Appendix

Table 1: US allies

America's European NATO Allies	*America's European NATO Allies (cont.)*
Albania	Sweden
Belgium	Turkey
Bulgaria	United Kingdom
Croatia	
Czechia	*America's Other Allies*
Denmark	Bahrain
Estonia	Canada
Finland	Egypt
France	Israel
Germany	Jordan
Greece	Kuwait
Hungary	Qatar
Iceland	Taiwan
Italy	Thailand
Latvia	
Lithuania	*America's Asian Treaty Allies*
Luxembourg	Australia
Montenegro	Japan
Netherlands	Philippines
North Macedonia	South Korea
Norway	
Poland	*UK Affiliate*
Portugal	Bahamas
Romania	Bermuda
Slovakia	British Virgin Islands
Slovenia	Cayman Islands
Spain	

Note: Japan, South Korea, Australia, Philippines all have bilateral defense pacts with the US

Note: "America's Other Allies" consists of (a) countries that are designated by the US as major non-NATO allies that also have more than 100 active duty US troops deployed there, (b) Canada, which is a member of NATO but is not located in Europe, and (c) Taiwan, which is effectively a US ally. See the following for information on Taiwan's status as a US Ally: US House of Representatives. "Taiwan Major Non-NATO Ally Status," 2002.

Note: Countries which are not US allies, but nonetheless imposed sanctions on Russia, include: Austria, Cyprus, Georgia, Ireland, Liechtenstein, Malta, Monaco, Singapore, Switzerland, Ukraine, Greenland (Den.)

Table 2: Coding between meta-sectors, Forbes sectors, and OECD-TiVA sectors

Meta sector	Forbes sector	OECD-TiVA sector
Natural Resources	Materials	Mining and quarrying, non-energy producing products
		Mining support service activities
		Other non-metallic mineral products
		Basic metals
		Wood and products of wood and cork
		Agriculture, hunting, forestry
		Fishing and aquaculture
	Oil & Gas Operations	Mining and quarrying, energy producing products
		Coke and refined petroleum products
Consumer Industries	Transportation	Other transport equipment
		Land transport and transport via pipelines
		Water transport
		Air transport
		Warehousing and support activities for transportation
		Postal and courier activities
	Construction	Construction
	Consumer Durables	Motor vehicles, trailers and semi-trailers
		Rubber and plastics products
	Food, Drink & Tobacco	Food products, beverages and tobacco
	Food Markets	
	Hotels, Restaurants & Leisure	Accommodation and food service activities
	Health Care Equipment & Services	Human health and social work activities
	Household & Personal Products	Paper products and printing
		Textiles, textile products, leather and footwear
	Media	Publishing, audiovisual and broadcasting activities
		Arts, entertainment and recreation
		Education
	Retailing	Wholesale and retail trade; repair of motor vehicles
	Utilities	Electricity, gas, steam and air conditioning supply
		Water supply; sewerage, waste management and remediation…
High-Tech Industries	Aerospace & Defense	
	Chemicals	Chemical and chemical products
	Capital Goods	Fabricated metal products
		Machinery and equipment, nec
	Drugs & Biotechnology	Pharmaceuticals, medicinal chemical and botanical products
	IT Software & Services	IT and other information services
	Technology Hardware & Equipment	Computer, electronic and optical equipment
		Electrical equipment
	Telecommunications Services	Telecommunications
	Semiconductors	Professional, scientific and technical activities
Financial and Business Services	Banking	Real estate activities
	Business Services & Supplies	Manufacturing nec; repair and installation of machinery and…
		Administrative and support services
		Other service activities
	Conglomerates	
	Diversified Financials	
	Insurance	Financial and insurance activities
	Trading Companies	
TiVA only	TiVA only	Public administration and defence; compulsory social security
		Activities of households as employers; undifferentiated goods…

Notes: There are some TiVA sectors, such as "Public administration and defence" and "Activities of households as employers" that clearly do not correspond to corporate activity and that are excluded from the analysis for that reason.

Data sources

We drew from a wide range of sources in drafting this book. A large share of our analysis was reliant on a small concentration of key data sources. We briefly describe some of these sources below.

- **S&P Capital IQ:** Capital IQ provides breadth of data and resources on the operations of corporations around the world. This dataset was instrumental to our analysis of the ownership of the world's largest companies we conducted in Chapter 2.
- **Forbes Global 2000:** The Forbes Global 2000 is a compendium of the world's largest companies. We use this dataset in chapters 2, 3, and 4 to highlight the influence that American companies hold over commerce—particularly in high-technology sectors.
- **UN Comtrade:** United Nations Comtrade aggregates detailed annual and monthly trade statistics by product and trading partner for use by governments and analysts. We use this analysis to assess the strength of gross trade flows between America, China, and the world.
- **OECD Trade in Value Added (TiVA):** Like UN Comtrade, OECD TiVA aggregates statistics by product and trading partner. Its key distinguishing feature is that it also considers the value that countries add to the goods they export. This helps to correct some of the bias injected into trade statistics by processing trade. The underlying input-output matrices of this dataset form the basis of our short-run trade cost calculations. Unless otherwise noted, our calculations used the 2023 version of the database, which has trade data extending up to 2020.
- **The World Input-Output Database (WIOD):** The WIOD provides a vast amount of data on the industry-level trade of countries, as well as the usage of this trade in the intermediate production of trading countries. This made the dataset suited to the long-run modeling we conducted in chapter four. Our calculations used the 2016 version of the database, which has trade data extending up to 2014.
- **Penn World Tables:** The Penn World Tables database provides information on the relative income, health, and productivity of nations. Throughout the book, this dataset provided a variety of helpful statistics to compare the economic attributes of America and China.

Modeling the trade costs of conflict

The basic trade model is often used by economists to consider the effects of trade shocks. Borrowing from Krugman, Obstfled, and Melitz, the model is built upon four relationships: (1) the relationship between the production possibility frontier and the relative supply curve, (2) the relationship between relative prices and relative demand, (3) the determination of world equilibrium prices through relative world supplies and demands, and, critically, (4) the effect of changes in terms of trade on a country's welfare.[1] We use this model to conceptualize the effects of reduced Chinese participation in international trade due to US-China military conflict or economic warfare.

The model assumes that countries produce two goods, X and Y. Some countries are more effective at producing one good than the other due to differences in their production possibility frontiers.[2] The ratio of X to Y at which countries produce is determined by the relative prices of X and Y. A high price of X relative to Y would encourage a country to produce more of X. Under free trade, countries' output of and demand for X and Y determines an equilibrium price of X and Y.

Producers then calibrate their output along their production possibility frontiers according to these trade-determined relative prices. Consumers maximize their utility by consuming at the highest possible utility level tangent to the equilibrium price level. This leads to differences in goods *produced* and goods *consumed* within countries. These differences between consumption and production of goods X and Y within countries are their exports and imports. Countries can specialize in the production of goods they can easily manufacture. They finance imported goods with exports.

This model can be applied to US-China trade shocks. Diagram A shows an equilibrium in which China and the rest of the world (ROW) export good X and import good Y. The US imports X and exports Y.[3] The price of X is on the Y axis. The quantity traded of X is on the X axis.

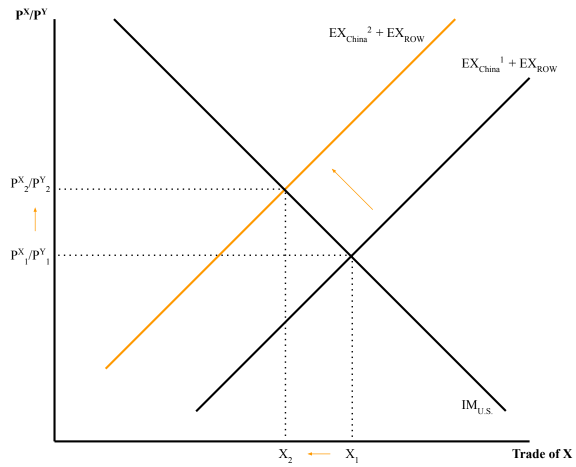
A US-China conflict would restrict China's trade with the world. This contraction in trade is shown as a leftward shift in the export supply curve from $EX_{China}^{1} + EX_{ROW}$ to $EX_{China}^{2} + EX_{ROW}$, representing trade declines from China. This decrease in Chinese exports of good X, and the resultant scarcity of X, then raises the relative price of X to Y from P_X^1/P_Y^1 to P_X^2/P_Y^2. Thus, the effects of a US-China conflict for importers of X from China would be felt as a rise in the price of good X.

[1] Paul Krugman, Maurice Obstfeld, and Marc Melitz, "Applications of the Basic Model," in *International Trade: Theory and Policy*, 11th ed. (London: Pearson, 2018), https://www.pearson.com/us/higher-education/program/Krugman-International-Trade-Theory-and-Policy-RENTAL-EDITION-11th-Edition/PGM1838560.html.

[2] A country N production possibility frontier more weighted toward good X than Y indicates that country N can produce more units of good X than good Y.

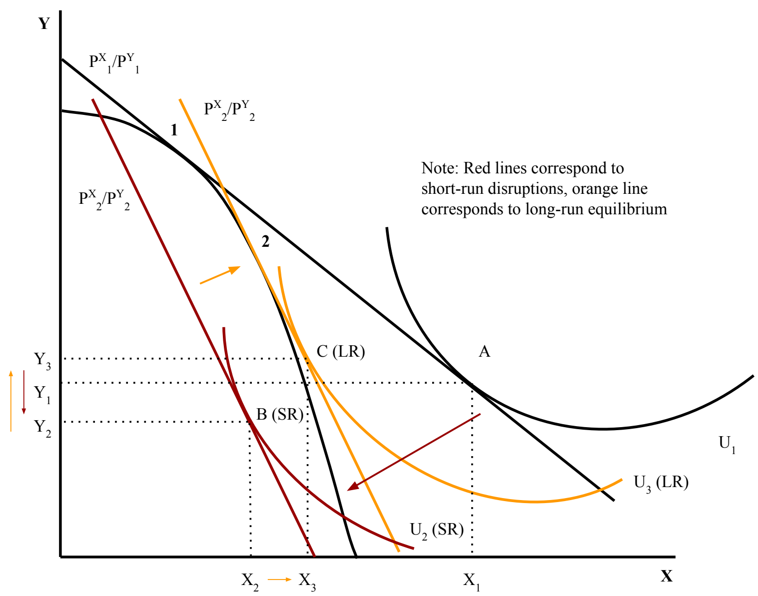
[3] Due to the importance of both the US and China in the world trading system, we assume that both are "large" countries, meaning that shifts in their respective import demand and export supply can alter world prices.

Diagram A: Global markets during a conflict with China



This rise in the relative price of X would cause the US, an X importer in this scenario, to experience a terms of trade decline, meaning that the price of its imports of X would become more expensive relative to its exports of Y. This can be visualized in Diagram B, which shows a shift from P_X^1/P_Y^1 to the steeper P_X^2/P_Y^2, representing this higher relative price of imports of X.

Diagram B: Short-run and long-run US losses during conflict with China



This decline in terms of trade for importers would have varying short-run and long-run costs. In the short run, the US would have only a limited ability to change its production patterns. Thus, it would pay a higher price for imports of X while not producing any additional units of X to offset these higher foreign prices.

Without production patterns adjusting to the price shock, the welfare implications for the US would be severe. This short-run scenario would most likely apply to a conflict between the US and China, in which a large degree of US-China trade ceases. A longer-term decoupling of the US and Chinese economies, however, would allow production to adjust.

We depict this short-run debacle in Diagram B, which shows US utility U_2 passing through its original production point 1, representing the inability of the US to alter short-run output from point 1 to point 2 to match the movement in consumption prices from P_X^1/P_Y^1 to P_X^2/P_Y^2. US welfare at U_2 and equilibrium B is lower than it would be under the pre-conflict equilibrium A. If US imports from China are large and not widely available, the costs of conflict would be stark.

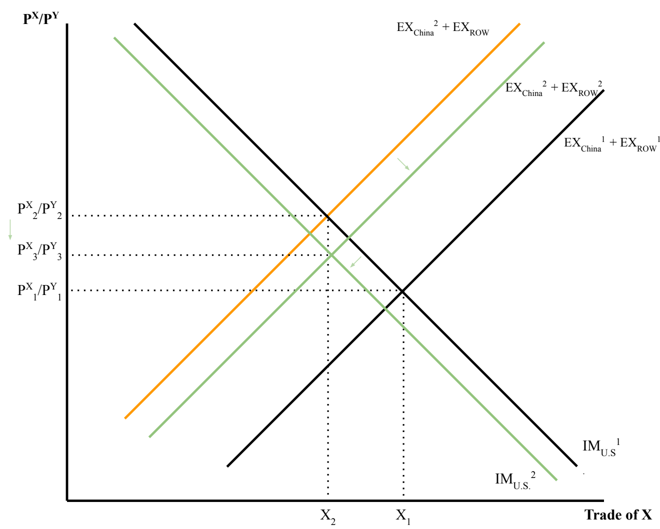
Remaining—non-Chinese—exporters of X would also be affected. Just as the US, an importer of X, experienced a welfare loss from good X becoming more expensive, exporters of X would see a terms of trade improvement and a *welfare gain* by selling X at a higher price. In a conflict, these producers could reap noteworthy welfare gains from selling their wares at these higher prices.

However, thus far this analysis has focused on what would happen to welfare in response to a US-China conflict in the *short run*, meaning that producers lack the ability to alter their production patterns to match conflict-caused changes in price levels. Of course, in the *long run,* producers can respond to price fluctuations and mitigate some of these short-run welfare effects.

In the long run, US producers would adjust to a conflict by producing more of X relative to Y, as shown by the movement along the US production possibility frontier from point 1 to point 2. This would result in a long-term increase in US welfare from U_2 to U_3. An increase in US production of good X would decrease US demand for imports of X, putting downward pressure on X's price on global markets and leading to a partial—though incomplete—restoration of welfare to pre-conflict levels. But because the US would still be unable to import good X at the lower prices provided by China, relative prices of X *could* remain higher than their pre-conflict equilibrium. This would make it challenging for U_3 to be lower than U_1. Finally, these short-run and long-run impacts could not only apply to the US. In a conflict in which China's trade with the rest of the world is depressed, they would impact any country that imports from China.

These long-run effects of production readjustments on export and import supplies are illustrated in Diagram C, which depicts US importers decreasing and non-Chinese exporters increasing import demand and export supply. This leads to a relative price of X to Y that is *lower* than the price of X to Y immediately after a conflict, though still above pre-conflict equilibrium prices. For importers of X, this leads to a terms of trade improvement and an increase in welfare relative to levels early in a conflict. A key lesson can be drawn from this: an ability to quickly shift production patterns in response to trade shocks would dampen the negative trade impacts of a US-China conflict by allowing a more bearable, but still costly, long-run trading equilibrium to be more quickly reached.

Diagram C: Long-run market shifts from US-China conflict



Analogous examples of China-based trade shocks can be found throughout the US-China trade relationship. Their effects have striking parallels to our predictions. At the outset of the COVID pandemic, Chinese export controls imposed upon facemasks and other PPE, of which China provided half the world's supply in 2020, restricted PPE supply and raised its price.[4] Many Americans will recall the very tangible "welfare losses" they experienced due to limited PPE supply at this critical juncture of the fight against the virus. As supply chains adjusted—both via countries producing more of their own PPE and through China's re-emergence as a PPE exporter—these welfare losses abated. The US could experience a larger, but parallel, shock in a conflict with China.

Though the US runs a large trade deficit with China, indicating that it imports more from China than it exports to it, the fate of US firms that export to China is another channel through which a US-China conflict could impact the US economy. The economic isolation of China during a conflict would eliminate Chinese demand for US exports, lowering the price of these exports on global markets and causing a terms of trade decline for US exporters.

Most indicators point to a US-China conflict being harmful to economic welfare. But there are channels through which conflict would *increase* economic well-being. Non-Chinese exporters of good X would see terms of trade and welfare

[4] Jennifer Cohen and Yana van der Meulen Rodgers, "Contributing Factors to Personal Protective Equipment Shortages during the COVID-19 Pandemic," *Preventive Medicine* 141 (December 2020): 5, https://doi.org/10.1016/j.ypmed.2020.106263.

enhancements due to a decrease in Chinese exports increasing the relative price of good X to good Y. If the US and China both exported good X, a war-imposed decline in Chinese exports would allow the US to "pick up the slack" from China, selling its exports of X at a higher price due to lower export Chinese supply of X. This would enhance US terms of trade and welfare. We evaluate whether such an occurrence could happen in the US-China context below as we construct our model of short-run trade costs.

Quantitative modeling:

Assumptions for trade costs in the short run

We calculate short-run trade costs as the sum of losses for exporters and importers. We model exporter losses via lost sales. We model importer losses via consumption foregone by trade friction. Several variables influence these losses: we describe them below and build them into our model.

First, exporter and importer losses are a function of export and import volume. A larger volume of trade between countries naturally makes such trade more costly to disrupt.

The second is intermediate production linkages. Caliendo and Parro note that "sectors and countries are interrelated."[5] If the US lost access to a Chinese import, this could not only affect the sector importing that good. Disruptions could also affect producers purchasing from that sector, and spill to other sectors thence. The costs of trade friction increase with trade's importance to production.

There is also a cross-national element to production disruptions. If a Japanese firm is deprived of Chinese exports, its own production might be disrupted, limiting its exports to America, and so on. It is key to capture how production disruptions in one country might spill into others, though it is also important to recognize that these spillovers could take time to have an effect. During that time, efforts may be undertaken to restore the good originally lost, which could dampen these cross-national disruptions.

Exporters are also adversely affected by trade shocks. But these losses take the form of foregone revenue, as opposed to losses in consumption. For example, exporters at the outset of the 2018 trade war did not respond to tariffs with large-scale production adjustments.[6] Their losses were revenue losses. And such losses, though important, do not equate to the production disruptions caused by losses in imports—especially if the government provides aid to harmed exporters.

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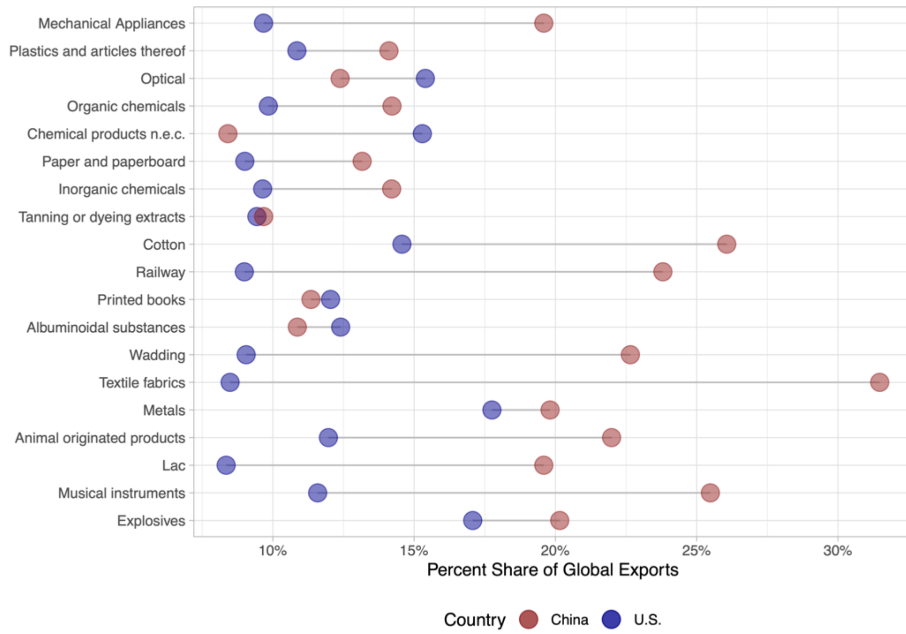
[5] Caliendo and Parro, "Estimates of the Trade and Welfare Effects of NAFTA."

[6] Mary Amiti, Stephen J. Redding, and David E. Weinstein, "The Impact of the 2018 Tariffs on Prices and Welfare," *Journal of Economic Perspectives* 33, no. 4 (November 1, 2019): 187–210, https://doi.org/10.1257/jep.33.4.187.

There are some assumptions our model does not capture. We do not model how trade frictions influence the price of exports—the "pick up the slack" point discussed in the prior section. For example, imagine one exporter is prevented from selling its wares. The reduction in the supply from this exporter will increase its price, benefiting the remaining exporters of that good. This is a common dynamic. Sanctions on Russia resulting from its invasion of Ukraine increased the price of oil, which reduced the losses to the Russian economy as the oil it could sell was sold for a higher price.

Figure 1: US and Chinese exports above 8 percent of the global share



Source: UN Comtrade, 2019.

But this dynamic is not applicable to how trade frictions would affect the US and China. Chinese exports are not fungible in the way Russia's commodities exports are. China is an exporter of intermediate goods, such as electronic and machinery equipment. These goods fulfill specialized functions in supply chains that can't easily be replaced. Chinese and American exports are also dissimilar. As the figure above shows, in only 19 of the 97 goods identified by UN Comtrade do America and China export above 8 percent of the global share. Such industries are peripheral. For instance, the US and China account for a large share of the world's cotton exports. A windfall for US cotton producers from sanctions on the Chinese economy would likely not improve the outlook of the US economy during a sanctions campaign.[7]

[7] China does export much of the world's machinery equipment, controlling a 19 percent share while the US controls 9 percent. An increase in the price of these goods could plausibly benefit US exporters. Yet within machinery equipment, China exports

In the advanced sectors of world commerce, the US and China specialize in different areas. It is thus unlikely that either country would garner a windfall from the other's exports being reduced, at least in the short run. Our not accounting for how exporters might benefit from a reduction in Chinese exports in the short run should not bias our estimates of the trade costs from conflict with China.

Our model also does not consider how the costs of lost trade could be limited in the medium term. Here, there are several channels through which the short-run effects of lost trade may be offset: (1) lost imports from one country may be substituted with imports from others, (2) domestic production may compensate for lost imports, (3) exporters may over time sell their wares to locations beyond their original destinations. But these variables require time to take effect. We thus exclude them from our headline model of the upfront effects of trade frictions.[8]

Calculating the costs of a short-run US-China trade rupture is challenging. The perfect may be the enemy of the good. Our framework does not capture all the ways America and China might lose—or gain—from trade frictions in the short run. Still, it captures those of the greatest relevance to America and China. With state-of-the-art trade data, our model of short-run trade costs provides a robust baseline of the losses that the US and China would suffer from lost trade.

Modeling short-run trade disruptions

To translate the above assumptions into a framework capable of interpreting trade data, we develop a model to outline the costs that would result from varying levels of trade frictions between countries. We outline the assumptions behind this model below.

Baseline model:

First, the costs of a disruption to a country n's *imports* are a function of the share of trade lost between country n and any exporting country i for industry j, τ_{in}^{j}, where $0 \leq \tau_{in}^{j} \leq 1$ and a greater τ_{in}^{j} value denotes a higher share of lost trade between countries. Second, it is also a function of the overall volume of country n's imports of industry j from country i, M_{in}^{j}. We express importer losses IM_n in Equation 1.

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computer hardware—accounting for 36 percent of China's exports of this industry. The US is specialized in goods upstream of these areas. Computer hardware only accounts for 12.5 percent of US machinery exports. America is far more involved in the production of machinery, 8.1 percent; equipment used for the manufacture of semiconductors, 7.5 percent; and turbo jets, 4.5 percent. Calculated with UN Comtrade data on China's exports disaggregated at the HS-4 level; see UN Comtrade International Trade Statistics Database, accessed October 5, 2022, https://comtrade.un.org/data.

[8] Though we have some iterations of the model that include them later.

1. $IM_n = \sum_{i=1}^{i} \sum_{j=1}^{j} \tau_{in}^{j} M_{in}^{j}$

Under Equation 1, the costs from declines in imports are: (1) higher when a larger share of trade is eliminated for a given country-industry trading pair, τ_{in}^{j} and (2) higher when there is a high volume of country n imports of industry j from country i, denoted by a larger M_{in}^{j} value.

Next, we must account for losses from disruptions to exports. Losses for exports EX_n can be expressed as a function of trade losses in terms of country n industry j exports to country i, τ_{in}^{j} and export value, E_{ni}^{j}.

2. $EX_n = \sum_{i=1}^{i} \sum_{j=1}^{j} \tau_{in}^{j} E_{ni}^{j}$

Total losses C_n is expressed as the sum of import and export losses in Equation 3.

3. $C_n = IM_n + EX_n$

These losses can be represented as a share of output. We use value-added output, V_n, to do so.[9] This allows an expression of losses as a percentage of output in Equation 4. This is the method we use to calculate losses in baseline model of chapter six.

4. $R_n = \frac{C_n}{V_n}$

Enhanced production disruptions

However, there are two ways in which our estimates of losses could be greater than those we display in the baseline model. The first is that losses can reverberate cross-nationally; reductions in imports destined for one country will disrupt its ability to export to others. Though it is challenging to capture how great such cross-national effects would be, we simulate them in a simple loop in which a country's economic losses inhibit its ability to export.

This allows us to represent cross-national trade frictions $\tau_{in}^{j}cn$ as a function of the total losses suffered relative to value-added output R_n in Equation 5. We allow trade frictions to increase in the manner specified in Equation 5 over the course of one iteration. This captures initial losses from a trade disruption and allows these losses to manifest as a new trade disruption.

[9] Value-added when aggregated across an entire economy is simply equal to gross domestic product.

5. $\tau_{in}^{j} cn = R_n * \tau_{in}^{j}$

The second is that if a good is heavily used in intermediate production, losing access to imports of it could be especially damaging, as its loss would cause a set of other goods to have their production disrupted. γ_n^j represents the importance of an import to production. A higher γ_n^j indicates that a good is widely used in domestic production and that its loss will inflict disproportionate harm. Equation 6 shows how we incorporate this intermediate production parameter into our model.

6. $IM_n = \sum_{i=1}^{i} \sum_{j=1}^{j} \tau_{in}^{j} \left[M_{in}^{j}\right]^{1/(1-\gamma_n^j)}$

We have intermediate consumption amplify importer losses through the expression $1/(1-\gamma_n^j)$. This means that if a good comprises 5 percent of a country's intermediate consumption, its loss could result in the entirety of a country's import losses being exponentiated by a value of $\frac{1}{1-.05} = 1.053$.

We incorporate the additional losses represented in Equations 5 and 6 in the "enhanced production disruptions model," which is shown in Equations 7 through 10.

7. $IM_n enhanced = \sum_{i=1}^{i} \sum_{j=1}^{j} \tau_{in}^{j} cn \left[M_{in}^{j}\right]^{1/(1-\gamma_n^j)}$

8. $EX_n \text{enhanced} = \sum_{i=1}^{i} \sum_{j=1}^{j} \tau_{in}^{j} cn E_{ni}^{j}$

9. $C_n enhanced = IM_n enhanced + EX_n \text{enhanced}$

10. $R_n enhanced = \frac{C_n enhanced}{V_n}$

Taking the short-run model to the data

With these conditions, all that is required to estimate the short-run costs of increased trade friction C_n is data on industry-level imports M_{in}^{j} and exports E_{ni}^{j}, intermediate consumption shares γ_n^j, value added V_n. We source this data from the OECD Inter-Country Input-Output (ICIO) tables. This dataset is appealing, as it receives frequent updates and maintenance from the OECD and has detailed trade data up to 2020 in the 2023 edition of the dataset.

Rather than using value-added trade to calculate short-run disruptions, we use gross trade.[10] While the value-added content of China's exports is important to the ability of the US to replace exports from China, such considerations do not

[10] *Gross trade* refers to the value of trade flowing between countries without accounting for the value that these countries might add to their exports. Gross trade is a measure also provided by the ICIO data within the econGTR matrix. This aggregates final and intermediate trade.

apply in the short run. The removal of China from supply chains would remove the *entire* value of China's exports from the trade system, not just the value it adds to them. All the intermediate goods flowing into China for processing—which is captured gross trade—could be bottlenecked by short-run trade reductions. Accounting for the full value of goods flowing through China—even when China does not produce them—is important to understand how the world economy could be disrupted by dislocations to China's trade.[11] We do, however, use a measure of value-added to represent these losses as a share of GDP.[12]

The Caliendo and Parro model:

We now discuss the assumptions behind the Caliendo and Parro model used to calculate the long-run costs of increased trade friction with China in Chapter 6. The Caliendo and Parro model assumes that each country has L_n households that maximize utility by consuming final goods C_n^j. Preferences are given by Equation 1 as a function of the quantity C_n^j of good j consumed by country n and consumption of good j relative to all other goods J.

(1) $$u(C_n) = \prod_{j=1}^{J} C_n^{j\,\alpha_n^j}, \text{ where } \sum_{j=1}^{J} \alpha_n^j = 1$$

Sector j produces a continuum of intermediate goods $\omega^j \in [0,1]$. These goods have two inputs: labor and composite intermediate goods from all sectors. With these inputs, country production of good ω^j is given as Equation 2.

(2) $$q_n^j(w^j) = z_n^j(\omega^j)\left[l_n^j(w^j)\right]^{\gamma_n^j} \prod_{k=1}^{J}\left[m_n^{k,j}(\omega^j)\right]^{\gamma_n^{j,k}}$$

$z_n^j(\omega^j)$ denotes the efficiency of producing intermediate goods in country n. $l_n^j(w^j)$ represents labor, while $m_j^{k,j}(\omega^j)$ refers to the composite intermediate goods used in the production of ω^j. $\gamma_n^{j,k} > 0$ represents the share of intermediates from sector k used in the production of intermediate good j. $\gamma_n^j > 0$ represents the share of value added.

Costs of an input bundle are given by Equation 3 as a function of the price of composite intermediate goods from sector k, P_n^k. φ_n^j is a constant. Thus, the cost of an intermediate good is contingent on the price of all other intermediate goods in the economy. This ensures that a price change for one good will affect the price of all goods.

(3) $$c_n^j = \varphi_n^j w_n^{\gamma_n^j} \prod_{k=1}^{J} P_n^{k\,\gamma_n^{j,k}}$$

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[11] Accessed via the econZ matrix of the ICIO data.

[12] Accessed via the econVA matrix of the ICIO data.

Producers of intermediate goods purchase intermediate goods ω^j from the lowest cost suppliers. There are costs to trade in goods, however. Caliendo and Parro assume iceberg costs and ad-valorem flat rate tariffs. Iceberg costs are the number of physical units of a good $d_{ni}^j > 1$ that must be produced to deliver $d_{nn}^j = 1$ units. Equation 4 represents costs κ_{ni}^j, with $\tilde{\tau}_{ni}^j$ corresponding to ad-valorem tariffs and d_{ni}^j corresponding to iceberg costs.

$$\textbf{(4)} \qquad \kappa_{ni}^j = \tilde{\tau}_{ni}^j d_{ni}^j$$

An intermediate good ω^j produced in country i is then sold in country n at a price of $\frac{c_i^j \kappa_{ni}^j}{z_i^j(\omega^j)}$. Consumers prefer goods at the lowest price. Thus, p_n^j can be defined as Equation 5.

$$\textbf{(5)} \qquad p_n^j(\omega^j) = min\left\{\frac{c_i^j \kappa_{ni}^j}{z_i^j(\omega^j)}\right\}$$

To introduce Ricardian motives, we assume that the efficiency of producing a good ω^j follows a Fréchet distribution, with a location parameter λ_i^j and a trade elasticity $\boldsymbol{\theta^j}$.

$$\textbf{(6)} \qquad P_n^j = A^j \left[\sum_{i=1}^N \lambda_i^j \left(c_i^j \kappa_{ni}^j\right)^{-\theta^j}\right]^{-1/\theta^j}$$

In this context, a higher λ_i^j indicates a higher average productivity in a sector. A small θ^j implies that productivity is dispersed. A large value of $\boldsymbol{\theta^j}$ implies that productivity is concentrated. Oil production, which only occurs in a small number of countries, has a high θ^j value. Plastic production, whose manufacture is an easier, more globally diluted process, has a low θ^j value.

Expenditure shares can be represented as the ratio of country n's expenditure on good j from country i relative to its total expenditure on good j, $\pi_{ni}^j = X_{ni}^j / X_n^j$. The parameter π_{ni}^j can also be expressed as a function of technologies, prices, and trade costs in Equation 6.

$$(7) \qquad \pi_{ni}^j = \frac{\lambda_i^j \left[c_i^j \kappa_{ni}^j\right]^{-\theta^j}}{\sum_{h=1}^N \lambda_h^j \left[c_h^j \kappa_{nh}^j\right]^{-\theta^j}}$$

The above takes the form of a gravity equation. Next, country n expenditure on sector j, X_n^j, sums expenditure on composite intermediate goods and expenditure by households.[13]

$$\textbf{(8)} \qquad X_n^j = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} X_i^k \frac{\pi_{in}^k}{1+\tau_{in}^k} + \alpha_n^j I_N$$

$I_n = w_n L_n + R_n$ represents the final absorption in country n, which is the sum of income to labor and tariff revenue, $R_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{ni}^j X_n^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j}$. Equation 8 allows for an equilibrium condition in Equation 9, which states that total expenditure in country n, excluding tariff payments, equals the sum of each country i's expenditure on goods produced by country n.

$$\textbf{(9)} \qquad \sum_{j=1}^{J} \sum_{i=1}^{N} X_n^j \frac{\pi_{ni}^j}{1+\tau_{ni}^j} = \sum_{j=1}^{J} \sum_{i=1}^{N} X_i^j \frac{\pi_{in}^j}{1+\tau_{in}^j}$$

Expressed in relative changes, this allows wage changes $\widehat{w}$ to be estimated for changes in trade tension with observations of labor income, $w_n L_n$, i.e., value added in production across sectors j, $\sum_{j=1}^{J} \gamma_n^j$; trade shares between countries, π_{ni}^j; intermediate consumption shares, $\gamma_n^{j,k}$; final consumption shares, α_n^j; and sectoral dispersion of productivity, θ^j.

Solving the Caliendo and Parro model in relative changes

The Caliendo and Parro model can be solved for an equilibrium under a given τ in relative changes, using exact hat algebra to estimate the changes in welfare for a given change in tariffs. This involves inputting a change in trade tension, and then iterating through guesses for $\widehat{w}$ to satisfy the equilibrium condition in relative changes in Equation 15. $\widehat{w}$ guesses are updated until they fall within a specified tolerance level, at which point the equilibrium condition is satisfied and the model generates a final $\widehat{w}$ estimate. Equations from the above section are presented in relative changes below, allowing for a $\widehat{w}$ guess for all changes in trade tension.

Cost of inputs

$$\textbf{(10)} \qquad \hat{c}_n^j = \widehat{w}_n^{\gamma_n^j} \prod_{k=1}^{J} \hat{P}_n^{k\,\gamma_n^{k,j}}$$

[13] Unlike Caliendo and Parro, we assume no trade deficits and normalize all data for their absence prior to running counterfactuals.

Price index

$$\text{(11)} \quad \hat{P}_n^j = \left[\left[\sum_{i=1}^{N} \pi_{ni}^j \left[\hat{\kappa}_{ni}^j \hat{c}_i^j\right]\right]^{-\theta^j}\right]^{\frac{1}{-\theta^j}}$$

Trade shares

$$\text{(12)} \quad \hat{\pi}_{ni}^j = \left[\frac{\hat{\kappa}_{ni}^j \hat{c}_i^j}{\hat{P}_n^j}\right]^{-\theta^j}$$

Total expenditure by country n on sector j

$$\text{(13)} \quad X_n^{j\prime} = \sum_{k=1}^{J} \gamma_n^{j,k} \sum_{i=1}^{N} \frac{\pi_{in}^{k\prime}}{1+\tau_{in}^j} X_i^{k\prime} + \alpha_n^j I_n^{\prime}$$

Trade balance

$$\text{(14)} \quad \sum_{j=1}^{J} \sum_{i=1}^{N} X_n^{j\prime} \frac{\pi_{ni}^j}{1+\tau_{ni}^{j\prime}} = \sum_{j=1}^{J} \sum_{i=1}^{N} X_i^{j\prime} \frac{\pi_{in}^{j\prime}}{1+\tau_{in}^{j\prime}}$$

Other assumptions

$$\text{(15)} \quad I_n^{\prime} = \hat{w}_n w_n L_n + \sum_{j=1}^{J} \sum_{i=1}^{N} \tau_{in}^{j\prime} \frac{\pi_{in}^{j\prime}}{1+\tau_{in}^{j\prime}} X_n^{j\prime} \text{ and } \hat{\kappa}_{ni}^j = \frac{1+\tau_{ni}^{j\prime}}{1+\tau_{ni}^j}$$

With an estimate of $\hat{w}$ generated through the above equilibrium condition, we estimate national changes in prices to calculate welfare changes $\hat{W}_n = \frac{\hat{w}_n}{\hat{P}_n}$. National price changes are calculated as $\hat{P}_n = \prod_{j=1}^{J} \hat{P}_n^{j\,\alpha_n^j}$, weighting estimated sector-level price changes in response to trade tension $\hat{P}_n^j$ by share of consumption of good j in country n α_n^j . We assume a lack of deficits, which means that, even without trade tension, the model is not in equilibrium, as trade deficits exist in the real world. Thus, without adjusting for deficits, estimated wages include the impact of deficit adjustments as well as trade tension. To eliminate this source of bias, we generate estimates for trade shares, total expenditure in the absence of trade tension, and labor income in response to deficit elimination. We then utilize these parameters as initial values for all counterfactuals to remove bias from the welfare effects of trade deficit reduction.

Taking the Caliendo and Parro model to the data

We construct the core parameters of the Caliendo and Parro model from the World Input-Output Database (WIOD). The WIOD provides annual timeseries of world input-output tables until 2014. It is built upon officially published, national input–output tables and national accounts data and trade statistics. The WIOD has 43 countries and 56 industries, including goods and services.

There are some limitations to using the WIOD. First, it does not include data beyond 2014. More recent data would be preferable, but there are few datasets that offer comparable detail on intermediate consumption.[14] Second, the WIOD only includes 44 countries. This concern is partially ameliorated by two factors: (1) the WIOD estimates input-output flows from the rest of the world; and (2) even with this limited sample, the WIOD countries account for 85 percent of global GDP.

Third, the WIOD may suffer from measurement error. Economists Arnaud Costinot and Andres Rodríguez-Clare circumvent this by collapsing some industries into narrower categories and merging some countries into the "rest of world" category.[15] After collapsing, we use 37 countries and 51 industries. We use sectoral dispersion of productivity θ^j estimates from Caliendo and Parro, who calculate these values using their model to exploit changes in trade from the creation of NAFTA.[16]

First, we define value added in production γ_n^j as V_n^j. Second, labor income is defined as the sum of value added for all sectors j, $\sum_{j=1}^{J} V_n^j$. Third, the WIOD reports final consumption C_{ni}^k and consumption of intermediates X_{ni}^{jk}. We aggregate consumption of households, governments, and nonprofits to create a measure of total final consumption $C_{ni}^k F$. We then compute sectoral trade as the sum of intermediate and final consumption $X_{in}^j = \sum_{k=1}^{K} X_{ni}^{kj} + C_{ni}^k F$.[17] This allows for calculations of expenditure on sector j $X_n^j = \sum_{i=1}^{I} X_{ni}^j$, and $\pi_{ni}^j = \frac{X_{ni}^j}{X_n^j}$.

Fourth, we define the share of country n sector j's spending on sector k, $\gamma_n^{j,k}$, as the share of intermediate consumption of sector k, X_n^{jk}, in sector j divided by the total intermediate consumption of sector j multiplied by 1 minus the share of value added in sector j, $1 - V_n^j$. Fifth, final consumption share α_n^j is defined as

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[14] The other is the OECD TiVA dataset we use in our short-run model. We show our results hold using this data later in the appendix.

[15] Arnaud Costinot and Andres Rodriguez Clare, "Online Appendix to Trade Theory with Numbers: Quantifying the Consequences of Globalization," Handbook of International Economics, 2013, 20, https://economics.mit.edu/sites/default/files/publications/Online%20Appendix%2013-18-09%20FINAL.pdf.

[16] Caliendo and Parro, "Estimates of the Trade and Welfare Effects of NAFTA."

[17] This method follows a procedure recommended by Costinot and Rodriguez Clare in their online appendix.

final consumption of country n on sector k goods $\sum_{i=1}^{I} C_{ni}^{k} F$ divided by total consumption of country n $\sum_{k=1}^{K} \sum_{i=1}^{I} C_{ni}^{k} F$.