Online Appendix—Sensitivity Analysis for "Comparison of Welfare Gains in the Armington, Krugman and Melitz Models"

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In this appendix we investigate the sensitivity of our results to: (i) our three calibration strategies for holding the trade response equal; (ii) the structural gravity estimate; (iii) not holding trade responses equal; (iv) increases rather than decreases in global iceberg trade costs; and (v) the labor supply elasticity.

A.1 Sensitivity to the Calibration Strategy for Holding the Trade Responses Equal

We find that our results are robust to our choice among our calibration strategies. We consider the following calibration strategies (defined in section 2.2 of the main text):

Calibration Strategy 1: hold the global trade responses equal;

Calibration Strategy 2: minimize the differences in the trade responses of the ten regions of the model;

Calibration Strategy 3: hold the trade responses of one region equal;

Calibration Strategy 3A: hold the trade responses of the USA equal;

Calibration Strategy 3B: hold the trade responses of the OECD NEC equal.

With respect to global shocks to trade costs, calibration strategy 1 is our central strategy. We assess the sensitivity of the results of using calibration strategy 1 to calibration strategies 2, 3A and 3B.

When we analyze welfare results and trade cost shocks in one region only, as in our unilateral tariff increases in section 3.6, we view calibration strategy 3 as the conceptually dominant strategy. Nonetheless, we execute these unilateral tariff simulations with calibration strategy 1 and find small differences. In particular, the sign of the welfare change for all ten regions in all three market structures is unchanged and the ranking of the welfare change among the Melitz, Krugman and Armington models is unchanged. See Balistreri and Tarr (2018) for the results of unilateral tariff increases with calibration strategy 1.

For our global shock, we evaluate the sensitivity of the welfare results to both a shock of a global ten-percent reduction in iceberg trade costs and the shock of moving to global free trade. We employ our nine-sector, ten-region policy model, which we used for the results in table 4a (columns 4-6 and 13-15). *Since we continue to take the trade response from the Melitz model, results for the Melitz model are independent of the calibration strategy.*

First compare the results between calibration strategies 1 and 2. The results are in table A.1, Panels A and, B. Consider the comparison of our global results (or average for the world). In the Krugman model, under both calibration strategies, the results for the average for the world with either iceberg cost reductions or global free trade are identical. In the Armington model, calibration strategy 2 yields larger Armington trade elasticities, resulting in larger welfare estimates for all regions. The ratio of gains in Melitz (and Krugman) relative to Armington fall to $M = (1.15)A$ for iceberg and $M = (1.70)A$ for the global free trade scenario. This compares to $M = (1.20)A$ for iceberg and $M = (2.08)A$ for global free trade under calibration strategy 1. But the ranking $M > K > A$ is preserved and there are no sign changes in the welfare rankings of any region, except the Middle Income Region with iceberg cost changes.

We execute the iceberg cost decrease and global free trade scenarios in the ten-region model using calibration strategy 3A for the United States and calibration strategy 3B for OECD NEC. We display the results in Panel C for the United States and Panel D for the OECD NEC. Since calibration strategy 3A (3B) holds the trade responses of the United States (OECD NEC) equal, it is designed to assess how much of a difference it makes for the results for the United States (OECD NEC) compared to calibration strategy 1. In Panels A, C and D, we highlight in bold the results we compare.

For the Krugman model, the results for either the United States or the OECD NEC are very close. The maximum difference is one hundredth of a percent welfare change as a percent of consumption either with iceberg cost reductions or global free trade.

For the Armington model, with iceberg trade costs reductions, the results are also close for either the United States or the OECD NEC. With global free trade, due to lower Armington elasticities with calibration strategies 3A and 3B, the Armington welfare estimates are slightly lower in Panel C for the United States and Panel D for OECD NEC. Calibration strategies 3A and 3B in this case preserve and accentuate the differences in the welfare ranking of $A_r < K_r < M_r$

$K = (3.19)A$ $K = (2.83)A$ in Panel A. For these two largest regions of the model, the results are robust between calibration strategies 1 and 3A or 3B.

Table A.1: Sensitivity to the Three Calibration Strategies of the Trade Response:

Global Free Trade and Global Iceberg Cost Reduction Scenarios in the Nine-Sector Policy Model

Iceberg costs scenario employs the model used for table 4a, columns 4-6;
Global Free Trade scenario employs the model used for table 4a, columns 13-15;
Results are Hicksian equivalent variation as a percent of consumption

	Panel A: Calibration Strategy 1: Hold the Global Trade Response Equal						Panel B: Calibration Strategy 2: Minimization of the Sum of the Squares of the Differences in the Regional Trade Responses					
	10% reduction in iceberg costs			Global Free Trade			10% reduction in iceberg costs			Global Free Trade		
	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz
Region	σ^A = 6.04*	σ^K = 5.55*	σ^M=5.0; a=4.58*	σ^A = 8.03*	σ^K = 5.83*	σ^M=5.0; a=4.58*	σ^A = 6.75*	σ^K = 5.57*	σ^M=5.0; a=4.58*	σ^A = 9.47*	σ^K = 5.54*	σ^M=5.0; a=4.58*
Australia-New Zealand	3.32%	2.91%	2.96%	0.58%	0.92%	1.04%	3.43%	2.92%	2.96%	0.67%	0.92%	1.04%
Canada	4.17%	4.97%	5.11%	0.18%	0.46%	0.57%	4.30%	4.97%	5.11%	0.23%	0.48%	0.57%
China	3.98%	5.25%	5.16%	0.30%	-1.15%	-2.17%	4.15%	5.25%	5.16%	0.34%	-1.36%	-2.17%
Japan	2.27%	3.13%	3.27%	0.44%	1.33%	1.60%	2.33%	3.13%	3.27%	0.50%	1.37%	1.60%
Mexico-Chile-Peru	4.64%	4.99%	5.08%	-0.05%	-0.01%	0.05%	4.78%	4.99%	5.08%	-0.03%	-0.01%	0.05%
Low Income NEC	7.13%	11.64%	12.72%	-0.19%	0.64%	0.90%	7.43%	11.63%	12.72%	-0.02%	0.73%	0.90%
Middle Income NEC	3.71%	3.74%	3.79%	-0.21%	0.02%	0.16%	3.88%	3.74%	3.79%	-0.17%	0.05%	0.16%
OECD NEC	2.55%	3.17%	3.28%	0.43%	1.21%	1.37%	2.65%	3.17%	3.28%	0.51%	1.24%	1.37%
Philippines	5.22%	6.30%	6.59%	0.14%	0.49%	0.69%	5.40%	6.31%	6.59%	0.17%	0.54%	0.69%
United States	2.06%	2.31%	2.37%	0.37%	0.40%	0.48%	2.13%	2.31%	2.37%	0.41%	0.41%	0.48%
average for the World	2.96%	3.47%	3.55%	0.24%	0.48%	0.51%	3.08%	3.47%	3.55%	0.30%	0.48%	0.51%

	Panel C: Calibration Strategy 3: Hold the Trade Response Equal for the United States						Panel D: Calibration Strategy 3: Hold the Trade Response Equal for the OECD NEC Region					
	10% reduction in iceberg costs			Global Free Trade			10% reduction in iceberg costs			Global Free Trade		
	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz
Region	σ^A = 6.03*	σ^K = 5.50*	σ^M=5.0; a=4.58*	σ^A = 6.92*	σ^K = 5.38*	σ^M=5.0; a=4.58*	σ^A = 5.87*	σ^K = 5.54*	σ^M=5.0; a=4.58*	σ^A = 7.17*	σ^K = 5.72*	σ^M=5.0; a=4.58*
Australia-New Zealand	3.32%	2.90%	2.96%	0.52%	0.92%	1.04%	3.30%	2.91%	2.96%	0.53%	0.92%	1.04%
Canada	4.16%	4.96%	5.11%	0.14%	0.49%	0.57%	4.13%	4.97%	5.11%	0.15%	0.47%	0.57%
China	3.98%	5.24%	5.16%	0.28%	-1.48%	-2.17%	3.94%	5.25%	5.16%	0.29%	-1.22%	-2.17%
Japan	2.27%	3.13%	3.27%	0.40%	1.39%	1.60%	2.25%	3.13%	3.27%	0.41%	1.35%	1.60%
Mexico-Chile-Peru	4.64%	4.98%	5.08%	-0.07%	-0.01%	0.05%	4.61%	4.98%	5.08%	-0.07%	-0.01%	0.05%
Low Income NEC	7.13%	11.65%	12.72%	-0.32%	0.79%	0.90%	7.06%	11.64%	12.72%	-0.29%	0.67%	0.90%
Middle Income NEC	3.71%	3.73%	3.79%	-0.24%	0.06%	0.16%	3.67%	3.74%	3.79%	-0.23%	0.03%	0.16%
OECD NEC	2.55%	3.17%	3.28%	0.37%	1.26%	1.37%	2.53%	3.17%	3.28%	0.38%	1.22%	1.37%
Philippines	5.22%	6.30%	6.59%	0.12%	0.57%	0.69%	5.18%	6.30%	6.59%	0.13%	0.51%	0.69%
United States	2.06%	2.30%	2.37%	0.33%	0.41%	0.48%	2.05%	2.31%	2.37%	0.34%	0.40%	0.48%
average for the World	2.96%	3.47%	3.55%	0.20%	0.48%	0.51%	2.94%	3.47%	3.55%	0.21%	0.48%	0.51%

* See table 3a for definitions of the elasticity parameters.

Source: Authors' estimates.

A.2 Sensitivity to the Trade Response

The key parameters that impact the trade response 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 nine-sector model 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, for a solution to the Melitz model with an untruncated above Pareto distribution of productivities, we must have $a > \sigma^M - 1$. Given our central values of 4.58 for the Pareto shape parameter, the upper bound on σ^M must be less than 5.58.[1] Since 5.0 is the central 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 equal trade responses consistent with the Melitz model.

The detailed results are in tables A.2A and A.2B. As expected, 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). Regarding the sensitivity of our welfare comparisons, we see that the welfare ranking across the three market structures in our central trade response case is unchanged in all but one of the 120 pairwise welfare comparisons in the high and low trade responses cases.[2]

[1] 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.

[2] In table A.2B for the Low-Income Region the ranking between the Krugman and Melitz model changes between the central and high trade response cases.

Table A.2: Sensitivity of the Global Free Trade Welfare Results to a Change in the Trade Response* All results in the Model with Nine-Sectors, Three Primary Factors with Labor-Leisure Choice and Trade Imbalances. Results are Hicksian Equivalent Variation as a Percent of Consumption.

A.2A: Change in the Pareto Shape Parameter**

	Low trade response			Central trade response			High trade response		
	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz
Pareto shape parameter (a)			4.13			4.58			5.03
Armington or Dixit-Stiglitz elasticity	7.53	5.2	5	8.03	5.83	5	8.51	6.38	5
change in global trade share	1.82%	1.82%	1.82%	1.99%	1.99%	1.99%	2.15%	2.15%	2.15%
Region									
Australia-New Zealand	0.5%	0.92%	0.95%	0.6%	0.9%	1.0%	0.6%	0.9%	1.1%
Canada	0.2%	0.50%	0.53%	0.2%	0.5%	0.6%	0.2%	0.4%	0.6%
China	0.3%	-1.6%	-1.9%	0.3%	-1.2%	-2.2%	0.3%	-0.9%	-2.4%
Japan	0.4%	1.4%	1.5%	0.4%	1.3%	1.6%	0.5%	1.3%	1.7%
Mexico-Chile-Peru	-0.1%	0.00%	0.02%	-0.1%	0.0%	0.1%	-0.05%	-0.02%	0.1%
Low Income NEC	-0.2%	0.86%	0.95%	-0.2%	0.6%	0.9%	-0.1%	0.5%	0.8%
Middle Income NEC	-0.2%	0.08%	0.12%	-0.2%	0.0%	0.2%	-0.2%	0.0%	0.2%
OECD NEC	0.4%	1.28%	1.32%	0.4%	1.2%	1.4%	0.5%	1.2%	1.4%
Philippines	0.1%	0.6%	0.7%	0.1%	0.5%	0.7%	0.1%	0.4%	0.7%
United States	0.4%	0.4%	0.4%	0.4%	0.4%	0.5%	0.4%	0.4%	0.5%
average for the World	0.2%	0.5%	0.5%	0.2%	0.48%	0.51%	0.3%	0.48%	0.53%

*The trade response is the change in the global trade share, defined above as $1-\hat{\lambda}_W$. It is calculated in the Melitz model; then the Dixit-Stiglitz and Armington elasticities are adjusted in the Krugman and Armington models such that the trade responses are equal in the three market structures.

**For the high and low value of the Pareto shape parameter, we take plus and minus two standard deviations from the mean of the preferred distribution estimated by Balistreri et al. (2011).

A.2B. Change in the Dixit-Stiglitz Elasticity of Substitution

	High trade response			Central trade response			Low trade response		
	Armington	Krugman	Melitz	Armington	Krugman	Melitz	Armington	Krugman	Melitz
Pareto shape parameter (a)			4.58			4.58			4.58
Armington or Dixit-Stiglitz elasticity	8.25	6.08	4.5	8.03	5.83	5	7.86	5.63	5.5
change in global trade share	2.06%	2.06%	2.06%	1.99%	1.99%	1.99%	1.93%	1.93%	1.93%
Region									
Australia-New Zealand	0.6%	0.9%	1.2%	0.6%	0.9%	1.0%	0.6%	0.92%	0.93%
Canada	0.2%	0.5%	0.7%	0.2%	0.5%	0.6%	0.2%	0.47%	0.49%
China	0.3%	-1.0%	-3.8%	0.3%	-1.2%	-2.2%	0.3%	-1.3%	-1.4%
Japan	0.4%	1.3%	1.9%	0.4%	1.3%	1.6%	0.4%	1.36%	1.39%
Mexico-Chile-Peru	-0.05%	0.0%	0.1%	-0.05%	0.0%	0.1%	-0.06%	-0.01%	0.00%
Low Income NEC	-0.2%	0.6%	0.2%	-0.2%	0.6%	0.9%	-0.2%	0.70%	0.75%
Middle Income NEC	-0.2%	0.0%	0.4%	-0.2%	0.0%	0.2%	-0.2%	0.0%	0.1%
OECD NEC	0.4%	1.2%	1.6%	0.4%	1.2%	1.4%	0.4%	1.23%	1.25%
Philippines	0.1%	0.5%	1.0%	0.1%	0.5%	0.7%	0.1%	0.52%	0.55%
United States	0.4%	0.4%	0.6%	0.4%	0.4%	0.5%	0.4%	0.40%	0.42%
average for the World	0.251%	0.479%	0.510%	0.242%	0.478%	0.505%	0.236%	0.477%	0.481%

Source: Authors' Estimates

A.3 Sensitivity to NOT Holding the Trade Responses Equal

To assess the quantitative importance of holding the trade responses equal, we re-estimated all scenarios with global iceberg cost reductions without holding trade responses equal. Given our estimate of the trade elasticity from gravity of $\varepsilon = 4.58$, we solve for the estimate of the Dixit-Stiglitz elasticity of substation σ from the elasticity equation derived by Costinot and Rodriguez-Clare (2014) in the one-sector model (see section 2.1 of the main text). In particular, we have: $\varepsilon + 1 = \sigma = 5.58$. Then we take $\sigma^A = \sigma^K = 5.58$ in all models. These values hold trade responses equal in the one-sector model, but not in multi-sector models. The relative welfare gains are presented in table 5, columns 6-9 of the main text. In all multi-sector models, there are larger differences between the Armington model and the monopolistic competition models, i.e., *M/A* and *K/A* are larger when the trade responses are not equal.

These results show that holding trade responses equal reduces the estimated welfare gains of the Melitz model relative to the Krugman and Armington models and similarly reduces the estimated welfare gains of the Krugman model relative to the Armington model. Therefore, holding trade responses equal raises the bar for the Melitz model to obtain the largest estimated welfare gains of the three market structures from a reduction in trade costs. Nonetheless, when we hold trade responses equal, we find that the Melitz model yields the largest global gains from global trade cost reductions in all our models beyond the first two stylized one-sector models summarized in table 6. A similar comment applies to the comparison between the Krugman and Armington models.

A.4. Symmetry of the Welfare Costs to Trade Cost Increases

While holding trade responses equal, we executed a ten-percent global *increase* in iceberg trade costs in all 14 models in which we executed global decreases in iceberg trade costs. The results preserve the symmetry with trade cost decreases of the *qualitative* ranking that $|M| > |K| > |A|$ in all model variants. Further, the *quantitative* values of $|K|/|A|$ and $|M|/|A|$ are close to being symmetric with iceberg cost decreases. We compare the values of $|K|/|A|$ and $|M|/|A|$ when iceberg costs increase to these ratios when global iceberg costs decrease in the same 14 models. The results are in table A.3. We find these values are within 2/100th in 21 of the 26 cases with a maximum difference of 08/100th.

Table A.3 Sensitivity to Global Iceberg Trade Cost Increases Rather than Decreases

Welfare Gains are Aggregated Equivalent Variation as a Percent of Consumption for the World from a change in global iceberg trade costs.

Armington model welfare gains are indexed at one.	1	2	3	4	5	6
All models contain ten heterogeneous endogenous regions	Trade Responses Held Constant			Trade Responses Held Constant		
	10% Global Iceberg Cost Decrease			10% Global Iceberg Cost Increase		
Model Assumption	**Armington**	**Krugman**	**Melitz**	**Armington**	**Krugman**	**Melitz**
I. Iceberg Trade Costs Change	σ^A = adjusted	σ^K = adjusted	σ^M=5.0; a=4.58	σ^A = adjusted	σ^K = adjusted	σ^M=5.0; a=4.58
I. Global 10% Reduction in Iceberg Trade Costs						
A. One-sector Model						
1. stylized model features*	1	1	1	1	1	1
2. stylized model with trade imbalances**	1	1	1	1	1	1
3. stylized with labor-leisure choice	1	1.06	1.07	1	1.056	1.064
4. stylized with an intermediate good	1	1.35	1.43	1	1.34	1.41
5. stylized with an intermediate good and labor-leisure choice	1	1.61	1.79	1	1.59	1.76
B. Four-Sector Model (one primary factor, no labor-leisure choice)						
6. with one aggregate intermediate good	1	1.38	1.47	1	1.36	1.44
7. with Cobb-Douglas demand for 4 intermediate goods	1	1.55	1.72	1	1.50	1.64
8. with CES demand for 4 intermediates and elas. of sub. = 0.5	1	1.20	1.24	1	1.19	1.23
C. Four-Sector Model (includes intermediates with esub = 0.5 and tariff data)						
9. with 1 mobile primary factor	1	1.18	1.22	1	1.16	1.19
10. with 3 mobile primary factors	1	1.18	1.21	1	1.16	1.19
11. with 3 primary factors with one of them (capital) 20% sector-specific	1	1.16	1.20	1	1.16	1.19
12. with 3 mobile primary factors and labor-leisure choice	1	1.26	1.32	1	1.25	1.31
D. Policy Model(see footnote **)**						
13. Policy Model except no labor-leisure choice	1	1.12	1.13	1	1.12	1.14
14. Policy Model	1	1.17	1.20	1	1.17	1.20

*Stylized model features are: one sector, one fully mobile primary factor; no intermediates; no labor-leisure choice; no initial tariffs; iceberg trade cost policy shock; and multiple regions with balanced trade in all regions.
**All additional models contain data-based trade imbalances.
***Policy Model includes nine sectors, labor-leisure choice, one sector-specific and two mobile primary factors, initial data-based tariffs and trade balances, CES demand for intermediates with data-based shares and elasticity of substitution of 0.5 and ten heterogeneous regions; the monopolistic competition models contain four Armington and five monopolistically competitive sectors,
Source: Authors' estimates.

A.5. Sensitivity to the Labor Supply Elasticity

We estimate the welfare effects where we assume larger elasticities of labor supply with respect to the real wage. We find that the estimated welfare gains in the monopolistic competition models increase relative to the Armington model.

To calibrate our CES utility function for leisure and goods, we use estimates of the compensated and uncompensated elasticities of labor supply with respect to the real wage. For our central value of the compensated elasticity, we take the value of 0.5, which is the preferred estimate of Chetty (2012, p. 1015); for the uncompensated elasticity, we take the value of 0.25 from Evers *et al*., (2008, p.40).[3] These labor supply elasticities imply our central elasticity of substitution between leisure and consumption is 2 and the share of total income spent on leisure is 0.25.[4]

We do sensitivity to the impact of labor-leisure on the welfare results of table 2a by increasing the uncompensated male elasticity of labor supply from 0.1 to 0.2; this value is within the 95 percent confidence interval of Evers *et al.* (2008). Then the uncompensated elasticity of labor supply increases to 0.31 while we preserve the value of the compensated elasticity of 0.5 from Chetty (2012). Since more labor supply leads to more varieties, the advantage of the monopolistic competition models increases compared to the results of table 3a. We obtain $M = (1.09)A$ and $K = (1.07)A$ compared with $M = (1.07)A$ and $K = (1.06)A$ in table 3a; and for all regions *r*, $M_r > K_r > A_r$.

We also employ this larger elasticity of labor supply in our policy model of table 5a with iceberg cost changes. Again, the advantage of the monopolistic competition models increases, as we obtain $M = (1.22)A$ and $K = (1.19)A$ with iceberg cost decreases, which is an increase from $M = (1.20)A$ and $K = (1.17)A$ in table 4a.

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[3] The uncompensated elasticity is a weighted average of 0.5 for females (at 38 percent of the labor force) and 0.1 for males, where the male and female elasticities are the preferred estimates of the meta study of Evers *et al*., (2008, p.40).

[4] The relationship between the labor supply elasticities and our CES parameters is: $\sigma^l = \varepsilon_{\bar{u}} / (\varepsilon_{\bar{u}} - \varepsilon)$ and $\theta = \varepsilon_{\bar{u}} - \varepsilon$, where $\varepsilon_{\bar{u}}(\varepsilon)$ is the compensated (uncompensated) elasticity of labor supply with respect to the real wage, σ^l is the elasticity of substitution between leisure and goods, and θ, is the share of total income spent on leisure in benchmark total income.