Trade Costs and Inflation Dynamics

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September 23, 2025
Bank of Canada - European Central Bank Conference

Globalization, Trade Disruptions, and the Macroeconomy

- Deeply interconnected global economy
- Trade disruptions, that is, shocks to broadly-defined **trade costs**, have important macroeconomic consequences, particularly for **inflation**.
  - Trade policies, supply-chain disruptions, geopolitical tensions, etc.
- Limited understanding of how trade costs affect inflation

  → Relative and/or agg. prices? One-time increase? Inflation persistence?

  - Studies focus on the real effects of trade costs
  - Divide between international trade and workhorse international monetary models.
  - First-order relevance for policy (reasonable positive view)

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What We Do in This Paper

- **Question:** How do trade costs affect inflation dynamics in a global economy?

  → Higher costs ⇒ ↓ supply shock (↑ π, ↓ Y),
  ⇒ trade in intermediate key for transmission and magnitudes

1. **Empirical analysis:**
   - Gravity + World IO data ⇒ bilateral trade costs, final & interm. (41 countries, 95-20)
     → Aggregate bilateral costs ⇒ import costs.
   - Panel LPs (Jordà, 2005) ⇒ variation across time and space in import costs
     → Estimate effects on CPI inflation, GDP,...
2. **Model development, calibration, and test:**
   - Dynamic multictry GE model → trade in final and interm. (gravity) + sticky prices.
   - Calibrate, test against empirical results, and unpack mechanisms.
3. **Model experiments:**
   - Monetary pol. alternatives / 2018-19 U.S.-China trade war / Post-Pandemic inflation.

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Preview of Key Results (and some existing literature)

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  - Higher import costs ⇒ ↑ π (↓ Y) and π dynamics depend type of shock:
    - Final goods → large but short-lived inflation
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  - Model replicates estimated inflation and GDP dynamics.
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    - U.S.: 10 p.p. ↑ in total import costs ⇒ 0.8 p.p. ↑ in π on impact, persists for extra three years.

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Empirics

Measuring Trade Costs

Armington Model of Trade

- Global economy comprised of countries indexed $i, h \in \mathcal{I} = \{1, \ldots, N\}$.
  - Each country produces a single tradable good
- Goods used as either final consumption (C) or intermediate production inputs (M).
- Differentiated goods aggregated as

$$Q_{i,t} = \left(\sum_{h=1}^{N} (Q_{ih,t})^{\frac{\eta^Q - 1}{\eta^Q}} \right)^{\frac{\eta^Q}{\eta^Q - 1}}, \quad Q \in \{C, M\}$$

- **Trade costs**: Delivering 1 unit requires shipping $\tau^Q_{ih,t} \geq 1$ units ($\tau^Q_{ii,t} = 1$).
- Assume *law of one price* holds.

Measuring Trade Costs (Cont'd)

- Let $X^Q_{ih,t} \equiv P^Q_{ih,t} Q_{ih,t}$, $X^Q_{i,t} = \sum_{h=1}^{N} X^Q_{ih,t}$.
- Cost minimization → **Gravity**:

$$\frac{X^Q_{ih,t}}{X^Q_{i,t}} \equiv \omega^Q_{ih,t} = \left(\frac{\tau^Q_{ih,t} P_{ih,t}}{P^Q_{i,t}} \right)^{-(\eta^Q - 1)}, \quad P_{ih,t} \equiv \mathcal{E}_{ih,t} P_{h,t}$$

- Combine to obtain measure of trade costs between country pairs (Head-Ries index):

$$\mathcal{T}^Q_{ih,t} \equiv \left(\tau^Q_{ih,t} \tau^Q_{hi,t}\right)^{\frac{1}{2}} = \left(\frac{\omega_{ih,t}}{\omega_{hh,t}} \frac{\omega_{hi,t}}{\omega_{ii,t}} \right)^{-\frac{1}{2(\eta^Q - 1)}}$$

- **Takeaway:** Bilateral expenditure shares + trade elasticity → measure of trade costs.

Data

OECD ICIO Tables (World Input-Output Database):

- Yearly data:
  - ICIO: 1995-2020, 41 countries, 16 non-service sectors (consistent with WIOD).
- Construct bilateral trade costs for final goods and intermediate inputs.

World Development Indicators:

- CPI inflation, Real GDP, Real Exports, Real Imports, Real Exchange Rate.

Global Crises Database:

- Country-specific controls for currency and banking crises.

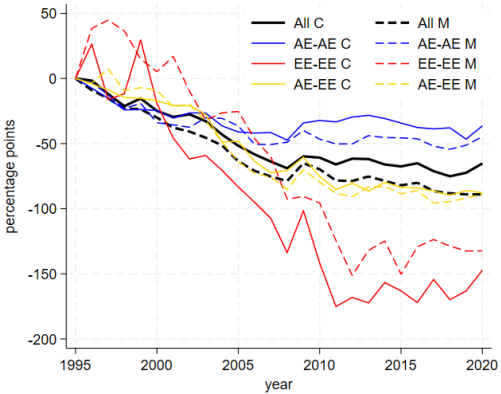
Trade elasticity:

- $\eta \equiv \eta^C = \eta^M = 5$ Head-Ries (2001), Simonovska-Waugh (2014), Caliendo-Parro (2014)

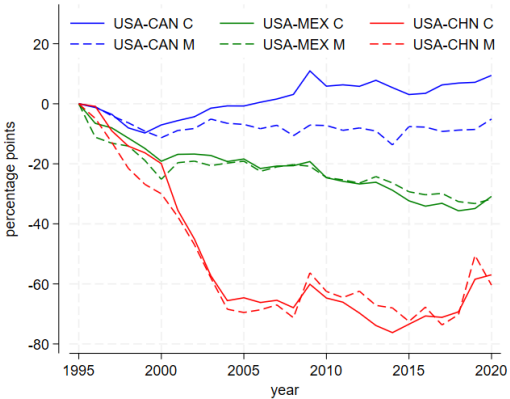
Bilateral Trade Costs Across Time and Space

Costs vary over time—reflecting integration—across space—in line with development—and reflect changes in trade policy

Δ in median trade costs



Δ in trade costs, main U.S. trade partners



Evolution of distribution | 1970-2014

Import Costs

Measured trade costs correlate with import tariffs

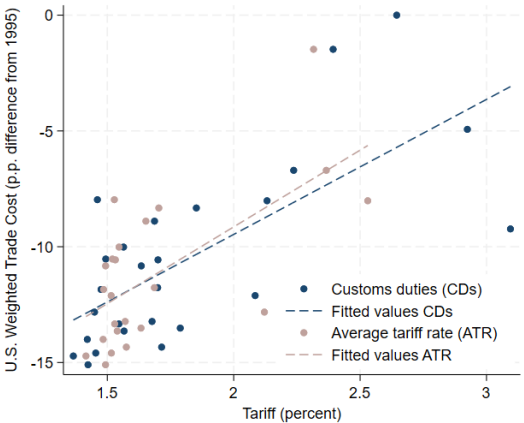
- Aggregate bilateral trade costs to country-level import costs using import shares:

$$\tau^{Q}_{i,t} = \sum_{h=1}^{N} \left(\frac{X^{Q}_{ih,t}}{\sum_{k \neq i} X^{Q}_{ik,t}} \right) \mathcal{T}^{Q}_{ih,t}$$

for $Q \in \{C, M\}$.

  - Estimate $\hat{\beta} = 1.1$ from

$$\log \tau_{i,t} = \alpha_i + \beta \log(1 + tariff_{i,t}) + \varepsilon_{i,t}.$$



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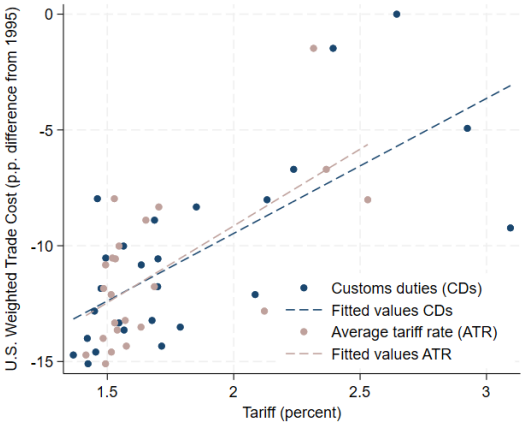

How do trade cost shocks affect inflation? Scatter

$$\pi_{i,t+h} = \delta^{Q}_{i,h} + \delta^{Q}_{t,h} + \beta^{Q}_{h} \cdot \Delta\tau^{Q}_{i,t} + \gamma^{Q}_{h} \cdot \Delta\tau^{\emptyset}_{i,t} + \Gamma'^{Q}_{h} Z_{i,t-1} + \varepsilon^{Q}_{i,t+h} \qquad \text{for } h \geq 1, \quad Q = \{C, M\}.$$

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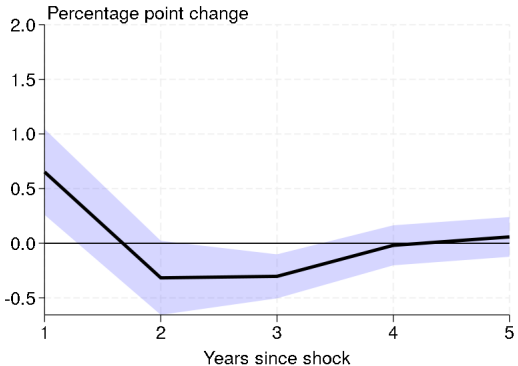
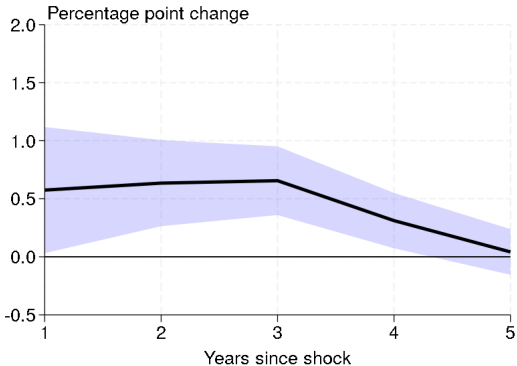
Inflation response, final's trade costs



Inflation response, interm.'s trade costs



GDP Effects: Trade cost shocks are negative supply shocks

$$\log GDP_{i,t+h} - \log GDP_{i,t} = \delta^{Q}_{i,h} + \delta^{Q}_{t,h} + \beta^{Q}_{h} \cdot \Delta\tau^{Q}_{i,t} + \gamma^{Q}_{h} \cdot \Delta\tau^{\emptyset}_{i,t} + \Gamma'^{Q}_{h} Z_{i,t-1} + \varepsilon^{Q}_{i,t+h} \text{ for } h \geq 1, Q = \{C, M\}.$$

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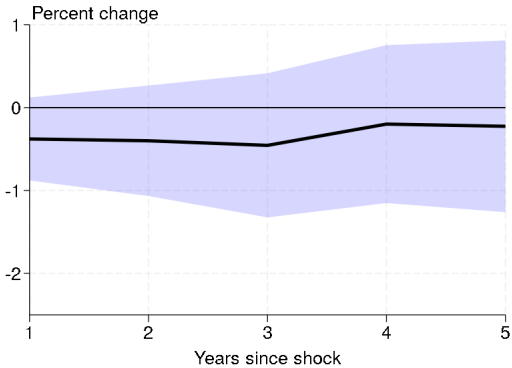

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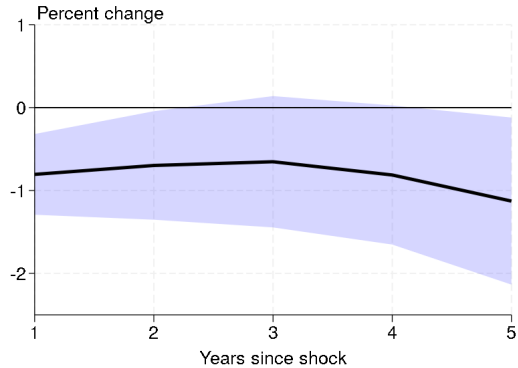

Model

Model Overview

- Multi-Country New Keynesian + Trade Model.
  - $N = 5$ countries (U.S., China, Asia excl. China, AFE, ROW).
- New Keynesian bloc:
  - Nominal rigidity in prices and wages.
  - Labor and intermediate inputs—domestic and imported—used in production.
- Trade bloc:
  - Armington model of trade in final consumption and intermediate inputs.
  - Iceberg trade costs in final consumption and intermediate inputs.

Households

Unit continuum of households indexed by ℓ in each country i maximize:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[U_i(C_{i,t}) - V_i(L_{i,t}^{\ell}) \right], \qquad C_{i,t} = \left(\sum_{h=1}^{N} C_{ih,t}^{\frac{\eta^C - 1}{\eta^C}} \right)^{\frac{\eta^C}{\eta^C - 1}}.$$

$$s.t. \sum_{h=1}^{N} \underbrace{\tau_{ih,t}^{C} P_{ih,t}}_{P_{ih,t}^{C}} C_{ih,t} + B_{ii,t} + \frac{B_{i1,t}}{\mathcal{E}_{1i,t}} \leq W_{i,t}^{\ell} L_{i,t}^{\ell} + R_{i,t-1} B_{ii,t-1} + R_{1,t-1} \Psi_{i,t-1} \frac{B_{i1,t-1}}{\mathcal{E}_{1i,t}} + T_{i,t},$$

Risk premium | Wage setting

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- η^C: Elasticicity of substitution for final goods (trade elasticity = $\eta^C - 1$)
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Differentiated Firms: non-tradable varieties

Unit continuum of differentiated firms indexed by j in each i have technology

$$Y_{i,t}^{j} = \left[(1-\nu)^{\frac{1}{\varepsilon_y}} L_{i,t}^{j} \, ^{\frac{\varepsilon_y - 1}{\varepsilon_y}} + \nu^{\frac{1}{\varepsilon_y}} M_{i,t}^{j} \, ^{\frac{\varepsilon_y - 1}{\varepsilon_y}} \right]^{\frac{\varepsilon_y}{\varepsilon_y - 1}},$$

Domestic labor input

Traded intermediate input

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Intermediate input sourcing: $\min_{M_{ih,t}} \sum_{h=1}^{N} \underbrace{\tau_{ih,t}^{M} P_{ih,t}}_{P_{ih,t}^{M}} M_{ih,t} \quad s.t. \quad M_{i,t} = \left[\sum_{h=1}^{N} M_{ih,t}^{\ \frac{\eta^M - 1}{\eta^M}} \right]^{\frac{\eta^M}{\eta^M - 1}}.$

Differentiated Firms: non-tradable varieties

Unit continuum of differentiated firms indexed by j in each i have technology

$$Y_{i,t}^{j} = \left[(1-\nu)^{\frac{1}{\epsilon_y}} L_{i,t}^{j\ \frac{\epsilon_y - 1}{\epsilon_y}} + \nu^{\frac{1}{\epsilon_y}} M_{i,t}^{j\ \frac{\epsilon_y - 1}{\epsilon_y}} \right]^{\frac{\epsilon_y}{\epsilon_y - 1}},$$

Domestic labor input

Traded intermediate input

ν: share of intermediate input in production, ϵ_y: e.o.s of factors of production.

Intermediate input sourcing: $\min_{M_{ih,t}} \sum_{h=1}^{N} \underbrace{\tau_{ih,t}^{M} P_{ih,t}}_{P_{ih,t}^{M}} M_{ih,t} \quad s.t. \quad M_{i,t} = \left[\sum_{h=1}^{N} M_{ih,t}^{\frac{\eta^M - 1}{\eta^M}} \right]^{\frac{\eta^M}{\eta^M - 1}}.$

- η^M: Elasticicity of substitution for intermediate inputs (trade elasticity = $\eta_M - 1$)
- $P_{ih,t}$: price in LCUs at which good produced in h is sold in i (at the dock)
- $\tau_{ih,t}^{M} = d_{ih,t}^{M}(1 + t_{ih,t}^{M})$ trade cost (iceberg cost + add-valorem tariff)
- $P_{ih,t}^{M}$: price in LCUs at which good produced in h is sold in i (cum-trade-costs)

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Retail firms: final tradable good producers

- Produce homogeneous output $Y_{i,t}$ aggregating domestic varieties:

$$Y_{i,t} = \left(\int_0^1 Y_{i,t}^{j \, \frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}$$

  Homogeneous output → used domestically (consumption or input) or exported

- Perfectly competitive firms in international markets $\Rightarrow P_{ii,t} = MC_{i,t}$ in LCUs and LOP holds.

- **Domestic price setting:** Firms face nominal rigidities and can only reset prices with probability θ.

Monetary Policy and Market Clearing

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Monetary Policy and Market Clearing

Calibration

Calibration strategy emphasizes common mechanisms at play

- Country heterogeneity only in trade shares and pop. size.
- Assume trade costs are of the form

$$\tau^{Q}_{ih,t} = \left(\omega^{Q}_{ih}\right)^{\frac{1}{1-\eta_Q}} \varepsilon^{Q}_{ih,t}$$

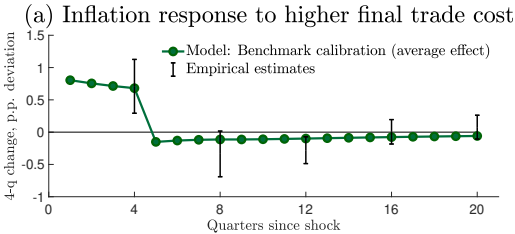
  where ω^{Q}_{ih} are time-invariant and $\sum_{h=1}^{N} \omega^{Q}_{ih} = 1$, and $\varepsilon^{Q}_{ih,t}$ are stationary shocks.
- Log-linear approximation of model around its steady state under balanced trade.
  - Balanced trade ($NX = 0$) $\Rightarrow$ calibrate half of ωs, rest determined by restrictions.
- Households' preferences:

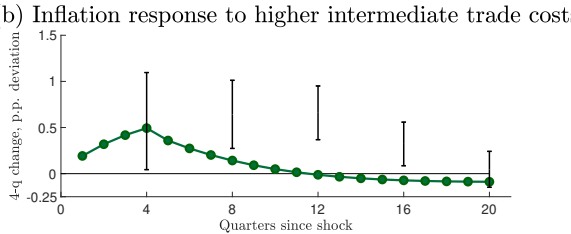
$$U_i(C_{i,t}, C_{i,t-1}) = \frac{\left(C_{i,t} - hC_{i,t-1}\right)^{1-\sigma} - 1}{1-\sigma} \quad \textbf{and} \quad V_i(L^{\ell}_{i,t}) = \frac{{L^{\ell}_{i,t}}^{1+\varphi}}{1+\varphi},$$

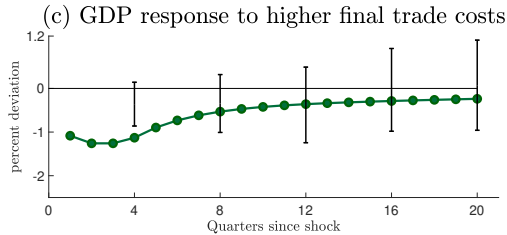
Macro Parameters | Trade Parameters

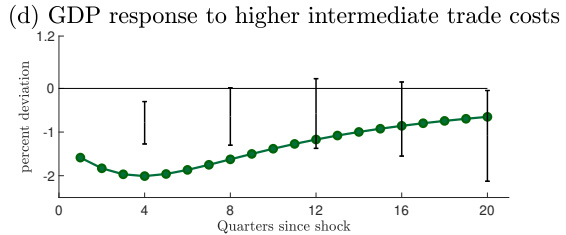
Model v. Data

Differential response to a 10 p.p. transitory increase in trade costs for average country



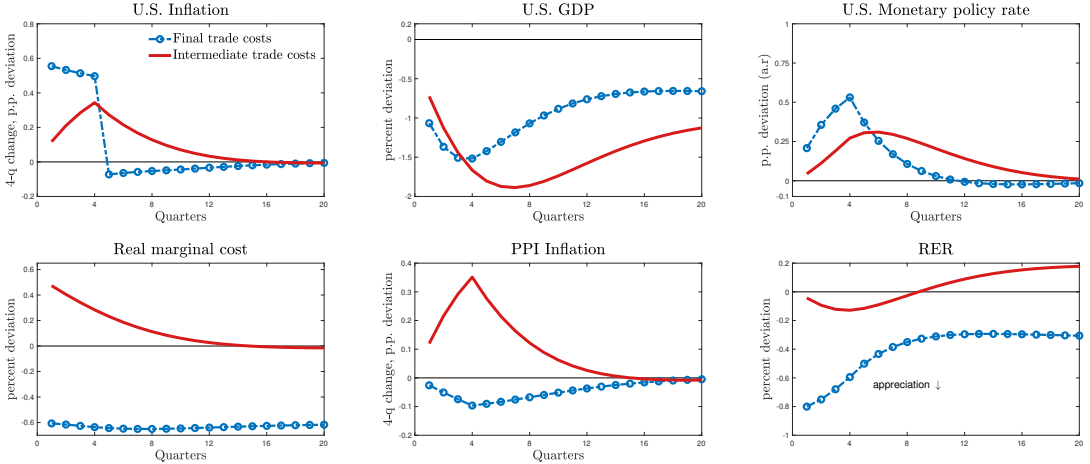






10 p.p. increase in U.S. trade costs

Higher τ^M increase real MC and lead to more prolonged stagflationary dynamics



X,M, and NX | Elasticity of substitution | Share of intermediates | Transitory trade costs | Extensions

Experiments

Experiments

- **Monetary policy rule options** Results MP
  - Consider rule targeting CPI vs PPI ("look-through" MP) inflation
  - Intermediates undo advantages of PPI targeting.
- **Macroeconomic effects of US-China 2018-19 trade war** Results US-China TW
  - Calibrate trade costs based on U.S.-China tariffs and measure of bilateral costs
  - U.S. CPI ↑ by more than 0.4%, tariffs on interm. explain bulk of π persistence and GDP ↓
- **Trade costs and post-pandemic U.S. inflation** Results Decomposition
  - Estimation of model of U.S. vs Rest-of-World (ROW)
  - Extend model to add quantitative realism: LCP, trade inertia, wage and price indexation
  - Trade costs: prevented (i) deflation during COVID-19 and (ii) lower inflation in 2022-23.

Conclusion

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- **Increases in trade costs are inflationary.**
  - Inflation dynamics depend on good type: Transitory for finished consumption goods, persistent for intermediate production inputs.
- **Model replicates the empirical responses of macro variables to trade cost shocks.**
  - Intermediates trade costs reduce production efficiency, raise domestic firms' marginal cost.
- **Ongoing work (w/ Schott & Bodenstein)**: Optimal monetary policy response to tariffs.
  - Quantitative framework.
  - Allow for inflation inertia (proxying for de-anchoring of π expectations).

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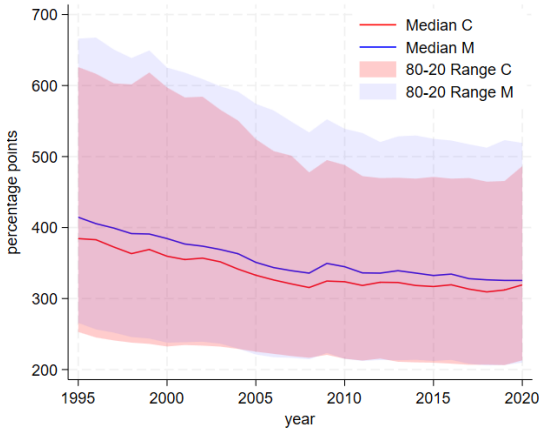
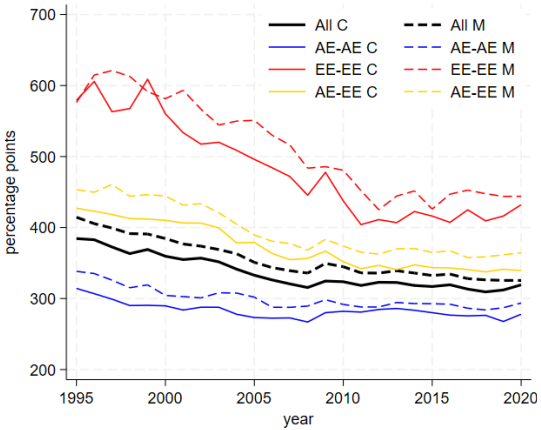
Appendix

Trade Costs Across Time and Space

Evolution of distribution (all 41 countries)



Evolution of medians by country group



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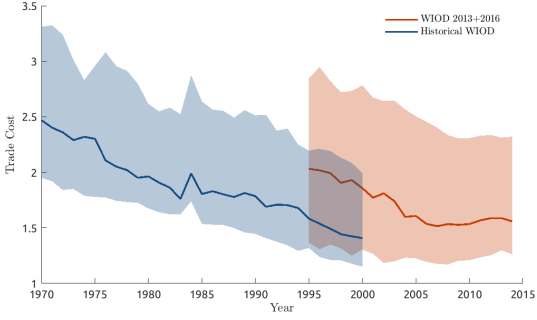
Empirics

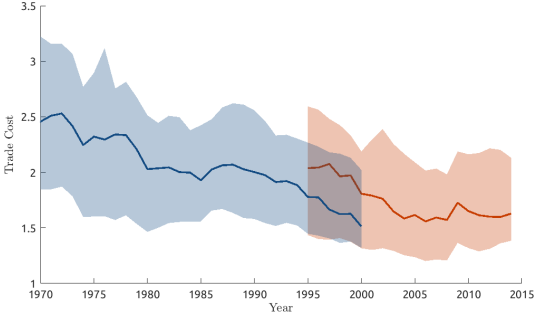
Historical Evolution of Global Trade Costs

Median Trade Cost: Final Goods (C)



Note: Shaded areas are bounded by the 20th and 80th percentiles.

Median Trade Cost: Intermediate Goods (M)



Note: Shaded areas are bounded by the 20th and 80th percentiles.

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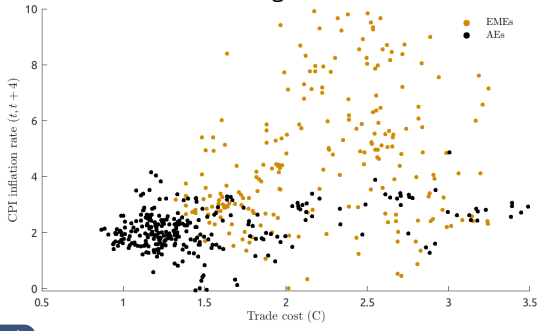
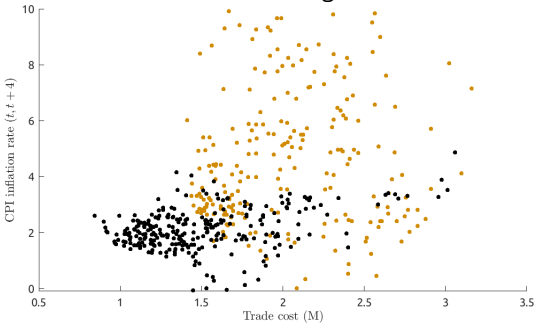
Empirics: Trade Costs and inflation

Import Costs and Inflation in the Data

Trade costs in final goods and inflation



Trade costs in intermediate gods and inflation



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Model: Risk Premium

- Maximization by household ℓ is subject to

$$\sum_{h=1}^{N} \underbrace{\tau^{C}_{ih,t} P_{ih,t}}_{P^{C}_{ih,t}} C_{ih,t} + B_{ii,t} + \frac{B_{1i,t}}{\mathcal{E}_{1i,t}} \leq W^{\ell}_{i,t} L^{\ell}_{i,t} + R_{i,t-1} B_{ii,t-1} + R_{1,t-1} \Psi_{i,t-1} \frac{B_{i1,t-1}}{\mathcal{E}_{1i,t}} + T_{i,t},$$

where $P_{ih,t} = \mathcal{E}_{ih,t} P_{h,t}$ and

- $B_{ih,t}$: holdings of country h's bond,
- $\mathcal{E}_{ih,t}$: country i's nominal exchange rate v. country h (country 1 is the U.S.),
- $P_{h,t}$: price in LCUs at which good produced in h is sold in h,
- $\tau^{C}_{ih,t} = d^{C}_{ih,t}(1 + t^{C}_{ih,t})$: exogenous trade cost (iceberg cost + add-valorem tariff),
- $\Psi_{i,t-1}$: currency risk premium (for $i = 2, \ldots, N$) such that

$$\Psi_{i,t} = (1 - \psi \frac{b_{i1,t}}{\mathbb{Q}_{1i,t} Y_{i,t}}) \varepsilon^{\psi}_{i,t}$$

where $b_{i1,t} \equiv \frac{B_{i1,t}}{P^{C}_{1,t}}$, $\mathbb{Q}_{1i,t} \equiv \frac{\mathcal{E}_{1i,t} P_{i,t}}{P_{1,t}}$, and $\varepsilon^{\psi}_{i,t}$ is AR(1).

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Model

Wage setting

- A labor union in each i aggregates labor varieties according to $L_{i,t} = \left(\int_0^1 L_{i,t}^{\ell \frac{\epsilon_w - 1}{\epsilon_w}} d\ell \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}$.
- Demand for labor variety ℓ

$$L_{i,t}^{\ell} = \left(\frac{W_{i,t}^{\ell}}{W_{i,t}} \right)^{-\epsilon_w} L_{i,t},$$

where

$$W_{i,t} = \left(\int_0^1 W_{i,t}^{\ell \, 1-\epsilon_w} d\ell \right)^{\frac{1}{1-\epsilon_w}}$$

- Household ℓ can reset the nominal wage $W_{i,t}^{\ell}$ only with prob. $1 - \theta_w$, and with prob. θ_w must set the previous-period nominal wage $W_{i,t-1}^{\ell}$.

Back

Monetary policy and market clearing

- Central bank in each country follows inertial Taylor rule:

$$R_{i,t} = \left(R_{i,t-1}\right)^{\phi_r} \left(\frac{1}{\beta} \left(\pi_{j,t}\right)^{\phi_\pi} \left(\frac{GDP_{i,t}}{GDP^*_{i,t}} \right)^{\phi_y} \right)^{1-\phi_r}.$$

  - $\pi_{i,t}$ is CPI inflation and $GDP^*_{i,t}$ is the *flex-price* level of GDP
  - Details of the policy rule are crucial for transmission into real activity and prices

- Market clearing: For $i = 1, \ldots N$,

$$\xi_i Y_{i,t} = \sum_{h=1}^{N} \xi_h (d^C_{hi,t} C_{hi,t} + d^M_{hi,t} M_{hi,t}),$$

  where ξ_i is country i's population (all variables are in per-capita terms).

- Standard definition of equilibrium with balanced government budget and balanced trade

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Back

Calibration: Macro Parameters

Parameter	Description	Value
β	Discount factor	0.99
σ	Inverse IES	0.5
h	Habit	0.75
η	Trade substitution elasticity consumption	5
η_m	Trade substitution elasticity intermediates	5
φ	Inverse labor supply elasticity	2
ϵ	Home varieties' substitution elasticity	6
ϵ_w	Labor varieties' substitution elasticity	6
θ, θ_w	Price, wage rigidity	0.80
ν	Intermediates weight in production	0.4
ε_y	Intermediates-labor substitution elasticity	0.5
ϕ_π	Taylor rule inflation coefficient	1.5
ϕ_y	Taylor rule output coefficient	0.2
ϕ_r	Taylor rule inertia	0.75
ψ	Risk premium elasticity to NFA	0.001

Back

Calibration: Trade Parameters

Parameter	Description	Value
ρ_τ	Trade cost shock autocorrelation	0.95
$[U.S., China, Asia, AE, ROW]$	Region size	[.20,.19,.19,.27,.14]

Consumption Expenditure Shares

	Source			
	U.S.	China	Asia	AE
U.S.	**0.94**	0.012	0.004	0.021
China		**0.95**	0.009	0.02
Asia			**0.94**	0.014
AE				**0.94**

Intermediate Expenditure Shares

	Source			
	U.S.	China	Asia	AE
U.S.	**0.88**	0.025	0.007	0.04
China		**0.94**	0.01	0.014
Asia			**0.81**	0.045
AE				**0.89**

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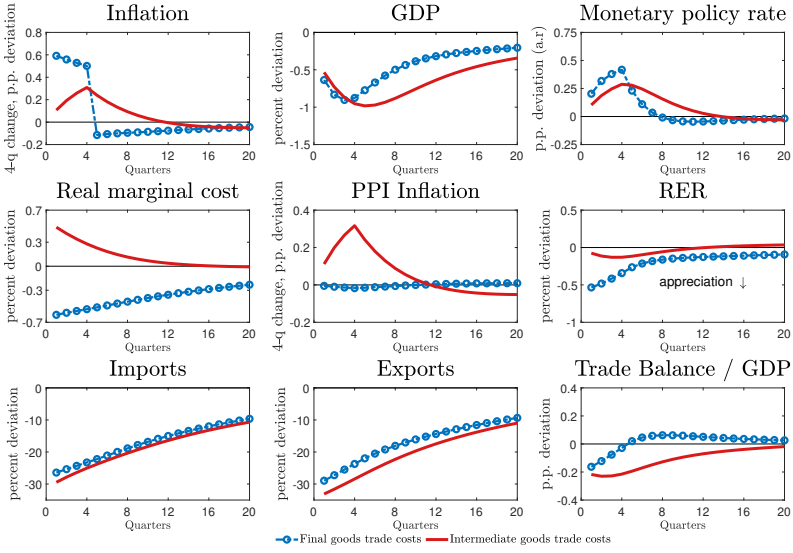
10 p.p. increase in U.S. trade costs



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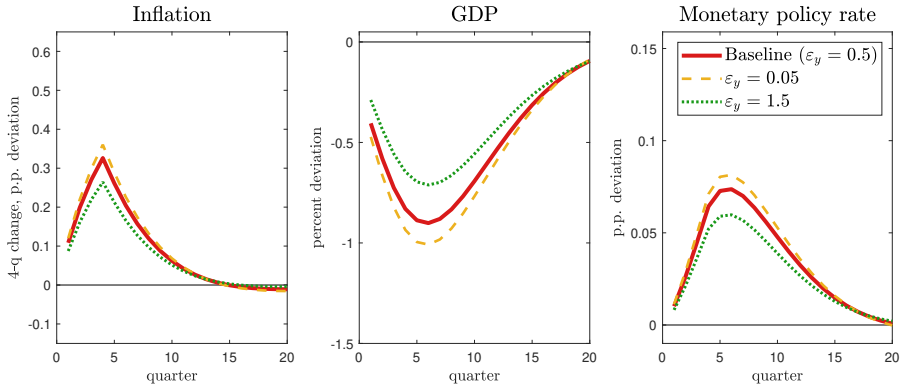
Model Experiments

Effects on the U.S. of an increase in intermediates trade costs, role of ε_y



Note: Effects of a 10 percentage point increase in the U.S.'s trade costs from all trading partners on intermediate inputs, baseline calibration with intermediates-labor substitution elasticity $\varepsilon_y = 0.5$ (red solid), $\varepsilon_y = 0.05$ (yellow dashed), and $\varepsilon_y = 1.5$ (green dotted).

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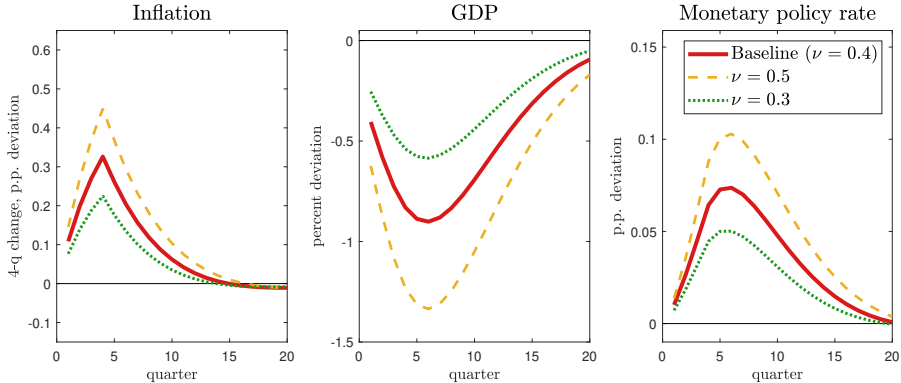
Model Experiments

Effects on the U.S. of an increase in intermediates trade costs, role of ν



Note: Effects of a 10 percentage point increase in the U.S.'s trade costs from all trading partners on intermediate inputs, baseline calibration with share of intermediates in production $\nu = 0.4$ (red solid), $\nu = 0.5$ (yellow dashed), and $\nu_y = 0.3$ (green dotted).

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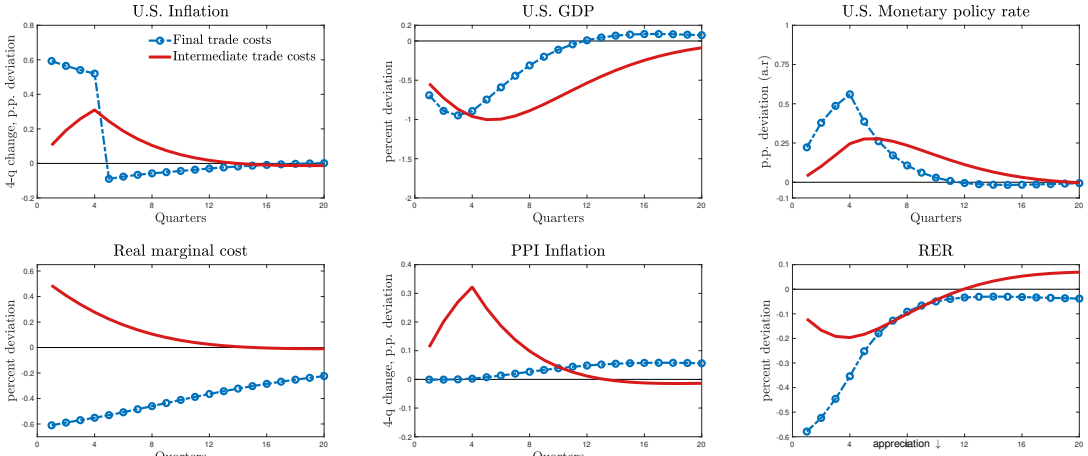
Model Experiments: 10 p.p. transitory increase in trade costs

Impulse responses



Note: Effects of a 10 percentage point increase in the U.S.'s trade costs from all trading partners.

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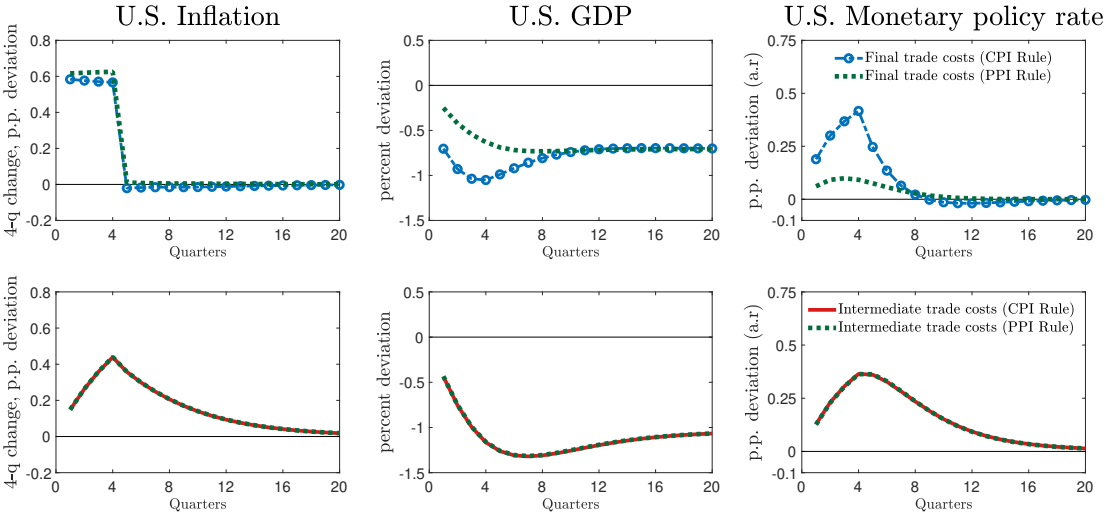
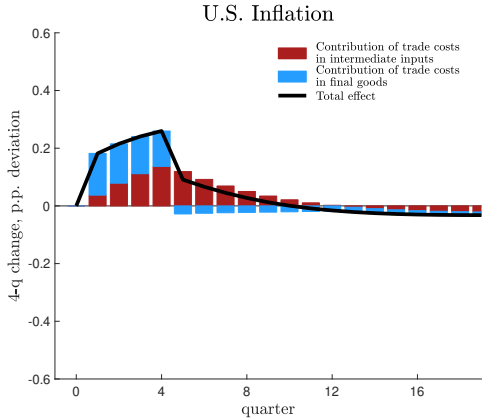
Monetary Policy: CPI v. PPI Rule (permanent trade shock)

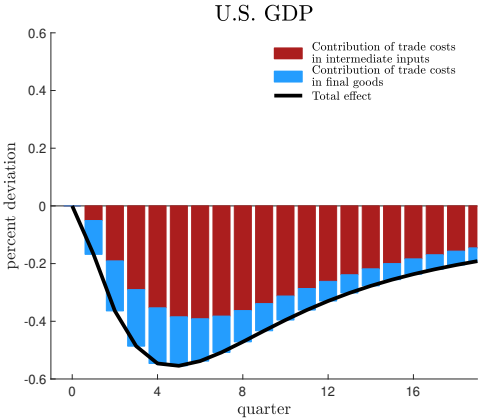


MP with Tariffs Back

2018-19 U.S.-China trade tensions, effects on U.S.

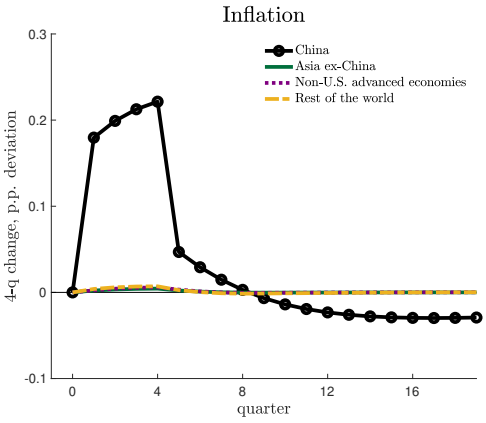
- Calibrate trade costs based on tariffs imposed by the U.S. and China's response
- Increase in average bilateral tariff in line with measured bilateral trade costs
- Tariffs on interm. inputs explain the bulk of inflation persistence and drag on GDP

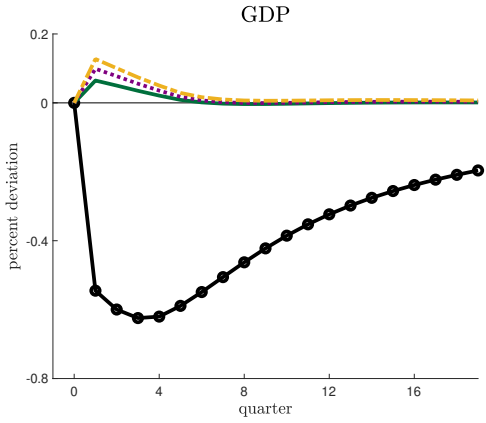




2018-19 U.S.-China trade tensions, effects on other regions

- Muted inflationary effects in foreign regions outside China
- Unaffected regions benefited modestly from trade diversion





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Estimation of model of U.S. vs Rest-of-World (ROW)

Extend model to add quantitative realism: LCP, trade inertia, wage and price indexation

Two-step approach:

- Estimate model with data from 1999:Q1 - 2019:Q4
- Filter shocks from 2020:Q1-2023:Q4

Standard macro data and shocks

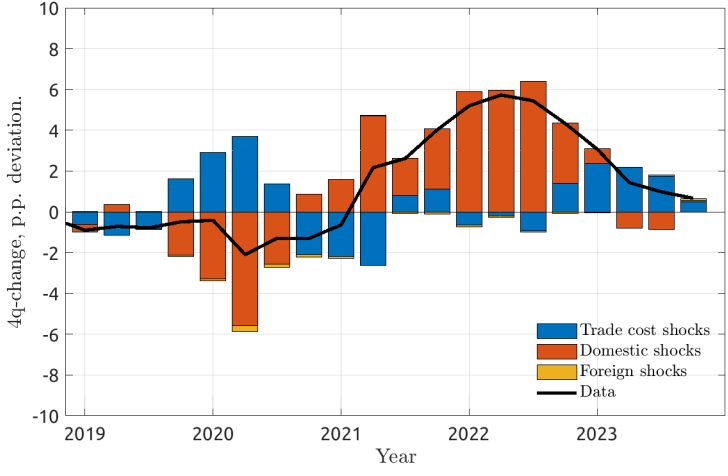
- U.S.: GDP growth, CPI inflation, nominal interest rate
- ROW: GDP growth, CPI inflation, nominal interest rate, U.S./ROW real exchange rate
- Shocks: TFP $(\times 2)$, Demand $(\times 2)$, Monetary Policy $(\times 2)$, UIP.

Trade data and trade shocks

- **New data:** quarterly domestic sourcing shares for final and intermediate goods
- **New shocks:** trade costs for final $(\tau^{C}_{US,ROW})$ and intermediate goods $(\tau^{M}_{US,ROW})$

U.S. sourcing shares | Identification

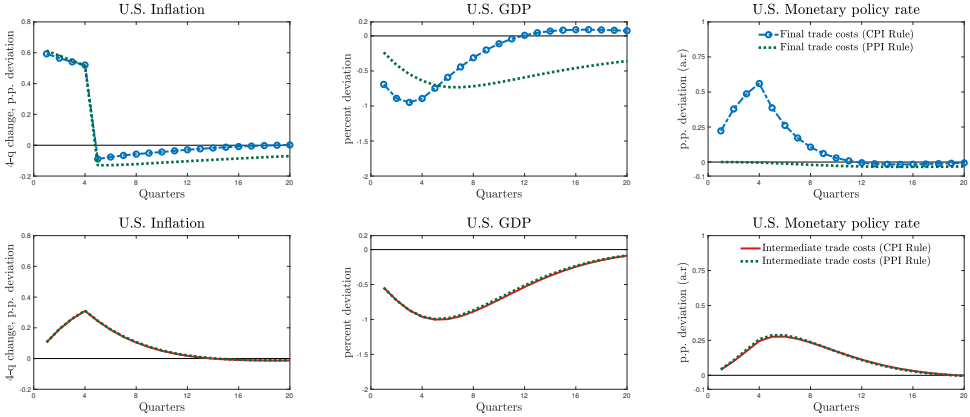
Significant Effect of Trade Costs During the Pandemic Inflation



Decomposition 1999-2017 Back

Monetary Policy Response

Transitory Tariffs



Note: Effects of a 10 percentage point increase in the U.S.'s trade costs from all trading partners.

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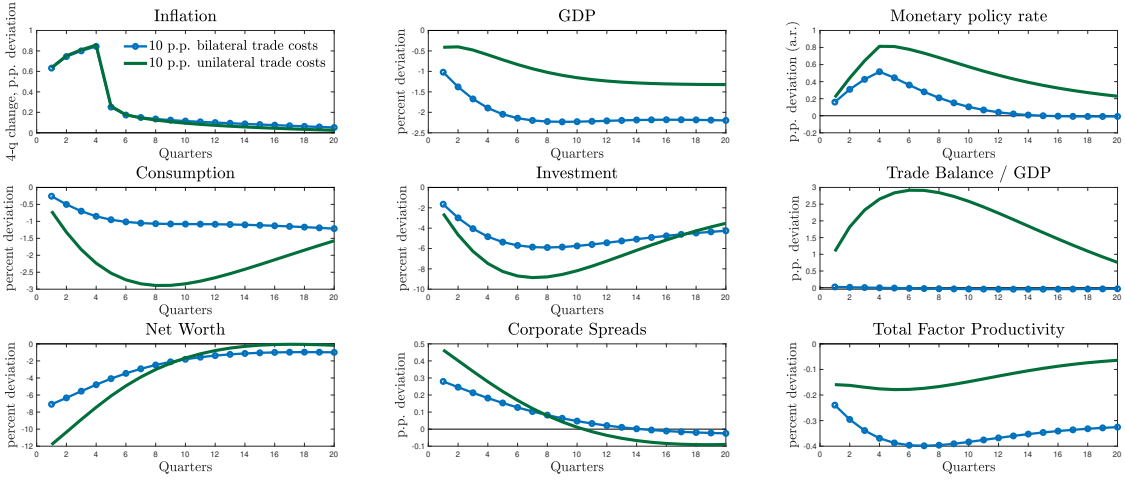
Extensions

Trade adjustment costs, capital utilization, investment (domestic and imported), LCP, financial frictions



Note: Effects of a permanent 10 percentage point increase in U.S.'s trade costs from all trading partners.

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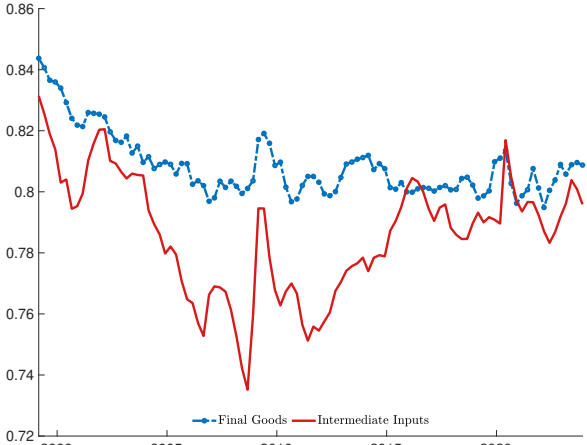
U.S. Quarterly Domestic Sourcing Shares



Notes: U.S. sourcing shares interpolated from BEA inpunt-output tables. The blue line corresponds to the domestic sourcing share of final goods. The red line depicts the domestic sourcing share for intermediate inputs. Sourcing shares correspond to tradable sectors in accordance to standard NAICS classification.

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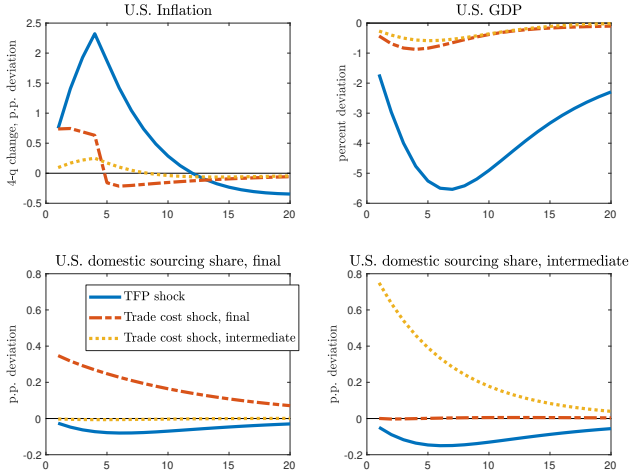
Identification of Trade Cost Shocks



Notes: Impulse response to a one standard deviation to total factor productivity shock (blue), trade cost shock for final goods (red), trade cost shock for intermediate inputs (yellow). Model calibrated at the estimated posterior mean parameters.

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