The Cost of a Global Tariff War: *A Sufficient Statistics Approach*

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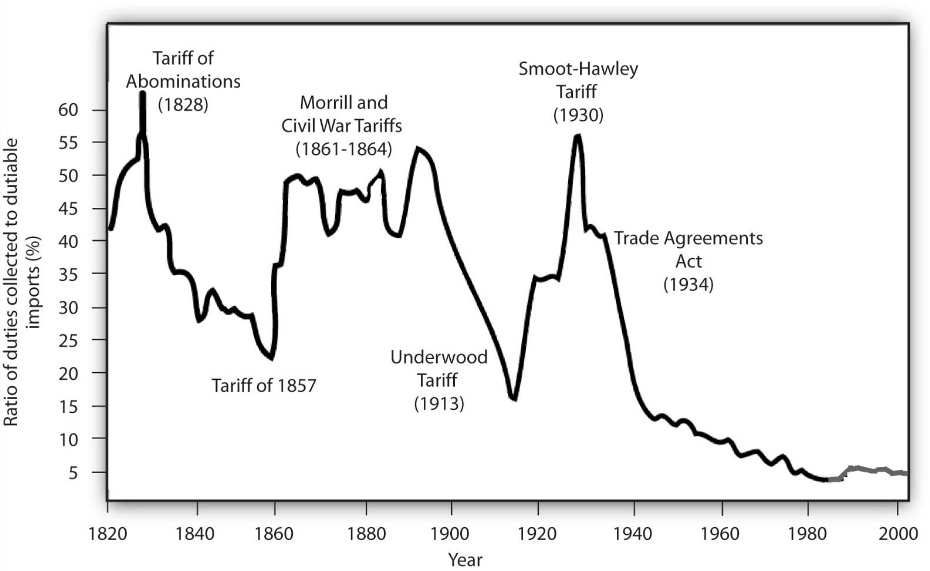
U Chicago: May 2021

Background

Thanks to FTAs, Tariffs had been Declining Since the 1930s



After Decades of Tariff Liberalization, We Have Entered an Era of Tariff Escalation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WSJ.com

U.K. VOTES TO LEAVE EU

Historic Election Sets Global Markets Reeling

Supporters of the Leave camp waved British flags and cheered as referendum results came in early Friday showing unexpectedly strong support for leaving the EU.

Pound Nose-Dives, Stocks Plunge, Bond Yields Fall


The Washington Post

By Thomas Heath March 2 at 12:45 PM

U.S. stocks take more losses in sell-off triggered by fears of a trade war

Here's how your state would get hit by a global trade war

John W. Schoen | @johnwschoen

Published 1 Hour Ago | Updated 41 Mins Ago

CNBC

REUTERS

BUSINESS NEWS MARCH 2, 2018 / 7:49 AM / UPDATED 25 MINUTES AGO

'Trade wars are good,' Trump says, defying global concern over tariffs

The New York Times

NEW YORK, FRIDAY, MARCH 2, 2018

Trump Proclaims Tariffs On Steel and Aluminum, And Stocks Sag in Reply

Says the U.S. Has Been Badly Treated — Move May Draw Retaliation

By ANA SWANSON

WASHINGTON — President Trump said on Thursday that he

The Guardian

Trump trade tariffs: Europe threatens US bikes, bourbon and bluejeans

IMF joins China in warning of potential harm from 25% tariff imposed on metal imports but Trump insists 'trade wars are good'

Free Trade Agreements have Come Under Attack

The New York Times | https://nyti.ms/3dbGdHQ

The W.T.O. Should Be Abolished

In concert with other free nations, America must restore its economic sovereignty.

By Josh Hawley
Mr. Hawley is a Republican senator from Missouri.

May 5, 2020

Global Leaders Worry that a Full-Fledged Global Tariff War is Imminent

Christine Lagarde (head of the IMF)

“the escalating US-China tariff war is the biggest risk to global economic growth.”

– G7 Summit, June 2018

How Costly are Trade Wars?

***Ex Post* Cost Analysis**

- Measure the welfare cost of a tariff conflict after its occurrence.
- Examples: Amiti-Redding-Weinstein (2019); Fajgelbaum et al. (2020); Flaaen-Hortaçsu-Tintelnot (2019); and Cavallo et al. (2019)

***Ex Ante* Cost Analysis**

- Predict Nash tariffs that will ensue after a full-fledged trade war and determine their welfare cost. schematic illustration
- Examples: Ossa (2014, 2016); Lashkaripour (2020); Beshkar-Lashkaripour (2020)

Roadmap for this Lecture

1. Introduce tariffs into an off-the-shelf quantitative trade model.
2. Derive analytic formulas for unilaterally optimal tariffs.
3. Perform *ex ante* cost analysis: use analytic formulas to compute Nash tariffs and their welfare cost under a global trade war.

Important Remark

– In principle, the same procedure can be performed via *numerical optimization* and without the aid of analytic optimal tariff formulas.

– The numerical approach, however, becomes infeasible unless we restrict attention to a small set of countries and industries.

Theoritical Framework

Baseline Model: Multi-Industry Armington/Eaton-Kortum Model

- Many countries: $i, j, n = 1, \ldots, \mathcal{N}$
- Many industries: $k, g = 1, \ldots, \mathcal{K}$
- Country i is populated by L_i workers who can move freely b/w industries.
  - Labor is the sole factor of production and is supplied inelastically

- Goods are indexed by origin–destination–industry

$$\text{good } ij, k \sim \text{ origin } i - \text{destination } j - \text{industry } k$$

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Demand-Side of Economy i

- Let $\mathbf{Q}_{ji} = \{Q_{ji,1}, ..., Q_{ji,K}\}$ denote the basket of goods sourced from origin j.
- The representative consumer's utility has a Cobb-Douglas-CES parametrization

$$U_i(\mathbf{Q}_{1i}, ..., \mathbf{Q}_{Ni}) = \prod_{k=1}^{K} \left(\sum_{j=1}^{N} \varsigma_{ji,k}^{1-\rho_k} Q_{ji,k}^{\rho_k} \right)^{\frac{e_{i,k}}{\rho_k}}, \qquad \text{where } \sum_{k=1}^{K} e_{i,k} = 1$$

- Utility maximization yields a standard CES demand function:

$$P_{ji,k} Q_{ji,k} = \frac{\varsigma_{ji,k} P_{ji,k}^{-\epsilon_k}}{\sum_{n \in \mathbb{C}} \varsigma_{ni,k} P_{ni,k}^{-\epsilon_k}} e_{i,k} Y_i, \qquad \text{where } \epsilon_k = \frac{1-\rho_k}{\rho_k}$$

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Supply-Side of the Economy

Perfectly competitive price of good ji, k (origin j–destination i–industry k):

$$P_{ji,k} = \underbrace{(1 + t_{ji,k})}_{\text{tariff}} \times \underbrace{\tau_{ji,k} a_{j,k}}_{\text{unit labor cost}} \times \underbrace{w_j}_{\text{wage rate}}$$

- $t_{ji,k}$ is chosen by the government in country i
- $\tau_{ji,k}$ and $a_{j,k}$ are invariant to tariffs.
- The wage rate, w_j, reacts to tariffs.

Equilibrium: *Expenditure Shares*

- Plugging $P_{ji,k}$ into the CES demand function, the expenditure share on variety ji, k can be expresses as a function of global wages, $\mathbf{w}$, and applied tariffs $\mathbf{t}$:

$$\lambda_{ji,k}(\mathbf{t}, \mathbf{w}) = \frac{\varsigma_{ji,k} \left[(1 + t_{ji,k}) \tau_{ji,k} a_{j,k} w_j \right]^{-\epsilon_k}}{\sum_{n=1}^{\mathcal{N}} \varsigma_{ni,k} \left[(1 + t_{ni,k}) \tau_{ni,k} a_{n,k} w_n \right]^{-\epsilon_k}}$$

- Gross expenditure on good ji, k is, accordingly, given by

$$\lambda_{ji,k}(\mathbf{t}, \mathbf{w}) \times e_{i,k} Y_i(\mathbf{t}; \mathbf{w}),$$

where $Y_i(.)$ is total expenditure in country i.

General Equilibrium: *Definition*

For a given choice of tariffs, $\mathbf{t}$, equilibrium is a vector of wages, $\mathbf{w}$, that satisfy *balanced trade* condition:

$$\sum_{j=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} \left[\frac{1}{1+t_{ji,k}} \lambda_{ji,k}(\mathbf{t};\mathbf{w}) e_{i,k} Y_i(\mathbf{t};\mathbf{w}) \right] = \sum_{j=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} \left[\frac{1}{1+t_{ij,k}} \lambda_{ij,k}(\mathbf{t};\mathbf{w}) e_{j,k} Y_j(\mathbf{t};\mathbf{w}) \right],$$

where total expenditure in country i equals wage income plus tariff revenues:

$$Y_i(\mathbf{t};\mathbf{w}) = w_i L_i + \underbrace{\sum_{j=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} \left(\frac{t_{ji,k}}{1+t_{ji,k}} \lambda_{ji,k}(\mathbf{t};\mathbf{w}) e_{i,k} Y_i(\mathbf{t};\mathbf{w}) \right)}_{\text{Tariff Revenue}}.$$

– Since $\boldsymbol{w} = \boldsymbol{w}(\boldsymbol{t})$ I hereafter express all eq. variables as a function of just $\boldsymbol{t}$.

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Welfare in Country i

National welfare in country i is given by

$$W_i(\mathbf{t}) = \frac{Y_i(\mathbf{t})}{\prod_{k=1}^{K} P_{i,k}(\mathbf{t})^{e_{i,k}}}, \quad \text{where} \quad P_{i,k}(\mathbf{t}) = \left(\sum_{n=1}^{N} \varsigma_{ni,k} \left[(1 + t_{ni,k}) a_{n,k} \tau_{ni,k} w_n(\mathbf{t}) \right]^{-\epsilon_k} \right)^{-\frac{1}{\epsilon_k}}$$

Unilaterally Optimal Tariffs

- Country i's *unilaterally* optimal tariff policy maximizes national welfare given applied tariffs in the rest of the world, $\mathbf{t}_{-i}$:

$$\boldsymbol{t}_i^*(\mathbf{t}_{-i}) = \arg\max_{\mathbf{t}_i} \quad W_i(\mathbf{t}_i; \mathbf{t}_{-i})$$

- Unilaterally optimal tariffs are *inefficient* from a global standpoint.

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Nash Tariffs under a Global Trade War

Nash tariffs solve the following system of $N(N-1)K$ equations

$$\begin{cases} \mathbf{t}_1 = \boldsymbol{t}_1^*(\mathbf{t}_{-1}) \\ \vdots \\ \mathbf{t}_N = \boldsymbol{t}_N^*(\mathbf{t}_{-N}) \end{cases}.$$

Numerical approach to solving the above system (Ossa, 2014):

1. start with an initial guess for $\mathbf{t}^*$
2. update $\mathbf{t}^*$ by performing N constrained global optimizations—one optimization per country each involving $(N-1)K$ tariff rates.
3. repeat (1) and (2) until convergence.

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Optimization-Free Approach to Determining Nash Tariffs

We can bypass the standard iterative optimization procedure by deriving an analytic formula for $\boldsymbol{t}_i^*(.)$.

Proposition 1. *Country i's optimal tariff is uniform and can be determined as*[1]

$$t_i^*(\boldsymbol{t}_{-i}) = \frac{1}{\sum_k \sum_{j\neq i}\left(\chi_{ij,k}\epsilon_k\left[1-(1-\frac{t_j\lambda_{jj,k}e_{j,k}}{1+t_j\lambda_{jj}})\lambda_{ij,k}\right]\right)}$$

as a function of (i) trade elasticities, ϵ_k; and (ii) observable shares:

$$\chi_{ij,k} \sim \text{export share}; \qquad \lambda_{ij,k} \sim \text{expenditure share}$$

Some Intuition:

- Ricardian production structure $\longrightarrow$ maximizing $W_i(.)$ is akin to maximizing $w_i/\mathbf{w}_{-i}$ with minimal distortion to prices in the local economy.
- Uniform tariffs deliver this exact objective.

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Sketch of Optimization-Free Quantitative Strategy

- Our goal is to simulate the counterfactual equilibrium under Nash tariffs.
- A bullet point summary of the optimization-free strategy:
  1. Use exact hat-algebra $\longrightarrow$ express each country's optimal tariff formula in changes
  2. Use exact hat-algebra $\longrightarrow$ express equilibrium conditions in changes
  3. Solve the system of equations derived under Steps (1) and (2)
- Step (3) determines the welfare cost of a global tariff war as a function of the following *sufficient statistics*:

$$\mathcal{B}_v \equiv \{\lambda_{ni,k}, e_{n,k}, w_n \bar{L}_n, Y_n\}_{ni,k} \qquad \mathcal{B}_e = \{\epsilon_k\}_k$$

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Expressing Optimal Tariff Formula in Changes

- Hat-Algebra Notation (for any variable x)

$$x \sim \text{factual value}, \qquad x^* \sim \text{value under Nash eq.}; \qquad \hat{x} \equiv x^*/x$$

- Using this notation, we can express optimal (~Nash) tariffs in changes

$$t_i^* = \frac{1}{\sum_k \sum_{j \neq i} \left(\chi_{ij,k}^* \epsilon_k \left[1 - \delta_{j,k}^* \hat{\lambda}_{ij,k} \lambda_{ij,k} \right] \right)},$$

where $\delta_{j,k}^*$ and $\chi_{ij,k}^*$ are respectively given by

$$\delta_{j,k}^* \equiv 1 - \frac{t_j^* \hat{\lambda}_{jj,k} \lambda_{jj,k} e_{j,k}}{1 + t_j^* \hat{\lambda}_{jj} \lambda_{jj}}, \qquad \chi_{ij,k}^* = \frac{\frac{1}{1+t_j^*} \hat{\lambda}_{ij,k} \lambda_{ij,k} e_{j,k} Y_j \hat{Y}_j}{\sum_{\jmath \neq i} \sum_g \frac{1}{1+t_\jmath^*} \hat{\lambda}_{i\jmath,k} \lambda_{i\jmath,k} e_{\jmath,k} Y_\jmath \hat{Y}_\jmath}.$$

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Proposition 2. Nash tariffs, $\{t_i^*\}$, and their effect on wages, $\{\hat{w}_i\}$, and total income, $\{\hat{Y}_i\}$, can be determined by solving the following system of equations with data on $\{\lambda_{ji,k}, e_{i,k}, w_i L_i, Y_i, t_{ji,k}\}$, and estimates for trade elasticities, $\{\epsilon_k\}$:

$$\text{[optimal tariff]} \qquad t_i^* = \frac{1}{\sum_{j\neq i}\sum_k \left(\chi^*_{ij,k}\epsilon_k\left[1-\delta^*_{j,k}\hat{\lambda}_{ij,k}\lambda_{ij,k}\right]\right)};$$

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$$\text{[balanced budget]} \qquad Y_i\hat{Y}_i = \hat{w}_i w_i \bar{L}_i + \sum_k\sum_{j\neq i}\left[\frac{t_i^*}{1+t_i^*}\hat{\lambda}_{ji,k}\lambda_{ji,k}e_{i,k}\hat{Y}_iY_i\right]$$

where the $\hat{\lambda}_{ji,k}$ is given as a function of wage and tariff changes:

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Computing Welfare Effects using Proposition 2's Output

After solving for Nash tariffs, $\{t_i^*\}$, wage changes, $\{\hat{w}_i\}$, and income changes, $\{\hat{Y}_i\}$, the change in each country's welfare can be calculated asThe solution to this system determines the welfare cost of dissolving FTAs

$$\hat{W}_i = \frac{\hat{Y}_i}{\prod_{k=1}^{\mathcal{K}} \left(\hat{P}_{i,k}^{e_{i,k}}\right)}.$$

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Extensions

The optimization-free approach can be extended to account for

1. market imperfections Details
2. political economy pressures
3. input-output linkages

The same approach can be used to measure the gains from *cooperative tariffs*:

- cooperative tariffs are *ToT-blind* and correct market imperfections (if any).
- cooperative tariffs are zero in the perfectly competitive Armington/EK setting.

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Quantitative Implementation

Data Sources

World Input-Output Database (2000-2014)

- expenditure matrix by *origin*×*destination*×*industry* + input-output tables.
- 44 Countries + 56 Industries
- matching tariff data from Unctad-Trains

Trade elasticities: I estimate ϵ_k using *Caliendo & Parro's (2014)* triple-difference estimation technique:

$$\ln \frac{\lambda_{ji,k}\lambda_{in,k}\lambda_{nj,k}}{\lambda_{ij,k}\lambda_{ni,k}\lambda_{jn,k}} = -\hat{\epsilon}_k \ln \frac{\left(1+t_{ji,k}\right)\left(1+t_{in,k}\right)\left(1+t_{nj,k}\right)}{\left(1+t_{ij,k}\right)\left(1+t_{ni,k}\right)\left(1+t_{jn,k}\right)} + \varepsilon_{jin,k}$$

Results: *Average Nash Tariff Rates*

- Baseline: **40.5%**
- Baseline + market imperfections: **37.5%**
- Baseline + market imperfections + Input Trade: **48.9%**

- In the tariff war that followed the Smoot-Hawley Tariff Act of 1930, Nash tariffs where around **50%**.

Results: *Total Cost to Global GDP*

- Baseline: **$1.2 trillion**
- Baseline + market imperfections: **$1.4 trillion**
- Baseline + market imperfections + Input Trade: **$1.6 trillion**

- To offer some perspective, the cost of a global tariff war is akin to erasing South Korea from the global economy!

Results: Select Countries

	Baseline Model		Baseline + distortions		Baseline + distortions + IO	
Country	Nash Tariff	%Δ Real GDP	Nash Tariff	%Δ Real GDP	Nash Tariff	%Δ Real GDP
CHN	40.7%	-0.35%	39.3%	-0.59%	78.5%	-0.43%
GRC	12.5%	-2.81%	30.6%	-2.14%	20.9%	-4.77%
NOR	17.2%	-2.05%	38.9%	-2.07%	55.7%	1.15%
USA	43.6%	-0.76%	39.7%	-0.56%	38.3%	-1.10%

Cross-national differences in welfare cost are driven by

- Overall reliance on imports (final goods + inputs)
- Tariff concessions given relative to the non-cooperative benchmark.

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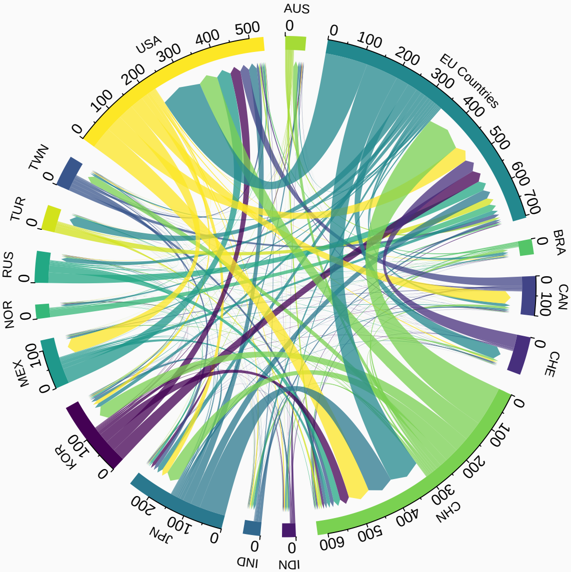
Country	Nash Tariff	%Δ Real GDP	Nash Tariff	%Δ Real GDP	Nash Tariff	%Δ Real GDP
CHN	40.7%	-0.35%	39.3%	-0.59%	78.5%	-0.43%
GRC	12.5%	-2.81%	30.6%	-2.14%	20.9%	-4.77%
NOR	17.1%	-2.23%	34.5%	-2.24%	91.7%	2.46%
USA	43.6%	-0.76%	39.7%	-0.56%	38.3%	-1.10%

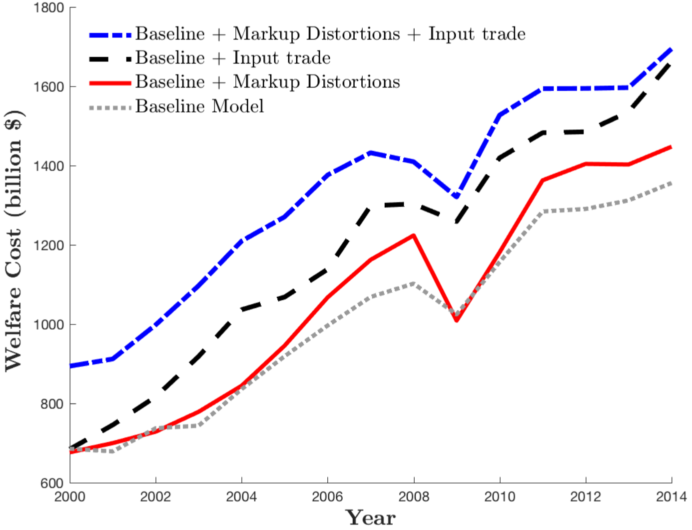
Cross-national differences in welfare cost are driven by

- Overall reliance on imports (final goods + inputs)
- Tariff concessions given relative to the non-cooperative benchmark.

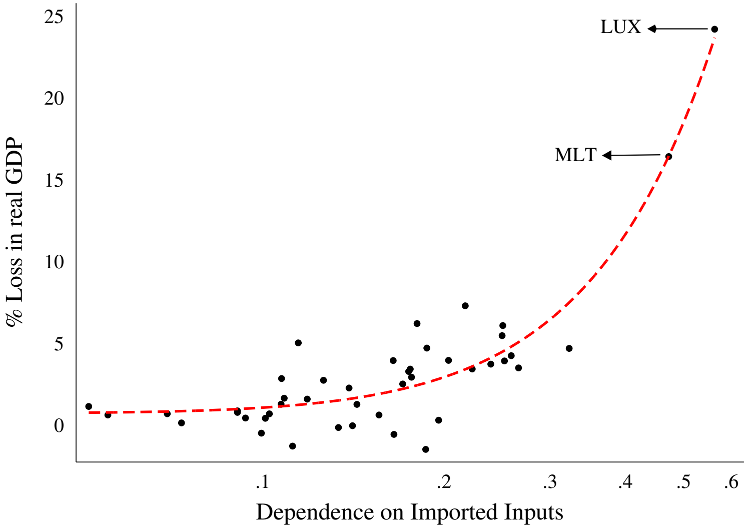
Tariff Concessions Undertaken by Different Countries



The Prospective Cost of a Global Tariff War Has Risen Over Time



Exposure to Tariff War *vs.* Dependence on Imported Inputs



Aggregating Many Countries into the RoW is Problematic

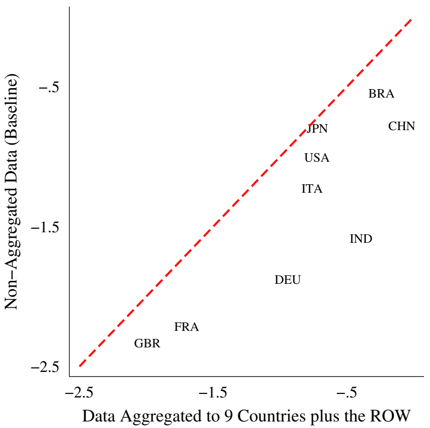
- As shown by the following table, traditional *optimization-based* analyses of trade wars are costly to perform.
- A widely used solution: shrink the number of countries by aggregating smaller countries into the rest of the world and treating them as one tax authority.

	# countries	# industries	Nash tariffs	Cooperative tariffs
Traditional approach	$N = 7$	$K = 33$	96 minutes	50 hours
Optimization-Free approach	$N = 44$	$K = 56$	4 seconds	15 seconds

Note: The computational times associated with Ossa (2014, AER) are based on the figures reported in the article's replication file: `https://doi.org/10.3886/E112717V1`. The computational times reported for the new approach developed in this paper are based on a MAC machine with the following specifications: Intel Core i7 @2.8 GHz processor, with 4 physical cores, and 16 GB of RAM. Both approaches are implemented in MATLAB.

Aggregating Many Countries into the RoW is Problematic

- This widely used aggregation choice leads to overstating the cost of a tariff war.
- **Why?** aggregating small countries into the RoW *artificially* assigns a high market power to them $\longrightarrow$ exaggerated Nash tariffs $\longrightarrow$ greater welfare loss

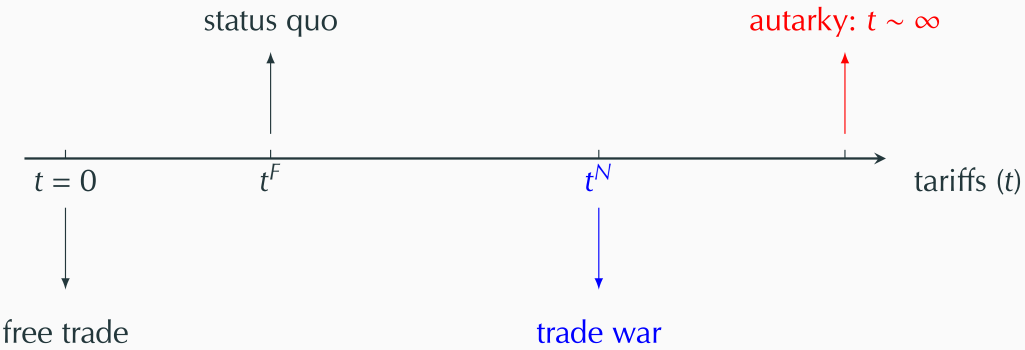


Directions for Future Research

- The present framework overlooks many important features of the global economy.
- Some possible directions for future work:
  1. Accounting for the spatial economy effects of trade wars.
  2. A more careful analysis of profit-shifting that accounts for multinational production.
  3. Adopting a richer labor market structure à la Roy-Ricardo.

Thank You.

Schematic Diagram: *Ex Post Cost Analysis*



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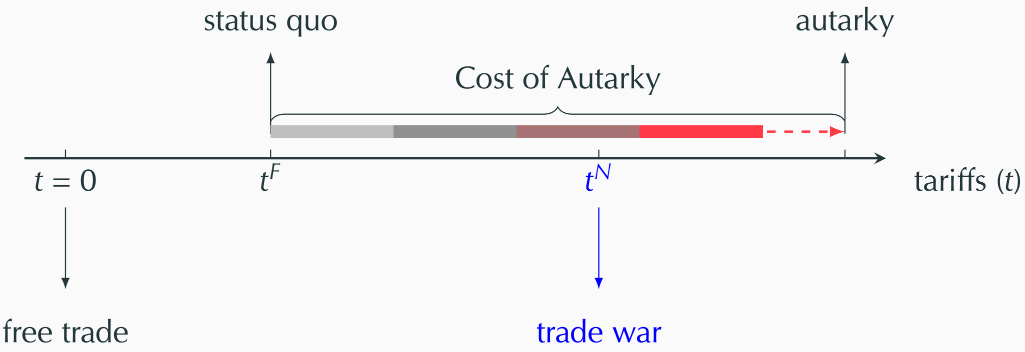

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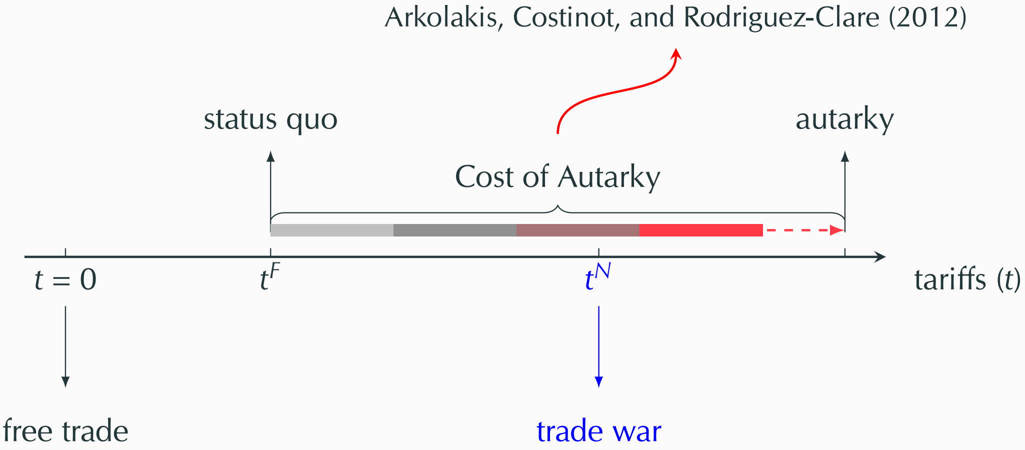

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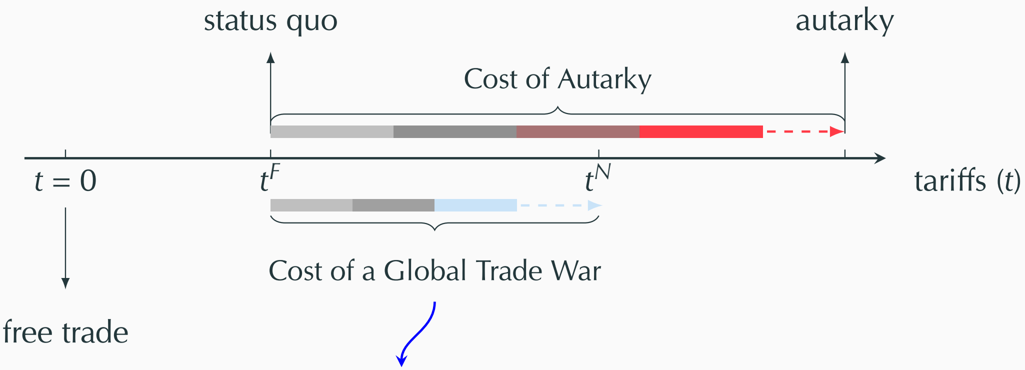

Ossa (2014), Lashkaripour(2020)

Return

Accounting for Market Imperfections

- Suppose firms compete under monopolistic competition and charge a constant markup $\mu_k \geq 1$ over marginal cost:

$$P_{ji,k} \;=\; (1 + t_{ji,k})\ \mu_k\ \tau_{ji,k} a_{j,k}\ w_j$$

- The balanced budget condition must be revised to account for aggregate profits:

$$Y_i(\mathbf{t};\mathbf{w}) = \underbrace{\overline{\mu}_i w_i L_i}_{\text{wage bill } + \text{ profits}} + \underbrace{\sum_{j \neq i} \sum_k \left(\frac{t_{ji,k}}{1 + t_{ji,k}} \lambda_{ji,k}(\mathbf{t};\mathbf{w}) e_{i,k} Y_i(\mathbf{t};\mathbf{w}) \right)}_{\text{tariff revenue}}$$

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average markup

Country i's optimal tariff is composed of a (i) uniform component, and (ii) an industry-specific component that is more restrictive in high-markup industries

$$1 + t^*_{i,k} = \underbrace{\left[1 + \frac{1}{\sum_g \sum_{j \neq i} \left(\chi_{ij,g} \epsilon_g \left[1 - \delta_{j,g} \lambda_{ij,g}\right]\right)}\right]}_{\text{unifrom}} \frac{1 + \epsilon_k \lambda_{ii,k}}{1 + \frac{\overline{\mu}_i}{\mu_k} \epsilon_k \lambda_{ii,k}},$$

Intuition

- The uniform component improves the terms-of-trade (i.e., inflates $w_i / \mathbf{w}_{-i}$).
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Limitation

- Tariffs are a *2nd-best* instrument for correcting misallocation in domestic industries.
- If governments have access to domestic subsides, the industry-specific component becomes redundant (see Lashkaripour-Lugovskyy, 2020).

Are Trade Wars More Costly under Market Imperfections?

With market imperfections a tariff war inflicts two types of cost:

1. **Standard trade reduction cost**

2. **Exacerbation of misallocation in domestic industries**:

– Output in high-markup industries is sub-optimal prior to a tariff war

– Tariff war occurs $\longrightarrow$ tariffs are set more restrictively on high-markup industries.

– These restrictions shrink global output in high-μ industries $\longrightarrow$ more efficiency loss! Return