Quantifying Disruptive Trade Policies

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The economic case for cooperative trade based on WTO principles is challenged by a new wave of protectionism. Economists can contribute to the policy debate by quantifying the economic impacts of trade barriers based on sound theory and empirical data. We present an innovative analytical framework that captures key mechanisms of international trade, and we demonstrate its usefulness as a tool for quantitative trade policy analysis. Our application relates to massive tariff changes implemented by the United States in 2018 with subsequent retaliations by partner countries, particularly China. The analytical framework is a multi-region multi-sector general equilibrium simulation model of the global economy that features a new monopolistic-competition structure of bilateral representative firms (BRF). We compare simulation results from this innovative trade representation with standard formulations of perfect and monopolistic competition to highlight its policy-relevant implications for economic impact assessment.

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1. Introduction

Academic arguments in favor of cooperative free trade are challenged by a wave of protectionist measures. Larger groups of voters feel disadvantaged by global integration and may even favor tariffs and other trade barriers as a means to secure prosperity. At the electorate level, the potential economic pain inflicted by protectionism such as the Smoot-Hawley Tariff Act of 1930 in the US is largely suppressed.[1] In 2018 the United States (US) imposed significant new tariffs, to which its trade partners have responded with tariffs on US goods. Since then, the tariffs have remained largely unchanged despite the Phase One Agreement

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[1] The Smoot-Hawley Tariff Act of 1930 raised US tariffs on over 20,000 imported goods to record levels followed by retaliatory tariffs of America's trading partners. It is the consensus view among economists and economic historians that "The passage of the Smoot-Hawley Tariff exacerbated the Great Depression" (Whaples, 1995) and thus worked counter the initial objective to strengthen the US economy.

between China and the US, the COVID-19 pandemic, and a change in US administrations (Bown, 2023). In our view, an empirically based assessment of the economic impacts of these tariffs is warranted to provide a more informed basis for the controversial debate on trade protectionism.

In this paper we use a suite of computational models of global trade to quantify the impacts of the 2018 trade war between the US and its main trading partners. We offer results under three alternative structural assumptions about international trade that include a traditional perfect competition model and two variations of monopolistic competition. Compared to perfect competition, adverse variety impacts under monopolistic competition significantly increase the welfare losses caused by tariffs. This is particularly true for our innovative structural trade representation that includes bilateral entry and exit of varieties (firms). We report structural sensitivities through a diagnostic decomposition of the effects at the sectoral level and aggregate welfare, starting with a simple partial equilibrium calculation. Our approach facilitates an intuitive and transparent explanation of the sources of the impacts from a more complex trade model.

In our simulation analysis we find that the 2018 US tariff escalation and retaliatory tariffs are costly for both the US and the Chinese economies, but indicate economic benefits for other regions (especially Europe) through trade diversion. These results are driven by the fact that beyond the US and China the distortions from additional trade barriers are small relative to aggregate trade. In our central case simulation with monopolistic competition and free entry and exit of bilateral firms, the welfare cost of the trade war for the US amounts to $81 billion (or 0.6% of private consumption).[2] The implications at the level of US industries are more accentuated and heterogeneous, including losers and winners. Steel and some manufacturing industries gain while many agriculture sectors lose. Economic returns to most US primary factors of production fall by over half a percent, with land rents showing acute losses of almost 7%. Rents on bilateral-specific factors in certain monopolistically-competitive sectors increase by over 5% on average, as additional returns from trade diversion on many trade links dominate concentrated foregone returns on shrinking trade links.

A 0.6% decline in US welfare may seem unimpressive. Yet, it is important to bear in mind that tariffs are, in fact, a relatively efficient instrument of protection compared to various non-tariff barriers. With tariffs, the rents from the distortions are retained by the US in the form of new tariff revenues (in our central case simulation equal to $40 billion which represents an increase in total US tariff revenues of 18.7%). In contrast, non-tariff distortions such as voluntary export restraints (VERs), which South Korea, Brazil, and Argentina agreed to after the US announced the (section 232) steel and aluminum tariffs in 2018, are more costly to the US relative to their tariff equivalents. With the VERs the foreign country

[2] We measure welfare as Hicksian equivalent variation in money-metric utility.

rather than the US captures the rents from the distortion. [3] Thus, our finding of a US welfare loss of $81 billion would increase by another 50% if the offsetting $40 billion in tariff revenues was lost to the US economy as well.

To illustrate the quantitative significance of the trade war in the context of real data, Figures 1 and 2 show the US and Chinese historical trade flows and initial (pre-trade-war) tariff rates in 2017, together with the first-order impacts of the new (after-trade-war) tariffs based on empirical trade elasticities provided by the GTAP database.[4] In the figures the black point with its adjacent commodity label indicates the trade volume along the horizontal axis and the gross-of-tariff import price on the vertical axis (with net-of-tariff prices normalized to one). The connected red point indicates the 2018 tariff escalation and the implied partial equilibrium trade response.[5] For example, for US imports of chemical, rubber and plastic products (`crp`) the benchmark trade volume is $31.8 billion at a tariff rate of 8%. With the 2018 tariff rate of 14% US imports fall to $25.4 billion as a partial equilibrium response. The figures for US and Chinese imports are drawn on the same scale to emphasize the relative importance of US imports of electronic equipment (`eeq`) and to illustrate the relatively small import base available for China in its retaliation.

We focus on the US and China because their tariff escalations are substantial and quantitatively dominate tariffs changes related to the steel and aluminum dispute between the US and its main trading partners (in this case, particularly the EU). We consider the full escalation of US-China tariffs in 2018, including those implemented on January 1, 2019. Commodities with more than $1 billion of benchmark trade are represented in the figures, with the full set of trade flows reported in Tables A.1 and A.2. The three-letter identifiers are mapped to descriptions in Table 2 in Section 4, which offers a complete taxonomy of the GTAP

[3] To ensure a coherent welfare analysis, we hold real government spending constant across policy counterfactuals , so that additional tariff revenues are returned to households.

[4] For our quantitative analysis, we rely on economic statistics from the Global Trade Analysis Project (GTAP). GTAP is a research consortium initiated in 1992 to provide the trade policy analysis community with a global economic dataset than can be used for the quantitative analysis of international economic issues. The GTAP project was founded by Thomas Hertel at Purdue University (see notably Hertel, 1997). The Center's staff economists are responsible for regular updates of the database (see e.g. Aguiar et al., 2023). Software development within the GTAP project was significantly supported by researchers from the Centre of Policy Studies, Victoria University, Australia.

[5] The calculations for Figures 1 and 2 are based on a simple Marshallian partial equilibrium model with linear supply and demand functions calibrated to GTAP 11 trade elasticities and benchmark transactions for 2017 as the most recent base year in the GTAP 11 database. The results shown here are almost identical to those obtained a partial equilibrium model with isoelastic supply and demand functions calibrated to the same elasticities and benchmark transactions, but the results differ from the three general equilibrium models that we investigate subsequently.

Figure 1. US imports from China: benchmark trade, tariffs, and implied partial equilibrium responses

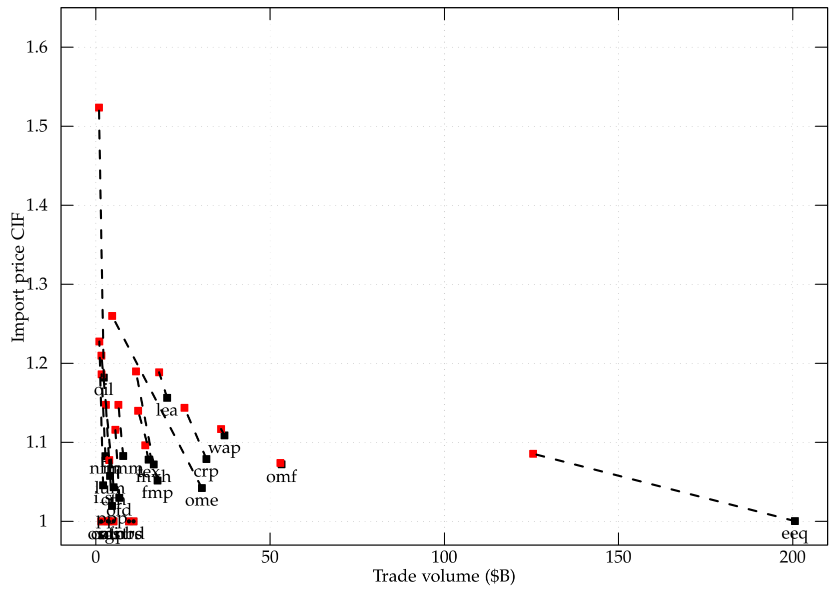
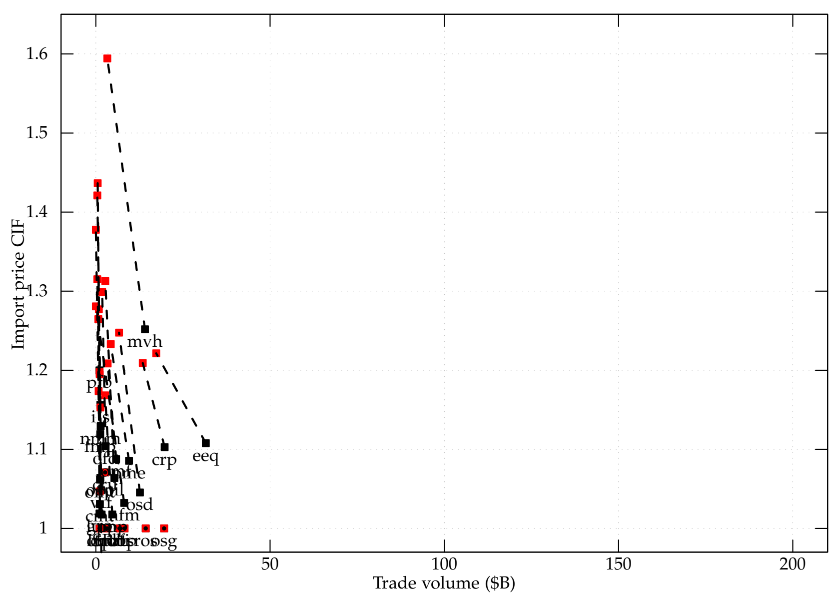


Figure 2. Chinese imports from the US: benchmark trade, tariffs, and implied partial equilibrium responses



database. The purpose of our partial equilibrium analysis (which assumes fully competitive markets) is to provide a point of comparison for the more elaborate general equilibrium analysis and to identify those sectors that are heavily impacted by the tariff war. Similar figures in Section 6 include general equilibrium responses together with partial equilibrium responses as the point of comparison.

We highlight a few key sectors based on GTAP 11 data and the the tariff escalations compiled by Li (2018) to provide additional context for the US-China trade war in 2018. The most important import sector for the US is electronic equipment (`eeq`). US imports from China of `eeq` in 2017 are reported to be valued at $200.6 billion with an initial tariff rate of less than 1%. This is represented in Figure 1 by the black square in the lower right corner of the figure. The 2018 US tariff rates on these imports increase to 8.6%. With the GTAP trade elasticities, this translates to a first-order partial equilibrium reduction in `eeq` imports from China to $125.5 billion, which is indicated by the red point in the figure connected to the black `eeq` point as the benchmark. Other goods imported from China that have substantial benchmark trade include machinery and equipment (`ome`), other manufactures (`omf`), wearing apparel (`wap`), chemical, rubber, and plastic products (`crp`), and leather products (`lea`).

In Figure 2 we consider trade in the other direction, i.e. Chinese imports from the US. In the 2017 base-year as our benchmark, the trade volumes are much lower and the tariffs are higher on China's imports from the US. Export of motor vehicles and parts (`mvh`) are a good example, with benchmark tariffs of over 25.2% on Chinese imports valued at $14.1 billion. These tariffs increase to 59.4% under the 2018 retaliatory tariffs. As a partial equilibrium response China's imports from the US plummet to $3.3 billion. The most important commodities among other imported commodities from the US into China include electronic equipment (`eeq`) at $31.6 billion, chemical, rubber, plastic products (`crp`) at $19.7 billion, and oil seeds (`osd` in the form of soybeans) at $12.6 billion. The partial equilibrium illustrations in Figures 1 and 2 are useful for first-round insights into how scheduled tariff changes translate into economic impacts driven by the magnitude of the tariff change, the base-year trade flows, and trade elasticities. In subsequent analysis, we refine these estimates based on more comprehensive and sophisticated general equilibrium models.

We choose the 2018 tariff changes as our policy scenario because these changes are well documented and the timing of the tariff escalations coincide with the benchmark data for 2017 provided by GTAP 11. Most other similar studies, including the earlier working paper (Balistreri, Böhringer, and Rutherford, 2018b), use 2014 as the base year. The changes in trade patterns between 2014 and 2017 are, however, important - e.g., US imports from China in the `eeq` category increased significantly during that period.[6] The shift in the composition of trade is

[6] A comparison of the Figures 1 and 2 with the figures in Balistreri, Böhringer, and Ruther-

important for our welfare analysis because US tariffs on eeq increased less significantly than on many of the goods with larger trade volumes in 2014. Applying the same structure and tariff increases to the 2014 base year resulted in a 1.0% reduction in US welfare (Balistreri, Böhringer, and Rutherford, 2018b), which is substantially higher than our central result in the current analysis (a 0.6% welfare reduction). Using a base year that is consistent with policy shocks is important for an appropriate impact assessment.

The remainder of this paper is organized as follows. In section 2 we provide a literature review on the evolution of theory-based quantitative analysis of trade policy which motivates the choice and design of our modeling framework. In section 3 we offer a description of our modeling framework. In section 4 we lay out the key empirical data sources underlying our quantitative simulation analysis. In section 5 we outline the disruptive trade policies triggered by the US in 2018. In section 6 we present our quantitative assessment of the trade disruptions. In section 7 we conclude.

2. Literature review

There are gains from international trade. Few things are more agreed upon by economists. From the original statement of comparative advantage (Ricardo, 1817) to the formal neoclassical general equilibrium (Samuelson, 1939, 1962; Kemp, 1962) to advanced models of industrial organization (Melitz, 2003) the intuition is clear and compelling. Equally clear, however, is the fact that the gains will not be distributed equally among countries that engage in trade (Ray, 1977), and the fact that some agents may lose from trade even if their country gains on average (Stolper and Samuelson, 1941). Furthermore, we know that the distribution of the gains can be manipulated by countries acting strategically (Johnson, 1953), or through the rent-seeking activities of special interest groups (Grossman and Helpman, 1994).

With a broad consensus on the potential benefits from international trade, the global community established a set of institutions, most notably the World Trade Organization (WTO) as governed by the General Agreement on Tariffs and Trade (GATT), to provide guidance towards a cooperative global trading system (Bagwell and Staiger, 1999).[7] The primary goal of the WTO is to promote free trade through a set of multilateral rules and dispute settlement procedures. These discourage countries from implementing trade distortions motivated either by strategic *beggar-thy-neighbor* incentives or by their interest in placating rent-seeking

ford (2018b) shows that eeq imports from China increased by about $40 B between 2014 and 2017, and other machinery and equipment (ome) imports fell by more than $40 B.

[7] The WTO started operations on January 1, 1995 as an implementation and enforcement mechanism for the General Agreement on Tariffs and Trade (GATT), which was created in 1947 as a framework for organizing post-war international trading rules.

special-interest groups. Bagwell and Staiger (1999) argue that the GATT's reciprocity and nondiscrimination rules assist governments in their implementation of globally sound trade policy when they face politically powerful constituents interested in distorting trade to capture rents.[8]

More recently, however, the global trading system seems to be entering a new order of disruptive unilateral policies. As the prime protagonist of protectionism, the United States is currently pursuing trade policies that put little weight on global efficiency and overall gains from trade. Starting with the Republican administration in 2017 the US has wielded unilateral tariff instruments to stem import surges under its safeguard and national security (section 201 and 232) authority and as a punishment for alleged intellectual property violations by the Chinese (section 301 tariffs). Disputes over intellectual property violations would have naturally fell under the dispute settlement procedures at the WTO, but the US acted unilaterally. In fact, over the last decade the US has expressed contempt for the WTO's principles and procedures. The 2018 US tariffs were met with quick retaliation. For a complete and up-to-date overview of the US-China trade war see Bown (2023). The Democratic administration, entering office in January 2021, largely maintained the US tariffs and proposed their escalation in May of 2024.

Against this backdrop, a quantitative economic impact assessment on what is at stake with disruptive trade policies is indispensable for informing the policy debate. To be fully useful the analysis needs to include sufficient detail to provide distributional consequences as a complement to the aggregate welfare analysis.

The international trade structure that dominates this type of computational (applied) trade policy analysis is based on the Armington (1969) assumption of differentiated regional goods within a constant-returns-to-scale (CRTS) perfect competition setting. The proposition to differentiate products by country of origin has several empirical advantages, but it has been criticized for its inconsistency with micro-level observations and questionable counterfactual implications. The Armington assumption provides a tractable solution to various problems associated with the standard neoclassical (Heckscher-Ohlin) perspective of trade in homogeneous goods (Whalley, 1985): (i) it accommodates the empirical observation that a country imports and exports the same good (so-called cross-hauling); (ii) it avoids over-specialization implicit to trade in homogeneous goods; and (iii) it is consistent with trade in geographically differentiated products. While the Armington assumption provides a convenient lens to view trade data, it may introduce

[8] The WTO has six key objectives: (1) to set and enforce rules for international trade, (2) to provide a forum for negotiating and monitoring further trade liberalization, (3) to resolve trade disputes, (4) to increase the transparency of decision-making processes, (5) to cooperate with other major international economic institutions involved in global economic management, and (6) to help developing countries benefit fully from the global trading system.

terms-of-trade effects which dominate the welfare results of policy changes. Even in the absence of market power by individual firms, the Armington assumption of product heterogeneity provides implicit market power for the policy authority in a perfectly competitive market context, which is the higher the larger are the trade flows and the smaller are the demand elasticities for the traded goods by trading partners (de Melo and Robinson, 1989; Balistreri and Markusen, 2009).

Balistreri and Rutherford (2013) discuss the inherent tensions between standard Armington (CRTS) models and more advanced computational approaches incorporating modern trade theory based on firm-level product differentiation and imperfect competition (Krugman, 1980; Melitz, 2003). Krugman (1979, 1980) uses firm-level product differentiation in a monopolistic-competition framework to illustrate that there are gains from trade even in the absence of comparative advantage. The Krugman (1980) model illustrates that additional varieties are a key source of the gains from trade under a standard constant-elasticity-of-substitution demand system. Ethier (1982) further expands the notion of variety gains to intermediate inputs, where new varieties, available through trade, increase the productivity of domestic firms. Foreign direct investment and the theory of multinationals are an additional source of gains, especially in producer services that are not easily traded (Markusen, 1989, 2002; Markusen and Venables, 1998; Ethier and Markusen, 1996). Markusen, Rutherford, and Tarr (2005) show that introducing foreign direct investment in services with endogenous variety effects and specialized *home-office* inputs substantially increase the gains.[9]

The theory of international trade moved forward again with Melitz (2003), who introduced the competitive selections of heterogeneous firms in a monopolistic competition model with fixed cost associated with supplying external markets. In the Melitz model trade induces a reallocation of within-industry resources away from low-productivity firms toward high-productivity firms. There is compelling empirical support for both the basic structure of heterogeneous firms (Bartelsman and Doms, 2000; Bernard and Jensen, 1999) and the endogenous reallocation toward more productive firms (Aw, Chen, and Roberts, 2001; Trefler, 2004). A key feature of the Melitz (2003) model is that there will be a unique number of varieties on each bilateral link, because trade policy affects selection. This is in contrast to models based on Krugman (1980) where once a variety is produced (a firm enters the market) that variety is consumed in every market. In the structure we introduce we have selection in the form of entry on each bilateral link, but we maintain the more simplified Krugman structure. We maintain convexity in the trade equilibrium by replacing the Melitz steady-state structure with specific-factor payments by the bilateral firms.

[9] We do not incorporate foreign direct investment in the version of the model used in this paper, but using a similar monopolistic-competition model Balistreri and Olekseyuk (2024) incorporate that extension.

Most of the conventional computational studies adopting the Armington-CRTS framework (i.e. ignoring innovations of monopolistic competition) focus on changes in rent generating tariffs triggered by trade policy reforms. The studies often report seemingly small welfare gains associated with trade liberalization, generally in the range of less than one percent. There is reason to suspect that the early studies understate the gains from trade. It is recognized that Armington models imply high optimal tariffs (Brown, 1987; Balistreri and Markusen, 2009). Balistreri and Markusen (2009) argue that the Armington structure misallocates market power over varieties away from firms and toward the discretion of the policy authority. The monopolistic competition structure properly allocates market power over varieties to firms and thus results in lower optimal tariffs. Another source of potential bias in trade modeling is the fact that many trade distortions do not generate tariff revenues for the importing country. An important example are the voluntary export restraints (VERs) that South Korea imposed to avoid the 2018 US steel and aluminum (Section 232) tariffs.[10] In general, non-tariff barriers to trade are important and substantially increase the welfare impacts. For example, de Melo and Tarr (1990) and Jensen and Tarr (2003) use standard perfect competition models to show substantial gains from trade liberalization when the rents associated with the distortion are surrendered.[11]

With the rise of the new trade theories, there is a growing number of computational studies that include imperfect competition. Harris (1984) considers the gains associated with behavioral responses by oligopolistic firms engaged in international trade. Adopting an oligopolistic model setting Harrison, Rutherford, and Tarr (1997) report small gains associated with increased firm size (reduced average cost). Rutherford and Tarr (2002) use an endogenous-growth model with variety gains to show that the welfare impacts can be many times larger than in a standard constant-returns perfect competition model. Markusen, Rutherford, and Tarr (2005) and Rutherford and Tarr (2008) introduce FDI in services with variety effects which generates substantially larger welfare impacts.

More recently, the Melitz (2003) theory has inspired a new generation of computational approaches to quantitative trade-policy analysis. Zhai (2008) introduces the first calibrated computational model that includes competitive selection of heterogeneous firms. This model is extended and applied in an analysis of the Trans-Pacific Partnership by Petri, Plummer, and Zhai (2012). The model, while including selection, does not include endogenous entry so the mass of potential

[10] Allowing a trade partner to collect the rents associated with a trade distortion, through a VER, is a good way to avoid retaliation; but it is also a good way to *lose* a trade war. Optimal tariffs rely on a collection of the tariff revenues!

[11] Regulations which increase trade costs, without retaining rents, produce "efficiency cost rectangles" and are more likely to lower welfare of both parties. Regulations such as VERs (and tariffs) which increase trade costs while transferring rents to one or the other party may improve outcomes for one country at the expense of the other.

firms is held fixed. Balistreri, Hillberry, and Rutherford (2011) implement a model with the full Melitz theory applied to the manufacturing sector. They find that, relative to an otherwise equivalent Armington model, the Melitz model generates welfare impacts that are on average four times larger. Balistreri and Rutherford (2013) provide a more comprehensive guide to applying monopolistic competition theories, including the Melitz structure, in computational models that are calibrated to data.[12] Other important CGE applications of the new theories include Dixon, Jerie, and Rimmer (2016) and their comprehensive book on the topic: Dixon, Jerie, and Rimmer (2018). Costinot and Rodríguez-Clare (2014) draw a closer link between the theory and traditional computational methods by quantify the welfare impacts of globalization in a large-scale model that extends the simple gravity-based welfare calculations put forward by Arkolakis, Costinot, and Rodríguez-Clare (2012). In a similar computational setting Caliendo et al. (2015) consider the welfare impacts of tariff liberalization over the period from 1990 to 2010. Our analysis is in the tradition of bringing contemporary trade theory into a theory-with-numbers empirical environment.

We conclude our literature review with a look at studies that directly assess the 2018 tariff escalations and the US-China trade war in particular. We already mentioned the earlier working paper (Balistreri, Böhringer, and Rutherford, 2018b), which was based on a 2014 base year (GTAP 10) with a different composition of US-China trade. Under the proposed BRF monopolistic-competition structure (Balistreri, Böhringer, and Rutherford, 2018b) find a 1.0% reduction in US welfare and a 1.7% reduction in China's welfare. For comparison our updated welfare impacts in this analysis are reductions of 0.6% for the US and 1.25% for China. Li, Balistreri, and Zhang (2020) also use the GTAP 10 2014 base year, but apply the perfect-competition canonical GTAPINGAMS model, with its nested Armington structure. The tariffs used by Li, Balistreri, and Zhang are slightly different than ours because theirs are updated to post Phase One rates. Li, Balistreri, and Zhang (2020) report welfare reductions of 0.2% and 1.7% for the US and China.

Zheng et al. (2023) perform a comprehensive analysis of the US-China dispute using the GTAP 10 data and the GTAP model.[13] While Zheng et al. (2023) use GTAP 10 data in a static model, their analysis relies on a recursively dynamic projection of the data out to the policy window. Under a scenario that closely matches ours (their scenario 2a), Zheng et al. find a welfare reduction of 0.2% for the US and a welfare reduction of 0.6% for China. Within a fully recursive dynamic modeling

[12] Although not directly related to trade policy, we have applied the Melitz structure in analysis of climate policy, carbon leakage, and carbon-content tariffs (Balistreri, Böhringer, and Rutherford, 2018a; Balistreri and Rutherford, 2012). In the context of policies that affect the competitive position of firms on world markets (i.e., sub-global emissions regulation) outcomes are shown to be especially sensitive to the assumed trade structure.

[13] In addition to the global accounts (the GTAP data), the Global Trade Analysis Project maintains and supports a core perfect-competition Armington model (Hertel, 1997).

environment based on the GTAP data and model, Itakura (2020) and Walmsley and Minor (2020) find similar impacts.[14] We also note that, as one might expect, Zheng et al. (2023) find small relative effects when they focus on the US-China Phase One agreement. The relative benefits of the Phase One tariff cuts measured by Zheng et al. where 0.02% for the US and 0.04 for China. This provides strong evidence that the Phase One agreement is an order of magnitude less important than the 2018 tariff escalation, and can be ignored in the broader context of the trade war.

In a recent analysis Robinson and Thierfelder (2024) use the perfect-competition *Globe* model calibrated to GTAP 11 data to consider US protectionism and retaliation. They consider a set of hypothetical scenarios (not the observed tariff increases we use) and so the welfare results are not directly comparable to ours. Under their long-run Combined trade-war scenario (US 10% tariffs on imports and 60% on China, with retaliation) they find changes in *real final demand* of -0.9% and -1.4% for the US and China. Our welfare results seem comparable given that Robinson and Thierfelder (2024) use a perfect competition model and examine a larger average tariff shock.

3. Modeling framework

In the interest of revealing the inherent structural sensitivity of quantitative trade policy analysis we develop a flexible modeling framework that encompasses three alternative representations of international trade denoted:

- **ARM:** **Armington** (1969) is based on perfectly competitive markets and constant returns to scale.
- **KRU:** **Krugman** (1980) is based on imperfect competition in which changes in the number of firms (varieties) influence aggregate productivity. An important feature of the Krugman trade specification is that all varieties are sold in all regions.
- **BRF:** **Bilateral Representative Firms** emphasizes the extensive margin of trade. Like Krugman, BRF incorporates a Dixit-Stiglitz variety effect, but unlike Krugman, not all varieties from a region are sold in every region.

We are motivated to develop and explore the BRF structure based on a shortcoming inherent in the standard Krugman framework, and the computational difficulty of applying the Melitz (2003) model of bilateral-selection in an empirical model with many commodities. The shortcoming of the Krugman structure is that reforms on relatively small trade links have an unrealistically small or negligible impact on the entry of supplying firms, and therefore the model fails to

[14] Welfare impacts are not well specified in a recursive-dynamic environment. Itakura (2020) reports real GDP reductions of 0.4% and 1.1% for the US and China under the tariff scenario. Walmsley and Minor (2020) find initial US GDP reductions of 0.45% rising to 0.86% by 2030; and initial Chinese GDP reductions of 1.5% rising to 2.84%.

reveal love-of-variety gains associated with small-country or relatively large bilateral shocks that do not significantly change global demand at the implied firm level. Rutherford and Tarr (2008) address this problem in an open-economy Krugman model application by adopting what is essentially the BRF structure on the modeled country's external trade links. Our analysis is the first application of the BRF structure in a multi-region framework.[15]

Apart from the differences in trade specification, which are laid out in more detail below, the model variants share an identical core logic consistent with the GTAPINGAMS structure. The model is a multi-region multi-sector general equilibrium simulation model. Decisions about the allocation of resources are decentralized, and the representation of behavior by consumers and firms in the model follows the canonical microeconomic optimization framework: (i) consumers maximize welfare through private consumption subject to a budget constraint; (ii) producers combine intermediate inputs, and primary factors (several categories of labor, land, resources, and physical capital) at least cost subject to technological constraints. Preferences and technological constraints are described through nested constant-elasticity-of-substitution (CES) functions that capture demand and supply responses to changes in relative prices. By default, primary factors are treated mobile across sectors within a region while specific factors are tied to sectors in each region. We assume that a portion of capital payments within any increasing-returns industry is tied to the specific destination market. We elaborate on these bilateral specific factors in the following description. Government demand, investment demand, and the balance of payment surplus are fixed at the base-year level.

In what follows we outline the key differences between our computational model and the canonical GTAPINGAMS model, which is documented in Lanz and Rutherford (2016). We focus on the BRF trade structure and then provide the specific restrictions implemented for the Krugman and Armington variations.

3.1 Monopolistic Competition with Bilateral Representative Firms (BRF)

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

[15] The first application appears in the working paper (Balistreri, Böhringer, and Rutherford, 2018b). The BRF structure with foreign direct investment is also applied by Balistreri and Olekseyuk (2024) in the context of an investment-facilitation agreement.

across firm varieties, we have the typical CES aggregation

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

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,

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

where the p_{isr} are the landed-duty-paid prices faced in destination r. Equation (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 (2) we can derive the conditional demand for each firm-level variety:

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

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:

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

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:

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

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 the 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

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

In equation (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:

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

Equations (2) through (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 (4) into the zero-profit condition (5). Solving for the quantity we have:

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

The only margin of adjustment on a bilateral link is entry and exit, N_{isr}. Further, from equation (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 (2) directly as a function of the bilateral cost and the proportional change in varieties:

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

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 (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:

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

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

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

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

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.

3.2 A comparable Krugman structure

In contrast to the BRF trade equilibrium a standard Krugman model has entry of national varieties. A firm considers profits across all markets and weighs this against the fixed cost of entering. Once entered the firm supplies its variety to all markets. The same features hold, however, where we have fixed markups and fixed output per firm. To capture the Krugman structure in a comparable model we simply need to replace the bilateral variety index with a country-specific index.

Let us assume that a Krugman firm's composite input is the upstream bilaterally-

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

mobile input with price w_{is}. In this regard, the bilateral charges in terms of specific-factor rents and transport margins are simply additional costs taken as parameters by the firm. Where the firm markup and operating profits are attached to w_{is}. Let us denote total demand for the Krugman input y_{is}, where

$$y_{is} = \sum_r x_{isr} \frac{\partial c_{isr}}{\partial w_{is}}.$$

Following the same logic as in the model above we can use an index on this quantity, $\hat{y}_{is}$ to indicate the variety effects as they enter the Dixit-Stiglitz price index. Under the Krugman structure the equilibrium conditions are as follows.

The Krugman trade equilibrium:

$$A_{ir} = D_{ir} \tag{12}$$

$$P_{ir}^{\text{KRU}} = \left[\sum_s \lambda_{isr} \hat{y}_{is} [(1 + t_{isr}) c_{isr}]^{1-\sigma_i} \right]^{1/(1-\sigma_i)} \tag{13}$$

$$x_{isr}^{\text{KRU}} = A_{ir} \lambda_{isr} \hat{y}_{is} \left(\frac{P_{ir}^{\text{KRU}}}{(1 + t_{isr}) c_{isr}} \right)^{\sigma_i} \tag{14}$$

$$c_{isr} = \left[\alpha_{is} \left(w_{is} + \gamma_{isr} \tau \right)^{1-\eta_i} + \beta_{is} z_{isr}^{1-\eta_i} \right]^{1/(1-\eta_i)}. \tag{15}$$

As in the previous model, these four equilibrium conditions correspond to the four endogenous variables: P_{ir}^{KRU}, A_{ir}, c_{isr}, and x_{isr}^{KRU}. There is no degeneration when we use $\hat{y}_{is}$ in the bilateral-input market clearance condition, so it is used directly as determined in the general equilibrium.

3.3 A comparable Armington structure

In the final structure we assume perfect competition. If we have perfect competition there are no markups over marginal cost and no variety impact from entry or exit. In this case we simply remove the variety index from the model.

The Armington trade equilibrium:

$$A_{ir} = D_{ir} \tag{16}$$

$$P_{ir}^{\text{ARM}} = \left[\sum_s \lambda_{isr} [(1 + t_{isr}) c_{isr}]^{1-\sigma_i} \right]^{1/(1-\sigma_i)} \tag{17}$$

$$x_{isr}^{\text{ARM}} = A_{ir} \lambda_{isr} \left(\frac{P_{ir}^{\text{ARM}}}{(1 + t_{isr}) c_{isr}} \right)^{\sigma_i} \tag{18}$$

$$c_{isr} = \left[\alpha_{is} \left(w_{is} + \gamma_{isr} \tau \right)^{1-\eta_i} + \beta_{is} z_{isr}^{1-\eta_i} \right]^{1/(1-\eta_i)}. \tag{19}$$

Again, these four equilibrium conditions correspond to the four endogenous variables: P_{ir}^{ARM}, A_{ir}, c_{isr}, and x_{isr}^{ARM}.

4. Data

Beyond structural assumptions on causal relationships (i.e., model logic) a quantitative impact assessment of disruptive trade policy calls for empirical data. To simulate the impacts of new tariffs introduced by trade wars we need globally-consistent data that characterize technologies and preferences at the country level as well as a set of price response parameters (elasticities). Our primary data source is the recently released GTAP version 11 database (Aguiar et al., 2023). These data are aggregated and organized using the GTAPINGAMS routines (Lanz and Rutherford, 2016). GTAP 11 features detailed national accounts on production and consumption (input-output tables) together with bilateral trade flows, initial tariff rates and export taxes for the base-year 2017 across 65 goods matched to sectors and 141 countries as well as 19 composite regions. In addition to the social accounts, the GTAP 11 database provides empirically estimated elasticities that determine the responses of agents to policy-induced price changes.

Our analysis utilizes recent versions of the General Algebraic Modeling System (GAMS Development Corporation, 2013) and the PATH solver (Dirkse and Ferris, 1995) which permits high-dimensional resolution. We maintain a highly detailed set of commodities to capture the effects of trade policy that may vary with initial input cost shares, the ease of input substitution (as reflected by sector-specific cross-price elasticities) and sector-specific regulations, e.g. with respect to tariff rates. We do aggregate a few commodities to be consistent with the 57 commodities provided in the GTAP version 10 database in order to match the 2018 tariff database (which relates to the 57 commodities in GTAP 10), covering the trade war. These tariffs are compiled in Li (2018). We focus on key regions of interest and therefore aggregate to the nine regions listed in Table 1. Table 1 also lists the primary factors of production. The set of 57 commodities in our aggregation is listed in Table 2. Those sectors that are potentially treated as monopolistically competitive, under the Krugman and BRF structures, appear in bold face. These include processing, manufacturing, and business services sectors.

5. Policy scenario

In 2018 the trade war between the US and most of its trade partners, although significantly biased toward China, escalated quickly to the point of substantial disruptions to the world trading system. The rapid escalation of US and Chinese tariffs was both surprising and haphazard. Our analysis finds that the US and Chinese tariffs are at levels in excess of their optimum, so as a matter of reality it is not a strategic *Nash trade war* as we typically study in international economics (e.g., Markusen and Wigle, 1989; Lashkaripour, 2021). The observed tariffs on different products at different rates where apparently determined in a bureaucratic and political environment with little thought given to strategic terms-of-trade manipulation.

Table 1. Regions and primary factors in the application

Regions (R)		Factors (F)	
GTAPINGAMS Identifier	Definition	GTAPINGAMS Identifier	Definition
EUR	EU-27 plus	LAB	Unskilled labor
USA	U.S.A	TEC	Technicians and Professionals
CHN	China		
CAN	Canada	CLK	Clerks
MEX	Mexico	MGR	Managers and Officials
MRC	Mercosur		
KOR	S. Korea	SRV	Service workers
OEC	Rest of OECD		
ROW	Rest of World	CAP	Capital
		LND	Land
		RES	Resource

A rough description of the progression of the 2018 trade war follows.[17] The trade war began with the US imposing tariffs on steel and aluminum imports under a national-security provision (section 232 tariffs). Major producers facing these tariffs retaliated. Exempted from the steel and aluminum tariffs are Australia, South Korea, Argentina, and Brazil. These countries negotiated and received exemptions based primarily on their willingness to impose Voluntary Export Restraints (VERs) in the form of export quotas. The next escalation was prompted by the US's announcement of 25% tariffs on $50 billion worth of imports from China over two rounds in retaliation of alleged intellectual property infringements (section 301 tariffs). China responded to each round with its own tariffs covering $50 billion of US exports to China. At the end of September 2018 the US announced and imposed tariffs on an additional $200 billion worth of imports from China, with initially lower tariff rates that escalate to their full value as of January 2019. China retaliated with tariffs covering an additional $60 billion of imports from the US.

For our scenarios we select the level of tariffs as of 1 January 2019 as a break point. Of course, policy and other economic shocked evolved after January of 2019. The Phase One Agreement between the US and China promised some relief from the trade war in 2020, but this was largely unrealized in terms of China's commitment to significantly increase its imports from the US (Bown, 2022). Coincidentally, the global economy was disrupted by the pandemic. Through this and a change in US administrations the 2018 tariff escalations remain (Bown, 2023), so we consider the 1 January 2019 as a good break point for our policy experiment and exploration of structural sensitivity. We run a comparative-static analysis of the 2018 tariffs relative to our calibrated 2017 benchmark.

[17] For details, see Chad P. Bown's (e.g., Bown, 2023) posts on the Peterson Institute for International Economics page https://www.piie.com/.

Table 2. Commodities and Industries (I) used in the application

GTAPINGAMS Identifier	Definition	GTAPINGAMS Identifier	Definition
pdr	Paddy rice	**lum**	Wood products
wht	Wheat	**ppp**	Paper products, publishing
gro	Cereal grains nec	**oil**	Petroleum, coal products
v_f	Vegetables, fruit, nuts	**crp**	Chemical, rubber and plastic products
osd	Oil seeds	**nmm**	Mineral products nec
c_b	Sugar cane, sugar beet	**i_s**	Ferrous metals
pfb	Plant-based fibers	**nfm**	Metals nec
ocr	Crops nec	**fmp**	Metal products
ctl	Cattle,sheep,goats,horses	**mvh**	Motor vehicles and parts
oap	Animal products nec	**otn**	Transport equipment nec
rmk	Raw milk	**eeq**	Electronic equipment
wol	Wool, silk-worm cocoons	**ome**	Machinery and equipment nec
frs	Forestry	**omf**	Manufactures nec
fsh	Fishing	ele	Electricity
col	Coal	gdt	Gas manufacture, distribution
cru	Crude oil	wtr	Water
gas	Natural gas	cns	Construction
omn	Minerals nec	trd	Trade
cmt	Meat: cattle, sheep, goats, horse	otp	Transport nec
omt	Meat products nec	wtp	Sea transport
vol	Vegetable oils and fats	atp	Air transport
mil	Dairy products	**cmn**	Communication
pcr	Processed rice	**ofi**	Financial services nec
sgr	Sugar	**isr**	Insurance
ofd	Food products nec	**obs**	Business services nec
b_t	Beverages and tobacco products	ros	Recreation and other services
tex	Textiles	osg	Public administration, defense, health, education
wap	Wearing apparel	dwe	Dwellings
lea	Leather products		

Notes: Monopolistically competitive sectors appear in **bold** face. "nec" indicates not elsewhere classified.

We use GTAP 11 data (with the GTAP 10 sectoral structure—57 commodities and corresponding industries) to calibrate the model. The GTAP 11 data include benchmark tariffs as of 2017. The source for the tariff changes is Li (2018).[18] Our

[18] The tariff data are available for download at https://www.card.iastate.edu/china/

central scenario includes the escalated tariff rates as implemented 1 January 2019. For those countries that negotiated an exemption from the steel tariffs (Brazil and Argentina, and South Korea) we apply a Voluntary Export Restraint (VER) equal to 15% ad valorem in the form of an export tax of the respective bilateral trade flows. This gives us a rough approximation of the VER impacts. The important issue here is that the rents associated with the VER accrue to the export region not the US. Brazil and Argentina are a part of our composite Mercosur region. Given the relatively small value of steel imports from Mercosur we simply apply the VER to the whole Mercosur region. We perform counterfactual comparisons, of the 2018 trade war against the established benchmark equilibrium consistent with the 2017 GTAP accounts.

6. Results

Our modeling framework permits us to investigate the outcome of policy shocks for three alternative structural assumptions which figure prominently in applied trade analysis. For our central case we rely on the BRF model variant which combines theoretical innovations in the area of bilateral firm-level product differentiation with imperfect competition.

Table 3 reports the welfare impacts on private households (measured as equivalent variation) across the three model structures. The largest impacts are under our new BRF structure. Figure 3 provides a graphical exposition. Across regions damages from the trade war are concentrated on the US and China as we might expect. The steel and aluminum tariffs affect a relatively small share of global trade, whereas the tariffs between the US and China represent significant distortions on those links. Our BRF simulations suggests that the trade war costs the US on the order of $81 billion annually. While this is a sizable cost in dollars its share of aggregate US consumption (0.6%) is not large. Spread evenly across the roughly 130 million households the annual welfare cost is on the order of about $615 per household. The cost are not spread evenly, however, and so it is useful to consider some of the detailed results generated by the model.

trade-war-data/. See Li (2018) for additional details.

Figure 3. Welfare impacts

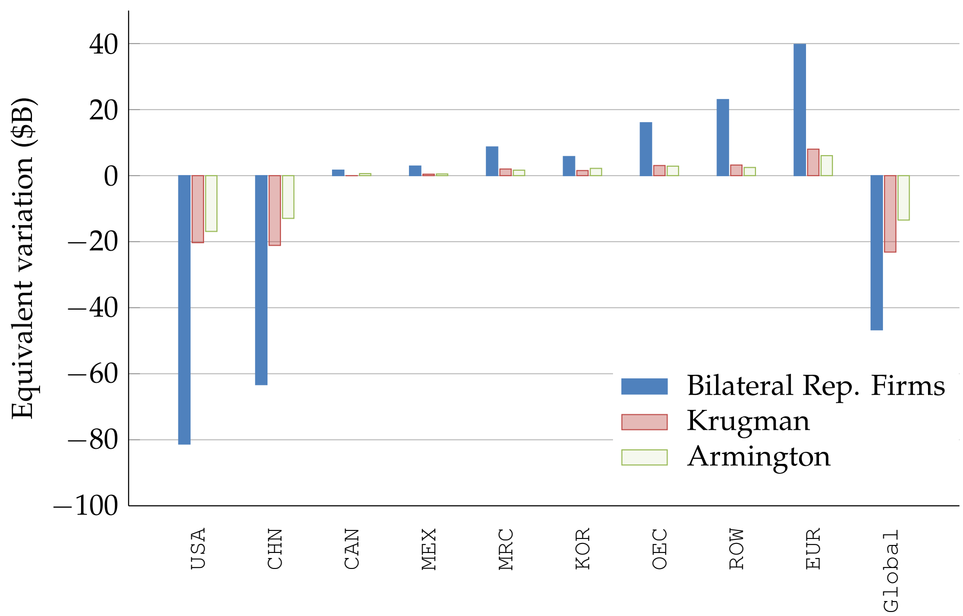


Table 3. Welfare impacts across model structures

	Benchmark GDP ($B)	Benchmark Consumption ($B)	Equivalent Variation ($B)			Equivalent Variation (%)		
			BRF	Krugman	Armington	BRF	Krugman	Armington
USA U.S.A	19,480	13,314	-81.3	-20.3	-16.9	-0.61	-0.15	-0.13
EUR EU-27 plus	18,708	10,582	39.8	8.0	6.1	0.38	0.08	0.06
ROW Rest of World	15,989	9,648	23.0	3.2	2.5	0.24	0.03	0.03
CHN China	12,652	5,071	-63.3	-21.1	-12.9	-1.25	-0.42	-0.26
OEC Rest of OECD	7,324	4,085	16.0	3.1	2.9	0.39	0.07	0.07
MRC Mercosur	2,810	1,832	5.8	1.5	2.2	0.32	0.08	0.12
CAN Canada	1,649	967	1.7	0.0	0.6	0.17	0.00	0.06
KOR S. Korea	1,624	751	8.7	2.0	1.7	1.16	0.27	0.22
MEX Mexico	1,159	754	2.9	0.4	0.5	0.39	0.06	0.07

Figure 4 reports the gross output changes for US sectors across the model structures. Figures 5 and 6 focus in on the ten sectors with the largest percentage losses and the ten sectors with the largest percentage gains. In the lower panel of Figures 5 and 6 we also report the losses and gains in dollars to give an indication of their importance in the broader economy.[19] The general pattern is that the bilateral representative firms model generates larger output responses, while the Krugman and Armington models generate similar output changes. There are a couple of exceptions, however. In particular, the Krugman and Armington models indicate larger output responses in a couple of agricultural sectors: the oil seed (primarily soybeans), plant based fiber (primarily cotton), and forestry products. These sectors are always modeled as constant-returns sectors indicating an important general equilibrium response. Under the BRF structure we have larger trade responses in the increasing-returns sectors, but the resource reallocation means slightly muted responses in the shrinking constant-returns sectors. The Krugman model, with national level entry and exit, indicates sectoral responses similar to the Armington structure despite the fact that welfare impacts are substantially larger in the Krugman model. Regardless of the trade structure it is clear that the Chinese retaliatory tariffs have a heavy impact on specific export dependent US agriculture sectors. Real revenue from oil seed production is off by between \$5.9B (11.6%) and \$6.6B (13.0%) across the model structures.

In Figure 6 we isolate the ten sectors with the greatest percentage increases in gross output. We show expansion in import-competing industries like ferrous metals (iron and steel) as well as machinery and equipment. There are some agriculture sectors that expand, e.g., wheat and crops nec, as factors used intensively in agriculture move out of those crops (mainly soybeans) exported to China. The most important expanding sectors, in terms of value, are again machinery and equipment and ferrous metals. Output for the machinery and equipment sector expands by between \$8.5B (2.0%) and \$18.7B (4.4%). In this case the difference between the market structures is critical. Under the bilateral representative firms model the output expansion is more than two times larger in this important increasing returns sector.

Another useful decomposition of the impacts involves considering the expenditure and income components of GDP. Table 4 provides the decomposition. In each record the value component is divided by the true-cost-of-living index (as established by the representative agent's unit expenditure function). Each record is thus measured in household consumption units, and the reported change in consumption expenditure represents equivalent variation in private consumption (welfare). It is important to note that the changes in the other expenditure accounts (investment (I), government (G), and exports less imports ($X - M$)) rep-

[19] Our measure of gross output in this case is calculated as the change in the sectoral revenue divided by the true-cost-of-living index for the US household. Thus, these reports are real revenue changes evaluated in household consumption units.

Figure 4. US sectoral impacts across models

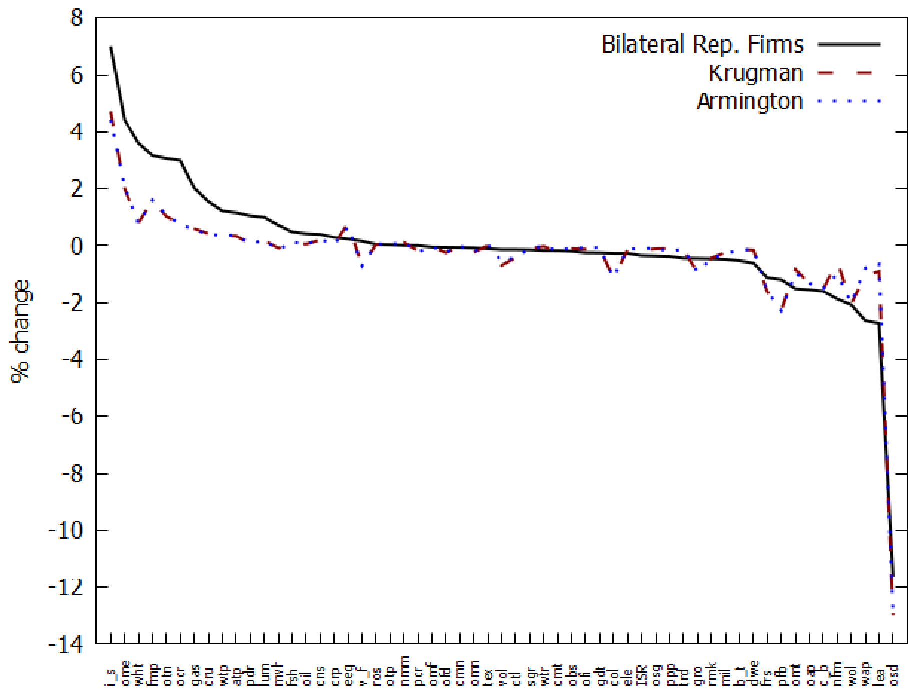


Figure 5. US Sectoral impacts: losers

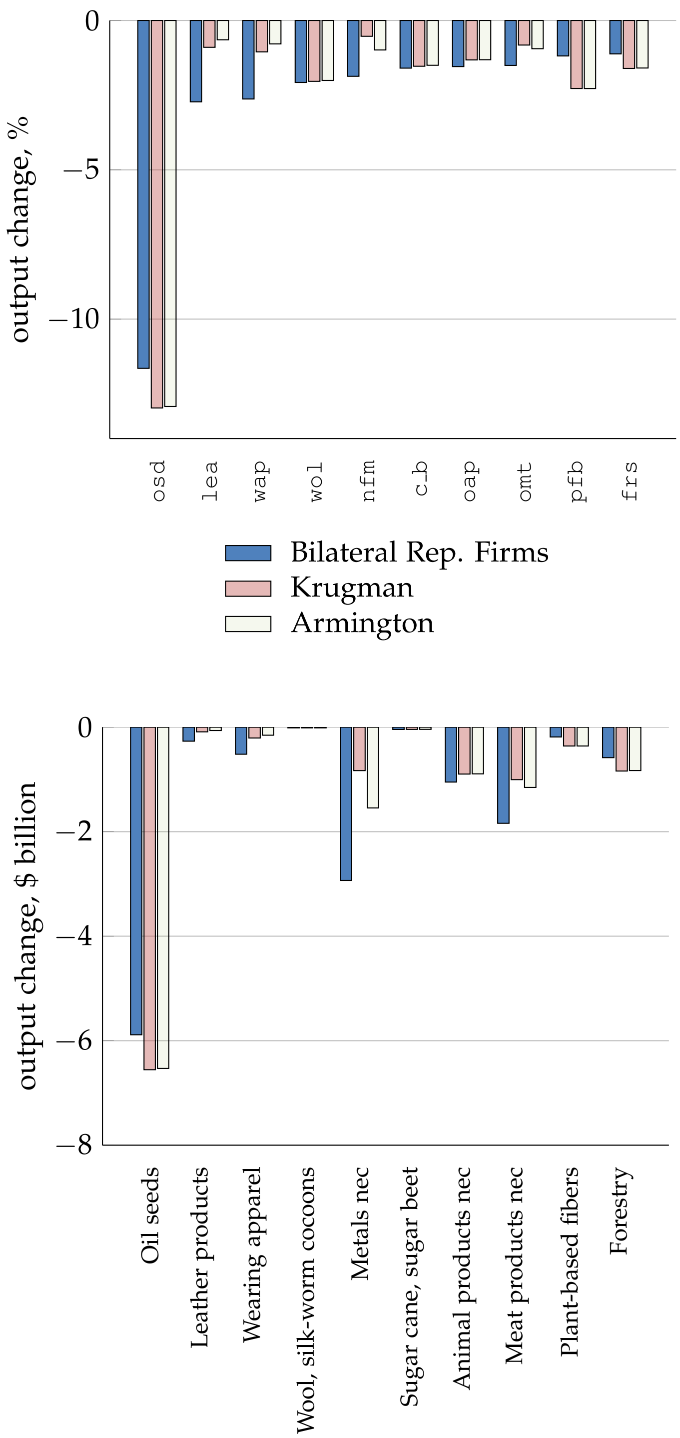
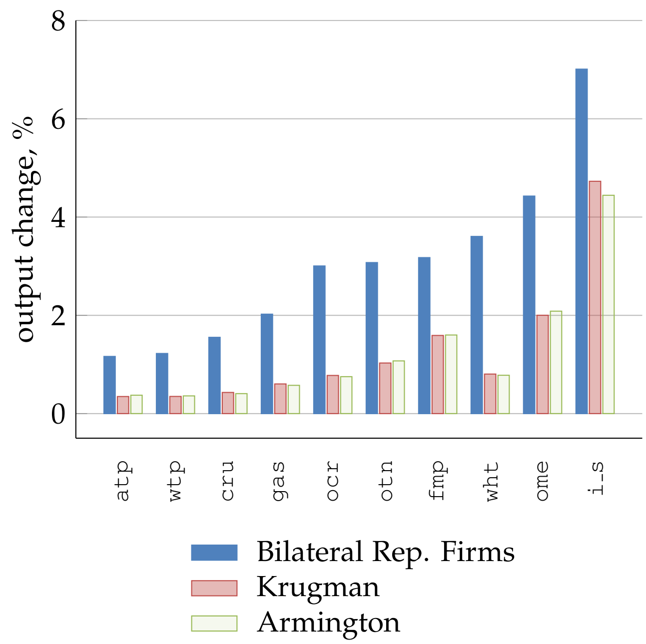
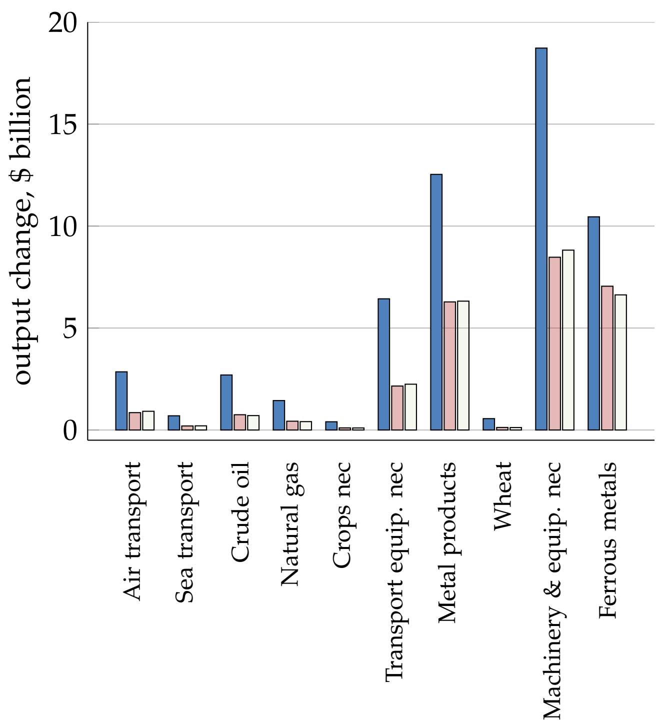


Figure 6. US sectoral impacts: winners





resent price changes, because the model is closed by holding these expenditures fixed (in their own prices). That is a -0.3% change in government expenditures reflects a -0.3% change in the price of the government's Leontief unit expenditure function relative to the price index associated with consumption (the true-cost-of-living index). It does not reflect a change in the quantity of any government expenditures. We make the simplest assumption about model closure: investment, government, and the trade balances are fixed in real quantity terms.[20]

Table 4. US real GDP impacts decomposed

	Benchmark ($B)	Change ($B)	Change (%)
Expenditures:			
Consumption	13,314	-81.3	-0.6
Investment	4,043	64.9	1.6
Government	2,746	-8.3	-0.3
Net Exports (X-M)	-622	-8.3	1.3
Total	19,480	-33.1	-0.2
Income by recipient:			
LAB Unskilled Labor	1,493	-11.0	-0.7
TEC Technicians and Professionals	868	-5.3	-0.6
CLK Clerks	1,118	-7.2	-0.6
MGR Managers and Officials	4,187	-26.9	-0.6
SRV Services workers	564	-3.1	-0.5
CAP Capital	6,466	-42.6	-0.7
LND Land	42	-2.9	-6.9
RES Resource	81	1.1	1.4
Specific factors	826	44.1	5.3
Direct factor tax	1,990	-12.2	-0.6
Output tax revenue	1,220	-2.4	-0.2
Indirect tax (domestic)	374	-2.3	-0.6
Tariff revenue	212	39.6	18.7
Export tax revenue	36	-2.1	-5.8
Total	19,480	-33.1	-0.2
Income by sector:			
obs Business services	3,925	-1.7	0.0
osg Public administration, defense, health, education	3,597	-24.1	-0.7
trd Trade	2,055	-14.3	-0.7

[20] In a neoclassical general equilibrium a real commodity unit (or a linearly homogeneous index of commodity units) must be established for the capital inflow ($M_r - X_r$). Summing across all regions global borrowing in the assumed capital good must be zero. To dissipate the impacts of choosing a particular good from a particular region, which might generate anomalous terms-of-trade effects, we choose an index over all goods consumed. Technically, the price index that establishes the fixed aggregated capital flow is constructed as the benchmark household-consumption weighted average of prices throughout the world.

dwe Dwellings	1,377	-9.6	-0.7
ros Recreation and other services	1,212	-2.6	-0.2
cns Construction	881	-5.1	-0.6
ofi Financial services	852	0.4	0.0
cmn Communication	767	0.2	0.0
isr Insurance	506	0.6	0.1
omf Manufactures	453	-1.9	-0.4
crp Chemical, rubber, plastic products	429	1.7	0.4
eeq Electronic equipment	368	12.0	3.3
otp Transport nec	341	-1.8	-0.5
ele Electricity	245	-1.6	-0.7
fmp Metal products	175	2.9	1.6
ome Machinery and equipment	171	5.4	3.2
mvh Motor vehicles and parts	148	-0.1	0.0
omn Minerals	138	-1.1	-0.8
ofd Food products	127	0.6	0.4
atp Air transport	121	0.9	0.7
cru Crude Oil	111	1.6	1.4
ppp Paper products, publishing	108	-0.3	-0.3
b_t Beverages and tobacco prod	104	-0.6	-0.6
wtr Water	101	-0.9	-0.9
otn Transport equipment	100	1.5	1.5
nmm Mineral products	52	0.3	0.5
gdt Gas manufacture, distribution	47	0.9	2.0
i_s Ferrous metals	45	6.6	14.5
v_f Vegetables, fruit, nuts	43	-0.2	-0.5
nfm Metals	42	0.8	1.9
oil Petroleum, coal products	35	1.1	3.1
frs Forestry	33	-0.5	-1.5
lum Wood products	30	0.4	1.2
cmt Meat: cattle,sheep,goats,horse	30	0.2	0.8
col Coal	29	-0.4	-1.4
gdt Gas manufacture, distribution	29	-0.2	-0.6
osd Oil seeds	28	-3.7	-13.2
oap Animal products	28	-0.8	-2.7
mil Dairy products	26	0.1	0.6
ctl Cattle,sheep,goats,horses	24	-0.3	-1.2
tex Textiles	23	0.2	0.9
omt Meat products	22	0.1	0.3
wap Wearing apparel	20	-0.1	-0.5
gro Cereal grains	19	-0.3	-1.8
wtp Sea transport	18	0.1	0.6
ocr Crops	12	0.3	2.4
sgr Sugar	10	0.0	0.3
lea Leather products	9	0.4	4.7
vol Vegetable oils and fats	9	0.2	2.0
rmk Raw milk	8	-0.2	-2.1

fsh Fishing	6	0.0	0.0
pfb Plant-based fibers	6	-0.1	-2.5
wht Wheat	6	0.1	2.6
c_b Sugar cane, sugar beet	2	0.0	-1.8
pdr Paddy rice	1	0.0	0.0
pcr Processed rice	1	0.0	1.8
wol Wool, silk-worm cocoons	0	0.0	-5.1
Consumption	282	-1.7	-0.6
Investment	-46	2.3	-5.0
Government	136	-0.4	-0.3
Total	19,480	-33.1	-0.2

In the second panel of Table 4 we decompose income to accommodate a standard functional incidence analysis. We see modest percentage losses for capital and the labor categories (in the 0.6% range consistent with percent equivalent variation), but larger losses for land owners (6.9%). This, again, reflects the focus of foreign retaliation on agricultural goods. It is important to consider that the nearly 7% loss in land income is a change in the income *flow*. With persistence, the decrease in land income can have a large capitalized value impacting farm values. There are, of course, sizable gains in tariff revenue on the income side. The third panel of Table 4 decomposes real income by sectors. These sectoral income accounts indicate value added by sector, but also include all tax revenue or payments associated with the sector including the payment of trade taxes on inputs and final demand. This is why the consumption, investment, and government accounts are included because some of the tax revenues are directly assigned to these final demand sectors.

In Table 5 we report the weighted-average Dixit-Stiglitz variety impacts for the monopolistically competitive sectors. The statistic reported is the percentage change in a multi-sector Feenstra ratio as developed by Balistreri and Tarr (2022).[21] The single-good Feenstra ratio is calculated for each of the monopolistically competitive sectors, and then averaged based on initial absorption (consumption plus intermediate use) shares. A key feature of the bilateral representative firms structure is that the number of firms can vary across trade partners. While US tariffs may induce *exit* of Chinese firms exporting to the US (resulting in adverse variety impacts on the US), the US tariffs may induce *entry* of Chinese firms exporting to Europe and Mexico, for example, resulting in variety gains for Europe and Mexico. This intensifies trade diversion along the extensive and intensive margins of trade. This bilateral extensive margin is not available under the standard Krugman structure. Under the Krugman structure varieties are only indexed by the

[21] In his Theorem 2, Feenstra (2010) provides a theoretic justification for his measure in a one sector model. The Feenstra ratio indicates the portion of the change in the composite price index in region r that is due purely to changes in the number of varieties.

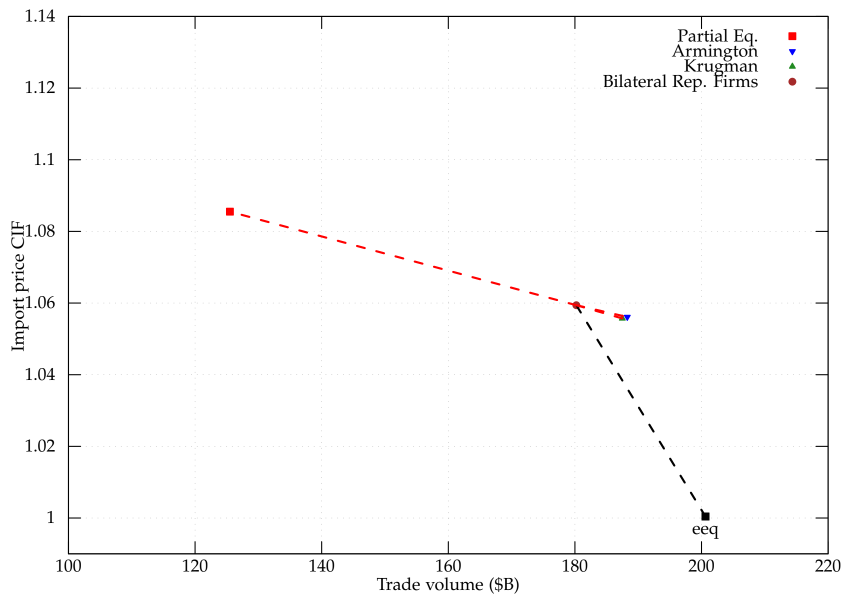
Table 5. Variety impacts across model structures

	Weighted average % change in Feenstra ratio	
	Bilat. Rep. Firm	Krugman
USA U.S.A	-0.100	-0.017
EUR EU-27 plus	0.025	0.003
ROW Rest of World	0.025	0.002
CHN China	-0.063	-0.029
OEC Rest of OECD	0.023	-0.001
MRC Mercosur	0.033	-0.027
CAN Canada	-0.020	-0.067
KOR S. Korea	0.035	-0.003
MEX Mexico	0.083	-0.016

exporting region. If the US tariffs induce exit of Chinese varieties this impact is felt by all of China's trade partners. Table 5 shows that the 2018 trade disruptions induce varieties losses for almost all regions of the world (with small gains in the EU and rest-of-world regions) under the Krugman structure. The Krugman structure, for example, indicates that Mexico benefits from the bilateral dispute between the US and China through trade diversion along the intensive margin, but suffers from an overall loss of varieties. In contrast, the bilateral representative firms model indicates variety gains for Mexico and all other regions except China, US, and Canada.

Figure 7 indicates trade and trade responses for US imports of Electronic Equipment (eeq) from China. The information is presented similar to that in Figures 1 and 2, but now our comparison is in the context of our general equilibrium simulations. In Figure 7 vertical shifts correspond to changes in protection and endogenous price responses, and horizontal shifts characterize consequent quantity adjustments (through interaction of supply and demand). The line that connects the benchmark point, labeled (eeq), with the BRF model outcome indicates the general equilibrium response. The line from the BRF point moving to the left connects to the first-order partial equilibrium outcome (the same response shown in Figure 1). This line indicates the difference between the partial equilibrium and BRF model responses. We can see that considering supply and demand in general equilibrium is important, because the trade volume falls by much less ($-20B under GE compared to $-75B under PE). Furthermore, the US landed price of electronic equipment rises by less than the tariff rate. This reflects a less than 100% tariff pass-through as the net price of Chinese eeq falls. The lines moving to the right of the BRF outcome, connect to the Armington and Krugman outcomes, indicating the differences in the trade responses across the three general equilibrium structures. We see that the BRF model indicates larger trade responses based on the bilateral-exit margin. It is striking how similar the responses are from the Armington and Krugman models despite the fact that we have larger

Figure 7. US Electronic Equipment (eeq) imports from China: benchmark trade, tariffs, and alternative model responses



welfare impacts in the Krugman model. This emphasizes the fact that in a multi-sector model variety impacts are important even under similar trade responses (see Balistreri and Tarr, 2022, for an extended analysis of this finding). The Krugman trade response is slightly larger than under Armington, but because Chinese electronic equipment firms only exit based on changes in global demand for their products the largely bilateral trade war does not indicate a trade response that is as dramatic as under the BRF structure.

Figures 8 and 9 provide the same analysis of trade responses as Figure 7 for goods with more than $1B in benchmark shipments (except US imports of eeq which is outside the scale of the graph). The full set of results are reported in Tables A.1 and A.2. For many of the important goods imported by the US we see a pattern similar to eeq. The partial equilibrium model exaggerates the trade response, and the Armington and Krugman models understate the response relative to a model with bilateral entry or selection. For Chinese imports we see many more cases where the partial equilibrium model understates the trade response relative to the BRF model. Motor vehicles and parts (mvh) is a good example. We mentioned in the introduction that the dramatic increase in Chinese tariffs on US mvh reduced trade from $14.1 B in the benchmark to $3.3 B based on the partial equilibrium response. Under the BRF structure scenario Chinese imports of mvh from the US are reduced to $2.3 B. An overall conclusion from the figures is that import responses are substantially higher in the bilateral representative firms en-

Figure 8. US imports from China (except eeq): benchmark trade, tariffs, and alternative model responses

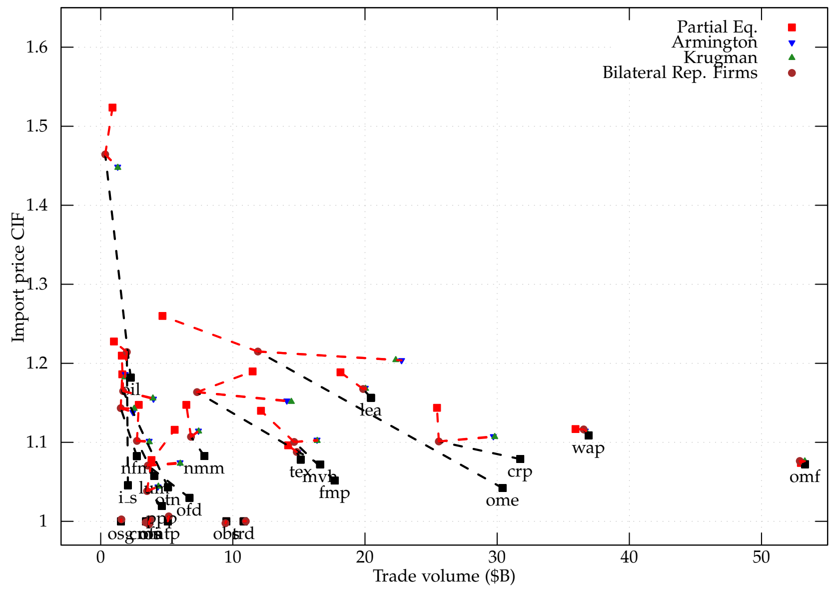
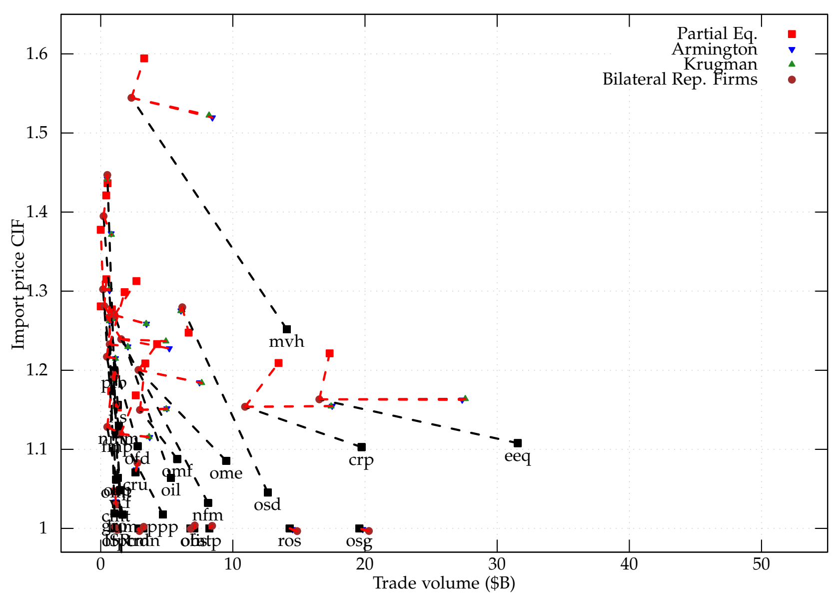


Figure 9. Chinese imports from the US: benchmark trade, tariffs, and alternative model responses



vironment relative to either the Armington or Krugman environments, although the models are build around the same *partial equilibrium* response parameters.

7. Conclusion

Protectionist movements around the world challenge the mainstream economic proposition that trade liberalization provides welfare gains. While such welfare gains may occur in aggregate, freer trade alone does not necessarily lead to Pareto improvements at the level of individual regions, industries, or households. Trade has heterogeneous distributional consequences, in which there are usually winners and losers. Given more recent waves of protectionism, applied economic analysis can play a useful role in informing the public debate on the magnitude and distribution of economic impacts triggered by trade policy interventions. At best, it helps to refute or confirm arguments by interest groups about the societal desirability of policy reforms. Such quantitative analysis must, however, be based on a rigorous assessment of the key drivers for trade and how these are affected by policy interventions. Once an analytical framework is established based on sound economic theory and empirical evidence, we can apply it coherent quantitative impact assessment .

Against this background, we conduct structural sensitivity analysis of the recent US-China trade war for three alternative microeconomic foundations of international trade: (i) the widely adopted Armington approach of regional product differentiation in competitive markets, (ii) the Krugman perspective of monopolistic competition and national-firm product varieties, and (iii) our more recent innovation emphasizing the role of firm selection into bilateral markets. This final structure is generally consistent with bilateral variety changes (as in Melitz, 2003), but does not lead to a significant increase in model complexity and its computational challenges.

Our application to the 2018 US-tariff escalation and trade-partner retaliation is relevant as an assessment of current policy. While we include the US steel and aluminum dispute with multiple partner countries, empirically this is dominated by the bilateral tariff war between the US and China. We find that the disruptive trade policies, restricting free trade largely through new tariffs, come at non-negligible welfare cost for the global economy. In their implementation, US tariffs have brought no national gains for the US, and in combination with retaliation generated substantial export losses for the US agricultural sectors. Overall, the trade war can hardly defended within the modeling framework we propose, even though it may benefit some at at the expense of others.

The structural sensitivity analysis on alternative trade assumptions shows how important it is to take scale economies and variety effects into account in order to quantify the magnitude and distribution of economic impacts at the level of countries and sectors. Trade barriers lead to a distortionary reallocation of resources across economies and this reallocation is amplified by variety effects. Extensions to the current framework can cover different dimensions, such as the inclusion of multinational enterprises and foreign direct investment. From an applied policy perspective, we demonstrate the computational power of our modeling framework by including considerable sectoral detail. This provides specific insights into the performance of individual industries and can reveal more subtle trade-offs as well as potential aggregation biases inherent to more aggregate policy assessments. Similarly, more refined incidence analysis calls for the incorporation of household heterogeneity to uncover and address equity problems. In terms of the methodological dimension, it would be instructive to compare our reduced-form approach of bilateral representative firms with a fully fleshed out Melitz structure, but this will likely require considerable sectoral aggregation to maintain analytical tractability.

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Appendix A.

Table A.1. US imports from China

	Benchmark		BRF		KRU		ARM		Partial Eq.	
Good	$B	Price	$B	Price	$B	Price	$B	Price	$B	Price
eeq	200.626	1.000	180.226	1.059	187.485	1.056	188.281	1.056	125.503	1.086
omf	53.291	1.072	52.895	1.076	53.275	1.076	53.128	1.075	52.977	1.074
wap	36.917	1.109	36.545	1.116	36.720	1.114	36.666	1.115	35.927	1.117
crp	31.750	1.079	25.583	1.101	29.813	1.107	29.706	1.107	25.447	1.144
ome	30.408	1.042	11.892	1.215	22.330	1.204	22.764	1.204	4.678	1.260
lea	20.452	1.156	19.859	1.167	20.041	1.168	20.018	1.169	18.141	1.189
fmp	17.703	1.052	14.640	1.101	16.387	1.102	16.371	1.103	12.128	1.140
mvh	16.603	1.072	7.290	1.163	14.426	1.151	14.087	1.153	11.497	1.190
tex	15.133	1.078	14.834	1.088	14.950	1.087	14.920	1.087	14.185	1.096
trd	10.818	1.000	10.980	1.000	10.909	0.999	10.851	1.001	10.818	1.000
obs	9.509	1.000	9.443	0.998	9.497	0.999	9.489	1.000	9.509	1.000
nmm	7.840	1.083	6.832	1.107	7.414	1.114	7.398	1.114	6.482	1.147
ofd	6.723	1.030	3.572	1.071	6.022	1.073	6.005	1.074	5.597	1.116
otn	5.095	1.043	1.699	1.165	3.953	1.156	3.996	1.155	1.599	1.210
atp	5.081	1.000	5.149	1.006	5.116	1.002	5.089	1.003	5.081	1.000
ppp	4.624	1.020	3.508	1.038	4.368	1.044	4.334	1.044	3.847	1.078
lum	4.053	1.058	2.743	1.102	3.680	1.100	3.665	1.102	2.882	1.147
ros	3.676	1.000	3.750	1.002	3.711	1.000	3.686	1.002	3.676	1.000
ofi	3.668	1.000	3.653	0.996	3.666	0.998	3.663	0.999	3.668	1.000
cmn	3.426	1.000	3.410	0.999	3.424	0.999	3.422	1.000	3.426	1.000
nfm	2.733	1.083	1.517	1.143	2.534	1.143	2.438	1.138	1.634	1.186
oil	2.270	1.182	0.342	1.464	1.295	1.448	1.285	1.449	0.892	1.524
i_s	2.059	1.046	1.978	1.214	1.830	1.183	1.859	1.186	1.002	1.228
osg	1.536	1.000	1.569	1.002	1.552	1.000	1.543	1.001	1.536	1.000
ISR	0.489	1.000	0.487	0.996	0.489	0.998	0.488	0.999	0.489	1.000
wtp	0.401	1.000	0.406	1.006	0.404	1.002	0.402	1.003	0.401	1.000
v_f	0.391	1.011	0.279	1.115	0.276	1.113	0.274	1.115	0.320	1.110
ocr	0.263	1.017	0.202	1.072	0.195	1.068	0.193	1.069	0.224	1.062
OMN	0.239	1.146	0.203	1.270	0.203	1.260	0.203	1.261	0.218	1.257
otp	0.234	1.000	0.238	1.005	0.236	1.001	0.234	1.003	0.234	1.000
oap	0.214	1.005	0.175	1.094	0.173	1.093	0.173	1.095	0.190	1.090
cns	0.170	1.000	0.173	1.007	0.172	1.001	0.171	1.003	0.170	1.000
cmt	0.117	1.000	0.050	1.047	0.102	1.049	0.102	1.051	0.072	1.100
vol	0.107	1.012	0.055	1.049	0.095	1.050	0.096	1.051	0.083	1.082
b_t	0.092	1.054	0.088	1.059	0.090	1.066	0.090	1.066	0.089	1.086
cru	0.025	1.375	0.009	1.535	0.009	1.519	0.009	1.519	0.012	1.512
frs	0.024	0.998	0.018	1.064	0.018	1.059	0.018	1.060	0.021	1.057
omt	0.019	1.026	0.008	1.072	0.017	1.073	0.017	1.074	0.011	1.121
osd	0.018	0.956	0.011	1.068	0.010	1.064	0.010	1.066	0.014	1.051
ele	0.009	1.000	0.006	1.072	0.006	1.066	0.006	1.067	0.007	1.064
fsh	0.007	1.003	0.006	1.075	0.006	1.076	0.006	1.079	0.007	1.078
sgr	0.006	1.245	0.004	1.256	0.005	1.266	0.005	1.268	0.005	1.320
gdt	0.004	1.000	0.002	1.111	0.003	1.101	0.003	1.102	0.003	1.097
pcr	0.003	1.058	0.001	1.104	0.003	1.105	0.003	1.107	0.002	1.158
wtr	0.002	1.000	0.002	1.003	0.002	1.000	0.002	1.001	0.002	1.000
mil	0.001	1.106	0.001	1.103	0.001	1.106	0.001	1.105	0.001	1.111
gro	0.001	1.002	0.001	1.107	0.001	1.105	0.001	1.107	0.001	1.102
pdr	0.000	0.953	0.000	0.996	0.000	0.995	0.000	0.997	0.000	0.993
wol	0.000	1.001	0.000	1.107	0.000	1.103	0.000	1.104	0.000	1.099
ctl	0.000	1.000	0.000	1.035	0.000	1.034	0.000	1.036	0.000	1.032
rmk	0.000	1.000	0.000	1.018	0.000	1.017	0.000	1.018	0.000	1.098
wht	0.000	1.015	0.000	1.103	0.000	1.101	0.000	1.103	0.000	1.015
col	0.000	1.159	0.000	1.290	0.000	1.280	0.000	1.282	0.000	1.275
pfb	0.000	0.958	0.000	1.109	0.000	1.105	0.000	1.107	0.000	1.053
c_b	0.000	1.000	0.000	1.059	0.000	1.056	0.000	1.058	0.000	1.100

Table A.2. China imports from US

Good	Benchmark		BRF		KRU		ARM		Partial Eq.	
	$B	Price	$B	Price	$B	Price	$B	Price	$B	Price
eeq	31.557	1.108	16.545	1.163	27.589	1.164	27.351	1.163	17.321	1.221
crp	19.741	1.103	10.920	1.154	17.435	1.155	17.517	1.155	13.461	1.209
osg	19.573	1.000	20.292	0.997	19.776	0.999	19.828	0.999	19.574	1.000
ros	14.299	1.000	14.868	0.997	14.475	0.999	14.524	0.999	14.299	1.000
mvh	14.086	1.252	2.329	1.545	8.196	1.522	8.452	1.519	3.291	1.594
osd	12.644	1.045	6.175	1.280	6.058	1.275	6.072	1.275	6.655	1.248
ome	9.499	1.086	2.855	1.200	7.643	1.184	7.478	1.184	4.267	1.233
atp	8.224	1.000	8.431	1.003	8.262	1.002	8.292	1.001	8.224	1.000
nfm	8.125	1.032	1.553	1.239	4.936	1.237	5.189	1.228	0.000	1.281
obs	7.072	1.000	7.120	1.004	7.080	1.000	7.087	1.001	7.072	1.000
ofi	6.788	1.000	6.815	0.999	6.792	0.999	6.799	1.000	6.788	1.000
omf	5.791	1.088	2.969	1.150	4.964	1.151	5.014	1.152	3.378	1.209
oil	5.317	1.064	1.054	1.270	3.441	1.259	3.469	1.259	2.704	1.313
ppp	4.709	1.018	1.511	1.119	3.662	1.116	3.708	1.115	2.654	1.168
cmn	3.240	1.000	3.252	1.002	3.241	1.000	3.244	1.001	3.241	1.000
trd	2.857	1.000	2.927	0.997	2.872	0.999	2.884	0.999	2.857	1.000
ofd	2.800	1.104	0.681	1.233	2.049	1.230	2.059	1.230	1.812	1.299
cru	2.635	1.071	2.778	1.083	2.682	1.074	2.681	1.074	2.635	1.071
lum	1.654	1.018	0.496	1.128	1.278	1.122	1.286	1.122	0.791	1.174
OMN	1.604	0.954	1.175	1.157	1.153	1.154	1.153	1.154	1.302	1.153
v_f	1.463	1.048	0.958	1.195	0.948	1.191	0.951	1.191	1.078	1.198
nmm	1.375	1.129	0.471	1.217	1.116	1.215	1.119	1.215	0.853	1.277
oap	1.297	1.064	1.027	1.191	1.019	1.188	1.022	1.188	1.090	1.195
i_s	1.291	1.156	0.215	1.395	0.813	1.372	0.794	1.373	0.418	1.421
ISR	1.265	1.000	1.269	0.998	1.266	0.998	1.267	1.000	1.265	1.000
fmp	1.253	1.119	0.276	1.281	0.888	1.265	0.886	1.265	0.431	1.315
omt	1.168	1.062	0.180	1.302	0.657	1.303	0.668	1.301	0.000	1.378
cmt	1.162	1.031	1.146	1.030	1.151	1.033	1.153	1.034	1.093	1.047
otp	1.057	1.000	1.085	1.002	1.062	1.001	1.068	1.001	1.057	1.000
gro	1.042	1.019	0.655	1.267	0.652	1.262	0.654	1.262	0.716	1.265
pfb	1.021	1.200	0.501	1.447	0.491	1.442	0.492	1.442	0.518	1.437
tex	0.969	1.089	0.352	1.169	0.799	1.166	0.804	1.166	0.521	1.223
wtp	0.915	1.000	0.936	1.004	0.918	1.002	0.921	1.002	0.915	1.000
lea	0.612	1.102	0.236	1.179	0.506	1.179	0.510	1.180	0.305	1.238
frs	0.610	0.985	0.486	1.045	0.469	1.043	0.470	1.043	0.512	1.048
ocr	0.607	1.068	0.262	1.257	0.257	1.251	0.258	1.251	0.257	1.257
b_t	0.487	1.072	0.078	1.297	0.287	1.292	0.290	1.291	0.338	1.357
col	0.479	1.263	0.142	1.568	0.140	1.557	0.140	1.558	0.134	1.562
gas	0.477	1.065	0.512	1.080	0.487	1.070	0.486	1.070	0.477	1.065
mil	0.477	1.073	0.101	1.232	0.325	1.230	0.328	1.230	0.117	1.294
wht	0.369	1.010	0.073	1.251	0.072	1.245	0.073	1.245	0.000	1.245
otn	0.313	1.083	0.079	1.214	0.237	1.201	0.234	1.201	0.095	1.258
fsh	0.258	1.067	0.253	1.080	0.253	1.077	0.254	1.077	0.255	1.076
wap	0.138	1.139	0.021	1.337	0.085	1.337	0.087	1.337	0.041	1.355
gdt	0.131	1.008	0.137	1.011	0.130	1.013	0.130	1.013	0.128	1.014
cns	0.095	1.000	0.097	1.004	0.095	1.002	0.096	1.002	0.095	1.000
vol	0.082	1.100	0.021	1.231	0.061	1.227	0.061	1.228	0.031	1.307
wtr	0.040	1.000	0.042	1.001	0.041	1.001	0.041	1.001	0.040	1.000
ele	0.031	1.000	0.033	0.999	0.031	0.999	0.032	0.999	0.031	1.000
sgr	0.018	1.065	0.005	1.167	0.014	1.165	0.014	1.165	0.011	1.215
ctl	0.017	1.005	0.018	1.001	0.018	0.998	0.018	0.998	0.017	1.005
wol	0.016	1.376	0.002	1.613	0.002	1.603	0.002	1.603	0.000	1.597
pcr	0.005	1.002	0.005	1.007	0.005	1.012	0.005	1.013	0.004	1.026
rmk	0.000	1.003	0.000	1.004	0.000	1.000	0.000	1.000	0.000	1.003
c_b	0.000	1.003	0.000	1.197	0.000	1.196	0.000	1.197	0.000	1.253
pdr	0.000	0.999	0.000	1.250	0.000	1.246	0.000	1.246	0.000	1.216