Online Appendix

Literature Review for "Comparison of Welfare Gains in the Armington, Krugman and Melitz Models: Insights from a Structural Gravity Model"

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This review begins with a summary of welfare equivalence of market structures result of Costinot, and Rodriguez-Clare (2012) and various results in a one-sector model that break that welfare equivalence in one-sector models. The review then surveys results in multi-sector models and includes table A.1 that summarizes all results from the literature prior to Balistreri and Tarr (2018). In the main text, we produce a table that summarizes all the results of our 18 model variants including a column that identifies which results are new to the literature.

Results in One-Sector Models

The Welfare Equivalence Result.

Arkolakis, Costinot, and Rodriguez-Clare (2012) show analytically that the welfare impacts of a global reduction in iceberg trade costs in the Armington, Krugman, and Melitz style models are identical in a what we call the "stylized one-sector model," provided the changes in the trade flows (what we call the trade responses) are held equal across the three market structures consistent with a common gravity estimate. We call this the welfare equivalence result. In their "stylized one-sector model" or simply "stylized model," Arkolakis *et al*. (2012) assume one production sector, no intermediates, no labor-leisure choice, one factor of production (with no sector-specific component), balanced trade in all of their multiple regions and no tariffs; they also take a parsimonious policy experiment---a global change in "iceberg" trade costs.

Breaking the Welfare Equivalence Result.

Arkolakis *et al*. (2012) however, find, two results that break the welfare equivalence: (i) with an aggregate intermediate good, the monopolistic competition models produce larger welfare gains than the Armington model; and (ii) adding additional sectors to their stylized model might break the welfare equivalence result, but the impact of additional sectors on the ranking of welfare gains across market structures is ambiguous.

Melitz and Redding (2015) impose a finite upper bound on the Pareto distribution of productivities in the stylized one-sector model of Arkolakis *et al*. (2012). They find that in response to a global decrease in trade costs, there are larger welfare gains in the Melitz model compared to the

Krugman model; and in response to a global increase in trade costs, the absolute value of the welfare losses is smaller in the Melitz model compared to the Krugman model.[1]

We explain in the main text why we believe it is important in a welfare comparison of market structure to hold trade responses equal consistent with a gravity estimate. The remaining papers in the literature have not held trade responses equal consistent with a gravity estimate.

Balistreri, Hillberry and Rutherford (2010) and Arkolakis and Esposito (2014) add a labor-leisure choice to the stylized one-sector model of Arkolakis *et al*. (2012) and find that the Melitz model yields larger welfare gains than the Armington model if and only if the elasticity of supply of labor with respect to the real wage is positive. These papers, however, did not include intermediates.

Multi-Sector Models

In a multi-sector model with initial tariffs and an aggregate intermediate good, Balistreri, Hillberry and Rutherford (2011) find larger gains in the Melitz model than in the Armington model global tariff reductions.[2] Jafari and Britz (2017) add non-tariff measures to the model of Balistreri *et al*. (2011) and find larger welfare gains in the Melitz model than in the Armington model from regional integration.

Using numerical methods, Costinot and Rodriguez-Clare (2014) extend to explicit tariff changes (starting from zero initial tariffs) the two results of Arkolakis *et al.* (2012) that break the welfare equivalence.[3] Costinot and Rodriguez-Clare (2014) quantify the impact of several additional model extensions, but only in the Armington structure. We show that one cannot infer what will happen in the monopolistic competition models based on the Armington model; even the sign of the impact may reverse. Costinot and Rodriguez-Clare (2014) report quantitative results in the Armington model for the following model extensions: (i) unilateral tariff changes; (ii) intermediate goods with input shares based on data from the input-output tables; (iii) non-uniform tariff changes; and (iv) multiple primary factors of production as opposed to labor as the sole primary factor. Our results show: (i) regarding unilateral tariff changes, the monopolist competition models produce significantly lower optimal tariffs than the Armington model; (ii) the relative gains from trade of the monopolistic competition models over Armington increase with data-based intermediate shares, but (iii) decrease with diverse tariffs based on data compared to uniform tariffs; and (iv) the Costinot and Rodriguez-Clare result of a very small impact

[1] Fernandes *et al*. (2019) show that if the Pareto distribution is replaced by the log- normal distribution in a heterogeneous-firms model, the trade responses differ significantly, but the welfare results in the one-sector Melitz model are not significantly changed.

[2] See also Balistreri and Rutherford (2013) for details of how to numerically model heterogeneous firms.

[3] In the special case of autarky exercises, trade responses must be held equal if all models are calibrated such that they are in equilibrium with the initial trade data. Numerical general equilibrium trade models, such as the GTAP model (Aguiar *et al*. 2019) and models based on the GAMS/MPSGE software of Rutherford (1999) are generally calibrated in this manner. Consequently, unlike in their richer comparative-static exercises, in the autarky exercises reported by Costinot and Rodriguez-Clare (2014, table 4.1), they hold trade responses equal. See section 2.1.1 of the main text for details.

of incorporating multiple factors of production under Armington is robust to the extension to the monopolistic competition models.[4]

[4] 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.

References

Aguiar, A., M. Chepeliev, E. Corong, R. McDougall and D. van der Mensbrugghe (2019), "The GTAP Data Base: Version 10," *Journal of Global Economic Analysis*, Vol. 4(1), 1-27. Available from: https://www.jgea.org/ojs/index.php/jgea/article/view/77

Arkolakis, Costas and Federico Esposito (2014), "Endogenous Labor Supply and the Gains from International Trade," unpublished manuscript. Available at: https://cpb-us-west-2-juc1ugur1qwqqqo4.stackpathdns.com/campuspress.yale.edu/dist/f/704/files/2014/11/Endogenous-labor-supply.pdf

Arkolakis, Costas, Arnaud Costinot and Andres Rodriguez-Clare (2012), "New Trade Models, Same Old Gains?" *American Economic Review*, 102(1), 94–130.

Balistreri, Edward J., Russell H. Hillberry and Thomas F. Rutherford (2011), "Structural Estimation and Solution of International Trade Models with Heterogeneous Firms," *Journal of International Economics*, Vol. 83(2), 95-108.

Balistreri, Edward J., Russell H. Hillberry and Thomas F. Rutherford (2010), "Trade and Welfare: Does Industrial Organization Matter," *Economics Letters*, 109(2), 85–87.

Balistreri, Edward J. and Thomas F. Rutherford (2013), "Computing General Equilibrium Theories of Monopolistic Competition and Heterogeneous Firms," in *Handbook of Computable General Equilibrium Modeling*, Vol 1B," P. Dixon and D. Jorgenson (eds.), 1513-1570, Amsterdam: Elsevier.

Balistreri, Edward J. and David G. Tarr (2020), "Comparison of Deep Regional Integration in the Melitz, Krugman and Armington models: the case of The Philippines in RCEP," *Economic Modeling,* Vol. 85, February, 255-271.

Balistreri, Edward J. and David G. Tarr (2018), "Comparison of Welfare Gains in the Armington, Krugman and Melitz Models: Insights from a Structural Gravity Model," World Bank Policy Research Working Paper No. 8570, September. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3247295.

Costinot, Arnaud and Andres Rodriguez-Clare (2014), "Trade Theory with Numbers: Quantifying the Consequences of Globalization," in *Handbook of International Economics,* Elhanan Helpman, Kenneth Rogoff and Gita Gopinath (eds.), Vol. 4, 197-262, Amsterdam: Elsevier.

Dixon, Peter, Michael Jerie and Maureen Rimmer (2018), *Trade Theory in Computable General Equilibrium Models: Armington, Krugman and Melitz*, Singapore: Springer.

Fernandes, Ana M, Peter Klenow, Sergii Meleshchuk, Martha Denisse Pierola and Andres Rodriguez-Clare (2019), "The Intensive Margin in Trade," CESifo Working Paper No. 7540. Available at: https://www.cesifo.org/en/publikationen/2019/working-paper/intensive-margin-trade

Jafari, Yaghoob and Wolfgang Britz (2018), "Modelling Heterogeneous Firms and Non-Tariff Measures in Free Trade Agreements Using Computable General Equilibrium," *Economic Modelling*, Vol. 73, June, 279-294.

Melitz. Marc J. and Stephen J. Redding (2015), "New Trade Models, New Welfare Implications," *American Economic Review*, Vol. 105(3), 1105-1146.

Rutherford, Thomas F. (1999), "Applied General Equilibrium Modeling with MPSGE as a GAMS Subsystem: An Overview of the Modeling Framework and Syntax," *Computational Economics*, Vol. 14, 1-46.

Table A.1: Summary of Literature Results: Relative Welfare Gains from the Armington, Krugman and Melitz Style Models

Key: *A, K, M* = Value of global welfare gains in Armington, Krugman and Melitz, respectively from a reduction in global trade costs. $|A|, |K|, |M|$ as their absolute values from an increase in global trade costs.

	Model Assumptions **Stylized Model defined:** One sector, no intermediates, labor is the only factor of production, no labor-leisure choice, zero trade balances between regions, zero tariffs, global iceberg cost decrease.	**Trade Responses Held Equal**	**Ranking of Welfare Gains**	**Authors**
	1. One Sector Models, Multiple Regions: (iceberg trade cost decreases)			
1.1	**Stylized model**	Yes	$A = K = M$	Arkolakis *et al*. (2012)
1.2	Stylized model with one aggregate intermediate good	Yes	$M > A;\ K > A$	Arkolakis *et al*. (2012)
1.3	Stylized model with labor-leisure choice	No	$M > A^{*}$	Balistreri *et al*. (2010)
1.4	Stylized model with finite upper bound on the Pareto distribution of productivity	Yes	$M > K$	Melitz and Redding (2015)
1.5	Stylized model with a log-normal productivity distribution compared to the Pareto distribution; plus trade imbalances incorporated.	No	*M*(log-normal) ≈ *M*(Pareto)	Fernandes *et al.* (2019)
1.6	Stylized model with multiple sectors	Yes	$M \neq K \neq A$	Arkolakis *et al*. (2012)
	2. Computer Simulations, Multiple Sectors and Regions, Move to Autarky Exercises			
2.1	Stylized model with multiple sectors**	Yes	$\|A\| > \|K\| = \|M\|$ **	Costinot and Rodriguez-Clare (2014, table 4.1, cols. 2,3)
2.2	Same as row 2.1 and one aggregate intermediate good	Yes	$\|M\| > \|K\| > \|A\|$ **	Costinot and Rodriguez-Clare (2014, table 4.1, cols. 5-7)
	3. Computer Simulations, Multiple Sectors and Regions, Comparative Static Exercises			
3.1	Stylized model with multiple sectors. Tariffs are zero initially. Policy shock: global uniform tariff of 40%.	No	$\|K\| > \|M\| > \|A\|$ **	Costinot and Rodriguez-Clare (2014, table 4.3, cols. 1-3)
3.2	Same as row 3.1 and one aggregate intermediate good	No	$\|M\| > \|K\| > \|A\|$ **	Costinot and Rodriguez-Clare (2014, table 4.3, cols. 4-6)
3.3	One aggregate intermediate good, no labor-leisure choice, multiple primary factors with initial tariff data and trade balances. Policy shock: global 50% reduction in tariffs in the Melitz sector.	No	$M > A$	Balistreri *et al*. (2011, table 6)
3.4	Same as row 3.1 with initial tariff data. Unilateral *increase* of tariffs by one region in the single Melitz sector.	No***	$A > M$	Dixon *et al*. (2018)
3.5	Same as row 3.3 except multiple intermediates. Policy: Preferential elimination of tariff and non-tariff barriers between the US and EU.	No	$M > A$ for the US and the EU	Jafari and Britz (2017, table 6)

*If the elasticity of labor supply to the traded goods sector is negative (zero), the estimated welfare gain under Melitz is less than (equal to) Armington. The methodology was a computer simulation.

**Based on average for the world. They define the "gains" from international trade as the absolute value of the real income change associated with the increase in trade costs.

***The Dixon *et al*. (2018) result is for the region (North America) that raises the tariff. They report that they hold the trade response constant in North America for the one Melitz sector in the model, but not the aggregate trade response of North America.