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Tariff: the most beautiful word in the dictionary?

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Abstract:
We consider the welfare impacts of US tariff policy at the levels proposed by President Trump. A transparent trade model reveals sizable welfare losses for the US, and these losses explode under more elaborate general-equilibrium models of trade.

JEL codes: C68, F12, F17

Keywords: Trump tariffs; Trade wars; China Tariffs.

1. Introduction

> ”To me, the most beautiful word in the dictionary is tariff, and it’s my favorite word.” Donald J. Trump, October 2024, Economic Club of Chicago (see Leonard, 2024).

A long standing responsibility of trade economists is to comment on the welfare effects of tariffs. This is particularly important as global politics move us away from the principles of cooperative trade as administered through the World Trade Organization. Measurement of the impacts of tariffs is, however, controversial because it requires the application of scarce and imprecise data in the context of model assumptions. Quantitative, and even qualitative, impacts are often conditional on model assumptions. The approach in contemporary economic analysis is to reveal these sensitivities as a path to robust inference.

We consider general equilibrium simulations over alternative model structures in a welfare analysis of Donald Trump’s campaign promise to impose broad-based tariffs. We also include partner retaliation as a feature of recent policy experience. We find robust evidence that the 60% minimum tariffs against China and 10% minimum tariffs on other trade partners, with symmetric retaliation, are costly in terms of US and global welfare.[1] How costly depends on the assumed structure. The simulations are comparative static, abstracting

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[1] Trump’s tariff proposals from the campaign, and post election, seem to be under continuous revision, where the revisions are more or less aggressive without reason. To establish a stationary target of analysis we pick one set of proposals—60% minimum tariffs on China and 10% minimum tariff on everyone else (Wolff, 2024). As argued by Bekkers et al. (2019), our recent experience with trade wars reveal them to be political not rational. In this regard we do not approach the scenarios as *Nash* interactions. The *Nash* literature is reviewed in Bekkers et al. (2019).

from intertemporal macroeconomic responses. In this regard they are not intended as forecasts. Rather they are ex ante measures of policy costs relative to the benchmark annual accounts and conditional on the assumed scenarios and structures.

We begin with a transparent model suggested by Anderson and van Wincoop (2003), which is widely acclaimed in the trade literature, and we find that the proposed tariffs, with symmetric retaliation, will cost the US close to $100 billion. Adding real-world features to the model (e.g., production, multiple sectors, traded intermediate inputs, and benchmark distortions) the welfare cost of the tariffs rises to $300 billion. Pushing the structure forward to a model of bilateral firms engaged in monopolistic competition in the manufacturing and business-services sectors the welfare costs for the US rise to over $900 billion.

The results from more complex models are criticized for their dependence on myriad assumptions and imprecisely estimated data. We replace, for example, the assumptions of no production responses and no intermediate inputs in the Anderson and van Wincoop model with one of a particular functional form for the production functions across 57 sectors in each region. Primary-factor and intermediate-input relations are those that accommodate the Global Trade Analysis Project (GTAP) data. The data are documented in Aguiar et al. (2023). The criticism is fair with regard to the assumed functional form as well as the data and measured price response parameters. This structural approach is useful, nonetheless, because the sensitivity of any result can be explored by changing the assumptions and data. As argued by Balistreri and Tarr (2022b), the one-sector stylized gravity model (i.e., Anderson and van Wincoop, 2003) mandates a particular set of restrictions and data simplifications on the more complex models commonly employed in policy analysis. Following Balistreri and Tarr (2022a) one can always work backward from the complex models to the transparent Anderson and van Wincoop (2003) model by adding restrictions on the data and structure.

We find empirical support for our multi-sector general-equilibrium structure in the limited econometric work examining the US's recent shift to protectionism. Fajgelbaum et al. (2020a), as updated in Fajgelbaum et al. (2020b), identify changes in sectoral US-market surplus induced by the 2019 US tariffs and retaliation. Summing across the sectors, their formulaic calculation of the net welfare change for the US is -$24.8 billion.[2] This lies between our estimates, in a comparable scenario, of -$16.9 billion under perfect competition and -$81.3 billion under imperfect competition. Relative to the Fajgelbaum et al. (2020b) estimates our perfect competition mulit-sector model yields relatively conservative welfare impacts. In contrast our imperfect competition model, which includes extensive-margin (variety) losses, indicates much larger losses. This indicates a key oversight in the formulaic based welfare analysis, because it fails to consider within-sector variety losses. In an analysis even closer to ours, Clausing and Lovely (2024) extrapolate the Fajgelbaum et al. (2020a) welfare analysis to Trump's proposal of 60% minimum China tariffs and 10% minimum across-the-board tariffs—but without retaliation. Clausing and Lovely report a welfare loss of 1.8% of GDP, which calculates to -$350 billion (applied to our reported GDP level). Under our perfect-competition structure we calculate the welfare change from this

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[2] The Fajgelbaum et al. (2020a) formula includes three components for each sector: the increase in the tariff inclusive cost of the benchmark import basket, the increase in the value of the benchmark export basket, and the change in tariff revenues. The authors use econometric evidence from the actual tariff changes to inform the price changes needed to apply the formula.

scenario to be -\$104 billion, and under imperfect competition the calculated loss is -\$511 billion. The conclusion is the same as for the 2019 trade war. We find important differences in our measures, which include extensive-margin adjustments and their induced variety impacts on welfare.

Taking the welfare results from any complex set of calculations seriously requires either a degree of trust or a non-trivial engagement with the documentation. We do not ask either from the reader. For those sympathetic to the *black box* critique of large-scale models, the results from the Anderson and van Wincoop model (or the formulaic calculations of Clausing and Lovely, 2024) are sufficient to make our primary point—the economic effects of tariffs at the levels of Trump's rhetoric do not match the beauty he finds in the word. Our secondary point is that adding model features and data, which we find reasonable and even compelling, indicate an explosive increase in the ugly consequences for the US and global efficiency. We even illustrate a central case where, under coordinated retaliation, the US bears a disproportionate share (250%) of the global cost and most other countries, including China, benefit from the trade conflict.

2. Anderson and van Wincoop (2003) model and reference simulations

The Anderson and van Wincoop (2003) trade structure is compactly represented in the general-equilibrium system proposed by Balistreri and Hillberry (2008).[3] With R regions there are $4R$ equilibrium conditions associated with $4R$ variables. Let $r \in R$ or $s \in R$ index regions. Under constant-elasticity-of-substitution (Armington, 1969) preferences over regional goods priced at p_r the true-cost-of-living indexes, P_s, are equal to the unit expenditure functions as extended to include tariff rates, t_{rs}:

$$P_s = \left[\sum_r \phi_{rs} [(1 + t_{rs}) p_r]^{1-\sigma} \right]^{1/(1-\sigma)}, \tag{1}$$

where σ is the substitution elasticity and the bilateral weights, ϕ_{rs}, can be interpreted as reflecting a combination of preference weights and (iceberg) transport costs. Letting U_s indicate a measure of money-metric indirect utility (with basis at initial prices) and scaling the ϕ_{rs} such that $P_s = 1 \; \forall s$, we can calculate bilateral compensated demand by applying the envelope theorem:

$$h_{rs}(\boldsymbol{p}, U_s) = U_s \frac{\partial P_s(\boldsymbol{p})}{\partial [(1 + t_{rs}) p_r]},$$

where we denote the vector of all prices $\boldsymbol{p}$. The function $P_s(\boldsymbol{p})$ is the right-hand side of equation (1). Let the endowment in region-r be denoted $\bar{e}_r$. These endowments will equal the sum of their compensated demands indicating the international market-clearance conditions:

$$\bar{e}_r = \sum_s \phi_{rs} U_s \left(\frac{P_s(\boldsymbol{p})}{(1 + t_{rs}) p_r} \right)^{\sigma}. \tag{2}$$

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[3] An alternative but consistent formulation is provided by Yotov et al. (2016, p. 74), in what they call their unconditional general-equilibrium.

Nominal income in region-r is the value of the endowment plus tariff revenue:

$$Y_r = p_r \bar{e}_r + \sum_s t_{sr} p_s \phi_{sr} U_r \left(\frac{P_r(\boldsymbol{p})}{[(1+t_{sr})p_s]} \right)^{\sigma}. \tag{3}$$

Finally, we compute the numeric value of indirect utility as real income

$$U_r = \frac{Y_r}{P_r} \tag{4}$$

offering a convenient measure of money-metric welfare. With initial measured income equal to y^0, counterfactual equivalent variation (EV) is given by the report

$$EV \equiv U_r - y^0.$$

The system of $4R$ equations (1)-(4) in $4R$ variables (U_r, Y_r, P_r, and p_r) suggested by Balistreri and Hillberry (2008) is our preferred environment for computing the unconditional general equilibrium discussed in the gravity literature (Yotov et al., 2016). Of course, in the Balistreri and Hillberry system one price equation is redundant by Walras' law, and we assign a numeraire to compute a unique numeric solution in prices and nominal income. The numeraire choice has no effect on the welfare calculations.

The data requirements for the Anderson and van Wincoop model are strikingly limited. Assuming zero initial tariffs we need a measure of the substitution elasticity and a matrix of (fitted) bilateral trade inclusive of home consumption. This allows us to calibrate the ϕ_{rs} and $\bar{e}_r$ (at assumed unitary benchmark prices) such that the equilibrium conditions are satisfied at the observed benchmark. We adopt $\sigma = 5$ following Anderson and van Wincoop (2003).[4] The trade matrix we use in our transparent central simulations is reported in Table 1. In Appendix A we consider generalizing the trade matrix to accommodate trade imbalances and econometric (PPML) gravity estimation.[5] The values in Table 1 are adapted from the GTAP 11 data. We aggregate to nine global regions to parallel the more complex models considered in the following section (which adopt the data and formulation of Balistreri, Böhringer, and Rutherford, 2024).[6] We aggregate the GTAP net-of-tariff trade to a single good. Then we take the average of trade in each direction, such that trade is balanced. Domestic consumption of domestic goods (the diagonals) are calculated as regional GDP less total exports. This provides a transparent benchmark that is consistent with the Anderson and van Wincoop structure. We extend the basic structure to accommodate benchmark trade imbalances in Appendix A.

We use the Anderson and van Wincoop model to perform a set of diagnostic simulations

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[4] The value of σ assumed by Anderson and van Wincoop (2003) is, in fact, very close to the trade-weighted aggregation of empirically estimated product-specific Armington elasticities reported in the GTAP 11 data. The trade-weighted elasticity of substitution among imports for the 2017 data is 4.93. The product-specific elasticities are used in the more complex models described below.

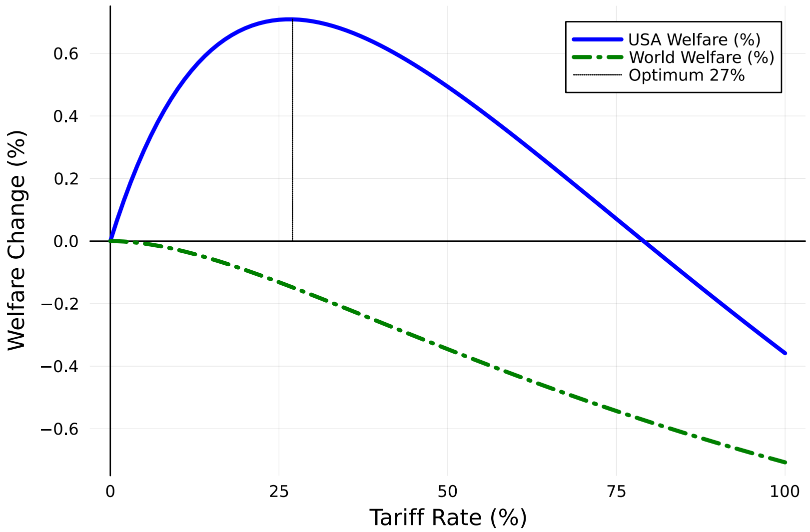
[5] The Poisson Pseudo Maximum Likelihood (PPML) estimator, with source and destination fixed effects, is the preferred econometric method for estimating a structural gravity model (Yotov et al., 2016; Fally, 2015; Santos Silva and Tenreyro, 2006)

[6] The regional aggregation is motivated by the policy intricacies of the 2018 trade war as examined by Balistreri, Böhringer, and Rutherford (2024). The EU-27 plus aggregate region includes the EU, the United Kingdom, and other contiguous non-EU European countries (e.g., Switzerland).

Table 1. Anderson and van Wincoop model trade matrix ($B)

	`USA`	`EUR`	`ROW`	`CHN`	`OEC`	`MRC`	`CAN`	`KOR`	`MEX`
`USA` US	16,962.0	605.8	578.5	362.9	183.8	63.9	331.9	75.5	315.4
`EUR` EU-27 plus	605.8	16,060.7	1,090.1	429.0	276.8	73.7	58.9	74.4	38.8
`ROW` Rest of World	578.5	1,090.1	12,633.6	894.3	440.5	83.1	40.9	197.1	30.9
`CHN` China	362.9	429.0	894.3	10,327.5	329.9	62.0	34.3	183.3	28.7
`OEC` Rest of OECD	183.8	276.8	440.5	329.9	5,977.7	12.6	16.4	74.1	11.9
`MRC` Mercosur	63.9	73.7	83.1	62.0	12.6	2,499.0	3.7	6.7	5.7
`CAN` Canada	331.9	58.9	40.9	34.3	16.4	3.7	1,148.7	5.6	8.9
`KOR` S. Korea	75.5	74.4	197.1	183.3	74.1	6.7	5.6	999.0	8.3
`MEX` Mexico	315.4	38.8	30.9	28.7	11.9	5.7	8.9	8.3	710.5
Total	19,479.7	18,708.1	15,989.1	12,651.7	7,323.6	2,810.4	1,649.3	1,623.9	1,158.9

Figure 1. Optimal tariff for the US in the Anderson and van Wincoop (**AVW**) model with no retaliation: US welfare as a function of its tariff rate on all imports



prior to the structural comparison.[7] In Figure 1 we show that the Anderson and van Wincoop structure implies a high optimal tariff for the US.[8] The benchmark is undistorted and

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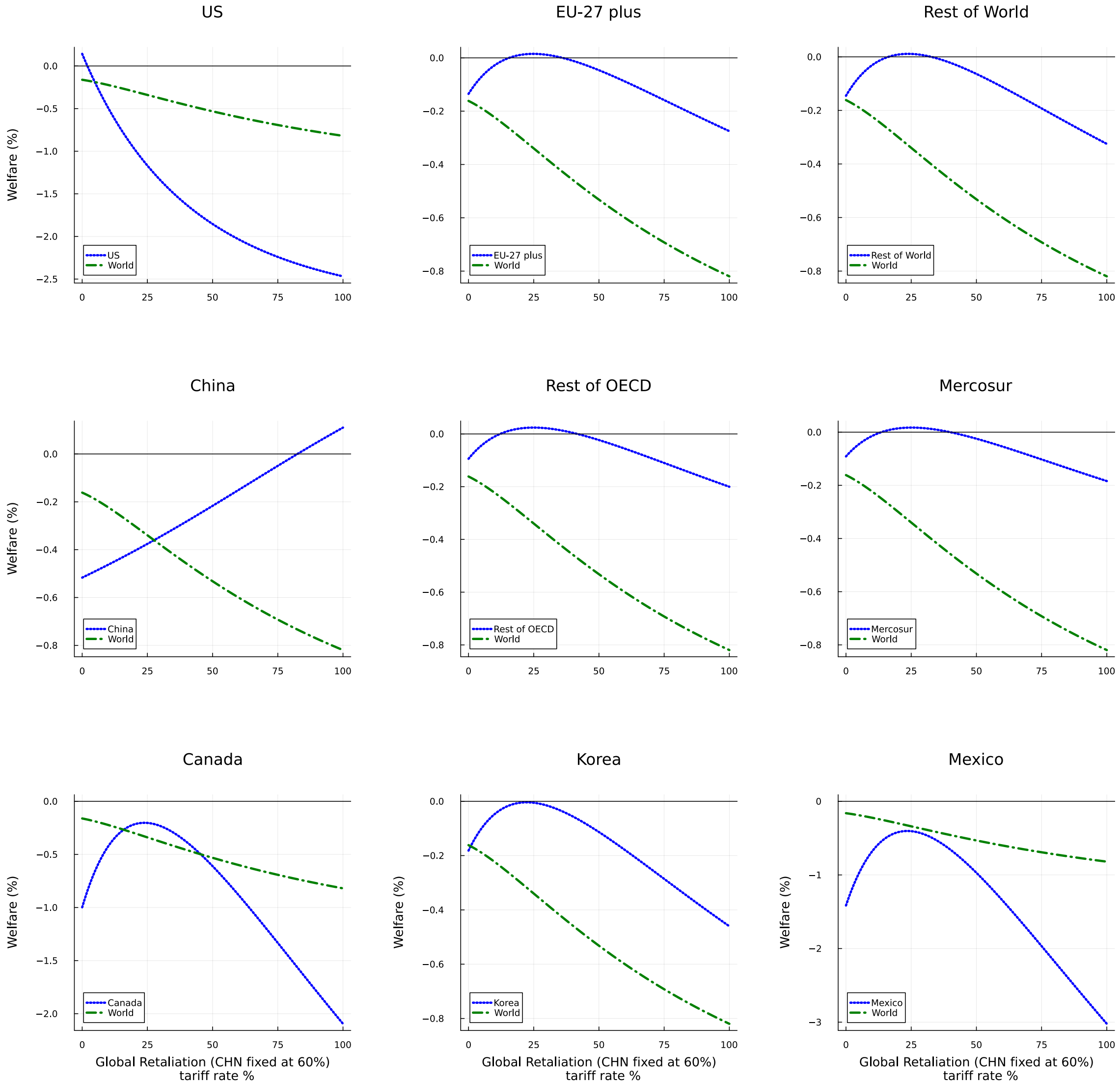
[7] The code used to produce the results for the Anderson and van Wincoop model is available in either the Julia modeling language or in the General Algebraic Modeling System (GAMS) language. The code for the other models used in this paper are available in GAMS.

[8] Brown (1987) explains that Armington models indicate high optimal tariffs because each region has a monopoly in its variety and the tariff is an indirect means of marking up exports, through the terms-of-trade effect of the tariff. Similarly, He et al. (2017) argue that analysis of optimal tariffs and retaliation in numeric simulations are biased by the unrealistically large optimal tariffs implied by the adoption of the Armington structure. While less extreme in the multi-sector model, the high optimal tariffs (exaggerated terms-of-trade gains) implied by the Armington structure likely contribute to our relatively low welfare losses under perfect competition in comparison to the losses reported in Fajgelbaum et al. (2020b) and Clausing and Lovely (2024). Fajgelbaum et al. (2020a) find

Figure 2. Welfare impacts of non-Chinese coordinated retaliation in the **AVW** model (base scenario of reciprocal 60% US-China tariffs and 10% US tariffs on all other imports)



initially US welfare increases as it imposes a uniform tariff against all trade partners. The optimal tariff is 27% with about a 0.71% US welfare gain. At the optimum this represents a $138 billion gain. Global efficiency falls, however, as the US extracts rents from its trade partners. At the optimum, for the US, global welfare falls by 0.15% or $120 billion.[9] Thus, the US's trade partners lose a combined $258 billion when the US imposes its optimal tariff, conditional on the Anderson and van Wincoop structure and data as presented.

The next set of scenarios applied to the Anderson and van Wincoop model includes Trump's proposal to impose a 60% minimum tariff on goods from China and a 10% minimum tariff on all other imports. We also include, in the base scenario, a symmetric retaliation by China. That is, China imposes a 60% minimum tariff on US sourced goods. This base scenario indicates a decrease in global welfare of $131B (0.16%), with the US gaining $28B (0.14%) and China losing $65B (0.52%). In Figure 2 we consider the base scenario with coordinated retaliation by other countries. Each panel of Figure 2 compares the percentage change in the region's welfare relative to the percentage change in global efficiency. At the vertical axis in each panel China is the only country retaliating against the US tariffs. As we move to the right the minimum tariff on all US exports to all countries (except China) escalates from zero to 100%. For everyone except China and the US we see the typical concave welfare functions. For the US, welfare is monotonically decreasing as its terms-of-trade deteriorate. For China, welfare is monotonically increasing as its terms-of-trade improve, and it takes advantage of improved relative trading opportunities with partners other than the US. Notice that at very high tariffs by other countries against the US, above 83%, China actually gains welfare relative to the undistorted benchmark. Unsurprisingly, increased distortions always decrease global welfare. An economic insight foundational to the cooperative-trade objectives of the World Trade Organization.

3. Simulations with perfect and imperfect competition

The Anderson and van Wincoop model provides a transparent starting point for policy analysis, but it ignores realistic features of the data and production responses to the tariffs. In this section we provide simulation results from three alternative models:

AVW: The **Anderson and van Wincoop** model (with tariff instruments) as described in the previous section.

ARM: Trade is in regionally differentiated **Armington** goods. Regional perfectly-competitive production (supply) is responsive to trade policy. There are 57 sectors or industries. Technologies and preferences are calibrated to the details in the GTAP 11 accounts including intermediate inputs, benchmark distortions, and imbalanced trade. The model, as calibrated, is described in Balistreri, Böhringer, and Rutherford (2024), with a more complete documentation of this class of perfectly-competitive models provided by Lanz and Rutherford (2016) and Balistreri and Tarr (2022a).

BRF: This is the **Bilateral Representative Firms** model proposed by Balistreri, Böhringer, and Rutherford (2024). This model maintains the core features of the **ARM** model, but also includes a monopolistically competitive trade formulation for a subset of

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little empirical evidence of US terms-of-trade improvements related to the 2019 trade war.

[9] We measure global welfare under a simple money-metric Bergsonian social welfare function, which is the sum across regions of each region's equivalent variation.

sectors (28 manufacturing and business services sectors). A key feature of this model is that it includes bilateral extensive-margin adjustments.

We cannot fully document the formulation of the **ARM** or **BRF** models in this paper, but we encourage the interested reader to engage with the documentation in Balistreri, Böhringer, and Rutherford (2024) for the **BRF** structure, and Balistreri and Tarr (2022a) and Lanz and Rutherford (2016) for the **ARM** trade structure and general-equilibrium formulation of demand, production, as well as product and factor markets.

> *For review purposes, and because the* **BRF** *structure is novel, we provide the Balistreri, Böhringer, and Rutherford (2024) model description in Appendix B.*

The **ARM** trade model is relatively conventional, and many similar applications can be found in the cited literature. The motivation behind the **BRF** structure is to accommodate bilateral selection and extensive margin adjustments. These margins have become familiar to trade economists following the Melitz (2003) model. The proposed **BRF** structure brings these margins into a computationally tractable applied model with many regions and sectors.[10] The Melitz model is, in fact, formulated on the basis of bilateral representative firms. In contrast, however, the **BRF** structure of Balistreri, Böhringer, and Rutherford does not tie the representative firm to a specific distribution of productivities, nor does it reconcile the profits of inframarginal firms with a national free-entry condition. Rather in the **BRF** structure rents on a bilateral trade link are captured by a bilateral specific factor.[11] A structural comparison of the Melitz and **BRF** models in high-dimensional applications is ongoing, but is beyond the scope of this study. Balistreri, Böhringer, and Rutherford (2024) do compare an implementation of a Krugman (1980) style model with country-wide free entry. The results of the Krugman model are similar to the **ARM** model, but the **BRF** structure indicates much larger welfare impacts of the 2018 US trade war. Our goal with the **BRF** model is to show that bilateral entry (selection) can be material to the welfare analysis, and it is a feature missed in the other structures.

As a first set of diagnostic simulations we consider the prospects of a US unilateral optimal tariff in the calibrated **ARM** and **BRF** models. Both models are calibrated to the same 2017 benchmark with measured distortions. In Figure 3 we impose a minimum US tariff on all imports that rises from 0% to 15%. As the minimum increases the set of tariff changes also rises, because some benchmark tariffs are above the minimum. We hold the tariffs set by other countries fixed (no retaliation). We find a lower optimal minimum tariff in the **ARM** model, 13%, relative to the **AVW** model (27%). This result is to be expected because the **AVW** model does not include benchmark distortions, sector-specific elasticities,

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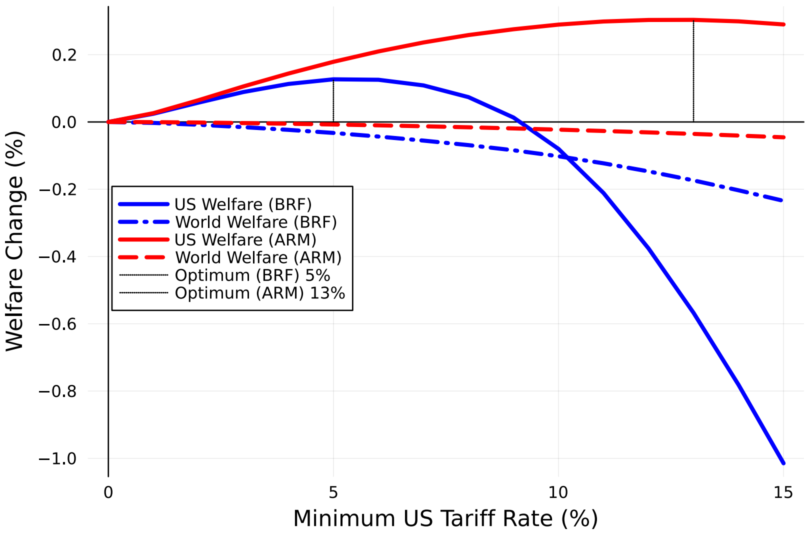
[10] Many authors have now computed versions of the Melitz model with one or a small number of monopolistically competitive sectors (e.g., Balistreri, Hillberry, and Rutherford, 2011; Balistreri, Böhringer, and Rutherford, 2018; Dixon, Jerie, and Rimmer, 2018, ch.7), a fixed number of entered firms (Zhai, 2008), or many completely symmetric sectors and countries with no intermediate inputs (Dixon, Jerie, and Rimmer, 2018, ch.6).

[11] The **BRF** structure has its origins in the single country open-economy models of Rutherford and Tarr (2008) and Jensen, Rutherford, and Tarr (2007). These authors modeled the Russian economy with a set of bilateral trade links that included extensive margin adjustments. Balistreri, Böhringer, and Rutherford (2024) propose a tractable multiregion general equilibrium model with bilateral entry and specific-factor rents.

Figure 3. US optimal minimum tariff in the **ARM** and **BRF** models (benchmark, 2017, tariffs included and no retaliation)



and the effect tariffs have on production through factor misallocation and intermediate-input prices. The optimal US minimum tariff is dramatically lower at 5% under the **BRF** trade structure. This is consistent with the literature considering optimal tariffs under monopolistic competition, when tariffs induce a supply response.[12] We also see in Figure 3 that global welfare drops more dramatically under imperfect competition. This reflects the compounding effect that lost varieties have on a globally inefficient policy.

We now consider the Trump tariff proposals across the structures and scenario variations. Table 2 reports the results from the different scenarios under the three structures. Across the columns we start with scenario (1) which includes the 2018 trade war tariffs. This scenario is a replication of the central scenario in Balistreri, Böhringer, and Rutherford (2024). It includes a careful application of the measured bilateral tariffs between the US and China and the US Steel tariffs (with retaliation and negotiated VERs). We use this as a base scenario given the persistence of the 2018 tariffs and the largely vacuous Phase One agreement. For the **AVW** model calibrated to an undistorted single-sector benchmark, however, we do not include these distortions in the interest of transparency. In that regard, the **AVW** welfare impacts in the other scenarios can be viewed as conservative because benchmark and 2018 distortions are ignored.

In scenario (2) we add the minimum 60% tariff on all Chinese goods entering the US. This is a major policy shift mainly because it significantly increases tariffs on electronic equipment. The tariff-line data compiled by Li (2018), which we use for the 2018 trade war rates, puts the trade-weighted tariff rate on the GTAP electronic equipment good at 8.6%

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[12] See, for example, Balistreri and Markusen (2009) and Balistreri and Tarr (2022b, section 3.6). Felbermayr, Jung, and Larch (2013) explore optimal tariffs in a monopolistic competition trade model with heterogeneous firms. In their one-sector model inter-sectoral misallocations are not possible, but the rent-generating tariffs distort intra-sectoral selection of firms and, therefore, productivity.

Table 2. Welfare impacts across scenarios and structures ($B)

Tariff Scenario:			(1)	(2)	(3)	(4)	(5)	(6)
2018 trade war (not in AVW model)*			yes	yes	yes	yes	yes	yes
USA 60% on CHN				yes	yes	yes	yes	yes
CHN 60% on USA					yes		yes	yes
USA 10% on Others						yes	yes	yes
Others 10% on USA								yes
	Benchmark							
AVW model:	GDP	Cons.	**Equivalent Variation ($B)**					
`USA` US	19,480	19,480		-23.0	-60.8	70.7	27.8	-96.0
`EUR` EU-27 plus	18,708	18,708		2.1	2.5	-25.7	-25.3	-5.2
`ROW` Rest of World	15,989	15,989		3.3	4.2	-24.1	-23.2	-5.0
`CHN` China	12,652	12,652		-44.3	-63.0	-49.5	-65.4	-58.5
`OEC` Rest of OECD	7,324	7,324		1.1	1.4	-7.2	-6.9	-0.7
`MRC` Mercosur	2,810	2,810		0.3	0.3	-2.6	-2.6	-0.4
`CAN` Canada	1,649	1,649		0.7	0.9	-16.6	-16.5	-7.0
`KOR` S. Korea	1,624	1,624		0.6	0.8	-3.2	-3.0	-0.8
`MEX` Mexico	1,159	1,159		0.6	0.9	-16.5	-16.4	-7.9
Total	81,395	81,395		-58.6	-112.7	-74.7	-131.4	-181.6
	Benchmark							
ARM model:	GDP	Cons.	**Equivalent Variation ($B)**					
`USA` US	19,480	13,314	-16.9	-223.3	-272.8	-104.1	-156.6	-310.3
`EUR` EU-27 plus	18,708	10,582	6.1	66.5	82.7	34.1	52.7	87.9
`ROW` Rest of World	15,989	9,648	2.5	48.9	52.6	16.0	23.6	39.4
`CHN` China	12,652	5,071	-12.9	-25.9	-59.6	-34.6	-72.2	-49.6
`OEC` Rest of OECD	7,324	4,085	2.9	25.1	32.6	17.6	25.9	36.7
`MRC` Mercosur	2,810	1,832	2.2	7.2	10.1	3.1	6.1	9.8
`CAN` Canada	1,649	967	0.6	1.1	5.6	-16.2	-10.7	3.4
`KOR` S. Korea	1,624	751	1.7	10.3	16.2	4.3	10.3	19.8
`MEX` Mexico	1,159	754	0.5	2.8	4.8	-9.7	-7.0	7.8
Total	81,395	47,003	-13.5	-87.3	-127.7	-89.6	-127.9	-155.1
	Benchmark							
BRF model:	GDP	Cons.	**Equivalent Variation ($B)**					
`USA` US	19,480	13,314	-81.3	-560.7	-665.5	-511.1	-602.3	-911.9
`EUR` EU-27 plus	18,708	10,582	39.8	176.6	193.5	141.8	162.6	234.6
`ROW` Rest of World	15,989	9,648	23.0	116.2	123.5	74.2	87.7	114.4
`CHN` China	12,652	5,071	-63.3	-70.6	-50.0	-26.2	-25.4	38.2
`OEC` Rest of OECD	7,324	4,085	16.0	65.9	75.1	63.9	73.4	93.9
`MRC` Mercosur	2,810	1,832	5.8	18.8	22.1	15.1	18.8	26.5
`CAN` Canada	1,649	967	1.7	8.3	12.2	-14.1	-9.8	-10.0
`KOR` S. Korea	1,624	751	8.7	26.9	32.1	24.6	29.3	41.0
`MEX` Mexico	1,159	754	2.9	10.8	12.4	-5.3	-3.2	9.1
Total	81,395	47,003	-46.7	-207.9	-244.5	-237.1	-268.8	-364.2

* The product-specific 2018 trade war tariffs and VERs are not applied in the AVW model.

(on a benchmark 2017 trade volume of $200.6 billion). Raising this to 60% is a major shock. In scenario (3) we include retaliation by China with a symmetric 60% tariff on US goods. This is a relatively smaller shock because of the lower trade volumes of US goods entering China (especially in the aftermath of the 2018 trade war).

In scenarios (4) and (5) we explore the impact of adding Trump's blanket minimum 10% tariff on all imports with and without China's retaliation on the 60% minimum tariff against China. While the 60% tariff on China is well above the optimum (scenario 2), the US is shown to have a chance of benefiting in the simple **AVW** model if it adds a 10% tariff on all other trade partners. That is, in scenarios (4) and (5), conditional on the **AVW** model, welfare impacts for the US are positive. This reflects the high uniform optimal US tariff under the **AVW** structure shown in Figure 1. By moving to a more uniform tariff across trade partners, the efficiency loss associated with the relatively high China tariff is mitigated. The potential benefits of the US tariffs disapear when we consider the standard perfect competition structure (**ARM**), the monopolistic competition (**BRF**) structure, or non-Chinese retaliation.

In scenario (6) we consider full symmetric retaliation, with China imposing a minimum 60% tariff on US goods and the rest of the world imposing a minimum 10% tariff on US goods. Under retaliation the US experiences clear adverse impacts of its actions. In scenario (6) the **AVW** model indicates a welfare loss of $96 billion (roughly 0.5% of GDP). The **ARM** and **BRF** models indicate substantially larger welfare losses of $310 billion (1.6% of GDP) and $912 billion (4.7% of GDP).[13] With roughly 130 million households in the US, and conditional on the **BRF** structure, the implied policy cost for the average American household is about $7,000.

A few robust results are revealed across the structures. First, the minimum 60% tariff on Chinese goods is clearly above the optimum. The 60% Chinese tariffs costs the US $23 billion relative to the undistorted **AVW** benchmark. In the more complex models, with benchmark distortions and the 2018 tariffs, the costs of Trump's proposal explode to $223 or $561 billion. Another robust finding, consistent with the theory of trade wars, is that global costs increase as the level of distortion increases. For each of the three models the total welfare losses across regions increase as the level of US tariffs and retaliation increase. Comparing scenarios (3) and (4) the Chinese minimum 60% retaliation against the US is shown to have a larger global efficiency loss than the 10% minimum US tariffs. Notice that the ordinal ranking of the scenarios in terms of global efficiency is the same across each structure. The alternative structures do, however, have a significant impact on the distribution of these costs across regions.

Another robust finding confirms the benefits for China of the US engaging in a reciprocal trade disputes with the rest of the world. Moving from scenario (5) to scenario (6) is consistent with the experiments in Figure 2. China benefits substantially from the tariffs on US goods. There is a terms of trade benefit for China of other countries imposing tariffs on the US. As US exports fall, other countries divert their import demand toward Chinese goods. The US tariffs on non-Chinese imports work in the same direction, as the world market prices of non-US goods fall China can take advantage of these less expensive

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[13] In the **ARM** and **BRF** models we measure equivalent variation in private consumption, which is a smaller base than GDP. At US welfare losses of $310 billion and $912 billion the percentage equivalent variation are calculated as 2.3% and 6.8%.

imports by diverting their imports away from the US.

Although this pattern of trade diversion is consistent across the structures, it is particularly important in a model with extensive margins that amplify the economic effects. Under the **BRF** structure China's welfare is above the benchmark (at a gain of $38 billion) in scenario (6). In fact, all regions, except for Canada and the US, benefit under full retaliation against the US in scenario (6). With monopolistic competition among firms operating on bilateral trade links the US bears 250% of the global cost of the trade conflict. Even in the perfect competition structures we see the residual benefits of trade diversion under either no dispute or under retaliation. With the US and China imposing reciprocal 60% tariffs all other regions have positive welfare impacts in the **AVW** and **ARM** models under scenarios (3) and (6). The US and China bear a disproportionate share of the efficiency cost of their conflict. Other regions benefit from lower import prices for US and Chinese goods, while demand in these markets is diverted to their export goods.

The finding of a positive welfare impact for China in the **BRF** model under scenario (6) is of particular interest. We explore this result further in Figure 4. As a basis for the figure we impose the distortions from scenario (5) and then plot each region's welfare as other countries increase their tariff on US goods. This parallels the analysis for the **AVW** model in Figure 2. Consistent, but more dramatic in the case of the **BRF** model, we show that retaliation for Trump's blanket tariffs give China an advantage. Relative to the 2017 benchmark, China's welfare turns positive under a modest retaliation of about 5% by other countries. Coordinated retaliation at a rate of 10% (scenario 6) creates a situation where many countries are still on the upward sloping portion of their optimal tariff curves. These would include Europe the rest of the OECD as well as Mercosur and Korea. While Mexico is close to its optimum at 10% retaliation, Canada suffers immediate losses from retaliation. Both Canada and Mexico's heavy dependence on the US market are apparent. In contrast, the trade conflict favors the large volume of trade already established between China and Europe.

To this point the analysis has focused on the geographic distribution of policy costs. The more complex models, however, can be used to explore the distributional effects within a region. In Table 3 we consider the impacts on US income decomposed by primary factor or value added by sector under the **BRF** structure for scenario (6). Income measures are inherently numeraire dependent. For Table 3 we measure income using the US consumer's unit expenditure index as the numeraire (analogous to P_s in equation (1)). Thus, the change in private consumption is our measure of equivalent variation. In the first panel of Table 3 we measure real income using the familiar $C + I + G + (X - M)$ decomposition. As a matter of a fair welfare analysis the model is closed by holding the real values of investment, government spending, and the trade imbalance fixed across the scenarios.[14] Changes in these values as reported in Table 3 reflect price changes relative to the price of US private consumption not economic-agent responses.[15]

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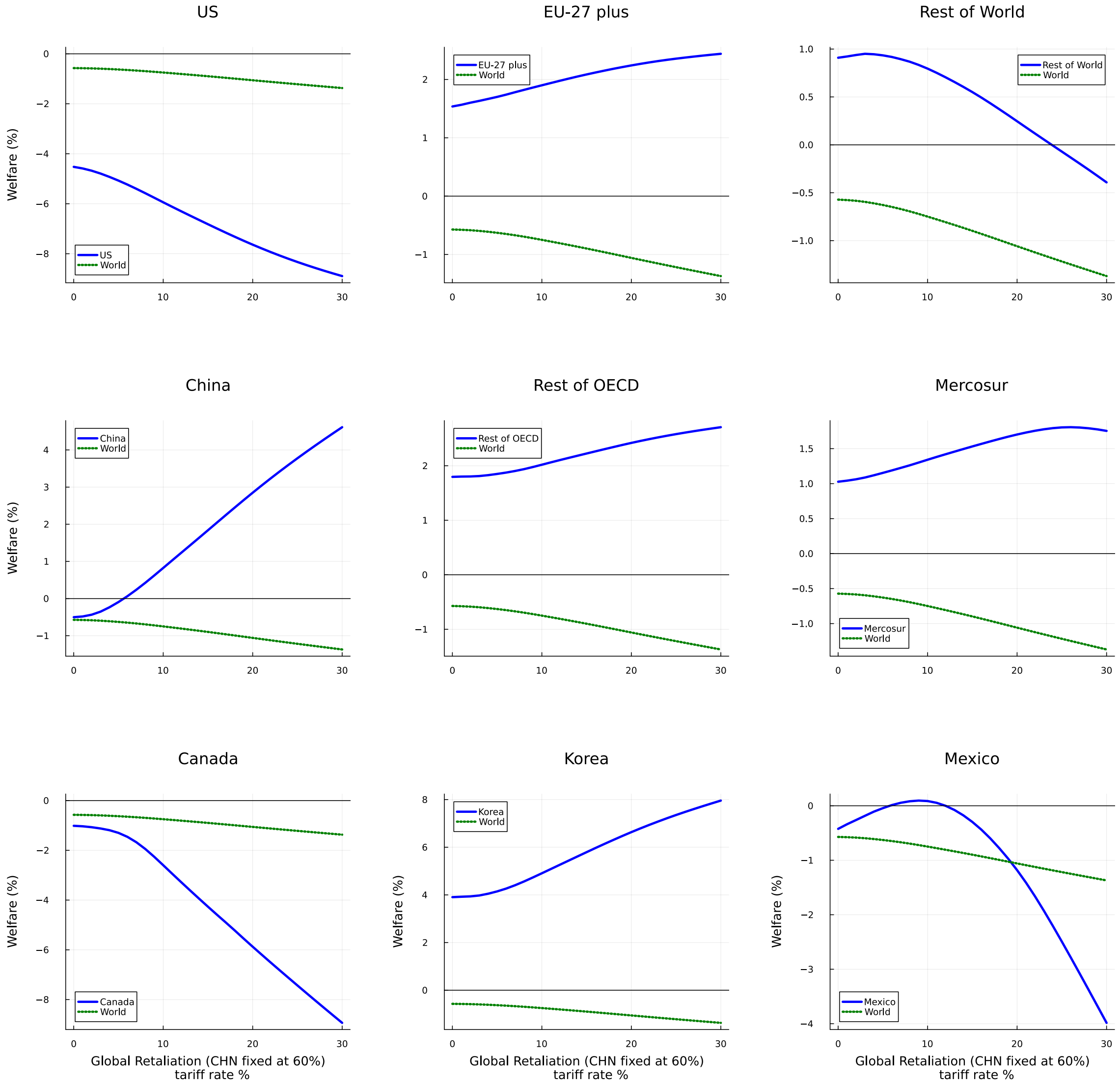
[14] Investment (I) and net international borrowing ($M - X$) involve intertemporal choices that are beyond the scope of our comparative static analysis of tariffs. Government expenditures (G) are assumed to provide a benefit to households that is separable from private consumption. A residual transfer from households reconciles government expenditures with tax revenes.

[15] Investment and government spending are held fixed on a commodity by commodity basis, so the 8.6% increase in investment indicates that the weighted average price of investment goods increased by 8.6% relative to the true-cost-of-living index for private consumption. In contrast, the prices of goods purchased by the government fall by 3.6% on average relative to the cost of con-

Figure 4. Welfare impacts of non-Chinese coordinated retaliation in the **BRF** model
(base scenario of reciprocal 60% US-China tariffs and 10% US tariffs on all other imports)


US

EU-27 plus

Rest of World

China

Rest of OECD

Mercosur

Canada

Korea

Mexico

Table 3. Trump Tariffs with symmetric retaliation (**BRF** model): US income impacts decomposed

	Benchmark ($B)	Change ($B)	Change (%)
(panel 1)			
Expenditures:			
Consumption	13,314	-911.9	-6.8
Investment	4,043	347.8	8.6
Government	2,746	-99.7	-3.6
Net Exports (X-M)	-622	-38.2	6.1
Total	19,480	-702.1	-3.6
(panel 2)			
Income by recipient:			
`LAB` Unskilled Labor	1,493	-105.0	-7.0
`TEC` Technicians and Professionals	868	-65.0	-7.5
`CLK` Clerks	1,118	-84.1	-7.5
`MGR` Managers and Officials	4,187	-315.0	-7.5
`SRV` Services workers	564	-41.0	-7.3
`CAP` Capital	6,466	-466.3	-7.2
`LND` Land	42	-2.7	-6.4
`RES` Resource	81	9.9	12.2
Specific factors	826	280.0	33.9
Direct factor tax	1,990	-145.8	-7.3
Output tax revenue	1,220	-39.7	-3.3
Indirect tax (domestic)	374	-21.6	-5.8
Tariff revenue	212	301.7	142.6
Export tax revenue	36	-7.5	-19.0
Total	19,480	-702.1	-3.6
(panel 3)			
Income by sector:			
`obs` Business services	3,925	-95.5	-2.4
`osg` Public administration, defense, health, education	3,597	-315.2	-8.8
`trd` Trade	2,055	-164.4	-8.0
`dwe` Dwellings	1,377	-105.9	-7.7
`ros` Recreation and other services	1,212	-94.9	-7.8
`cns` Construction	881	-57.7	-6.6
`ofi` Financial services	852	-20.4	-2.4
`cmn` Communication	767	-8.9	-1.2
`isr` Insurance	506	-5.2	-1.0
`omf` Manufactures	453	13.6	3.0
`crp` Chemical, rubber, plastic products	429	20.7	4.8
`eeq` Electronic equipment	368	92.3	25.1

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sumption. Holding net international borrowing fixed requires us to first establish a real commodity unit (or linearly homogeneous index of commodity units) associated with the capital flow. We use the weighted average index of Balistreri, Böhringer, and Rutherford (2024, p27, footnote 10) to denominate international borrowing and lending. The reported change in $(X - M) = 6.1\%$ reflects an increase in this price index relative to the price of private consumption in the US.

`otp` Transport nec	341	-23.1	-6.8
`ele` Electricity	245	-16.9	-6.9
`fmp` Metal products	175	8.4	4.8
`ome` Machinery and equipment	171	15.3	8.9
`mvh` Motor vehicles and parts	148	26.8	18.1
`omn` Minerals	138	-7.7	-5.6
`ofd` Food products	127	3.4	2.7
`atp` Air transport	121	-3.4	-2.8
`cru` Crude Oil	111	23.1	20.9
`ppp` Paper products, publishing	108	1.8	1.6
`b_t` Beverages and tobacco prod	104	1.0	0.9
`wtr` Water	101	-9.3	-9.2
`otn` Transport equipment	100	5.1	5.1
`nmm` Mineral products	52	3.0	5.7
`gas` Natural gas	47	1.2	2.6
`i_s` Ferrous metals	45	8.6	18.9
`v_f` Vegetables, fruit, nuts	43	1.8	4.1
`nfm` Metals	42	5.0	11.8
`oil` Petroleum, coal products	35	9.3	26.8
`frs` Forestry	33	-2.2	-6.9
`lum` Wood products	30	1.8	5.8
`cmt` Meat: cattle,sheep,goats,horse	30	0.7	2.4
`col` Coal	29	-2.5	-8.7
`gdt` Gas manufacture, distribution	29	-2.1	-7.2
`osd` Oil seeds	28	-5.4	-19.1
`oap` Animal products	28	-2.4	-8.6
`mil` Dairy products	26	0.6	2.3
`ctl` Cattle,sheep,goats,horses	24	-1.2	-5.1
`tex` Textiles	23	3.5	15.4
`omt` Meat products	22	1.0	4.6
`wap` Wearing apparel	20	0.9	4.4
`gro` Cereal grains	19	-1.0	-5.4
`wtp` Sea transport	18	-1.2	-6.7
`ocr` Crops	12	2.9	23.1
`sgr` Sugar	10	0.0	-0.2
`lea` Leather products	9	2.6	28.8
`vol` Vegetable oils and fats	9	1.6	17.9
`rmk` Raw milk	8	-0.8	-9.0
`fsh` Fishing	6	-0.1	-1.1
`pfb` Plant-based fibers	6	-0.8	-13.6
`wht` Wheat	6	0.0	-0.8
`c_b` Sugar cane, sugar beet	2	-0.1	-7.4
`pdr` Paddy rice	1	0.0	0.1
`pcr` Processed rice	1	0.1	19.9
`wol` Wool, silk-worm cocoons	0	0.0	-20.4
Consumption	282	-19.4	-6.9
Investment	-46	15.0	-32.6
Government	136	-5.1	-3.7
Total	19,480	-702.1	-3.6

In the second panel of Table 3 we decompose income by its recipients. We hold factor endowments fixed across the scenarios (with no labor-leisure choice), so income changes reflect price responses. For example, unskilled labor returns fall by $105 billion or 7.0% reflecting a 7.0% reduction in the real wage relative to the cost of living. We see that all labor categories, capital, and land experience real income losses in the range of 6.4 to 7.5 percent. The resource endowment (primarily petroleum reserves) gains by 12%. This is attributed to the 10% tariff on crude oil imports. Specific factors associated with the bilateral increasing-returns firms benefit from the tariffs. This is because, although rents on international-trade firms plummet, there are more firms with factors specific to the domestic market. Rents from protection of these domestic-only specific factors dominates. The remaining accounts in panel 2 of Table 3 represent tax revenues. Of course, tariff revenues rise dramatically despite significant import quantity reductions. An endogenous transfer from the government to the household adjusts such that net changes in tax revenues do not result in changes in government expenditures.

In the third panel of Table 3 we examine income as value added by each of the 57 sectors inclusive of net tax payments. The sectors are sorted by their initial value added. Sectors with major losses include those with little trade exposure and export sectors. Oil seeds (soybeans), for example, sees a 19% reduction in farm income. Similarly, income from cereal grains falls by over 5%. There are many import-competing sectors that benefit from the tariffs as the prices of their products increase. Among these are electronic equipment manufacturers (25%), motor vehicles and parts manufacturers (18%), crude extraction (20%), and ferrous metals (19%). The final three accounts in the third panel (C, I, and G) are included to capture the net tax payments directly associated with final demand transactions.

One thing to note about the industry results is the difference between domestic value added and the returns to factors and multinational firms. For example, we see large gains in value added in the motor vehicle and parts industry. Domestic auto production is stimulated by tariffs, but the individual firms face higher intermediate input costs and lose revenue from their foreign affiliates. Overall, we see that inter-sectorally mobile capital and labor returns in the US fall by over 7%. The only factors that are shown to benefit are the sector-specific factors in the protected import-competing industries.

4. Conclusion

We provide a quantitative analysis of President Trump's proposed blanket tariffs across different model structures. Regardless of model structure, the tariffs prove costly. First, the 60% minimum tariff on Chinese goods is well above the optimum. Second, retaliatory tariffs result in significant cost increases for the US. In particular, under 60% reciprocal tariffs with China and 10% reciprocal tariffs with the rest of the world, US welfare falls by between $100 billion and $900 billion depending on the trade structure. These economic modeling results suggest that a US tariff war is not justified as a punitive instrument or as a means of increasing negotiating leverage because, with retaliation, most countries actually gain. Even China gains when we consider the imperfect competition model. The US is shown to bear a disproportionate share of the global costs of the conflict with a burden share of between 53%, in the transparent Anderson and van Wincoop model, to as much as 250%, in the imperfect competition model. In this model we calculate that the annual policy cost to the average US household would be as much as $7,000. This seems a high price to pay for any aesthetic one might attach to *tariffs*.

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Appendix A.

AVW model: Imbalanced trade and econometric (PPML) calibration

In this appendix we consider benchmark trade imbalances and structural gravity estimates in the context of the Anderson and van Wincoop (2003) model. We find changes in the quantitative results, but the findings and conclusions are unchanged. Most of the differences are driven by imbalanced trade (not the econometric calibration). Imbalanced trade, in the context of a comparative static analysis, requires a material abstraction from the intertemporal drivers of the imbalance. The standard assumption to hold the trade imbalance fixed as a proportion of global income leads to an escalation of the US's, already high, optimal tariff in the **AVW** model.

A.1 Imbalanced-trade extension

Trade data is characterized by imbalances. Unlike the constructed data in Table 1, only by chance would the value of a region's exports equal the value of its imports. A net trade surplus in region r indicates that region r is acquiring claims on foreign assets (net lending). A natural feature of the global equilibrium is that some countries will be lending and others borrowing. These inherently intertemporal activities (trade in assets) are beyond the scope of static trade models typically used to analyze tariff policy. To accommodate the imbalances in a transparent comparative static analysis many studies make the simplest assumption possible—that the trade imbalances are exogenous or separable from the tariff experiment.

In Table A.1 we report the source GTAP data used to construct the balanced data in Table 1. These data are presented in this paper for replication purposes and in the interest of transparency of analysis. Any subsequent use of these data may require a GTAP license. In Table A.1 we can measure the capital account surplus for a region r as the difference between the region's consumption and its GDP. Let us define the capital account surplus as follows: $vb_r \equiv C_r - GDP_r$. Under the transparent **AVW** structure investment and government are subsumed in expenditures (consumption), so $GDP_r = C_r + (X_r - M_r)$ or equivalently $-vb_r = (X_r - M_r)$. Thus, $-vb_r$ measures the benchmark trade imbalance (current account balance).

Table A.1. Trade matrix ($B) from GTAP with imbalances

	Importer									
	`USA`	`EUR`	`ROW`	`CHN`	`OEC`	`MRC`	`CAN`	`KOR`	`MEX`	GDP
Exporter										
`USA`	17,280.7	528.8	524.0	208.3	178.3	79.3	331.7	69.2	279.4	19,479.7
`EUR`	682.8	15,967.2	1,055.0	418.2	311.1	83.3	66.8	74.7	49.0	18,708.1
`ROW`	633.0	1,125.2	12,600.9	852.7	459.4	59.0	43.3	184.7	30.8	15,989.1
`CHN`	517.4	439.8	935.8	10,220.8	287.7	48.2	38.4	122.9	40.8	12,651.7
`OEC`	189.4	242.4	421.6	372.1	5,968.3	9.6	15.2	90.7	14.2	7,323.6
`MRC`	48.5	64.0	107.3	75.8	15.5	2,483.3	5.0	5.5	5.4	2,810.4
`CAN`	332.0	50.9	38.5	30.1	17.6	2.4	1,166.5	5.2	5.9	1,649.3
`KOR`	81.8	74.2	209.5	243.7	57.4	7.9	6.0	931.2	12.2	1,623.9
`MEX`	351.4	28.6	31.0	16.6	9.5	5.9	11.9	4.3	699.8	1,158.9
Consumption	20,117.1	18,521.1	15,923.7	12,438.4	7,304.8	2,779.1	1,684.7	1,488.3	1,137.6	81,394.6

Accommodating the trade imbalances in the **AVW** model requires an extension of the theory even if the imbalances are held fixed in counterfactual analysis. We want to hold fixed the net borrowing of region r represented in the measure of vb_r, but to do so we need to make a specific decision about the *real* units associated with the nominal measure vb_r. Dekle, Eaton, and Kortum (2008) hold the proportion of the non-manufacturing regional trade imbalance fixed relative to world income. They normalize on world income. This is equivalent to setting a numeraire (for measuring vb_r) that is the endowment-weighted average of global endowments. This gives us a concrete definition of the units associated with the real claims transferred in the measured vb_r. It is also neutral in that it does not assume that the transfer is in a specific regional numeraire good.

To operationalize the Dekle, Eaton, and Kortum (2008) assumption let us select endowment units such that $p_r = 1 \; \forall r \in R$ at the observed benchmark. Now, define the benchmark endowment share $\gamma_r \equiv \bar{e}_r / \sum_s \bar{e}_s = GDP_r / \sum_s GDP_s$. The Dekle, Eaton, and Kortum normalization can be incorporated into the model by noting that the net capital flow for region r is given by the value $\sum_s \gamma_s p_s (vb_r)$ at any equilibrium and under any numerical choice of numeraire. Clearly, if we normalize on global income (net of tariffs) the value $\sum_s p_s \gamma_s$ is fixed as long as endowments are fixed (and the vb_r are data). Any other valid price normalization is available, however, because we have clearly defined the units associated with the capital transfer (it is the endowment-weighted average of global endowment units). In terms of the model presented in Section 2, consider the relationship between regional expenditures (C_r) and regional income measured in arbitrary numeraire units:

$$C_r = Y_r + \sum_s \gamma_s p_s (vb_r).$$

Now, we simply substitute this into equation (4) such that money-metric indirect utility is given by real expenditures:

$$U_r = \frac{Y_r + \sum_s \gamma_s p_s (vb_r)}{P_r}. \tag{A.1}$$

Notice that this equilibrium condition is properly homogeneous of degree zero in prices. The equilibrium is still defined in $4R$ equations (1), (2), (3), and (A.1) in $4R$ variables (U_r, Y_r, P_r, and p_r), with a unique solution under an arbitrary choice of numeraire. If the capital-account term in (A.1) did not include multiplicative endogenous price(s) associated with the constant vb_r it would not be in numeraire units. Notice also that assuming a fixed ratio of C_r to Y_r would generally be inconsistent with Dekle, Eaton, and Kortum (2008) and fails to clearly define the capital-account unit of transfer.

A.2 Structural gravity under PPML estimation

Authors concerned with a structural interpretation of trade flows often adopt the Anderson and van Wincoop (2003) model as a starting point for deriving an empirical gravity model. Yotov et al. (2016) and, of course, Anderson and van Wincoop show how the basic assumptions of the model presented in Section 2 indicate a gravity equation for trade flows, with importer and exporter fixed effects. Furthermore, applying the Poisson Pseudo Maximum Likelihood (PPML) estimator to the gravity regression generates model-consistent fitted trade flows (Fally, 2015). The assumption is that trade is determined by a set of trade-cost regressors (i.e., distance and borders), fixed effects representing endowments

Table A.2. Trade matrix (\$B) PPML fitted values ($\hat{X}_{rs}$)

	Importer								
	`USA`	`EUR`	`ROW`	`CHN`	`OEC`	`MRC`	`CAN`	`KOR`	`MEX`	GDP
Exporter										
`USA`	17,322.3	410.8	533.7	247.7	321.9	156.2	290.1	37.1	159.9	19,479.7
`EUR`	551.4	16,414.0	741.6	287.6	363.0	131.3	120.5	39.8	58.9	18,708.1
`ROW`	687.2	711.4	12,971.7	529.4	609.4	186.9	142.8	71.3	79.0	15,989.1
`CHN`	351.2	303.7	582.9	10,617.8	484.0	71.7	73.2	127.1	40.3	12,651.7
`OEC`	414.1	348.0	608.9	439.2	5,221.9	88.6	85.3	69.1	48.4	7,323.6
`MRC`	200.0	125.2	185.9	64.8	88.2	2,072.4	38.1	9.1	26.8	2,810.4
`CAN`	328.0	101.5	125.4	58.4	75.0	33.6	889.8	8.7	28.8	1,649.3
`KOR`	65.6	52.4	97.9	158.5	95.0	12.6	13.6	1,120.8	7.6	1,623.9
`MEX`	197.2	54.1	75.6	35.0	46.4	25.8	31.4	5.3	688.1	1,158.9
Consumption	20,117.1	18,521.1	15,923.7	12,438.4	7,304.8	2,779.1	1,684.7	1,488.3	1,137.6	81,394.6

and preferences, as well as measurement error. This is useful because it indicates how trade patterns are influenced by the trade-cost regressors and the indexes of multilateral resistance (Yotov et al., 2016).

To see how an application of the PPML estimation affects our **AVW** model results we first run the following regression on the GTAP data in Table A.1:

$$X_{rs} = \exp\left[\pi_r + \chi_s + \beta_1 \ln \mathrm{DIST}_{rs} + \beta_2 \mathrm{INTL}_{rs}\right] \times \varepsilon_{rs}$$

as advised in Yotov et al. (2016). We find estimates of $\beta_1 = -0.711 \quad (0.0923)$ and $\beta_2 = -2.402 \quad (0.1534)$, which are close to the estimates in Yotov et al. (2016, p.104). The benchmark fitted flows from the regression are presented in Table A.2.

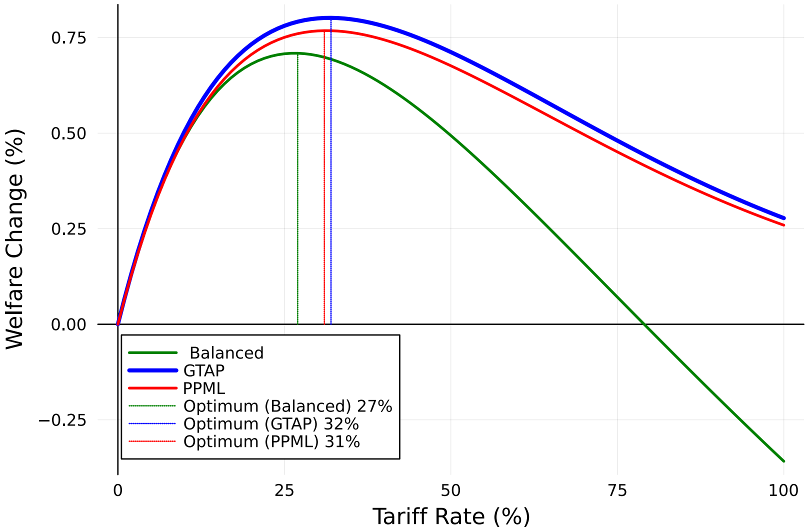
A.3 Results of applying different approaches to the **AVW** *model*

Given the variations in the data we use to calibrate the **AVW** model, we extend the analysis around our diagnostic and scenario analysis. Figure A.1 indicates the unilateral optimal US tariffs across the data variations. Incorporating trade imbalances leads to higher optimal US tariff rates. The intuition is clear under the Dekle, Eaton, and Kortum (2008) assumption concerning the capital account unit. The US starts with a large capital account surplus, so the rest of the world is lending significantly to the US. While the tariffs elevate US welfare global efficiency falls. The rest of the world maintains its lending as a proportion of global income (under the Dekle, Eaton, and Kortum, 2008, assumption). So they are transferring a larger share of their own (depressed) real income to the US. This creates a positive spillover to the US of its tariffs. Of course, the results might be very different if one considers changes in the intertemporal drivers that originally drove the capital account imbalance.

The material nature of the Dekle, Eaton, and Kortum (2008) static simplification becomes apparent in Figure A.1 as we move to very high US tariff rates. As the US approaches autarky it still receives the transfer, and even at a 100% tariff rate US welfare impacts do not turn negative. This seems very unlikely under capital-account decisions driven by intertemporal economics. Unfortunately, considering the economics of the capital account requires a significant departure from the relatively accessible AVW structure, defeating the purpose of the model in this paper.

In Figure A.2 we replicate our analysis of non-Chinese coordinated retaliation for the

Figure A.1. Optimal tariff for the US in the Anderson and van Wincoop (**AVW**) model with no retaliation: US welfare as a function of its tariff rate on all imports



blanket 10% US tariffs. The key differences we see relate to the incorporation of the trade imbalance not the addition of econometric calibration. There is general agreement between the direct calibration to the GTAP data and the PPML fitted values. Where we do see differences (e.g., China, Canada, and Mexico), we can attribute them to differences between the fitted and observed flows. Adding logical gravity regressors (i.e., a contiguity fixed effect) to the PPML estimation will further improve the fit and draw the GTAP and PPML results together. For the US, its higher optimal tariff is apparent as the US welfare losses are mitigated under the GTAP and PPML calibrations. For China, the benefits to rest-of-world retaliation against the US is mitigated because it runs a large capital account deficit in the imbalanced calibrations.

In Table A.3 we run the full set of tariff scenarios across the alternative calibrations. Again we generally see lower welfare losses for the US because of the spillover built into holding the US trade imbalances fixed. In general, the costs of the proposed Trump tariffs are less for the US with the imbalances incorporated. We caution the reader, however, that this largely driven by our less than satisfactory treatment of the capital account. Fundamentally, we think US optimal tariffs are exaggerated in the simplified AVW Armington structure, and accommodating trade imbalances following established methods (Dekle, Eaton, and Kortum, 2008) exacerbates the problem.

Figure A.2. Welfare impacts of non-Chinese coordinated retaliation in the **AVW** model (base scenario of reciprocal 60% US-China tariffs and 10% US tariffs on all other imports)

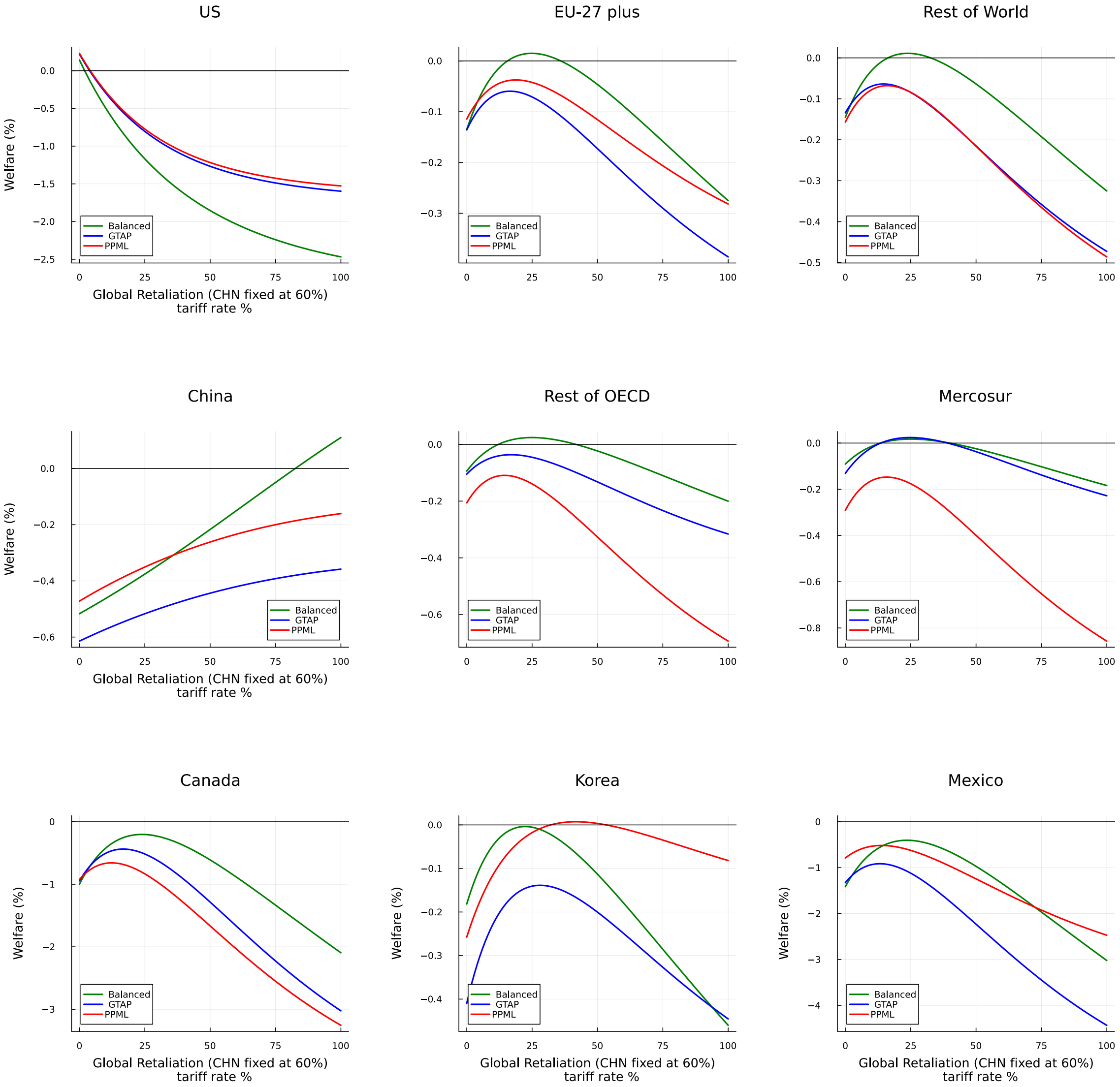


Table A.3. Welfare impacts across scenarios and **AVW** variations

Tariff Scenario:			(2)	(3)	(4)	(5)	(6)
USA 60% on CHN			yes	yes	yes	yes	yes
CHN 60% on USA				yes		yes	yes
USA 10% on Others					yes	yes	yes
Others 10% on USA							yes
	Benchmark						
Balanced:	GDP	Cons.	**Equivalent Variation ($B)**				
`USA` US	19,480	19,480	-23.0	-60.8	70.7	27.8	-96.0
`EUR` EU-27 plus	18,708	18,708	2.1	2.5	-25.7	-25.3	-5.2
`ROW` Rest of World	15,989	15,989	3.3	4.2	-24.1	-23.2	-5.0
`CHN` China	12,652	12,652	-44.3	-63.0	-49.5	-65.4	-58.5
`OEC` Rest of OECD	7,324	7,324	1.1	1.4	-7.2	-6.9	-0.7
`MRC` Mercosur	2,810	2,810	0.3	0.3	-2.6	-2.6	-0.4
`CAN` Canada	1,649	1,649	0.7	0.9	-16.6	-16.5	-7.0
`KOR` S. Korea	1,624	1,624	0.6	0.8	-3.2	-3.0	-0.8
`MEX` Mexico	1,159	1,159	0.6	0.9	-16.5	-16.4	-7.9
Total	81,395	81,395	-58.6	-112.7	-74.7	-131.4	-181.6
	Benchmark						
GTAP:	GDP	Cons.	**Equivalent Variation ($B)**				
`USA` US	19,480	20,117	-36.5	-54.9	65.9	44.3	-58.8
`EUR` EU-27 plus	18,708	18,521	6.0	4.9	-24.2	-25.1	-12.8
`ROW` Rest of World	115,989	15,924	8.1	6.9	-20.4	-21.4	-11.0
`CHN` China	12,652	12,438	-64.7	-74.4	-68.4	-76.4	-71.2
`OEC` Rest of OECD	7,324	7,305	0.5	0.9	-8.0	-7.7	-3.3
`MRC` Mercosur	2,810	2,779	-0.6	-0.2	-3.9	-3.6	-0.6
`CAN` Canada	1,649	1,685	0.8	0.9	-15.9	-15.9	-8.5
`KOR` S. Korea	1,624	1,488	-1.2	-0.4	-6.8	-6.1	-3.4
`MEX` Mexico	1,159	1,138	2.7	2.1	-14.5	-15.1	-10.6
Total	81,395	81,395	-84.9	-114.3	-96.2	-127.0	-180.3
	Benchmark						
PPML:	GDP	Cons.	**Equivalent Variation ($B)**				
`USA` US	19,480	20,117	-26.2	-48.6	72.9	46.4	-55.2
`EUR` EU-27 plus	18,708	18,521	2.7	2.1	-20.7	-21.2	-9.4
`ROW` Rest of World	15,989	15,924	4.2	3.2	-24.1	-25.0	-12.4
`CHN` China	12,652	12,438	-43.6	-54.8	-49.6	-58.7	-52.1
`OEC` Rest of OECD	7,324	7,305	3.2	2.4	-14.4	-15.1	-8.5
`MRC` Mercosur	2,810	2,779	0.9	0.7	-7.8	-8.1	-4.5
`CAN` Canada	1,649	1,685	1.2	1.0	-15.2	-15.6	-11.2
`KOR` S. Korea	1,624	1,488	-0.1	0.4	-4.3	-3.8	-1.7
`MEX` Mexico	1,159	1,138	0.8	0.6	-8.7	-9.0	-6.1
Total	81,395	81,395	-56.7	-93.1	-71.9	-110.1	-161.2

Appendix B. Monopolistic Competition with Bilateral Representative Firms (BRF)

Not for Publication: Model description from
Balistreri, Böhringer, and Rutherford (2024)
for review purposes.

Consider variety-adjusted supply of a *Dixit-Stiglitz* composite of goods $i \in \{\text{IRTS goods}\}$ from each source region $s \in R$ available for absorption in region $r \in R$. We denote composite supply in r as A_{ir} with firm-level component quantities of the representative bilateral variety as q_{isr}. The number of firms operating on each bilateral link is given by N_{isr}. With a constant elasticity of substitution of σ_i across firm varieties, we have the typical CES aggregation

$$A_{ir} = \psi_{ir} \left[\sum_s N_{isr} q_{isr}^{(\sigma_i - 1)/\sigma_i} \right]^{\sigma_i/(\sigma_i - 1)}, \tag{B.1}$$

where ψ_{ir} is a scale parameter. In the model formulation it is more convenient to represent the aggregation in terms of its dual price index, which embeds optimal choice,

$$P_{ir} = \left[\sum_s N_{isr} p_{isr}^{1-\sigma_i} \right]^{1/(1-\sigma_i)}, \tag{B.2}$$

where the p_{isr} are the landed-duty-paid prices faced in destination r. Equation (B.2) indicates the minimized cost of supplying one unit of the composite good i in region r as a function of the price vector.

Applying the envelope theorem to (B.2) we can derive the conditional demand for each firm-level variety:

$$q_{isr} = A_{ir} \left(\frac{P_{ir}}{p_{isr}} \right)^{\sigma_i}. \tag{B.3}$$

With a marginal cost (inclusive of transport payments) of c_{isr} a firm facing this demand will maximize profits by charging a gross price in the destination in accord with the standard markup formula:

$$p_{isr} = (1 + t_{isr}) \frac{c_{isr}}{1 - 1/\sigma_i}, \tag{B.4}$$

where we have introduced the policy instrument t_{isr} as an ad valorem tariff.

Free entry with increasing-returns firms indicates that all operating profits will be exhausted on fixed cost. That is, firms will enter to the point that the economic profits from creating a new variety are zero. We assume, consistent with the literature, that the input price of fixed cost payments is the same as for variable costs. Let $\mathtt{f}_{is}$ be the fixed cost in terms of input quantity such that entry of a firm operating on the s to r trade link costs $\mathtt{f}_{is} c_{isr}$. Setting this equal to net operating profits gives us the free-entry (zero-profit) condition:

$$c_{isr} \mathtt{f}_{is} = \frac{p_{isr} q_{isr}}{\sigma(1 + t_{isr})}. \tag{B.5}$$

We now turn to the input market and technology. The bilateral variable c_{isr} can be thought of as the price of a composite input used by the increasing-returns firms for their fixed and variable costs. It is a composite because it embeds optimization over a set of primary-factor inputs, intermediate inputs, and bilateral transport margins. Let us assume a nested-CES constant-returns technology for producing the composite-input quantity x_{isr}. At the top level let us assume that a nested CES aggregate of all other inputs substitutes against a *bilateral specific factor* with fixed supply. Inclusion of this specific factor is critical to the convexity of the BRF formulation. Without a specific factor indexed bilaterally all firms would either enter or exit a given market resulting in *bang-bang* responses to price changes. With the bilateral specific factor, however, we have bilateral rents that adjust continuously to price changes, and firms will only abandon a given trade link if price of the specific factor goes to zero. Let us represent the price of the bilateral specific factor as z_{isr}, the price of global transport services τ, and the price of a nested CES composite of all other industry inputs as w_{is}. Under decentralized optimization the price of the composite input is given by the unit-cost function

$$c_{isr} = \left[\alpha_{is} \left(w_{is} + \gamma_{isr}\tau\right)^{1-\eta_i} + \beta_{is} z_{isr}^{1-\eta_i}\right]^{1/(1-\eta_i)}. \tag{B.6}$$

In equation (B.6) we have parameters that represent the relative weights on mobile versus specific factors (α_{is}, and β_{is}) and the bilateral transport-margin coefficient (γ_{isr}). The substitution elasticity, η_i, along with the assumed relative weight on the specific factor determines the continuous supply response of the bilateral composite input quantity, x_{isr}.

We have market clearance in the bilateral composite input, where supply is given by x_{isr} and demand is given by each firm's use of the input for fixed and operating costs:

$$x_{isr} = N_{isr}\left(\mathtt{f}_{is} + q_{isr}\right). \tag{B.7}$$

Equations (B.2) through (B.7) fully capture the assumed BRF structure and its intuitive underpinnings. We can greatly simplify the system in the computational model, however, by noting a few key results from theory.

First, note that we can show that firm-level output is a constant by substituting the optimal price from (B.4) into the zero-profit condition (B.5). Solving for the quantity we have:

$$q_{isr} = \mathtt{f}_{is}(\sigma_i - 1).$$

The only margin of adjustment on a bilateral link is entry and exit, N_{isr}. Further, from equation (B.7), this indicates that proportional changes in input supply will be matched by proportional changes in the number of varieties. Using the popular "hat" notation we have

$$\hat{x}_{isr} = \hat{N}_{isr}.$$

Adding a bilateral calibration parameter λ_{isr} which captures observed trade data as well as the constant implied markup we can restate the price index in (B.2) directly as a function of the bilateral cost and the proportional change in varieties:

$$P_{ir} = \left[\sum_s \lambda_{isr}\hat{x}_{isr}[(1+t_{isr})c_{isr}]^{1-\sigma_i}\right]^{1/(1-\sigma_i)}.$$

Now directly deriving conditional composite-input demand we have

$$A_{ir}\frac{\partial P_{ir}}{\partial(1+t_{isr})c_{isr}} = A_{ir}\lambda_{isr}\hat{x}_{isr}\left(\frac{P_{ir}}{(1+t_{isr})c_{isr}}\right)^{\sigma_i}.$$

Inserting this on the right-hand side of equation (B.7) is problematic, however, because it causes a degeneracy.[16] To solve this we assume that only 90% of the variety effect is realized so $\hat{x}_{isr}$ is replaced in the system with

$$\tilde{x}_{isr} \equiv 0.9\hat{x}_{isr} + 0.1.$$

In that regard our BRF computational model gives an approximation. The benefit of this approximation is that we can capture the BRF structure with no more computational overhead than a standard Armington model. To illustrate this, consider that the broader general equilibrium determines demand for the Dixit-Stiglitz composite in the importing region (denoted here as D_{ir}). Further, the general equilibrium determines the relevant input prices (w_{is}, z_{isr}, τ) in the source region. With these variables given, the BRF trade-equilibrium conditions in the model are as follows.

The BRF trade equilibrium:

$$A_{ir} = D_{ir} \tag{B.8}$$

$$P_{ir}^{\text{BRF}} = \left[\sum_s \lambda_{isr}\tilde{x}_{isr}[(1+t_{isr})c_{isr}]^{1-\sigma_i}\right]^{1/(1-\sigma_i)} \tag{B.9}$$

$$x_{isr}^{\text{BRF}} = A_{ir}\lambda_{isr}\tilde{x}_{isr}\left(\frac{P_{ir}^{\text{BRF}}}{(1+t_{isr})c_{isr}}\right)^{\sigma_i} \tag{B.10}$$

$$c_{isr} = \left[\alpha_{is}\left(w_{is}+\gamma_{isr}\tau\right)^{1-\eta_i} + \beta_{is}z_{isr}^{1-\eta_i}\right]^{1/(1-\eta_i)}. \tag{B.11}$$

These four equilibrium conditions correspond to four endogenous variables: P_{ir}^{BRF}, A_{ir}, c_{isr}, and x_{isr}^{BRF}. The constructed variety effect $\tilde{x}_{isr}$ is substituted directly into the conditions according to its definition.

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[16] With the derived demand on the right-hand side of (B.7), we effectively have $x = \phi x/x^0$ or $1 = \phi/x^0$ where the key endogenous variable drops from the equilibrium condition.