Pandemic-Era Inflation Drivers and Global Spillovers

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This paper

- **What?**
  - Quantify inflation drivers when economy is hit by different set of shocks
  - Key: open economy $\rightarrow$ allow to study spillovers across countries-sectors

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  - Key: open economy $\rightarrow$ allow to study spillovers across countries-sectors
- **Why?**
  - Highest inflation of last four decades
  - Characterized by:
    - Collapse and rebound in domestic demand, GDP and international trade
    - Consumption substitution across sectors
    - Labor shortages
  - Requires a model

This paper

- **How?** $\rightarrow$ Multi-country multi-sector model
  - Theory: extends Baqaee and Farhi (2022, AER) to an open economy
  - Segmented factor markets + downward nominal wage rigidity
  - Allow for a nominal block to tie real shocks to nominal variables
    - countries conduct independent monetary policy $\rightarrow$ flexible exchange rates
  - Takes model to the data
    - 4 Countries: United States, Euro Area, Russia, and China+RoW
    - 4 Sectors: durables, non-durables, services, and energy (extension to 44 in the paper)
    - Rich set of shocks: sectoral supply, sectoral demand, aggregate demand and energy shocks
    - Conduct counterfactuals: what if only supply shocks? ... demand shocks? ... energy shocks?

What we find

- 2020

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  - Negative aggregate demand shocks: ↓ inflation
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  - Positive aggregate demand shocks e.g. fiscal stimulus: ↑ inflation
  - Lower role for sectoral demand shocks but not negligible: ↑ inflation

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  - Positive aggregate demand shocks e.g. fiscal stimulus: $\uparrow$ inflation
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- 2022

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- 2021
  - Negative supply shocks: ↑ inflation
  - Positive aggregate demand shocks e.g. fiscal stimulus: ↑ inflation
  - Lower role for sectoral demand shocks but not negligible: ↑ inflation
- 2022
  - Still strong aggregate demand: ↑ inflation
  - Sectoral supply shocks started to recede: ↓ inflation
  - Energy price changes
    - Higher impact on the euro area but increases inflation everywhere: ↑ inflation

What we find cted’

- International spillovers: larger in euro area than the US.
- Model matches well
  - other aggregate moments: current account to GDP ratio, bilateral exchange rates (qual.)
  - cross-sectional moments: sector-level prices and wages
- Role of disaggregation: model with more sectors does better

Related literature

Inflation with sectoral demand and supply shocks: theory and empirics

- *Closed economy*

  Baqaee and Farhi (2022), La'O and Tahbaz-Salehi (2022), Rubbo (2022), Afrouzi and Bhattarai (2022), Pasten et al (2020), Ferrante et al (2023), Guerrieri et. al (2021, 2022), Lorenzoni and Werning (2023), Blanchard and Bernanke (2023), Gagliardone and Gertler (2023), Benigno and Eggertson (2023), Harding et al (2023), Fornaro and Wolf (2023), Jorda et al (2022), LaBelle and Santacreu (2022), Shapiro (2022), de Soyres et al. (2024), Bai et al (2023)

- *Open economy*

  di Giovanni et al (2021), Amiti et al (2022), Silva (2023), Comin et al (2023), Andrade et al (2023), Cuba-Borda et al (2024)

- **Our contribution:** a structural *GE* model to quantify inflation drivers with
  - global input-output linkages
  - downward nominal wage rigidity + segmented factor markets
  - endogenous exchange rates
  - rich set of shocks and counterfactuals

Outline

- Model
- Calibration
- Results
- Conclusion

Model

Inflation in a multi-country multi-sector model

- Open economy extension of Baqaee and Farhi (2022, AER):
  - Two-period multi-country model ($n, m = 1, \dots, \mathcal{N}$)
  - Multiple sectors ($i, j = 1, \dots, \mathcal{J}$) produce using factors and intermediate inputs
  - Ricardian households with perfect foresight
  - Have access to a domestic and a world bond denominated in US dollars
  - Perfect competition in factors and good markets
  - Monetary policy is conducted independently in each country
- Frictions:
  - Downward nominal wage rigidity (in local currency)
  - Segmented factor markets

Households in Country n: Inter-temporal Problem

$$\max_{\{C_{n,0},C_{n,1},F_{n,0},B_{n,0}\}} (1-\beta_{n,0})\frac{C_{n,0}^{1-\sigma}}{1-\sigma} + \beta_{n,0}\frac{C_{n,1}^{1-\sigma}}{1-\sigma}$$

s.t.

$$P_{n,0}C_{n,0} + B_{n,0} + \mathcal{E}_{n,0}F_{n,0} \leq \sum_i (W_{ni,0}L_{ni,0} + R_{ni,0}K_{ni,0}),$$

$$P_{n,1}C_{n,1} \leq \mathcal{E}_{n,1}\sum_i (W_{ni,1}L_{ni,1} + R_{ni,1}K_{ni,1}) + (1+i_{n,0})B_{n,0} + \mathcal{E}_{n,1}(1+i_{US,0})F_{n,0},$$

- B_n: domestic bond denominated in local currency. Traded domestically.
- F_n: world bond denominated in US dollars. Internationally traded.
- $\mathcal{E}_n$: exchange rate between country n and the US (lcu per dollar)
- i_n: domestic interest rate
- i_{US}: US interest rate

Households in Country "n": Intertemporal Optimality

- Optimality conditions

$$\phi_{n,0}\frac{C_{n,0}^{-\sigma}}{P_{n,0}} = \frac{C_{n,1}^{-\sigma}(1+i_{n,0})}{P_{n,1}} \qquad \text{(Euler Equation)}$$

$$(1+i_{n,0}) = (1+i_{US,0})\frac{\mathcal{E}_{n,1}}{\mathcal{E}_{n,0}} \qquad \text{(Interest Parity Condition)}$$

- $\phi_{n,0} = (1-\beta_{n,0})/\beta_{n,0}$: country-level aggregate demand shifter
- X: steady-state value. 0 present where shocks happen, 1 future.
- $\hat{X}_t = X_t/X$: deviation from steady-state.
- From now on, assume future variables are at steady state and $\sigma = 1$.

Monetary policy and exchange rates

- World expenditure (in US dollars) is *endogenous*

$$\widehat{E}^{\$}_{W,0} = \frac{1}{(1 + i_{US,0})} \sum_n \alpha_n \hat{\phi}_{n,0}; \qquad \alpha_n = (P_n C_n / \mathcal{E}_n) \Big/ \sum_m P_m C_m / \mathcal{E}_m$$

- Bilateral exchange rates depend only on stance of domestic monetary policies

$$\frac{\mathcal{E}_{n,0}}{\bar{\mathcal{E}}_n} = \frac{(1 + i_{US,0})}{(1 + i_{n,0})}$$

- We use data on E_n and $1 + i_{n,0}$ to back out discount factor changes

$$\hat{\phi}_{n,0} = \widehat{E}_{n,0}(1 + i_{n,0})$$

Disaggregated Consumption

- Country-level consumption bundle C_n
  - Aggregates country-specific sectoral consumption bundles $C_{n,j}$
  - Cobb-Douglas aggregator: $\sum_j \Omega^C_{n,j} = 1$
  - Introduce country-sector demand shifters via changes in $\Omega^C_{n,j}$ with $\sum_j \mathrm{d}\Omega^C_{n,j} = 0$
- Country-specific sectoral consumption bundles: $C_{n,j}$
  - Aggregates $C_{n,mj}$ across countries m with elasticity ξ^C

Disaggregated Production

- Nested CES structure
- Gross output: Y_{ni}
  - Combines value added bundle (VA_{ni}) and intermediate bundle (Z_{ni}) with elasticity θ
  - Country-sector productivity A_{ni}
- Value added bundle: VA_{ni}
  - Combines sector-specific labor (L_{ni}) and sector-specific capital (K_{ni}) with elasticity η
- Intermediate input bundle: Z_{ni}
  - Combines sector specific sectoral bundles $X_{ni,j}$ with elasticity ε
- Country-specific sectoral bundles: $X_{n,j}$
  - Combines country-specific bundles $X_{n,mj}$ across countries (m) with elasticity ξ^s

Market clearing

- Goods market clearing (as consumption or intermediate goods)

$$Y_{ni} = \sum_{m=1}^{\mathcal{N}} (X_{m,ni} + C_{m,ni}) \quad \text{for each country-sector } n, i$$

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- Segmented labor markets with downward nominal wage rigidities

$$W^{\$}_{ni} \geq \frac{\overline{W}_{ni}}{\mathcal{E}_n}, \quad \bar{L}_{ni} \geq L_{ni}, \qquad (\bar{L}_{ni} - L_{ni}) \left(W^{\$}_{ni} - \frac{\overline{W}_{ni}}{\mathcal{E}_n} \right) = 0 \quad \text{for each country-sector } n, i$$

  * $\bar{L}_{ni}$: country-sector potential labor supply shocks

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  * $\bar{L}_{ni}$: country-sector potential labor supply shocks
- Segmented capital markets: *no* price rigidities $\rightarrow K_{ni} = \bar{K}_{ni}$
- Asset markets clear: $\sum_n F_{n,t} = 0$, $B_{n,t} = 0$

Calibration

Parameters

- Calibrate the model with ICIO 2018 Table from OECD
  - 4 sectors: durables, non-durables, services, and energy
  - 4 countries: United States, Euro Area, Russia, and China+RoW
  - Final use shares
  - Input shares
  - Value added shares
  - Expenditure shares
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  - Input shares
  - Value added shares
  - Expenditure shares
  - Allow for initial trade imbalances
- Elasticities: p-complementarities
  - Between value added and intermediate inputs: $\theta = 0.6$ (Atalay, 2017; Carvalho et. al, 2021)
  - Between labor and capital: $\eta = 0.6$ (Raval, 2019; Oberfield and Raval, 2021)
  - Among intermediates: $\varepsilon = 0.2$ (Atalay, 2017; Boehm, Flaaen, and Pandalai-Nayar, 2019)
  - Cross-country Armington: $\xi^s = \xi^c = 0.6$ (Boehm, Levchenko and Pandalai-Nayar, 2023)
  - more configurations in the paper

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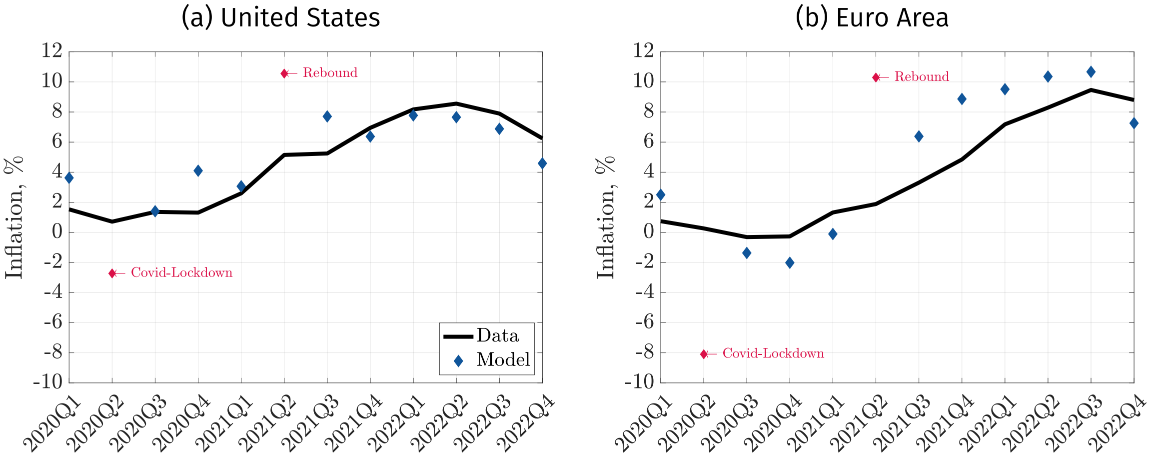
  5. Shutdown productivity changes for all other country-sector pairs: $\hat{A}_{ni,0} = 1$

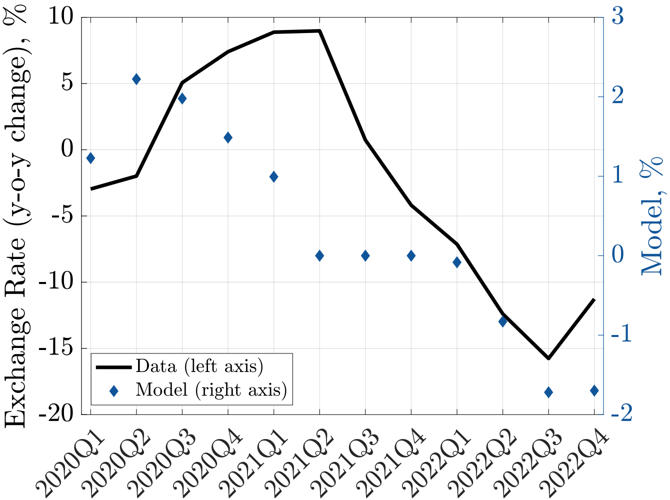
Aggregate results

Model with all shocks: headline inflation



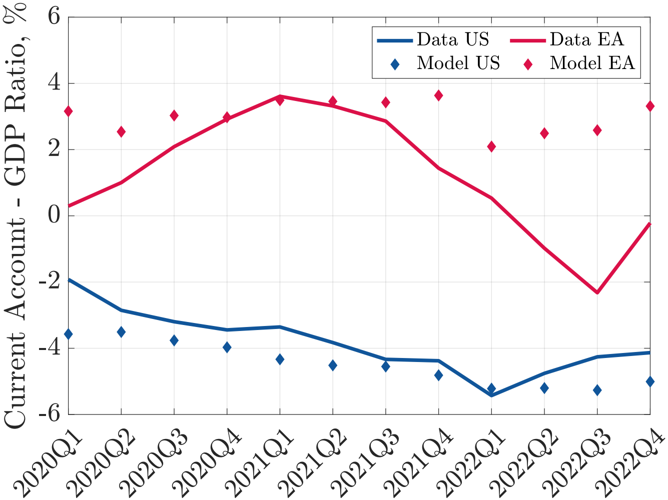
- Full model can replicate most inflation pattern in both countries

Euro-USD exchange rate changes



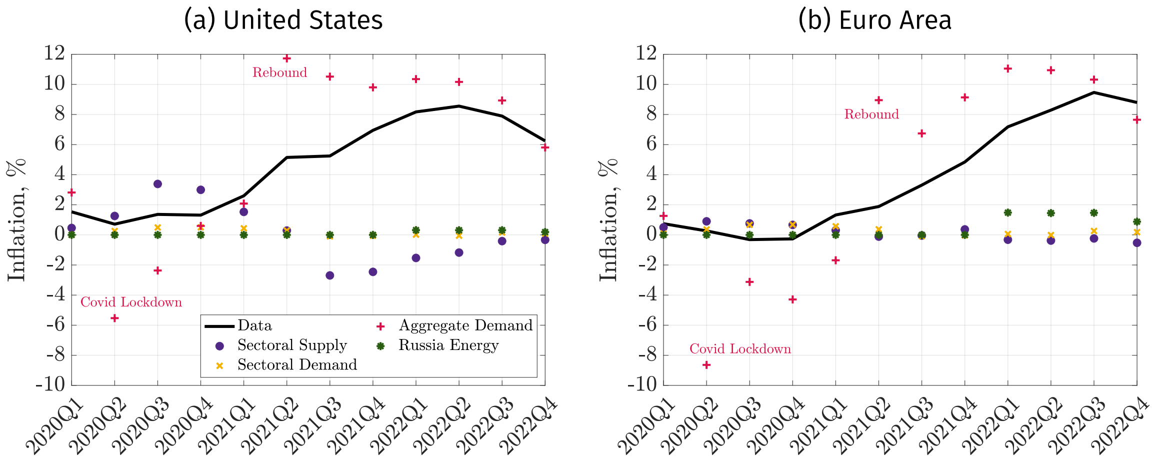
- Model predict *qualitatively* similar behavior to nominal exchange rate in the data

Current account



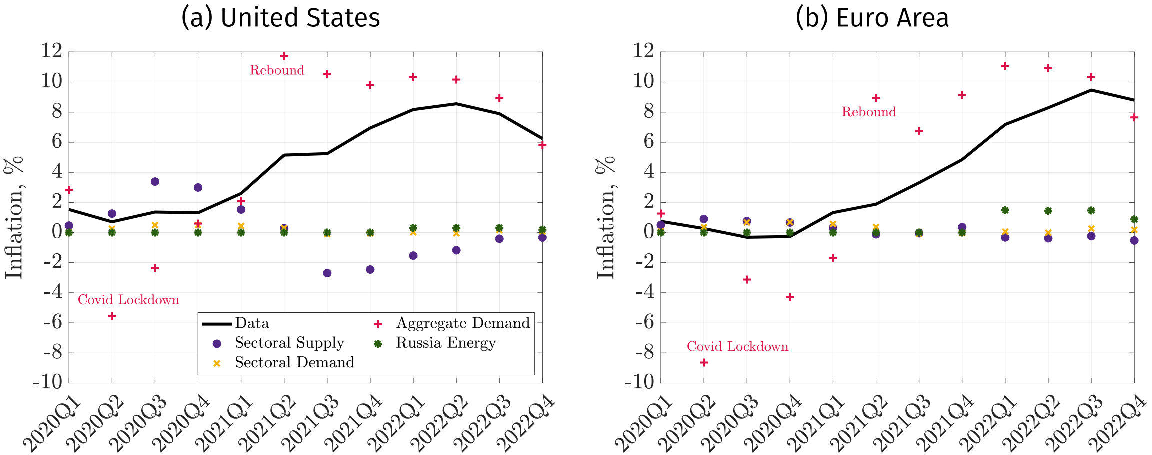
- Reasonable current account movements

Counterfactuals with single shock



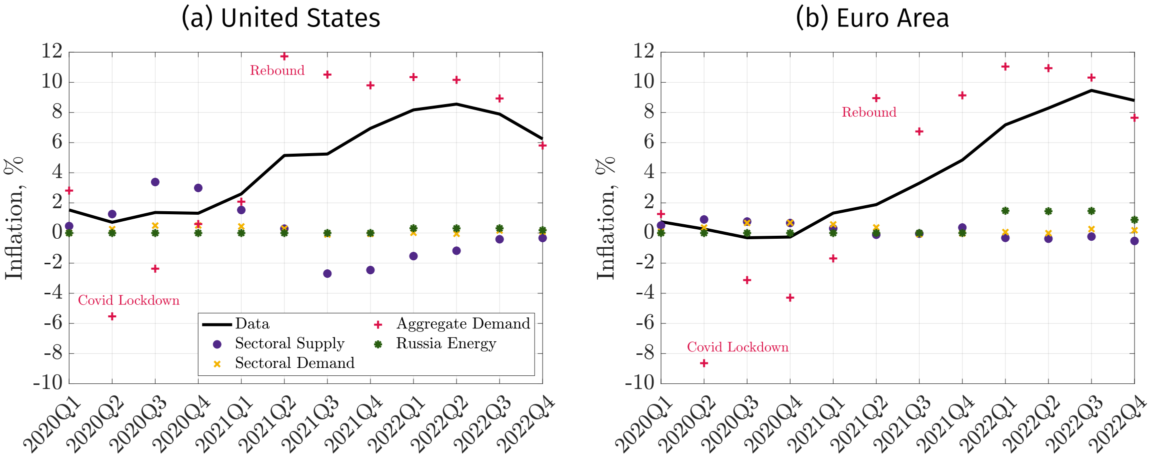
- Sectoral supply inflationary in 2020 – 2021

Counterfactuals with single shock



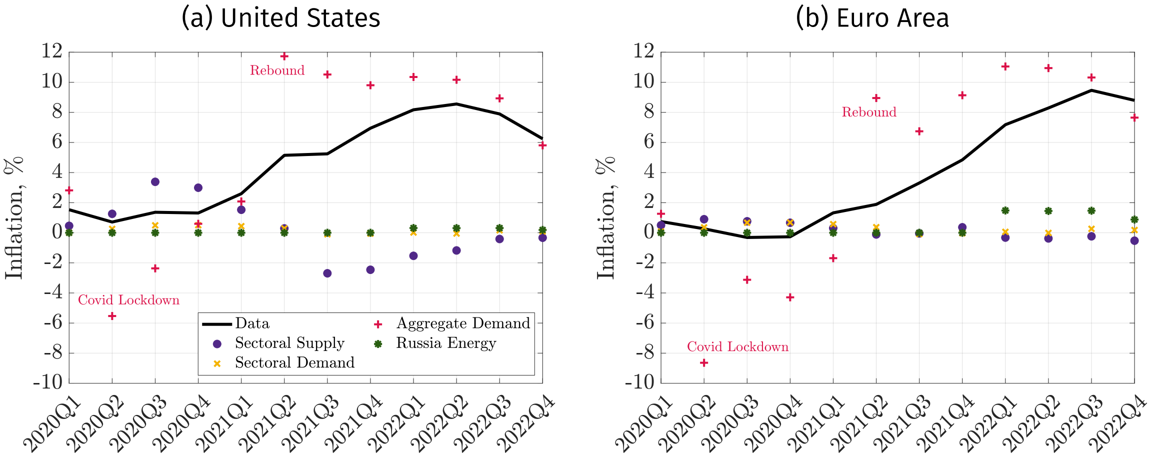
- Not much role for sectoral demand changes

Counterfactuals with single shock



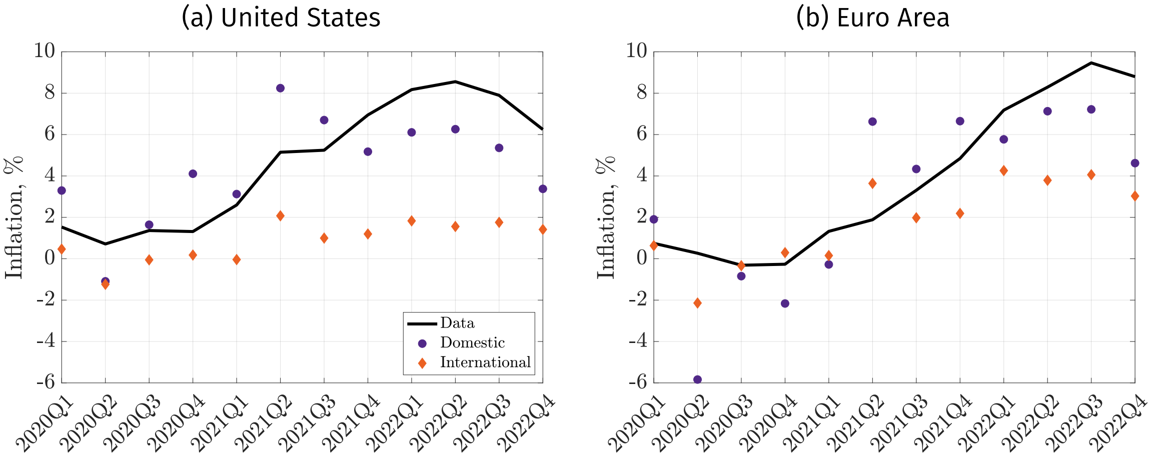
- Aggregate demand deflationary in 2020, inflationary thereafter

Counterfactuals with single shock



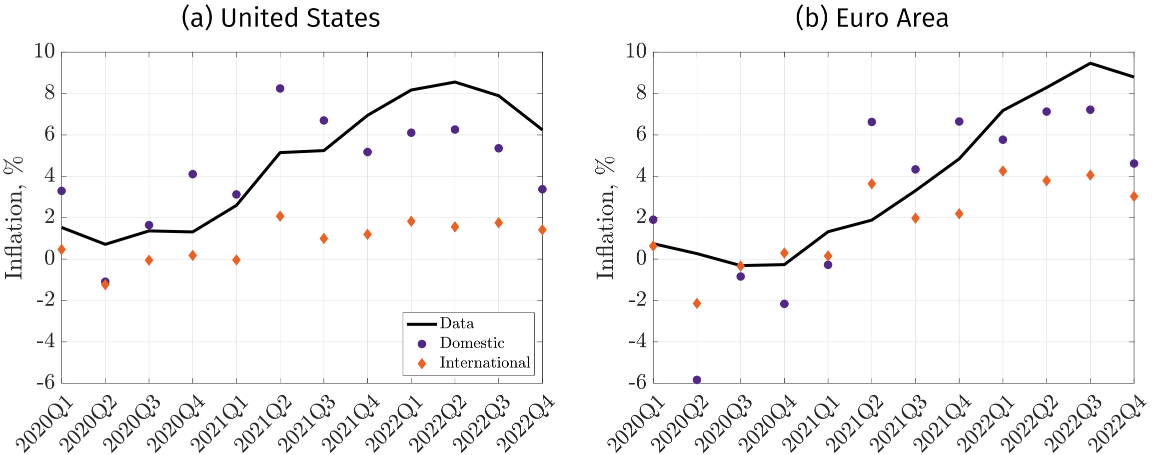
- Energy shocks important for Euro Area

Domestic and international shocks



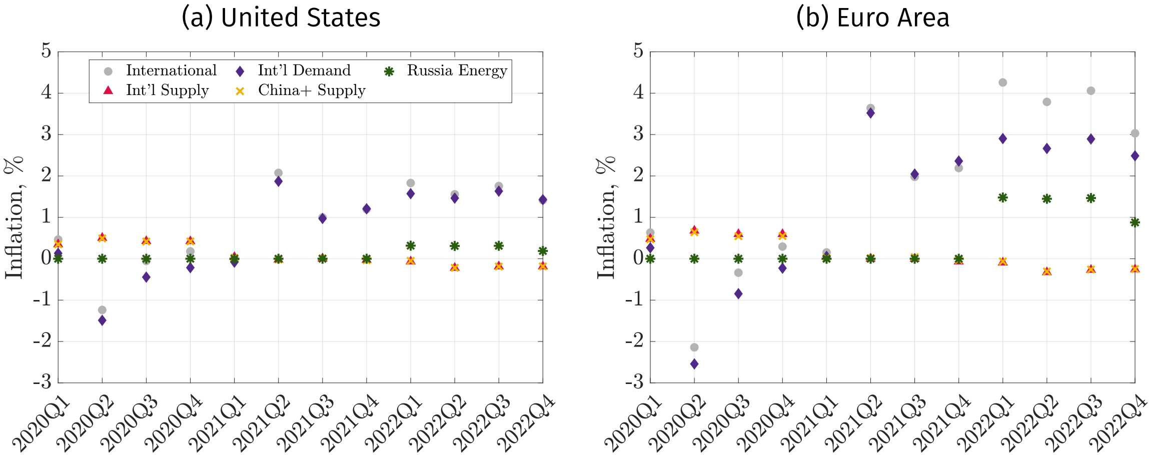
- Domestic shocks were the predominant force.

Domestic and international shocks



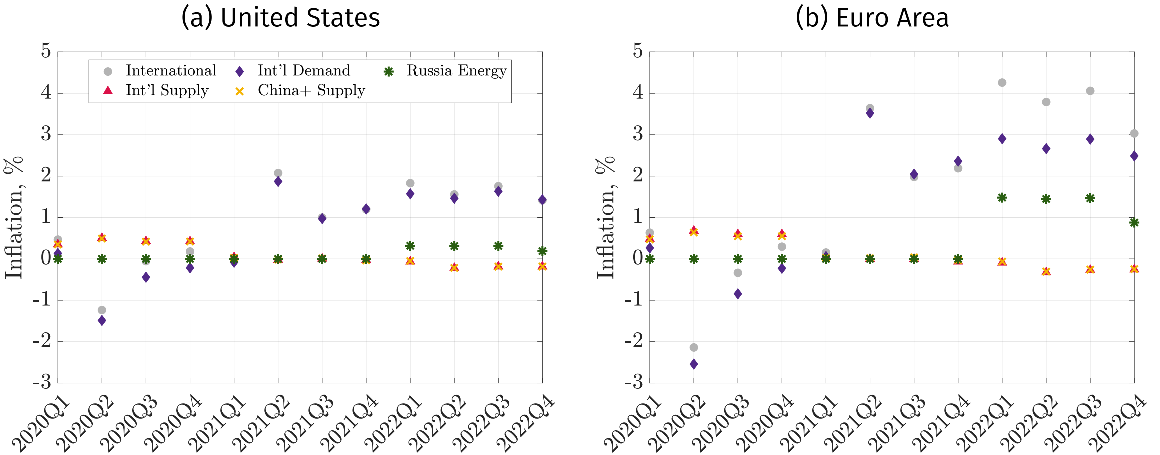
- Important International spillovers, especially in the Euro Area.

International demand account for international spillovers



- International demand account for most of international spillover in the US.

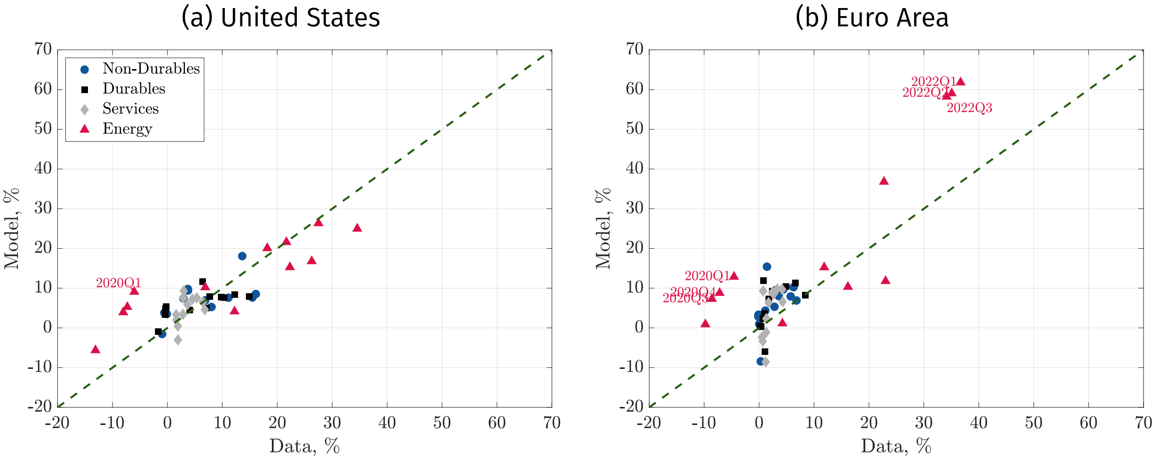
International demand account for international spillovers



- International demand/energy account for the international spillover in the Euro Area.

Cross-sectional results

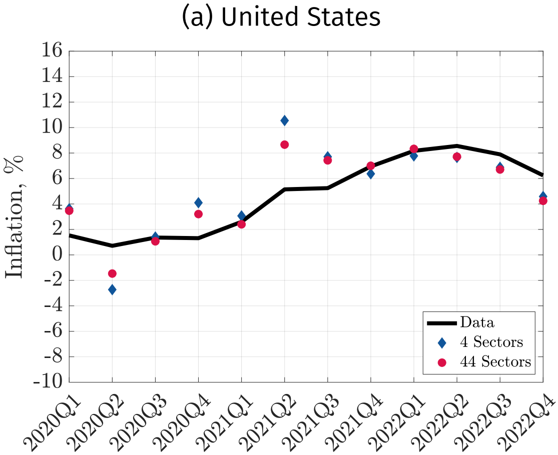
Sectoral prices

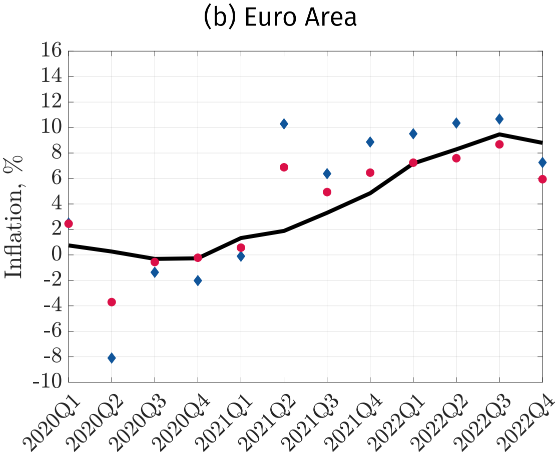


- Able to quantitatively match cross-sectional price changes.

Does more disaggregation give us anything?

YES!


(a) United States
Inflation, %
Data
4 Sectors
44 Sectors
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
2020Q1
2020Q2
2020Q3
2020Q4
2021Q1
2021Q2
2021Q3
2021Q4
2022Q1
2022Q2
2022Q3
2022Q4


(b) Euro Area
Inflation, %
16
14
12
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-6
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2020Q1
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Conclusion

Conclusion

- We develop a model with IO linkages, nominal rigidities and trade across countries
- We use it to study the recent inflationary episode 2020–2022
- Model can match aggregate and sectoral outcomes
- Provided a set of shocks $\rightarrow$ useful for policy makers
- Takeaway: more about supply-demand imbalances than supply/demand alone.
- Much more work to do!

Thank you!

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Calculating Inflation – Auxiliary Matrices

- Industry shares in consumption baskets:

$$\Omega^{CS} \equiv \Omega^{C}\Omega^{CB}.$$

- Industry to industry flows:

$$\Omega^{SS} \equiv \Omega^{Y}\Omega^{Z}\Omega^{X}.$$

- All direct and indirect flows from industry to industry (Leontief Inverse):

$$\Psi = \left[I - \Omega^{SS}\right]^{-1}$$

- Factor shares (for all factors, including labor and capital):

$$\Omega^{F} \equiv \Omega^{Y}\Omega^{VA}.$$

Domestic CPI inflation in a global economy

1. Prices in dollars ($\mathrm{d}\log P^{\$}$):

$$\mathrm{d}\log P^{\$} = -\Psi \mathrm{d}\log A + \Psi \Omega^{F} \mathrm{d}\log W^{\$}$$

2. Country's n CPI changes

$$\mathrm{d}\log CPI_n = (\Omega_n^{CS})^T \mathrm{d}\log P^{LC,n} = \mathrm{d}\log \mathcal{E}_n + (\Omega_n^{CS})^T \mathrm{d}\log P^{\$}$$

3. Relate factor price f to its factor share at the *world level* $\Lambda_f = W_f^{\$} L_f / E_W^{\$}$

$$\mathrm{d}\log W_f^{\$} = \mathrm{d}\log E_W^{\$} + \mathrm{d}\log \Lambda_f - \mathrm{d}\log L_f$$

Domestic CPI inflation in a global economy

- CPI changes (where $(\lambda^n)^T = (\Omega_n^{CS})^T \Psi$ and $(\Lambda^n)^T = (\lambda^n)^T \Omega^F$)

$$\mathrm{d}\log \mathrm{CPI}_n = \underbrace{\mathrm{d}\log E_W^{\$}}_{\text{World Expenditure}} + \underbrace{\mathrm{d}\log \mathcal{E}_n}_{\text{Exchange Rate}} - \underbrace{(\lambda^n)^T \mathrm{d}\log A}_{\text{Productivity Shocks}}$$

$$- \underbrace{(\Lambda^n)^T \mathrm{d}\log L}_{\text{Factor Changes}} + \underbrace{(\Lambda^n)^T \mathrm{d}\log \Lambda}_{\substack{\text{Local-Global} \\ \text{D-S Imbalance}}}$$

- *World expenditure*: US interest rate and countries intertemporal shifters.

Domestic CPI inflation in a global economy

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$$- \underbrace{(\Lambda^n)^T \mathrm{d}\log L}_{\text{Factor Changes}} + \underbrace{(\Lambda^n)^T \mathrm{d}\log \Lambda}_{\text{Local-Global D-S Imbalance}}$$

- *Exchange rate term*: country interest rate relative to the US.

Domestic CPI inflation in a global economy

- CPI changes (where $(\lambda^n)^T = (\Omega_n^{CS})^T \Psi$ and $(\Lambda^n)^T = (\lambda^n)^T \Omega^F$)

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- *Productivity shocks*: Productivity changes weighted by the importance of sector in consumption basket of country n.

Domestic CPI inflation in a global economy

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- *Factor quantity changes*: Labor changes weighted by the importance of factor in providing for the consumption basket of country n.
  * An endogenous object due to downward-wage rigidity.

Domestic CPI inflation in a global economy

- CPI changes (where $(\lambda^n)^T = (\Omega_n^{CS})^T \Psi$ and $(\Lambda^n)^T = (\lambda^n)^T \Omega^F$)

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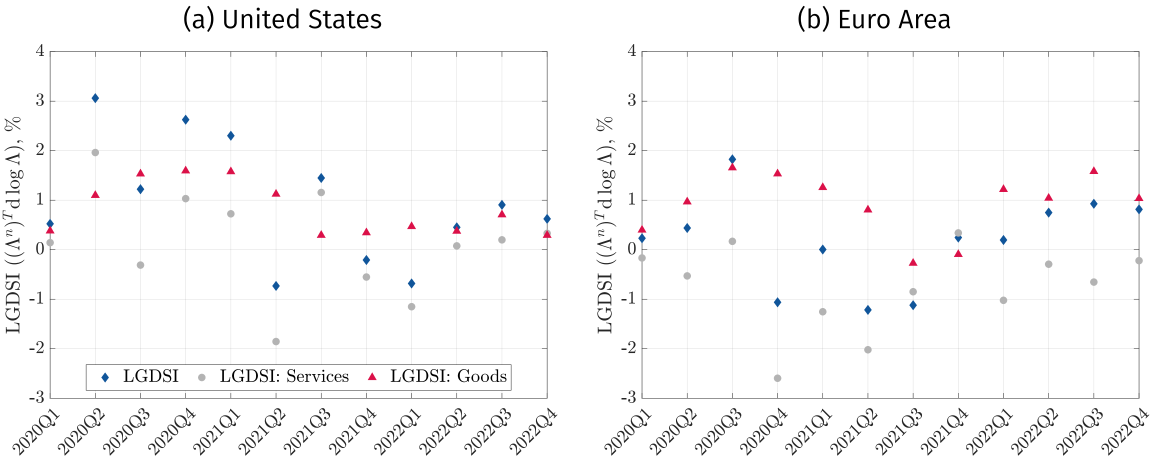
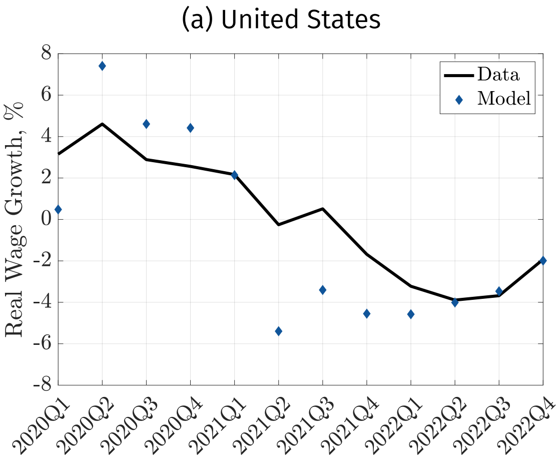
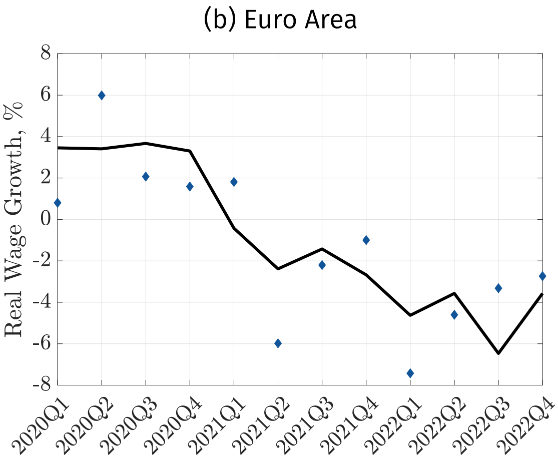
- Changes in global factor shares and local factor shares.
  - Endogenous object: integrates changes in demand and supply factors.
  - Depends on global IO structure and substitution patterns.

Local-Global Demand-Supply Imbalance

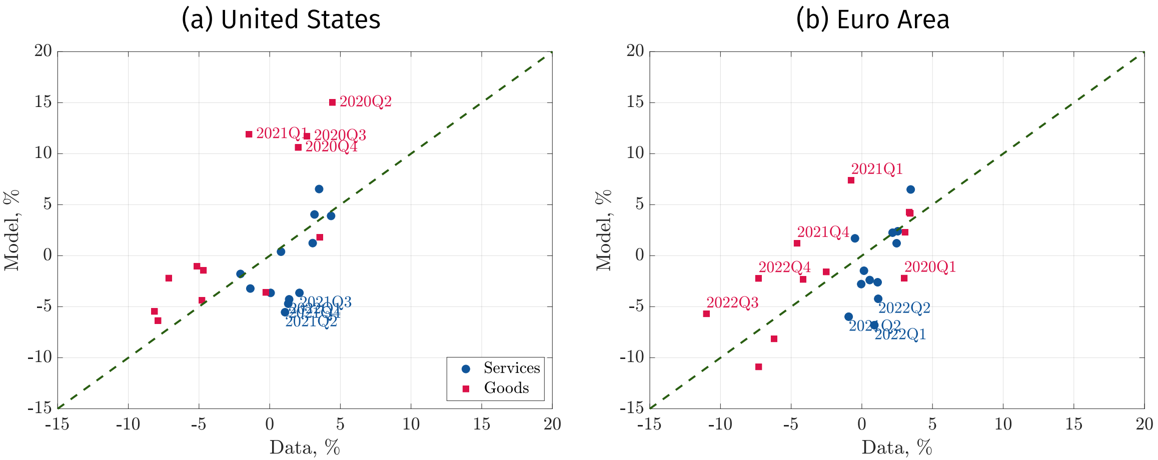


Aggregate real wages





Real wages: cross-section



Disaggregated Consumption

- Consumption bundle consists of country-specific sectoral consumption bundles:

$$C_n = \prod_{j=1}^{\mathcal{J}} C_{n,j}^{\Omega^C_{n,j}}, \quad \sum_{j=1}^{\mathcal{J}} \Omega^C_{n,j} = 1$$

- Country-specific sectoral consumption bundles: Armington aggregator

$$C_{n,j} = \left[\sum_{m=1}^{\mathcal{C}} (\Omega^{CB}_{n,mj})^{\frac{1}{\xi^C}} C_{n,mj}^{\frac{\xi^C - 1}{\xi^C}} \right]^{\frac{\xi^C}{\xi^C - 1}}, \quad \sum_{m=1}^{\mathcal{N}} \Omega^{CB}_{n,mj} = 1$$

Disaggregated Production

- Sectors produce combining factors (value-added) and intermediate bundle.

$$\min_{\{VA_{ni}, M_{ni}\}} P^{VA}_{ni} VA_{ni} + P^{M}_{ni} Z_{ni}$$

$$\text{s.t.}$$

$$Y_{ni} = A_{ni} \left[(\Omega^{Y}_{ni,VA})^{\frac{1}{\theta}} VA_{ni}^{\frac{\theta-1}{\theta}} + (\Omega^{Y}_{ni,Z})^{\frac{1}{\theta}} Z_{ni}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \quad \text{with} \quad \Omega^{Y}_{ni,VA} + \Omega^{Y}_{ni,Z} = 1$$

- Value-added bundle is composed of Labor and Capital:

$$VA_{ni} = \left[(\Omega^{VA}_{ni,L})^{\frac{1}{\eta}} (L_{ni})^{\frac{\eta-1}{\eta}} + (\Omega^{VA}_{ni,K})^{\frac{1}{\eta}} (\bar{K}_{ni})^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad \text{with} \quad \Omega^{VA}_{ni,L} + \Omega^{VA}_{ni,K} = 1$$

Intermediate goods' aggregation

- Intermediate bundle consists of country specific sectoral bundles:

$$Z_{ni} = \left[\sum_{j=1}^{\mathcal{J}} (\Omega^Z_{ni,j})^{\frac{1}{\varepsilon}} X_{ni,j}^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad \text{with} \quad \sum_{j=1}^{\mathcal{J}} \Omega^Z_{ni,j} = 1$$

- Country-specific sectoral bundles: Armington aggregator

$$X_{n,j} = \left[\sum_{m=1}^{\mathcal{N}} (\Omega^X_{n,mj})^{\frac{1}{\xi^S_j}} X_{n,mj}^{\frac{\xi^S_j-1}{\xi^S_j}} \right]^{\frac{\xi^S_j}{\xi^S_j-1}} \quad \text{with} \quad \sum_{m=1}^{\mathcal{N}} \Omega^X_{n,mj} = 1$$

$X_{n,j} = \sum_i X_{ni,j}$ for i's within country n.