The Causal Effects of Global Supply Chain Disruptions on Macroeconomic Outcomes: Theory and Evidence

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November 12, 2024

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Motivation

- Lots of interest in the health of the global supply chain triggered by COVID-19 and the Red Sea crisis.
- Future wars? Geopolitical tensions?
- Question 1: What are the *causal effects* of global supply chain disruptions?
- Question 2: And what are the *policy implications*?

Our paper

1. Data = A new machine learning algorithm to transform the satellite data from container ships into a high-frequency measure of port congestion.

2. Identification = A novel (and simple) model to disentangle the different shocks (supply, demand, supply chain) that drive our measure of port congestion.

3. Causal analysis = Data+identification+SVARs and LPs $\Rightarrow$ inflation in 2020-2023.

4. State-dependent analysis = interplay between supply chain disruptions and the changes in the effectiveness of monetary policy to control inflation and output.

Why containerized trade?

- We measure congestion at container ports.
  - Containerized trade accounts for $\approx$ 46% of world trade.
  - Most of the rest is accounted for by bulk cargo (e.g., oil) and specialized vessels (e.g., roll-on/roll-off).
- Container ships behave as regular flights or bus lines:
  - Regular schedules picking up/delivering containers from/to feeders.
  - Seaports serve as international hubs for freight collection and distribution.
  - Routes and speed are rarely changed (e.g., speed has next-to-no relation with oil prices).
  - "Hurry up and wait."

Why port congestion?

- Port congestion: a container ship must first moor in an anchorage within the port (random areas to lower anchors) before docking at a berth (designated spots to load/unload the cargo).
- Prior to the pandemic, waiting times at ports were just a few hours. However, disruptions related to COVID-19 led to extended delays, with waiting times reaching 2-3 days at major ports.
- Even mild congestion has tremendous financial and logistic consequences.
- MSC Loreto: carries around 24,346 TEUs, with 240k tons of cargo.


MSC LORETO
MSC
msc
FleetMon
Tracking the Seven Seas

The AIS system

- We use movement data of container ships from the automatic identification system (AIS).
  - A real-time satellite tracking system mandated by the IMO.
  - Each data entry includes the IMO number, timestamp, current draft, speed, heading, and geographical coordinates.
  - The AIS updates information as frequently as every two seconds.
- Machine learning allows us to handle the data: situation of ships at top 50 container ports worldwide.

Raymarine AIS 4000 Class A AIS Transceiver

RAYMARINE AIS 4000 Class A AIS - Designed for commercial vessels, luxury yachts, and SOLAS high-seas shipping, the AIS4000 Automatic Identification System (AIS) transceiver delivers robust Class A AIS network capability and is engineered to withstand the harsh weather, shock, and vibration of any vessel class. Power supply: 12 to 24 VDC. Frequency: 156.025 MHz to 162.025 MHz. E70601 **Free US Shipping.**

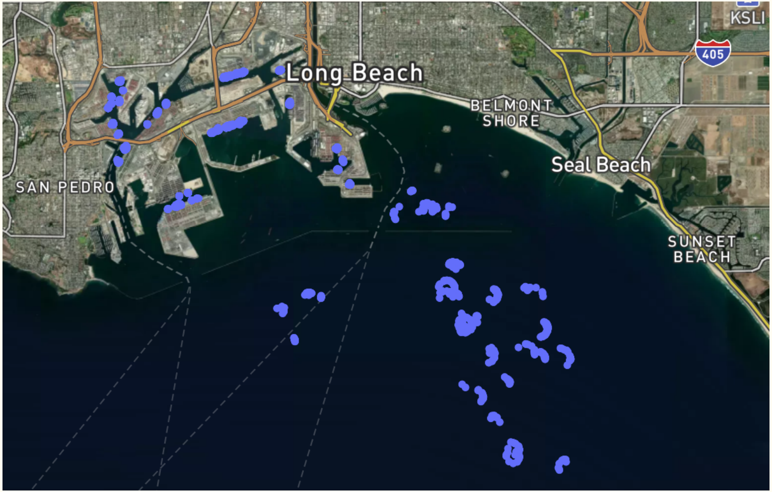
Reference: E70601 **In Stock:** 1

Reg Price: $2,799.99

CPlus Price: $2,701.99

What is Citimarine Plus Membership?
Click here for details

Sample AIS data



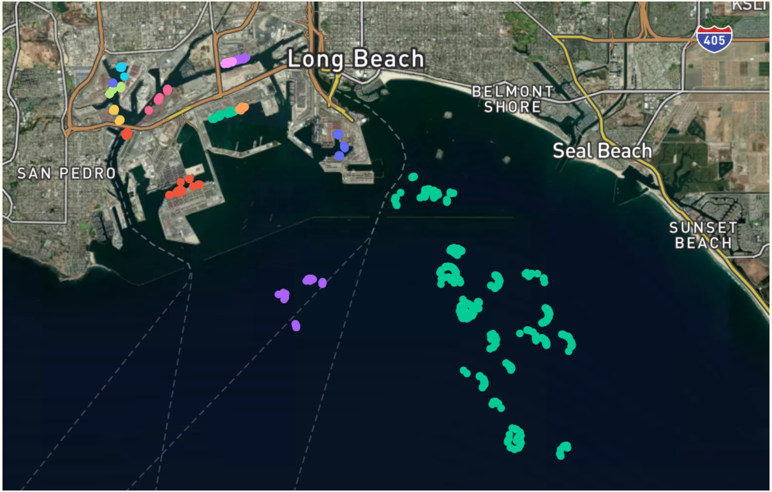
The first 50,000 AIS observations of containerships entering the Ports of Los Angeles and Long Beach since January 1, 2020.

A machine learning, spatial clustering algorithm

Headings at a berth.

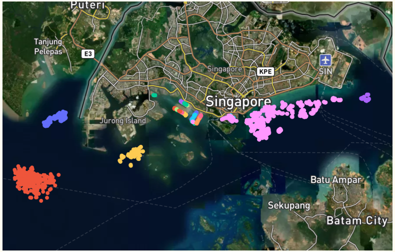
Headings at an anchorage.

Results

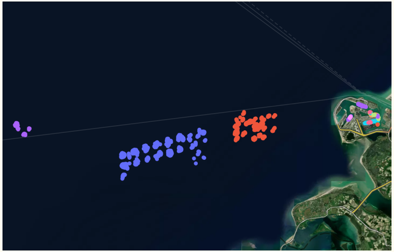


Identification of anchorages (cyan and purple) and berths (other colors) in Los Angeles and Long Beach ports.

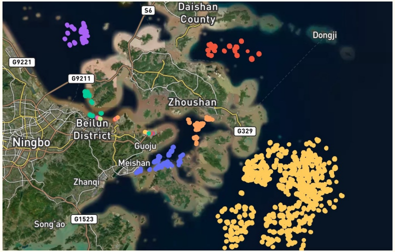
Other ports



Singapore.

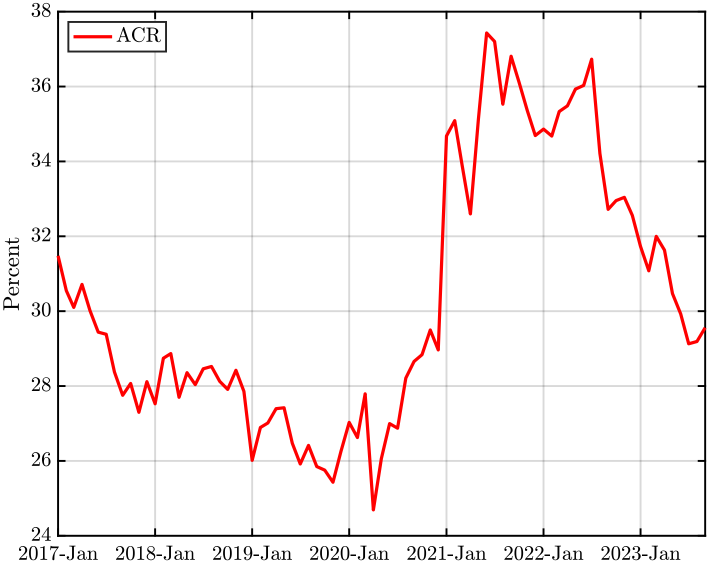


Rotterdam.



Ningbo-Zhoushan.

Average congestion rate (ACR)



Discussion

- Extensions:
    - Canals and other choke points.
    - Regional indices.
    - Indices for bulk, specialized, and liner.
- Comparison with Harper Peterson Time Charter Rates Index (HARPEX), New York Fed's Global Supply Chain Pressure Index (GSCPI), and the Supply Disruptions Index (SDI).
- Webpage: `https://zhongjunma.github.io/port-congestion/congestion.html`

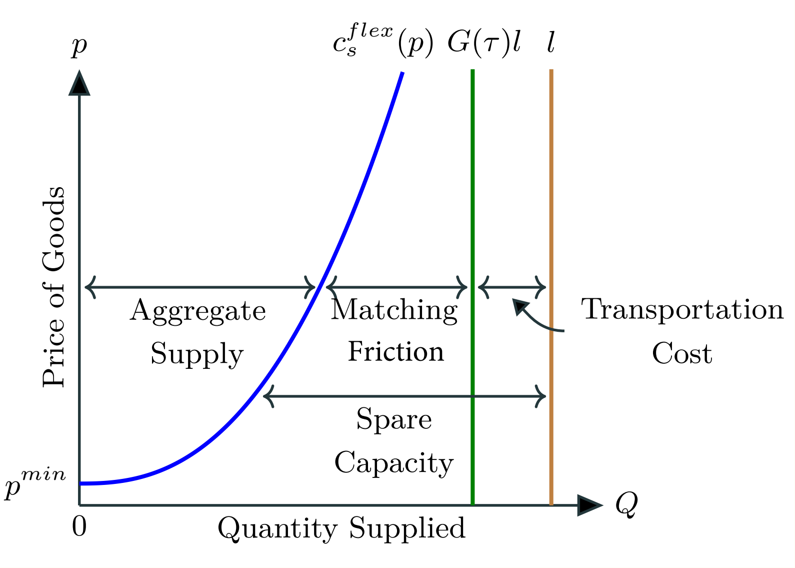
Why a model?

- Identification restrictions for standard causality assessment methods: ACR index is driven by many shocks.
- Desiderata:
  1. The model can generate high spare production capacity jointly with supply scarcity in the retail market.
  2. The model must have demand, productive capacity, and global supply chain shocks.
- Three ways to go:
  1. A network model: hard to handle with shocks (although I am working on such a model right now).
  2. A New Keynesian model with suppliers.
  3. A search and matching model.
- The last two classes of models can be mapped into each other in terms of identification, but, for today, a search and matching model is more transparent.

A model of congestion and sparse capacity

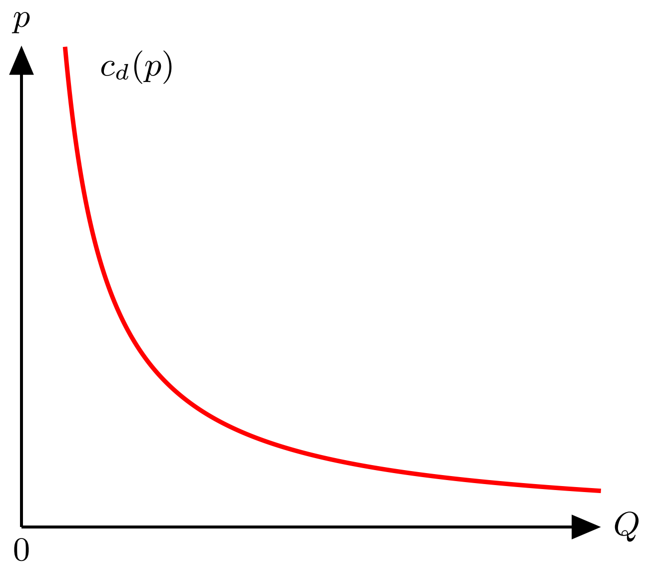
- Producers:
  - Produce goods with a capacity determined by labor inputs and subject to stochastic transportation costs.
  - Supply goods to retailers, yet matching frictions prevent full capacity utilization.
- Retailers:
  - Purchase goods by visiting producers (at a cost), yet not all visits would result in a match due to matching frictions.
  - Sell goods to the representative household.
- Representative household: consumes, supplies labor inputs inelastically, and holds money.

Supply side

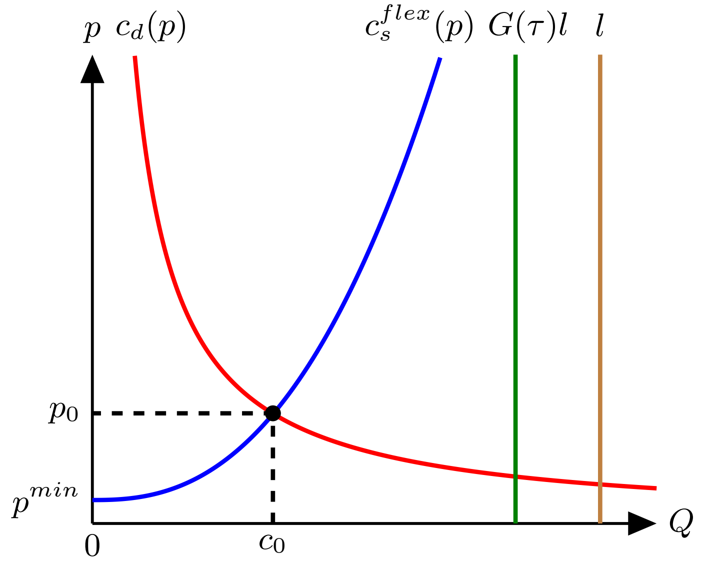


p
$c_s^{flex}(p)$
$G(\tau)l$
l
Price of Goods
Aggregate Supply
Matching Friction
Transportation Cost
Spare Capacity
p^{min}
Q
0
Quantity Supplied

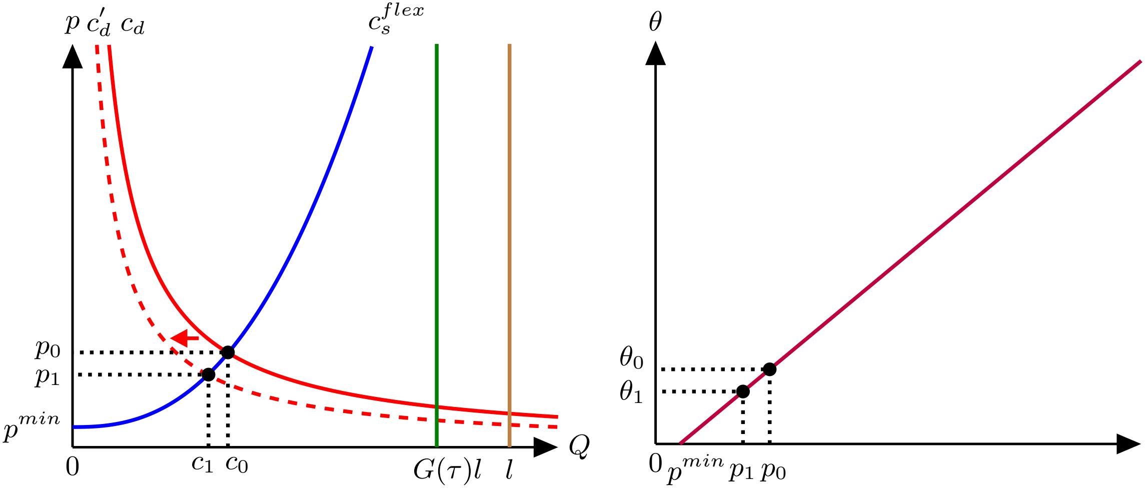
Demand side



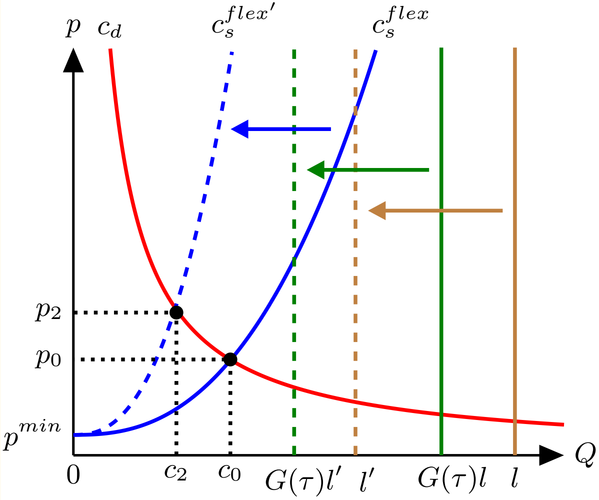
Equilibrium

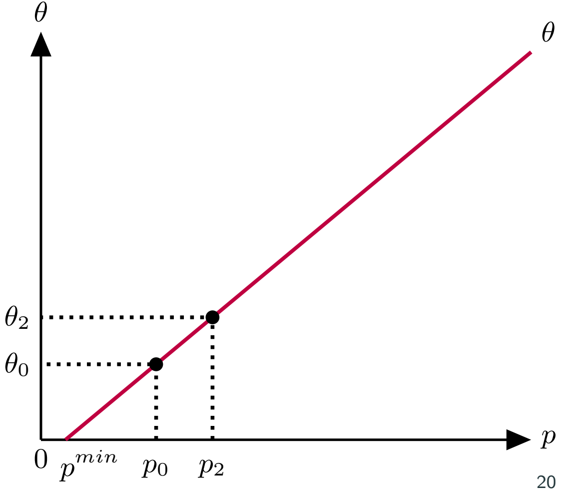


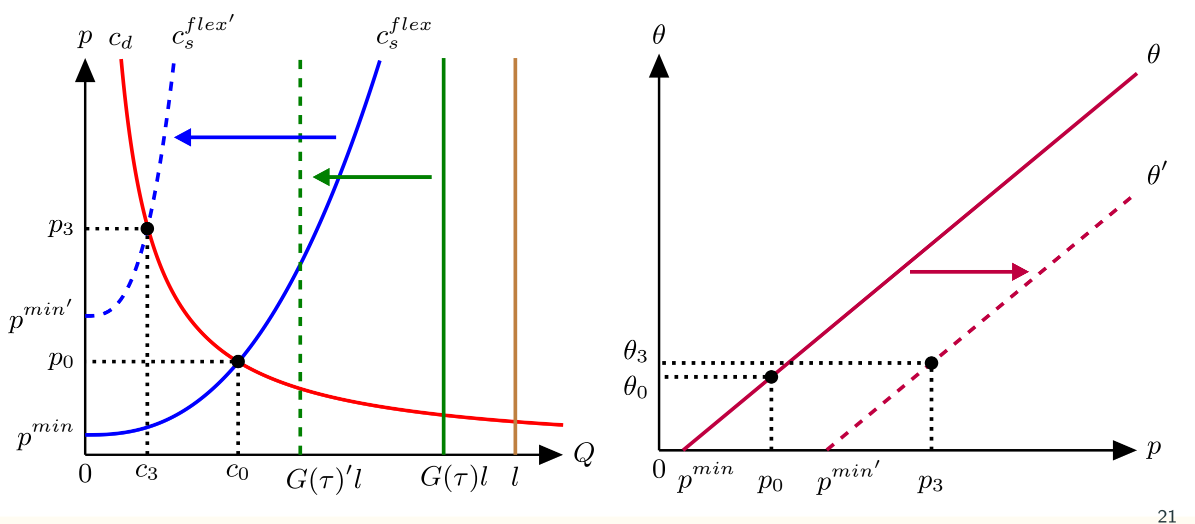
An adverse shock to aggregate demand



An adverse shock to productive capacity






p
c_d
c_s^{flex'}
c_s^{flex}
p_3
p^{min'}
p_0
p^{min}
0
c_3
c_0
G(τ)'l
G(τ)l
l
Q
θ
θ
θ'
θ_3
θ_0
0
p^{min}
p_0
p^{min'}
p_3
p

Identification restrictions on structural shocks

Table 1: Comparative Statics

Adverse Shock To:	**Effects On:** Consumption (or Output) c	Price p	Product Market Tightness θ	Wholesale Price r	Matching Cost $\frac{AG(\tau)}{1-(1-A)G(\tau)}l - c$	Spare Capacity (or Unemployment) $l - c$
Aggregate Demand ($\mu \downarrow$ or $\chi \downarrow$)	$-$	$-$	$-$	$-$	$+$	$+$
Productive Capacity ($l \downarrow$)	$-$	$+$	$+$	$+$	$-$	$-$
Supply Chain ($\gamma \uparrow$)	$-$	$+$	Undetermined	Undetermined	Undetermined	$+$
Supply Chain ($A \downarrow$)	$-$	$+$	$+$	$+$	Undetermined	$+$

A SVAR model with sign and zero restrictions

- Approach based on Uhlig (2005), Rubio-Ramírez *et al.* (2010), and Arias *et al.* (2018):

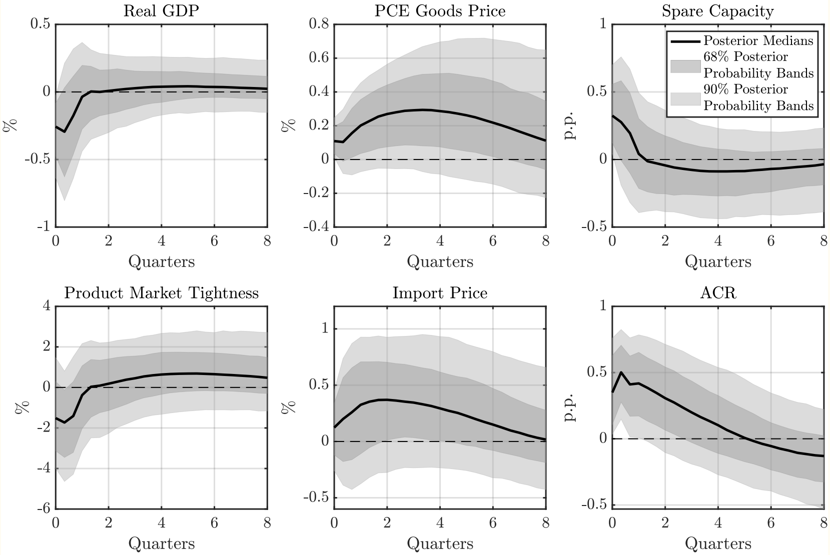
$$\boldsymbol{y}_t'\boldsymbol{A}_0 = \boldsymbol{x}_t'\boldsymbol{A}_+ + \boldsymbol{\epsilon}_t', \quad \forall t \in [1, T]$$

- Six endogenous variables: U.S. real GDP, U.S. PCE goods price, U.S. import price, spare capacity, product market tightness, and ACR.
- All the series are seasonally adjusted. The sample runs from 2017M1 through 2023M9.
- We set two lags in the baseline specification, but the results are robust to considering other lags.
- Key: ACR is driven by autoregressive components and all the shocks.

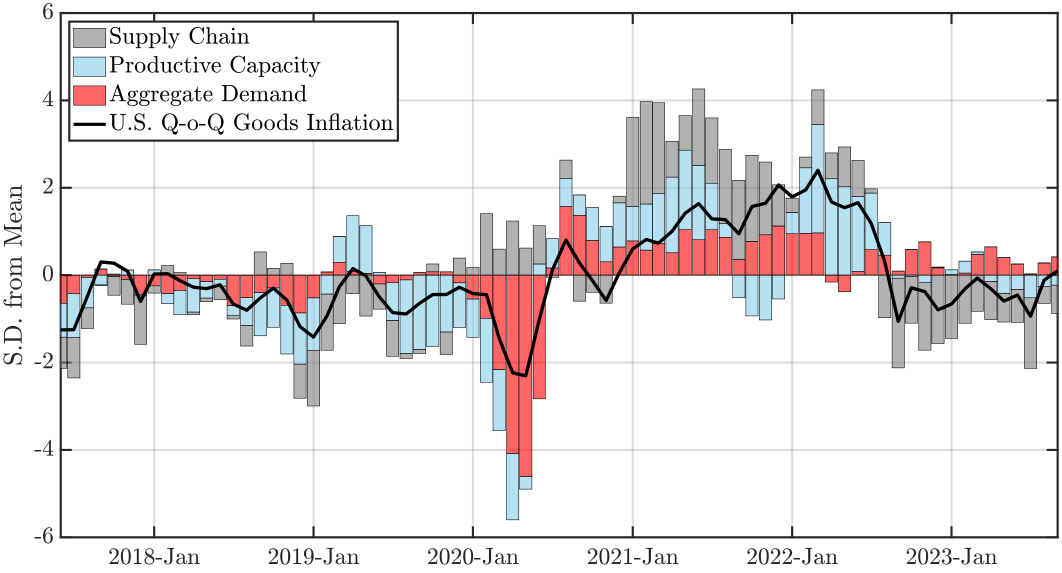
Shocks and identification restrictions

- **Restriction on aggregate demand shock.** An adverse shock to aggregate demand leads to a negative response of real GDP, PCE goods price, product market tightness, and import price, and a positive response of spare capacity at $k = 1$. The ACR does not respond at $k = 1$.
- **Restriction on productive capacity shock.** An adverse shock to productive capacity leads to a negative response of real GDP and spare capacity, and a positive response of PCE goods price, product market tightness, and import price at $k = 1$. The ACR does not respond at $k = 1$.
- **Restriction on supply chain shock.** An adverse shock to the supply chain leads to a negative response of real GDP, and a positive response of PCE goods price, spare capacity, and the ACR at $k = 1$.

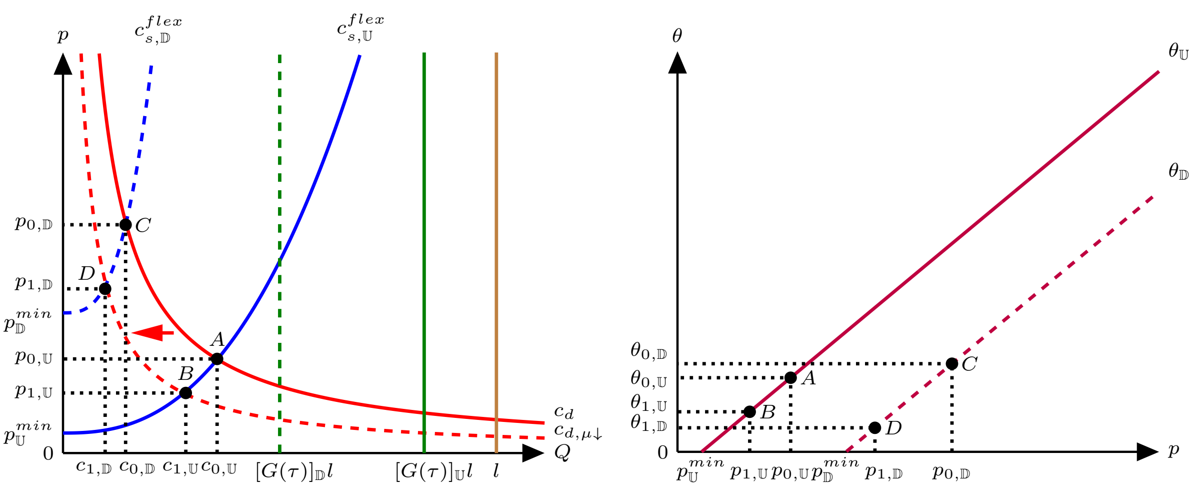
IRFs to an adverse shock to supply chain



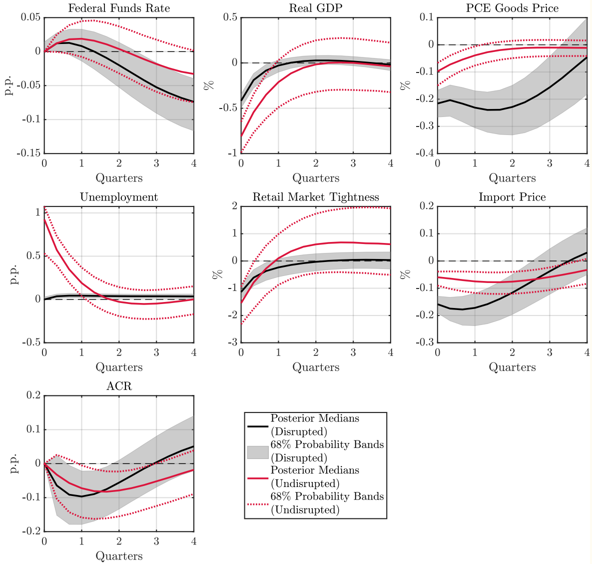
Historical contribution of each shock to U.S. inflation



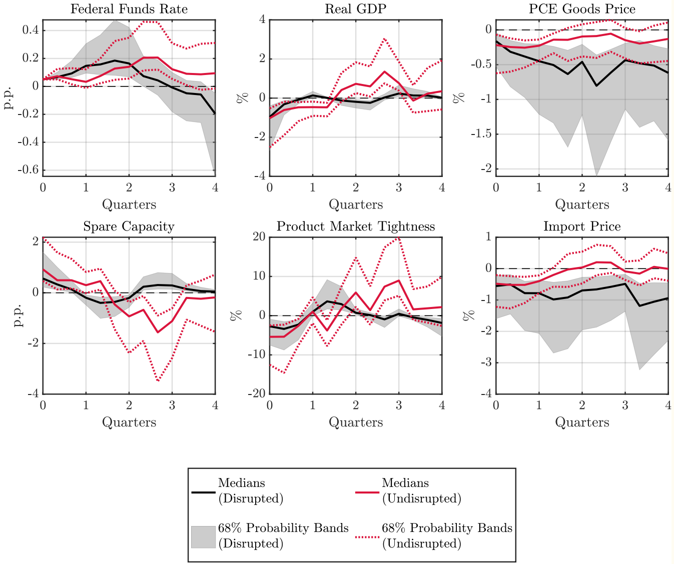
The state-dependence of monetary policy shocks



IRFs to a contractionary monetary policy shock (TVARs)



IRFs to a contractionary monetary policy shock (LPs)



Conclusion

- We study the causal effects and policy implications of global supply chain disruptions.
- We construct a new index, develop a novel theory, and integrate them with state-of-the-art methods for assessing causality in time series.
- Two main results:
  1. Supply chain disruptions generate stagflation accompanied by an increase in spare capacity.
  2. Monetary tightening can tame inflation at reduced costs of real activity during times of supply chain disruption.