarios is: (i) the number of sectors; and (ii) in our nine-sector models, we assume four of the sectors are perfectly competitive, even when we allow five sectors to be monopolistically competitive.

In our nine-sector model, for our Low-Income region we have $M > K > A$, whereas in the four-sector model we have $A > K = M$ (compare columns 1-3 table 4, with columns 7-9 of table 3). We see that for the Low-Income region, in the nine-sector model there are larger terms-of-trade gains in the monopolistic competition models; we had the opposite terms-of-trade ranking in the four-sector model. This shows that in multi-sector, multi-region models, how the data are aggregated may impact the qualitative ranking of the welfare gains.

While the welfare ranking for the average for the world remains $M > K > A$, the relative gains in the monopolistic competition models falls. The ratio of the gains in Melitz to the gains in Armington fall from 1.20 to 1.13 without labor-leisure choice (compare columns 1-3 table 4, with columns 7-9 of table 3)

[24] In the Melitz model, without labor-leisure choice, value-added declines in both CRTS and IRTS sectors, but the percentage decline is larger in absolute value in the Melitz case. In the case of labor-leisure choice, value added in the CRTS sectors falls by 0.4%, but value-added in the Melitz sectors of the model falls by 1.3%. In our Krugman model, with labor-leisure choice, we find that value-added in the CRTS sectors in China increases by 0.2% while value-added in the IRTS sectors falls by a considerably smaller 0.1%.

and from 1.32 to 1.20 with labor-leisure choice. Since a smaller share of the economy is monopolistically competitive in the nine-sector models, the variety gains are smaller. Inspection of the Feenstra ratios verifies the smaller variety gains.[25] The values of the parameter $R_{K/M}$ for the relative importance of the Krugman model to the Melitz model in our iceberg cost reduction scenarios are: .88 without labor-leisure choice and .87 with labor-leisure choice.

5. Sensitivity: *Unilateral* Tariffs Changes, the Trade Response and Symmetry of the Trade Cost Change

We examine sensitivity to the nature of the trade shock by examining a *unilateral* increase in tariffs by each of our ten regions. We also examine the sensitivity of the results to a change in the trade response. For these simulations, we choose the nine-sector, ten-region model that we employed for the simulations shown in table 4, columns 13-15. We also test for the symmetry of the results to the sign of the trade cost shock by rerunning all 12 models in tables 1-4 involving iceberg trade costs with an *increase* in iceberg trade costs.

5.1 Impact of a Unilateral Increase of Tariffs to Forty Percent

For each of our ten regions, we simulate a unilateral *increase in tariffs* to 40 percent and compare results for the three market structures, were we adjust elasticities in the Krugman and Armington models to match the trade response of the Melitz model. We only present the results for the region that is imposing the increase it its tariffs to a uniform 40 percent; the results of the 30 simulations are presented in table 5. For majority of the regions of our model, we find *gains* from the increase in tariffs in our Armington model, but losses in the monopolistic competition models and the losses in the Melitz model are larger in absolute value than the losses in the Krugman model.

In the Armington model, all countries gain from the unilateral imposition of a 40 percent uniform tariff, i.e., $A > 0$. In the absence of retaliation from trade partners, there are terms-of-trade gains that lead to welfare gains from the unilateral imposition of tariffs up to the optimal tariff for the region. Given our elasticities based on structural gravity, both a theoretical derivation[26] and our numerical simulations are consistent with the optimal tariff for these countries in the range of about 23 percent. Although the countries experience a welfare loss by further increasing the tariff above 23 percent, the gains from

[25] As defined above, the Feenstra ratio in a CRTS sector is one.
[26] See Harrison, Rutherford and Tarr (1997a, appendix C).

increasing tariffs from initial levels to the optimal level dominate the losses for the increase above the optimal level to 40 percent.

In the monopolistically competitive models, the *sign* of the welfare result for seven of the ten regions is opposite of the Armington result, i.e., they lose from the imposition of 40 percent uniform tariffs (the Unites States, Australia-New Zealand and the Middle-Income regions excepted). Even small increases in tariffs typically result in a loss of the Dixit-Stiglitz variety externality. The Feenstra ratios in table 5 show there is a welfare loss due to the loss of varieties in all but one case, and the variety loss is larger in the Melitz model than in the Krugman model.

In the cases of the United States and the Middle-Income region, the Feenstra ratios show that they experience a loss of welfare from the variety loss (although smaller than most regions), but their terms-of-trade gains dominate the welfare loss from the loss of varieties. In the case of the Australia-New Zealand region, we have an unexpected welfare ranking of $M > K > A$. We see that the terms-of-trade gain is larger in the monopolistically competitive models for Australia-New Zealand. Moreover, in the model with Krugman sectors, we do not observe a loss of welfare from varieties (Feenstra ratio is 100.2%). We have four perfectly competitive sectors in our model; a shift in expenditures toward the monopolistically competitive sectors would increase the value of varieties; a higher expenditure share can offset the loss in the number of varieties.[27]

5.2 Sensitivity to the Trade Response

The key parameters that impact the trade elasticity in the Melitz model are the Pareto shape parameter and the Dixit-Stiglitz elasticity. We conduct sensitivity on these parameters separately in our global free trade scenario based on the model in table 4 with labor-leisure choice and initial tariffs.

For the high and low values of the Pareto shape parameter, *a*, we take plus and minus two standard deviations from the mean of the preferred probability distribution estimated by Balistreri *et al*. (2011). Regarding sensitivity to the Dixit-Stiglitz elasticity, σ^M, for a solution to the Melitz model, we must have $a > \sigma^M - 1$. Given our central values of 4.58 for the Pareto shape parameter and 5.0 for the Dixit-Stiglitz elasticity, we take plus and minus 0.5 for the Dixit-Stiglitz elasticity in our sensitivity analysis. We adjust the elasticities in our Armington and Krugman models to achieve the same trade responses consistent with the Melitz model elasticities. Our full set of results are in table 7A and 7B of Balistreri and Tarr (2018).

[27] Consistent with the Feenstra ratio for the Australia-New Zealand region, we also calculate a 5.7 percent decline in the value-added of the perfectly competitive sectors and a 1.6 percent increase in the value added of the monopolistically competitive sectors.

We find that a larger trade response leads to larger welfare gains for the world, but the differences from the estimates of the central elasticities are not large (a maximum difference of eight percent of their central values for the average for the world in any market structure). Further, we do not see any cases of a sign change in the welfare impacts: those regions that lose with the central trade response, lose with the high and low trade responses.

5.3. Symmetry of the Welfare Costs to Trade Cost Increases

We executed a ten percent global increase in iceberg trade costs in all 12 model variations involving iceberg trade costs that are shown in tables 1-4. We find symmetry of the results for the average for the world in all cases with the results for iceberg trade costs reductions. That is, for the average of the world, we have $|M| > |K| > |A|$, independent of the sign of the trade cost change.

6. Conclusion

In response to global changes in trade costs, in all of our multi-sector models and single sector models with intermediates or labor-leisure choice, we find that the ranking of global welfare gains is $|M| > |K| > |A|$**.** We find that the Krugman model captures the majority of the increase in the gains above the Armington model. Regarding individual regions, however, we find several cases of reversed welfare rankings. i.e., $|M| < |K| < |A|$. Terms-of-trade effects are the usual explanation for the larger gains in the Armington model. When we have $|M| < |K|$, we usually find that the variety externality is greater in the Krugman model, reflecting a shift in expenditure shares toward sectors with smaller variety gains or less of a variety increase in the Melitz model. With unilateral increases in tariffs, for the majority of regions in our model, we found that the Armington model produced gains, while the monopolistic competition models produced losses. We conclude that for individual regions, the welfare ranking of the Armington, Krugman and Melitz market structures is model, data, scenario and parameter dependent.

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Table 1: Breaking the Equivalence: Labor-Leisure Choice, Intermediates and Multiple Sectors

Impacts of Global Ten Percent Reduction in Iceberg Trade Costs

Results are Hicksian Equivalent Variation as a Percent of Consumption

All scenarios include trade imbalances, but have zero tariffs and a single primary factor

	1	2	3	4	5	6	7	8	9
	Labor-Leisure Choice			Cobb-Douglas Demand for Intermediates					
	Single Sector-No intermediates			Single Sector			Four Sectors		
	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz
Region	σ^A = 5.58*	σ^K = 5.58*	σ^M=5.0; a=4.58*	σ^A = 5.58*	σ^K = 5.58*	σ^M=5.0; a=4.58*	σ^A = 6.12*	σ^K = 5.64*	σ^M=5.0; a=4.58*
Australia-New Zealand	3.1%	3.23%	3.26%	3.2%	4.2%	4.4%	3.59%	3.71%	3.66%
Canada	4.1%	4.32%	4.36%	4.1%	5.1%	5.3%	4.2%	6.3%	6.9%
China	4.0%	4.19%	4.23%	3.9%	6.7%	7.5%	3.5%	9.8%	12.5%
Japan	2.1%	2.25%	2.27%	2.3%	2.9%	3.1%	2.1%	4.3%	4.9%
Mexico-Chile-Peru	4.8%	5.02%	5.07%	4.7%	5.9%	6.1%	4.9%	6.4%	6.8%
Low Income NEC	5.7%	6.10%	6.15%	5.7%	7.4%	7.7%	6.5%	5.8%	5.5%
Middle Income NEC	3.3%	3.49%	3.52%	3.4%	4.4%	4.6%	3.7%	3.7%	3.6%
OECD NEC	2.3%	2.42%	2.44%	2.4%	3.2%	3.4%	2.3%	3.8%	4.2%
Philippines	4.6%	4.91%	4.95%	4.7%	5.9%	6.1%	4.8%	7.2%	7.8%
United States	1.7%	1.85%	1.86%	1.9%	2.3%	2.4%	1.9%	2.8%	3.0%
average for the World	2.69%	2.85%	2.87%	2.79%	3.76%	3.98%	2.80%	4.34%	4.83%

* σ^A is the Armington elasticity of substitution between goods and services from different regions; σ^K (σ^M) is the Dixit-Stiglitz elasticity of substitution between varieties in a Krugman (Melitz) sector; and "a" is the shape parameter in the Pareto distribution.

Source: Authors' estimates.

Table 1 (continued)--the Feenstra ratio and Proportional Changes in the Terms-of-trade (TOT).*

	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16
	Labor-Leisure Choice					Cobb-Douglas Demand for Intermediates					Cobb-Douglas Demand for Intermediates				
	Single Sector-No intermediates					Single Sector					Four Sectors				
	Armington	Krugman		Melitz		Armington	Krugman		Melitz		Armington	Krugman		Melitz	
Region	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra
Australia-New Zealand	1.004	1.004	1.030	1.004	1.031	1.005	1.005	1.019	1.005	1.020	1.021	1.013	1.016	1.013	1.014
Canada	1.007	1.008	1.040	1.007	1.042	1.003	1.004	1.025	1.004	1.027	1.009	1.020	1.029	1.021	1.037
China	1.008	1.009	1.037	1.009	1.039	1.003	1.006	1.020	1.007	1.024	0.993	1.003	1.030	1.004	1.042
Japan	0.996	0.996	1.023	0.996	1.023	0.999	0.998	1.0145	0.998	1.0149	0.990	0.999	1.021	0.999	1.026
Mexico-Chile-Peru	1.011	1.012	1.044	1.012	1.046	1.007	1.009	1.028	1.008	1.030	1.012	1.013	1.030	1.012	1.033
Low Income NEC	1.007	1.009	1.059	1.009	1.061	0.998	1.001	1.037	1.001	1.039	1.016	1.009	1.028	1.009	1.025
Middle Income NEC	1.006	1.006	1.032	1.006	1.033	1.005	1.006	1.020	1.005	1.021	1.014	1.003	1.018	1.002	1.013
OECD NEC	0.996	0.996	1.025	0.996	1.025	0.998	0.997	1.015	0.997	1.016	0.993	0.997	1.018	0.997	1.020
Philippines	1.001	1.002	1.051	1.002	1.051	0.996	0.997	1.033	0.997	1.034	0.997	1.006	1.037	1.006	1.042
United States	0.983	0.9828	1.023	0.9832	1.022	0.987	0.984	1.015	0.985	1.014	0.987	0.986	1.0172	0.987	1.0174
average for the World															

*See section 3 for a definition of the Feenstra ratio. We present the inverse of the Feenstra ratio, so an increase is a decline in the cost of a unit of utility due to variety increases. In the Armington model, the Feenstra ratio = 1 in all cases, so is not presented.

Source: Authors estimates

Table 2: Intermediate Modeling Structure with Four Sectors. Impacts with a Ten Percent Iceberg Cost Reduction*   Results are Hicksian Equivalent Variation as a Percent of Consumption

		1	2	3	4	5	6	7	8	9
	domestic trade share	Cobb-Douglas Demand Single Composite Intermediate			Cobb-Douglas Demand for Intermediates ; real data			Elasticity of Substition for Intermediates = 0.5; real data		
		Armington	**Krugman**	**Melitz**	**Armington**	**Krugman**	**Melitz**	**Armington**	**Krugman**	**Melitz**
Region	λ_{rr}	σ^A = 5.86*	σ^K = 5.59*	σ^M=5.0; a=4.58*	σ^A = 6.13*	σ^K = 5.65*	σ^M=5.0; a=4.58*	σ^A = 5.96*	σ^K = 5.61*	σ^M=5.0; a=4.58*
Australia-New Zealand	89.3%	3.5%	3.7%	3.7%	3.59%	3.71%	3.66%	3.6%	3.1%	3.0%
Canada	84.4%	4.3%	5.3%	5.5%	4.2%	6.3%	6.9%	4.2%	5.0%	5.2%
China	91.1%	3.6%	7.8%	9.1%	3.5%	9.7%	12.5%	3.5%	6.1%	6.7%
Japan	91.6%	2.1%	3.4%	3.6%	2.1%	4.3%	4.9%	2.0%	3.2%	3.5%
Mexico-Chile-Peru	82.9%	4.8%	6.0%	6.2%	4.9%	6.4%	6.8%	4.8%	5.4%	5.5%
Low Income NEC	76.9%	6.3%	6.2%	6.1%	6.5%	5.8%	5.5%	6.5%	5.0%	4.7%
Middle Income NEC	88.3%	3.6%	3.8%	3.9%	3.68%	3.70%	3.58%	3.6%	3.1%	3.0%
OECD NEC	91.4%	2.3%	3.3%	3.6%	2.3%	3.8%	4.2%	2.3%	3.0%	3.1%
Philippines	79.2%	4.7%	6.5%	6.8%	4.8%	7.2%	7.8%	4.8%	5.9%	6.1%
United States	90.6%	1.9%	2.4%	2.5%	1.9%	2.8%	3.0%	1.9%	2.28%	2.34%
average for the World	90.0%	2.77%	3.83%	4.09%	2.80%	4.34%	4.83%	2.76%	3.32%	3.42%

*All scenarios with four IRTS sectors and trade imbalances included; but single primary factor and zero tariffs. See table 1 for the definition of parameters.

Source: Authors' calculations.

Table 2 (continued): --the Feenstra ratio and Proportional Changes in the Terms-of-trade*

	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16
	Cobb-Douglas Intermediate Single Composite Intermediate					Cobb-Douglas Demand for Intermediates real data					Elasticity of Substition for Intermediates = 0.5 real data				
	Armington	Krugman		Melitz		Armington	Krugman		Melitz		Armington	Krugman		Melitz	
Region	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra
Australia-New Zealand	1.0186	1.0110	1.0160	1.0112	1.0157	1.0209	1.0129	1.0159	1.0134	1.0139	1.0220	1.0113	1.0134	1.0112	1.0119
Canada	1.0103	1.0117	1.0251	1.0116	1.0272	1.0091	1.0199	1.0290	1.0207	1.0366	1.0108	1.0160	1.0236	1.0160	1.0270
China	0.9940	1.0020	1.0242	1.0024	1.0307	0.9928	1.0025	1.0303	1.0036	1.0424	0.9925	1.0000	1.0195	1.0000	1.0229
Japan	0.9927	0.9984	1.0166	0.9981	1.0188	0.9897	0.9991	1.0209	0.9986	1.0265	0.9892	0.9990	1.0160	0.9989	1.0191
Mexico-Chile-Peru	1.0117	1.0122	1.0279	1.0120	1.0302	1.0120	1.0126	1.0304	1.0123	1.0329	1.0129	1.0120	1.0256	1.0117	1.0266
Low Income NEC	1.0141	1.0089	1.0297	1.0090	1.0297	1.0163	1.0092	1.0275	1.0092	1.0255	1.0181	1.0081	1.0240	1.0078	1.0230
Middle Income NEC	1.0125	1.0047	1.0179	1.0046	1.0163	1.0144	1.0030	1.0176	1.0025	1.0134	1.0149	1.0039	1.0147	1.0037	1.0116
OECD NEC	0.9937	0.9967	1.0159	0.9967	1.0172	0.9931	0.9968	1.0181	0.9968	1.0204	0.9925	0.9976	1.0143	0.9978	1.0155
Philippines	0.9971	1.0049	1.0342	1.0049	1.0382	0.9973	1.0056	1.0372	1.0056	1.0424	0.9982	1.0046	1.0309	1.0047	1.0339
United States	0.9871	0.9865	1.0151	0.9867	1.0148	0.9869	0.9865	1.0172	0.9866	1.0174	0.9866	0.9875	1.0141	0.9879	1.0140
average for the World															

*See section 3 for a definition of the Feenstra ration. In the Armington model, the Feenstra ratio = 1 in all cases.

Source: Authors estimates

Table 3: Multiple Primary Factors, Sector-Specific Factors and Labor-Leisure Choice—Impacts of a Ten Percent Global Iceberg Cost Reduction

Results are Hicksian Equivalent Variation as a Percent of Consumption

All scenarios with four sectors; trade imbalances and initial tariffs incorporated; intermediates with CES demand**

	1	2	3	4	5	6	7	8	9	10	11	12
	Labor as the single factor			Three mobile factors			Three mobile factors			Three mobile factors		
	Sector Specific Factor: No			Sector Specific Factor: No			Sector Specific Factor: Yes			Sector Specific Factor: Yes		
	Labor-Leisure Choice: No			Labor-Leisure Choice: No			Labor-Leisure Choice: No			Labor-Leisure Choice: Yes		
	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz
Region	σ^A = 5.98*	σ^K = 5.60*	σ^M=5.0; a=4.58*	σ^A = 5.97*	σ^K = 5.60*	σ^M=5.0; a=4.58*	σ^A = 5.81*	σ^K = 5.59*	σ^M=5.0; a=4.58*	σ^A = 5.81*	σ^K = 5.59*	σ^M=5.0; a=4.58*
Australia-New Zealand	3.8%	3.4%	3.3%	3.8%	3.4%	3.3%	3.8%	3.6%	3.5%	3.74%	3.87%	3.88%
Canada	4.4%	5.1%	5.3%	4.4%	5.1%	5.3%	4.3%	5.0%	5.2%	4.3%	5.5%	5.7%
China	4.0%	6.5%	7.2%	4.0%	6.5%	7.1%	3.9%	6.1%	6.5%	3.9%	6.7%	7.4%
Japan	2.2%	3.4%	3.7%	2.2%	3.4%	3.6%	2.2%	3.2%	3.4%	2.2%	3.4%	3.7%
Mexico-Chile-Peru	5.0%	5.5%	5.7%	5.0%	5.5%	5.6%	5.0%	5.4%	5.5%	4.9%	5.7%	5.9%
Low Income NEC	7.9%	6.7%	6.5%	7.9%	6.7%	6.5%	7.8%	7.4%	7.4%	7.8%	8.0%	8.1%
Middle Income NEC	4.3%	3.8%	3.6%	4.3%	3.8%	3.6%	4.2%	4.0%	3.9%	4.2%	4.2%	4.2%
OECD NEC	2.5%	3.2%	3.4%	2.5%	3.2%	3.4%	2.5%	3.0%	3.1%	2.5%	3.3%	3.4%
Philippines	5.0%	6.1%	6.3%	5.0%	6.0%	6.3%	5.0%	5.8%	6.0%	5.0%	6.2%	6.5%
United States	2.0%	2.3%	2.4%	2.0%	2.3%	2.4%	1.9%	2.3%	2.3%	2.0%	2.5%	2.6%
average for the World	3.08%	3.63%	3.74%	3.07%	3.62%	3.73%	3.03%	3.53%	3.63%	3.03%	3.82%	3.99%

* See table 1 for the definition of the parameters.
**CES demand for intermediates with elasticity of substitution = 0.5.
Source: Authors' estimates.

Table 3 (continued): the Feenstra ratio and Proportional Changes in the Terms-of-trade*

	1	2	3	4	5	7	8	9	10	11
	Labor as the Single Factor					Three Mobile Factors				
	Sector Specific Factor: No					Sector Specific Factor: No				
	Labor-Leisure Choice: No					Labor-Leisure Choice: No				
	Armington	Krugman		Melitz		Armington	Krugman		Melitz	
Region	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra
Australia-New Zealand	1.022	1.011	1.013	1.011	1.012	1.022	1.011	1.013	1.011	1.012
Canada	1.011	1.016	1.024	1.016	1.027	1.011	1.016	1.024	1.016	1.027
China	0.992	1.000	1.019	1.000	1.023	0.992	1.000	1.019	1.000	1.023
Japan	0.988	0.998	1.016	0.998	1.019	0.988	0.998	1.016	0.998	1.019
Mexico-Chile-Peru	1.013	1.012	1.025	1.012	1.027	1.013	1.012	1.025	1.012	1.026
Low Income NEC	1.020	1.010	1.024	1.010	1.025	1.020	1.010	1.024	1.010	1.025
Middle Income NEC	1.016	1.005	1.014	1.005	1.012	1.016	1.005	1.014	1.005	1.012
OECD NEC	0.992	0.997	1.014	0.998	1.015	0.992	0.997	1.014	0.998	1.015
Philippines	0.998	1.005	1.031	1.005	1.034	0.998	1.005	1.031	1.005	1.034
United States	0.986	0.987	1.014	0.987	1.014	0.986	0.987	1.014	0.987	1.014
average for the World										

	12	13	14	15	16	17	18	19	20	21
	Three Mobile Factors					Three Mobile Factors				
	Sector Specific Factor: Yes					Sector Specific Factor: Yes				
	Labor-Leisure Choice: No					Labor-Leisure Choice: Yes				
	Armington	Krugman		Melitz		Armington	Krugman		Melitz	
Region	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra
Australia-New Zealand	1.023	1.014	1.014	1.014	1.013	1.022	1.014	1.015	1.014	1.015
Canada	1.011	1.015	1.023	1.015	1.026	1.011	1.015	1.025	1.015	1.029
China	0.992	0.998	1.018	0.998	1.021	0.992	0.998	1.020	0.998	1.024
Japan	0.989	0.997	1.015	0.996	1.018	0.989	0.996	1.016	0.996	1.019
Mexico-Chile-Peru	1.013	1.013	1.025	1.012	1.026	1.013	1.013	1.026	1.012	1.028
Low Income NEC	1.021	1.017	1.027	1.017	1.029	1.020	1.018	1.029	1.018	1.032
Middle Income NEC	1.016	1.008	1.015	1.008	1.014	1.016	1.008	1.016	1.008	1.015
OECD NEC	0.992	0.996	1.014	0.996	1.015	0.992	0.995	1.015	0.995	1.016
Philippines	0.998	1.003	1.030	1.003	1.032	0.998	1.003	1.032	1.003	1.035
United States	0.986	0.986	1.014	0.986	1.013	0.986	0.986	1.015	0.986	1.015
average for the World										

*See section 3 for a definition of the Feenstra ratio. In the Armington model, the Feenstra ratio = 1 in all cases.
Source: Authors estimates

Table 4: Global Free Trade, Uniform Tariffs and Iceberg Cost Reduction in a More Realistic Nine-Sector Model.

All scenarios with: Ten Regions, 4 CRTS and 5 IRTS sectors in the monopolistic competition models; initial tariffs and trade imbalances; Cobb-Douglas demand for three factors of production where part of the third factor is sector specific; and intermediates with CES demand based on data shares and elasticity of substitution = 0.5.

Results are Hicksian equivalent variation as a percent of consumption

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	10% reduction in iceberg costs			10% reduction in iceberg costs			Global Free Trade			Global Free Trade			Global Free Trade		
							Uniform Tariff: No			Uniform tariff: Yes			Uniform Tariff: No		
	Labor-Leisure Choice: No			Labor-Leisure Choice: Yes			Labor-Leisure Choice: No			Labor-Leisure Choice: No			Labor-Leisure Choice: Yes		
	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz
Region	$\sigma^A = 6.03$*	$\sigma^K = 5.55$*	$\sigma^M=5.0; a=4.58$*	$\sigma^A = 6.04$*	$\sigma^K = 5.55$*	$\sigma^M=5.0; a=4.58$*	$\sigma^A = 8.00$*	$\sigma^K = 5.81$*	$\sigma^M=5.0; a=4.58$*	$\sigma^A = 6.88$*	$\sigma^K = 5.88$*	$\sigma^M=5.0; a=4.58$*	$\sigma^A = 8.03$*	$\sigma^K = 5.83$*	$\sigma^M=5.0; a=4.58$*
Australia-New Zealand	3.3%	2.8%	2.9%	3.3%	2.9%	3.0%	0.6%	0.8%	0.9%	0.2%	0.1%	0.1%	0.6%	0.9%	1.0%
Canada	4.2%	4.8%	4.9%	4.2%	5.0%	5.1%	0.2%	0.4%	0.5%	0.1%	0.3%	0.3%	0.2%	0.5%	0.6%
China	4.0%	4.8%	4.6%	4.0%	5.2%	5.2%	0.3%	-1.4%	-2.4%	0.0%	0.5%	0.4%	0.3%	-1.2%	-2.2%
Japan	2.3%	3.0%	3.2%	2.3%	3.1%	3.3%	0.4%	1.2%	1.5%	0.1%	0.3%	0.4%	0.4%	1.3%	1.6%
Mexico-Chile-Peru	4.7%	4.9%	4.9%	4.6%	5.0%	5.1%	-0.1%	-0.03%	0.03%	0.2%	0.3%	0.3%	-0.1%	0.0%	0.1%
Low Income NEC	7.1%	10.4%	11.0%	7.1%	11.6%	12.7%	-0.2%	0.1%	0.2%	-0.1%	1.4%	2.4%	-0.2%	0.6%	0.9%
Middle Income NEC	3.7%	3.7%	3.7%	3.7%	3.7%	3.8%	-0.2%	0.0%	0.1%	-0.2%	-0.1%	-0.1%	-0.2%	0.0%	0.2%
OECD NEC	2.6%	3.0%	3.1%	2.6%	3.2%	3.3%	0.4%	1.1%	1.2%	0.1%	0.4%	0.4%	0.4%	1.2%	1.4%
Philippines	5.2%	6.2%	6.4%	5.2%	6.3%	6.6%	0.1%	0.5%	0.7%	0.3%	0.6%	0.7%	0.1%	0.5%	0.7%
United States	2.0%	2.2%	2.2%	2.1%	2.3%	2.4%	0.36%	0.39%	0.5%	0.1%	0.1%	0.1%	0.37%	0.40%	0.5%
average for the World	2.96%	3.31%	3.36%	2.96%	3.47%	3.55%	0.24%	0.40%	0.41%	0.05%	0.22%	0.25%	0.24%	0.48%	0.51%

* See table 1 for definitions of elasticities. **Source: Authors' estimates**

Table 4 (continued): the Feenstra ratio and Proportional Changes in the Terms-of-trade*

	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
	10% Reduction in Iceberg Costs					10% Reduction in Iceberg Costs					Global Free Trade					Global Free Trade					Global Free Trade				
											Uniform Tariff: No					Uniform Tariff: Yes					Uniform Tariff: No				
	Labor-Leisure Choice: No					Labor-Leisure Choice: Yes					Labor-Leisure Choice: No					Labor-Leisure Choice: No					Labor-Leisure Choice: Yes				
	Armington	Krugman		Melitz		Armington	Krugman		Melitz		Armington	Krugman		Melitz		Armington	Krugman		Melitz		Armington	Krugman		Melitz	
Region	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra	TOT	TOT	Feenstra	TOT	Feenstra
Australia-New Zealand	1.014	1.008	1.010	1.007	1.012	1.015	1.010	1.010	1.009	1.013	1.015	1.020	1.000	1.020	1.002	1.007	1.007	1.000	1.006	1.000	1.016	1.021	1.000	1.021	1.002
Canada	1.006	1.014	1.019	1.014	1.022	1.006	1.015	1.020	1.015	1.023	0.999	1.000	1.001	1.000	1.001	1.003	1.004	1.001	1.003	1.001	0.999	1.000	1.001	1.000	1.001
China	0.997	1.001	1.010	1.001	1.011	0.996	1.000	1.012	1.000	1.013	1.003	1.011	0.993	1.011	0.995	0.998	0.999	1.001	0.999	1.001	1.003	1.010	0.994	1.010	0.996
Japan	0.998	1.007	1.010	1.008	1.011	0.998	1.006	1.010	1.007	1.012	1.011	1.023	1.002	1.025	1.004	1.005	1.006	1.001	1.006	1.001	1.010	1.022	1.003	1.024	1.005
Mexico-Chile-Peru	1.009	1.017	1.018	1.017	1.023	1.009	1.018	1.019	1.017	1.024	0.995	0.995	0.999	0.995	1.000	1.005	1.005	1.000	1.005	1.001	0.995	0.995	1.000	0.995	1.000
Low Income NEC	1.011	1.044	1.021	1.045	1.050	1.012	1.050	1.023	1.053	1.058	0.977	0.983	1.000	0.978	1.008	0.986	1.017	0.995	1.027	1.021	0.977	0.987	1.001	0.984	1.014
Middle Income NEC	1.005	1.002	1.013	1.001	1.013	1.006	1.003	1.014	1.002	1.014	0.985	0.979	1.001	0.978	1.000	0.991	0.991	1.000	0.991	1.000	0.985	0.979	1.001	0.979	1.000
OECD NEC	0.998	0.997	1.010	0.997	1.010	0.998	0.996	1.011	0.996	1.011	1.003	1.005	1.003	1.006	1.003	1.005	1.004	1.001	1.003	1.001	1.003	1.005	1.003	1.006	1.003
Philippines	1.002	1.019	1.023	1.019	1.031	1.002	1.018	1.024	1.019	1.032	0.996	0.996	1.002	0.997	1.002	1.006	1.010	1.001	1.010	1.003	0.996	0.996	1.002	0.997	1.002
United States	0.991	0.983	1.011	0.984	1.010	0.990	0.983	1.012	0.983	1.010	1.016	1.010	1.000	1.010	1.000	1.006	1.003	1.000	1.002	1.000	1.016	1.010	1.000	1.009	1.000

*See section 3 for a definition of the Feenstra ratio. In the Armington model, the Feenstra ratio = 1 in all cases.
Source: Authors estimates

Table 5: Impact of a *Unilateral* Increase in the Tariff Rates to a Uniform Forty Percent, Starting from Initial Tariffs.

All results are for the region raising the tariffs*

Model is the same as in table 4 with labor-leisure choice

	Hicksian Equivalent Variation as a percent of consumption				Terms of Trade Changes				Feenstra ratios	
Region	**Armington**	**Krugman**	**Melitz**		**Armington**	**Krugman**	**Melitz**		**Krugman**	**Melitz**
Australia-New Zealand	0.34%	1.029%	1.031%		113.4%	114.4%	114.9%		100.2%	99.7%
Canada	0.80%	-0.71%	-1.01%		116.5%	114.5%	114.6%		99.4%	98.3%
China	0.91%	-4.12%	-4.72%		116.2%	113.5%	113.3%		98.6%	98.3%
Japan	0.41%	-1.52%	-1.79%		115.5%	113.6%	113.6%		99.2%	98.9%
Mexico-Chile-Peru	1.17%	-0.46%	-0.74%		115.7%	112.5%	112.8%		99.6%	98.2%
Low Income NEC	0.16%	-0.21%	-0.33%		111.6%	110.7%	111.0%		99.9%	98.6%
Middle Income NEC	0.82%	0.61%	0.55%		114.8%	114.7%	114.9%		99.9%	99.6%
OECD NEC	0.66%	-0.79%	-1.03%		117.4%	116.3%	116.3%		99.4%	99.3%
Philippines	0.86%	-1.97%	-2.30%		119.6%	114.9%	115.3%		99.0%	97.6%
United States	1.88%	0.51%	0.40%		125.8%	124.1%	124.1%		99.4%	99.3%

*Thirty simulations: separate simulations for each region-market structure pair, with only the results for the region raising the tariffs shown.

Source: Authors' estimates.