SUPPLY & DEMAND SHOCKS, GLOBAL NETWORKS AND INFLATION

Julian di Giovanni

Federal Reserve Bank of New York and CEPR

Şebnem Kalemli-Özcan

University of Maryland, CEPR and NBER

Alvaro Silva

University of Maryland

Muhammed A. Yıldırım

The Growth Lab at Harvard University
Koç University

RBA Conference
September 25, 2023

Inflation in the age of Covid-19

- Since early 2020 large swings in economic activity characterized by:
  - Collapse and rebound in domestic demand, GDP, and international trade
  - Consumption substitution across sectors (goods for services and back)
  - Labor shortages across sectors/countries (pandemic/lockdowns and recovery)
  - Energy shocks after Russian incursion into Ukraine

Inflation in the age of Covid-19

- Since early 2020 large swings in economic activity characterized by:
  - Collapse and rebound in domestic demand, GDP, and international trade
  - Consumption substitution across sectors (goods for services and back)
  - Labor shortages across sectors/countries (pandemic/lockdowns and recovery)
  - Energy shocks after Russian incursion into Ukraine

- Result: **highest inflation of last four decades!**

- Global supply chains played a critical role in amplifying shocks within and across borders

$\Rightarrow$ **Important to quantify the role of sectoral shocks to design policies that mitigate the cost of re-locating supply chains/production (first order for climate and energy transition)**

Quantification of Inflation Drivers based on a Structural Model

- Approach: Try to mimic real-life 2020-2022 events as much as we can
  - Co-existence of slack and inflation
  - Output lower than potential $\Rightarrow$ cannot be all demand shocks
  - Timing and sectoral heterogeneity: Goods vs services, sectoral inflation becoming broad based

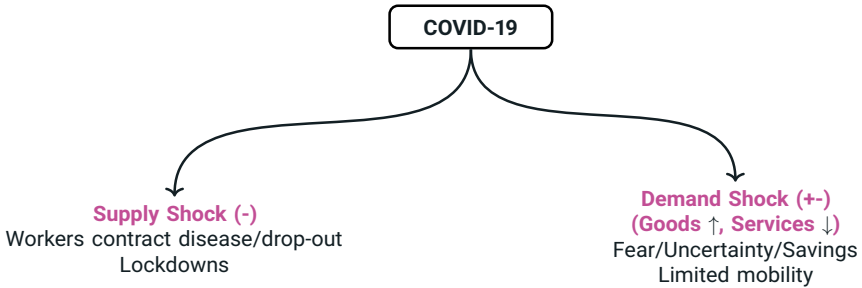
Quantification of Inflation Drivers based on a Structural Model

- Approach: Try to mimic real-life 2020-2022 events as much as we can
  - Co-existence of slack and inflation
  - Output lower than potential $\Rightarrow$ cannot be all demand shocks
  - Timing and sectoral heterogeneity: Goods vs services, sectoral inflation becoming broad based

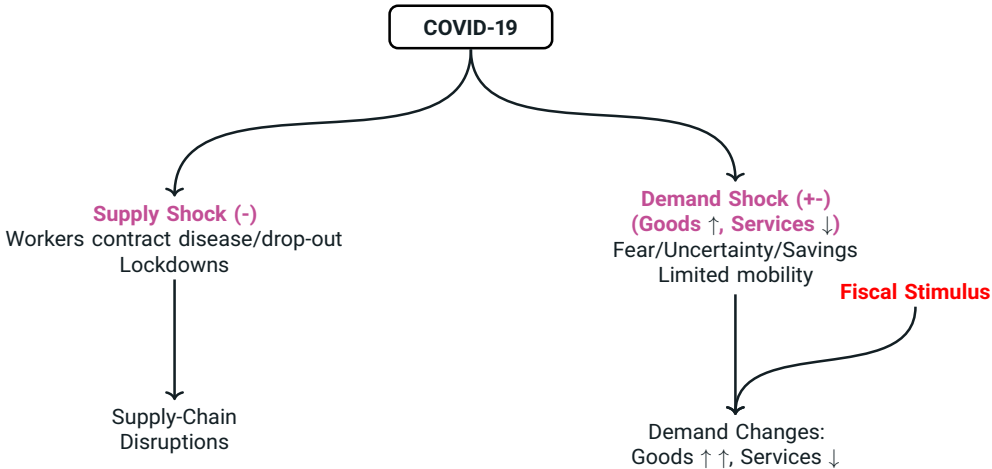
Important to focus on:

- Covid is a set of disaggregated demand and supply shocks with asymmetric recovery
- Sectoral imbalances and labor shortages—demand (slack) and supply (tight) constrained sectors
- Global and local supply chain disruptions—sectoral shifts in consumption demand connected with sectoral production using intermediate inputs and labor

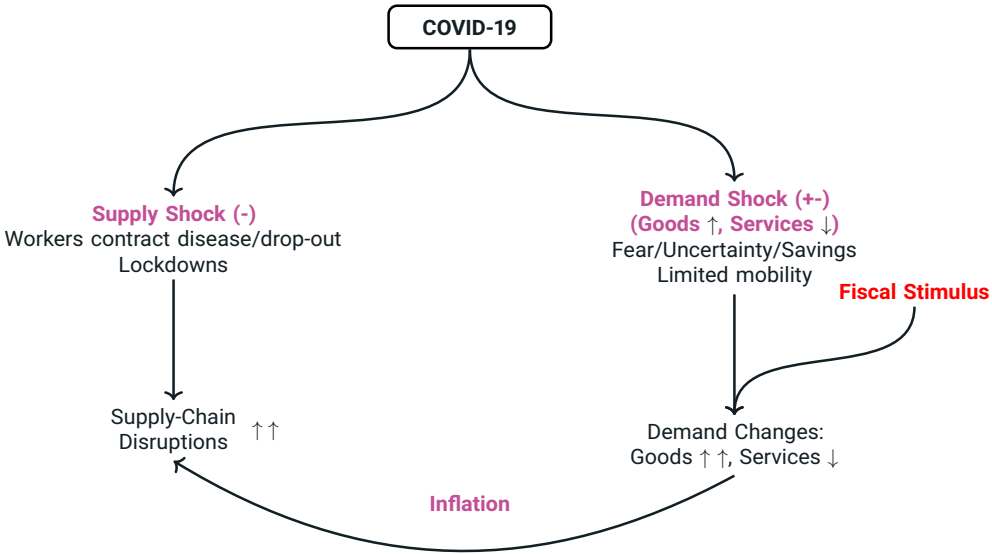
Supply-Demand Imbalances ↑ with Fiscal Stimulus via Global Network



Supply-Demand Imbalances ↑ with Fiscal Stimulus via Global Network



Supply-Demand Imbalances ↑ with Fiscal Stimulus via Global Network

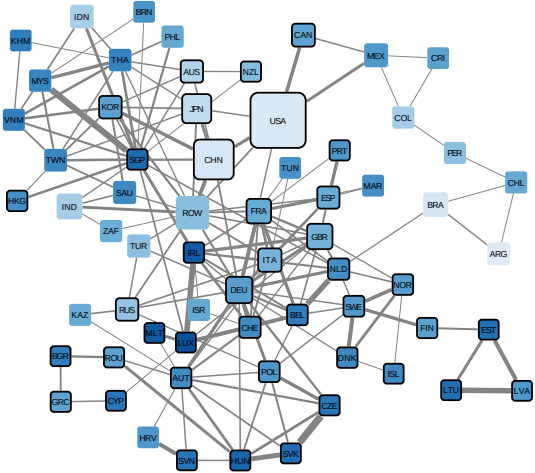


Today

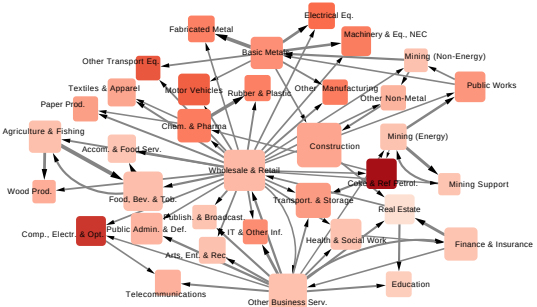
1. Provide a multicountry-multisector quantitative framework to measure drivers of inflation and shock transmission across countries
   - Open economy version of Baqaee and Farhi (2022), *AER* $\Rightarrow$ useful for quantification + policy
   - Endogenous non-linear adjustment of price and sector expenditure shares as a response to sectoral and aggregate shocks

2. Quantify contribution of multiple aggregate and sectoral shocks to countries' inflation rates and spillovers

Importance of Country-Sector Dimension: Production and Trade Network



(a) 65 Countries



(b) 45 Industries

Results from our Research Agenda so far

What are the sources of inflation in the US and Euro Area between 2019Q4–2021Q4?

1. "Global Supply Chain Presures, International Trade, and Inflation"
   (prepared for June 2022 ECB Sintra conference)

   - Closed-econ quantification of Baqaee and Farhi (2022, AER): network + sectoral shocks

   $\Rightarrow$ **Supply-side account for $\approx 1/2$ for Euro Area and $\approx 1/3$ for US (rest is demand)**

   - Open-econ quantification of Çakmaklı, Demiralp, Kalemli-Özcan, Yeşiltaş, Yıldırım (2022, RESTUD RR)
     $\Rightarrow$ FIXED exchange rates

   $\Rightarrow$ **Foreign shocks account for $\approx 2/3$ of observed Euro Area inflation (Euro Area vs ROW)**

Results from our Research Agenda so far

What are the sources of inflation in the US and Euro Area between 2019Q4–2021Q4?

1. "Global Supply Chain Presures, International Trade, and Inflation"
   (prepared for June 2022 ECB Sintra conference)
   - Closed-econ quantification of Baqaee and Farhi (2022, AER): network + sectoral shocks

   $\Rightarrow$ **Supply-side account for $\approx 1/2$ for Euro Area and $\approx 1/3$ for US (rest is demand)**

   - Open-econ quantification of Çakmaklı, Demiralp, Kalemli-Özcan, Yeşiltaş, Yıldırım (2022, RESTUD RR)
     $\Rightarrow$ FIXED exchange rates

   $\Rightarrow$ **Foreign shocks account for $\approx 2/3$ of observed Euro Area inflation (Euro Area vs ROW)**

2. "Quantifying the Inflationary Impact of Fiscal Stimulus under Supply Constraints"
   (AER P&P 2023)
   - Separate aggregate demand shock into fiscal stimulus and the rest for the US (65% of AD shock is fiscal stimulus)

Today: introduce a new multicountry-multisector model with full global network, quantifying inflation drivers and spillovers under endogenous exchange rates

Related literature

- **Theory-closed**: **Inflation, Production Networks, Sectoral Demand and Supply Shocks**

  Baqaee and Farhi (2022), La'O and Tahbaz-Salehi (2022), Rubbo (2022), Afrouzi and Bhattarai (2022), Pasten, Schoenle, and Weber (2020)

- **Theory-closed/open**: **Inflation, Demand and Supply (Energy) Shocks**

  Guerrieri, Lorenzoni, Straub, and Werning (2021, 2022), Amiti, Heise, Karahan, and Sahin (2022), Ferrante, Graves, and Iacovello (2022), Blanchard and Bernanke (2023), Comin, Johnson, and Jones (2023)

- **Theory-open:**
  - Production Networks and Trade with Supply Shocks

    Bonadio, Huo, Levchenko, and Pandalai-Nayar (2021), Boehm and Pandalai-Nayar (2022)
  - Production Networks and Trade with Demand and Supply Shocks (NK-sticky price: fixed FX)

    Çakmaklı, Demiralp, Kalemli-Özcan, Yeşiltaş, Yıldırım (2022), Gourinchas, Kalemli-Özcan, Penciakova, Sander (2021)

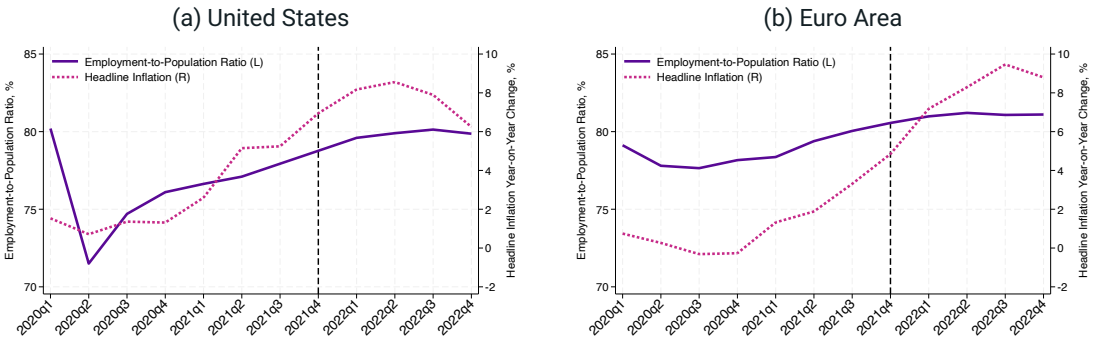
- **Existing Empirical Work on Inflation**: Reduced form regressions, VAR sign restrictions

  Jorda, Liu, Nechio, and Rivera-Reyes (2022), LaBelle and Santacreu (2022), Shapiro (2022) . . .

$\Longrightarrow$ **Our contribution:** a structural network NK-GE model with global I-O linkages, endogenous exchange rates and empirically valid EOS to quantify inflation drivers and spillovers

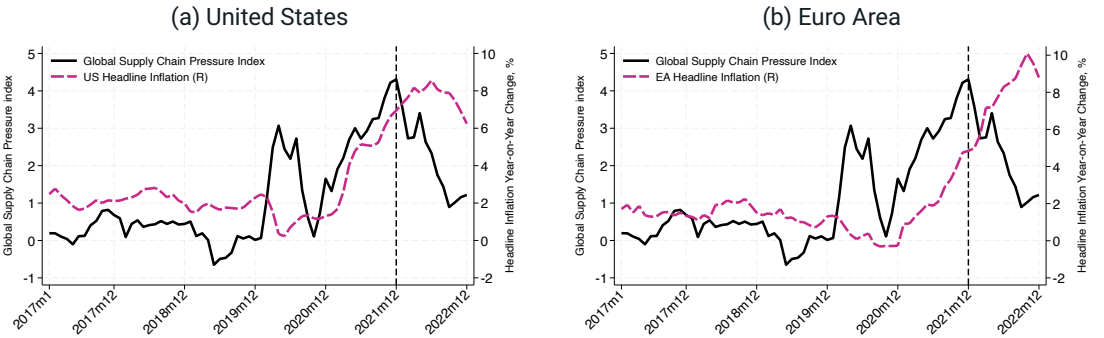
Stylized Facts

Simultaneous slack and inflation



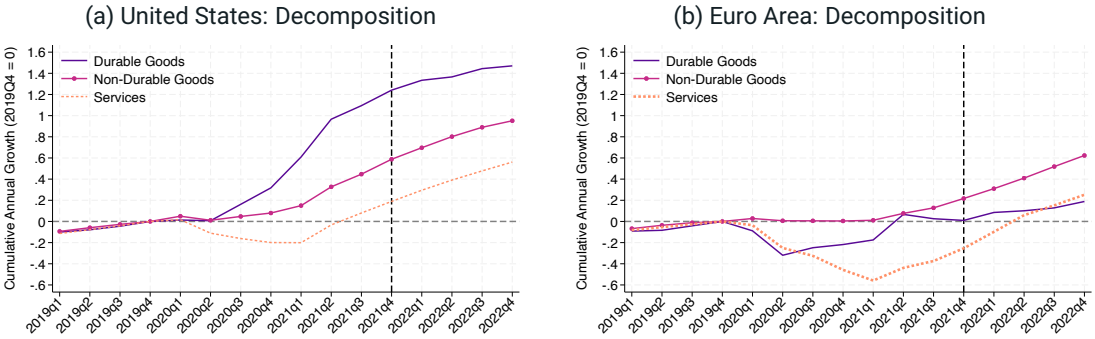
Source: FRED

Simultaneous increase in inflation and supply chain pressures



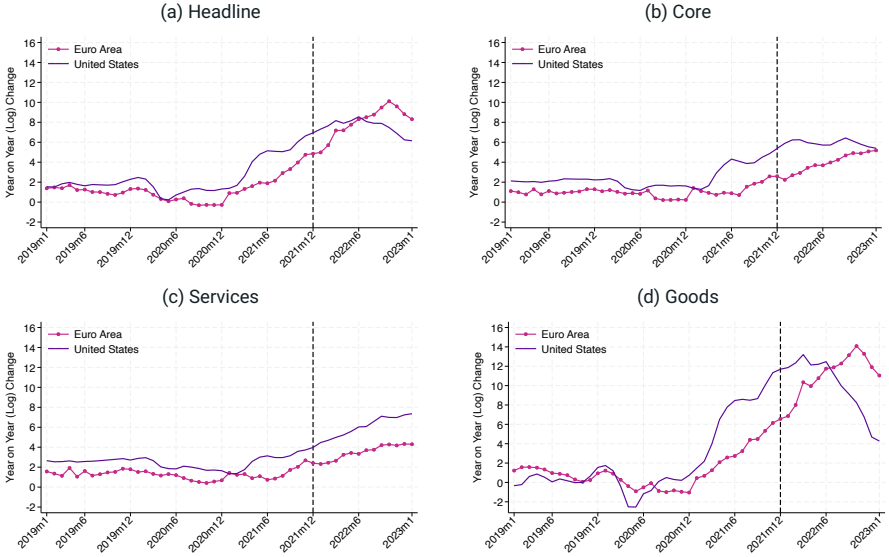
Source: FRBNY, FRED.

Substitution between goods and services consumption



Notes: Seasonally-adjusted real private consumption. Source: OECD Quarterly National Accounts.

Inflation in goods picked up earlier than inflation in services



Source: FRED.

Model Sketch

Inflation in a multicountry network-macro model

- We build on Baqaee and Farhi (2022) w/simplifications:
  - Two-period multicountry model ($n, m = 1, \ldots, \mathcal{N}$)
  - Ricardian households with perfect foresight
  - Multiple sectors ($i, j = 1, \ldots, \mathcal{J}$) produce using factors and intermediate inputs
  - Perfect competition in factors and good markets
  - Downward nominal wage rigidity + sector-specific factor, zero-lower bound

- Model allows for rich set of shocks:
  - Country level aggregate demand
  - Country-sector demand shifts
  - Country-sector factor supply and productivity (including energy shocks)

Households

Inter-temporal maximization problem

$$\max_{\{C_n C_n^*\}} (1-\beta_n)\log U(C_n) + \beta_n \log U(C_n^*)$$

s.t.

$$P_n C_n + \frac{P_n^* C_n^*}{1+i_n} = I_n + \frac{I_n^*}{1+i_n}$$

Note: Steady-state variables –including future levels– (denoted by $*$) are exogenous

Consumption

- Consumption Bundle consists of Country-specific Sectoral Consumption Bundles:

$$U(C_n) = \frac{C_n^{1-\sigma} - 1}{1-\sigma}; \qquad C_n = \prod_{j=1}^{\mathcal{J}} C_{n,j}^{\Omega_{n,j}^C}, \quad \sum_{j=1}^{\mathcal{J}} \Omega_{n,j}^C = 1$$

Consumption

- Consumption Bundle consists of Country-specific Sectoral Consumption Bundles:

$$U(C_n) = \frac{C_n^{1-\sigma} - 1}{1-\sigma}; \qquad C_n = \prod_{j=1}^{\mathcal{J}} C_{n,j}^{\Omega_{n,j}^C}, \quad \sum_{j=1}^{\mathcal{J}} \Omega_{n,j}^C = 1$$

- Country-specific Sectoral Consumption Bundles are formed by varieties (Armington aggregator)

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

Production

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

$$\min_{\{\mathsf{VA}_{ni}, M_{ni}\}} P_{ni}^{\mathsf{VA}} \mathsf{VA}_{ni} + P_{ni}^{M} Z_{ni}$$

s.t.

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

Production

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

$$\min_{\{\mathsf{VA}_{ni}, M_{ni}\}} P_{ni}^{\mathsf{VA}} \mathsf{VA}_{ni} + P_{ni}^{M} Z_{ni}$$

s.t.

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

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

$$\mathsf{VA}_{ni} = \left[\Omega_{ni,L}^{\mathsf{VA}} (L_{ni})^{\frac{1-\gamma}{\gamma}} + \Omega_{ni,K}^{\mathsf{VA}} (K_{ni}^{*})^{\frac{1-\gamma}{\gamma}} \right]^{\frac{\gamma}{1-\gamma}} \quad \text{with} \quad \Omega_{ni,L}^{\mathsf{VA}} + \Omega_{ni,K}^{\mathsf{VA}} = 1$$

Intermediate goods' aggregation

- Intermediate bundle consists of country specific sectoral bundles:

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

Intermediate goods' aggregation

- Intermediate bundle consists of country specific sectoral bundles:

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

- Country-specific Sectoral Bundles are formed by varieties (Armington aggregator):

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

Steel (j) comes from country $m = 1 \ldots \mathcal{N}$ into the U.S. $= X_{n,mj}$ as an intermediate input
U.S. (n) creates a steel bundle $= X_{n,j}$ to use in different industries such as U.S. car industry $= Z_{ni}$

Monetary policy and the inter-temporal budget

- Monetary policy: assume all countries at zero-lower bound ($i = 0$)
- Inter-temporal budget constraint becomes:

$$P_n C_n + P_n^* C_n^* = I_n + I_n^*$$

- Set $P_n^* = 1$ and I_n^* to the steady-state expenditure level
- Inter-temporal optimization yields:

$$I_n = P_n C_n = \frac{1 - \beta_n}{\beta_n} I_n^*$$

- Note that the aggregate shock is driven by a change in β_n. Corresponding expenditure is given in local currencies

The current account

- At the world level: Expenditure $=$ GDP, but for individual countries: $I_n \neq \text{GDP}_n$

$$I_n = \text{GDP}_n + \underbrace{\text{Imports}_n - \text{Exports}_n}_{-\text{Current Account}}$$

- Define bilateral trade balance between countries m and n as:

$$D_{nm} \equiv \text{Exports}_{m \to n} - \text{Exports}_{n \to m}$$

The current account

- At the world level: Expenditure $=$ GDP, but for individual countries: $I_n \neq \text{GDP}_n$

$$I_n = \text{GDP}_n + \underbrace{\text{Imports}_n - \text{Exports}_n}_{-\text{Current Account}}$$

- Define bilateral trade balance between countries m and n as:

$$D_{nm} \equiv \text{Exports}_{m \to n} - \text{Exports}_{n \to m}$$

- Bilateral trade balance is financed by the ownership of factors of country m in country n:

$$\chi_{nm} \equiv \begin{cases} \frac{D_{nm}}{\text{GDP}_m} & \text{if } D_{nm} > 0 \\ 0 & \text{otherwise} \end{cases}$$

The current account

- At the world level: Expenditure $=$ GDP, but for individual countries: $I_n \neq \text{GDP}_n$

$$I_n = \text{GDP}_n + \underbrace{\text{Imports}_n - \text{Exports}_n}_{-\text{Current Account}}$$

- Define bilateral trade balance between countries m and n as:

$$D_{nm} \equiv \text{Exports}_{m \to n} - \text{Exports}_{n \to m}$$

- Bilateral trade balance is financed by the ownership of factors of country m in country n:

$$\chi_{nm} \equiv \begin{cases} \frac{D_{nm}}{\text{GDP}_m} & \text{if } D_{nm} > 0 \\ 0 & \text{otherwise} \end{cases}$$

- The total income of country n is (running CA deficit, financed with factor income flows):

$$I_n = \text{GDP}_n - \underbrace{\sum_m \chi_{mn} \text{GDP}_n}_{\text{Factors owned by foreigners in } n} + \underbrace{\sum_m \chi_{nm} \text{GDP}_m}_{\text{Factors owned abroad by } n}$$

Exchange rates

- In terms of factor income, the GDP of country n can be written as:

$$\text{GDP}_n = \sum_i (W_{ni} L_{ni} + R_{ni} K^*_{ni})$$

- This is given in the common world currency. Hence the income of country n is given in the common currency
- We know the expenditure in the local currency from the inter-temporal budget constraint
- The exchange rate of country n is then:

$$e_n \equiv \frac{\text{Local currency Income}}{\text{Common currency Income}} = \frac{(1-\beta_n) I^*_n / \beta_n}{(1 - \sum_m \chi_{mn}) \text{GDP}_n + \sum_m \chi_{nm} \text{GDP}_m}$$

Market clearing

- Goods market clearing (as consumption or intermediate goods): for each country n sector i:

$$Y_{ni} = \sum_{m=1}^{\mathcal{N}} X_{m,ni} + C_{m,ni}$$

Market clearing

- Goods market clearing (as consumption or intermediate goods): for each country n sector i:

$$Y_{ni} = \sum_{m=1}^{\mathcal{N}} X_{m,ni} + C_{m,ni}$$

- Segmented labor markets: the labor market in country n, sector i, with wage W_{ni}, satisfies
  - Downward wage limit is given in the local currency but the model solves in common currency:

$$e_n W_{ni} \geq W_{ni}^* \quad \Rightarrow \quad W_{ni} \geq \frac{W_{ni}^*}{e_n}$$

  - The labor cannot go beyond the available labor and one of the constraints should be binding:

$$\overline{L}_{ni} \geq L_{ni}, \qquad \left(\overline{L}_{ni} - L_{ni}\right)\left(W_{ni} - \frac{W_{ni}^*}{e_n}\right) = 0$$

Market clearing

- Goods market clearing (as consumption or intermediate goods): for each country n sector i:

$$Y_{ni} = \sum_{m=1}^{\mathcal{N}} X_{m,ni} + C_{m,ni}$$

- Segmented labor markets: the labor market in country n, sector i, with wage W_{ni}, satisfies
  - Downward wage limit is given in the local currency but the model solves in common currency:

$$e_n W_{ni} \geq W_{ni}^* \quad \Rightarrow \quad W_{ni} \geq \frac{W_{ni}^*}{e_n}$$

  - The labor cannot go beyond the available labor and one of the constraints should be binding:

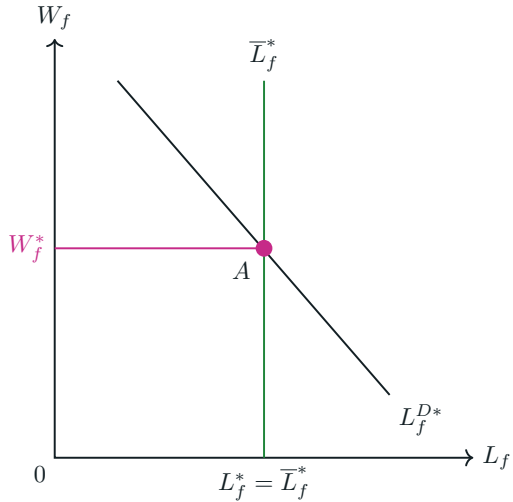
$$\overline{L}_{ni} \geq L_{ni}, \qquad \left(\overline{L}_{ni} - L_{ni}\right)\left(W_{ni} - \frac{W_{ni}^*}{e_n}\right) = 0$$

- Segmented capital markets with *no* price rigidities (always at the steady-state level):

$$K_{ni} = K_{ni}^*$$

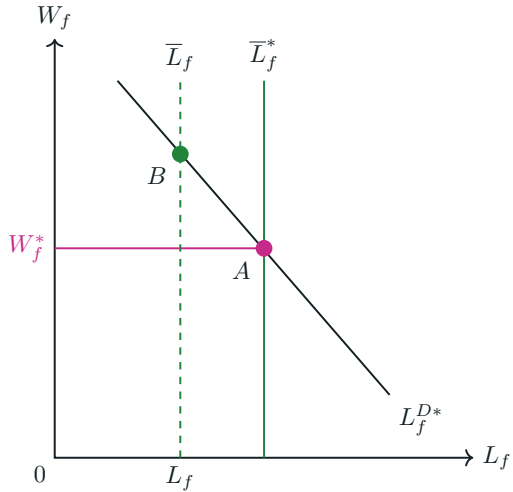
Segmented factor (e.g., labor) markets during collapse and recovery

- $\overline{L}_f$: Potential level for factor f. Decrease due to sick workers, shutdowns, etc.



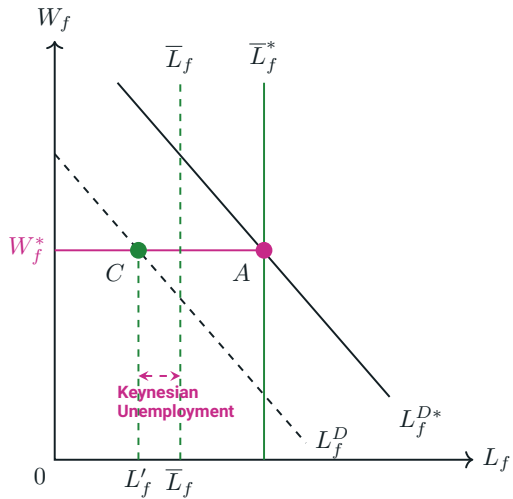
Segmented factor (e.g., labor) markets during collapse and recovery

- $\overline{L}_f$: Potential level for factor f. Decrease due to sick workers, shutdowns, etc.



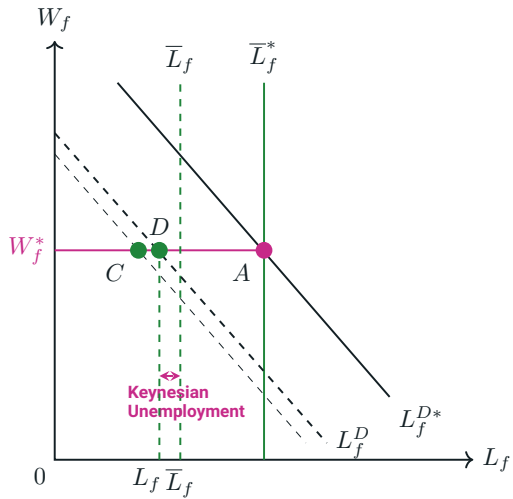
Segmented factor (e.g., labor) markets during collapse and recovery

- $\overline{L}_f$: Potential level for factor f. Decrease due to sick workers, shutdowns, etc.
- L_f: Equilibrium employment level for factor f
  - Demand effects+downward wage rigidity $\Rightarrow$ workers employed might be lower than *potential*
- Difference between $\overline{L}_f$ and L_f: Keynesian unemployment



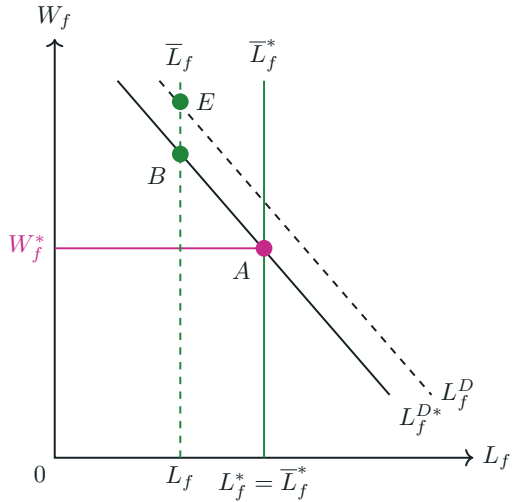
Segmented factor (e.g., labor) markets during collapse and recovery

- $\overline{L}_f$: Potential level for factor f. Decrease due to sick workers, shutdowns, etc.
- L_f: Equilibrium employment level for factor f
  - Demand effects+downward wage rigidity $\Rightarrow$ workers employed might be lower than *potential*
- Difference between $\overline{L}_f$ and L_f: Keynesian unemployment
- An increase in aggregate demand can decrease Keynesian unemployment.

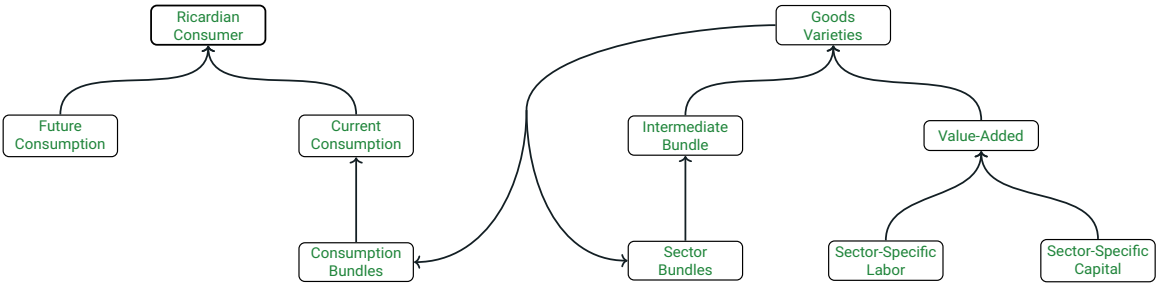


Segmented factor (e.g., labor) markets during collapse and recovery

- $\overline{L}_f$: Potential level for factor f. Decrease due to sick workers, shutdowns, etc.
- L_f: Equilibrium employment level for factor f
  - Demand effects+downward wage rigidity $\Rightarrow$ workers employed might be lower than *potential*
- Difference between $\overline{L}_f$ and L_f: Keynesian unemployment
- An increase in aggregate demand can decrease Keynesian unemployment.
- During recovery: unemployment gaps are closed (heterogeneous across sectors, may not be back to 2019 but still inflationary)



Model Schematic



Structure of the Input-Output matrix

$\Omega =$

	C	Y	Z	VA	X	CB	L	K	Ric	Fut
C	0	0	0	0	0	Ω^{C}	0	0	0	0
Y	0	0	Ω^{Y}_{Z}	Ω^{Y}_{VA}	0	0	0	0	0	0
Z	0	0	0	0	Ω^{Z}	0	0	0	0	0
VA	0	0	0	0	0	0	Ω^{VA}_{L}	Ω^{VA}_{K}	0	0
X	0	Ω^{X}	0	0	0	0	0	0	0	0
CB	0	Ω^{CB}	0	0	0	0	0	0	0	0
L	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0
Ric	$1-\beta$	0	0	0	0	0	0	0	0	β
Fut	0	0	0	0	0	0	0	0	0	0

Index	Description	Size	Elasticity
C	Current Consumption	$\mathcal{N}$	1
Y	Goods / Varieties	$\mathcal{N} \times \mathcal{J}$	θ
Z	Intermediate Bundle	$\mathcal{N} \times \mathcal{J}$	ε
VA	Value-Added	$\mathcal{N} \times \mathcal{J}$	γ
X	Country-Sector Bundles	$\mathcal{N} \times \mathcal{J}$	ξ_i
CB	Consumption Bundles	$\mathcal{N} \times \mathcal{J}$	ξ'_i
L	Sector Specific Labor	$\mathcal{N} \times \mathcal{J}$	
C	Sector Specific Capital	$\mathcal{N} \times \mathcal{J}$	
Ric	Ricardian Consumer	$\mathcal{N}$	1
Fut	Future Consumption	$\mathcal{N}$	

Structure of the Input-Output matrix

$\Omega =$

	C	Y	Z	VA	X	CB	L	K	Ric	Fut
C	0	0	0	0	0	Ω^C	0	0	0	0
Y	0	0	Ω^Y_Z	Ω^Y_{VA}	0	0	0	0	0	0
Z	0	0	0	0	Ω^Z	0	0	0	0	0
VA	0	0	0	0	0	0	Ω^{VA}_L	Ω^{VA}_K	0	0
X	0	Ω^X	0	0	0	0	0	0	0	0
CB	0	Ω^{CB}	0	0	0	0	0	0	0	0
L	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0
Ric	$1-\beta$	0	0	0	0	0	0	0	0	β
Fut	0	0	0	0	0	0	0	0	0	0

Index	Description	Size	Elasticity
C	Current Consumption	$\mathcal{N}$	1
Y	Goods / Varieties	$\mathcal{N} \times \mathcal{J}$	θ
Z	Intermediate Bundle	$\mathcal{N} \times \mathcal{J}$	ε
VA	Value-Added	$\mathcal{N} \times \mathcal{J}$	γ
X	Country-Sector Bundles	$\mathcal{N} \times \mathcal{J}$	ξ_i
CB	Consumption Bundles	$\mathcal{N} \times \mathcal{J}$	ξ'_i
L	Sector Specific Labor	$\mathcal{N} \times \mathcal{J}$	
C	Sector Specific Capital	$\mathcal{N} \times \mathcal{J}$	
Ric	Ricardian Consumer	$\mathcal{N}$	1
Fut	Future Consumption	$\mathcal{N}$	

- Rows: Price equations

$$\theta_i \neq 1 \quad \Rightarrow \quad P_i^{1-\theta_i} = \sum_j \Omega_{ij} P_j^{1-\theta_i}$$

$$\theta_i = 1 \quad \Rightarrow \quad \log(P_i) = \sum_j \Omega_{ij} \log(P_j)$$

Structure of the Input-Output matrix

$\Omega =$

	C	Y	Z	VA	X	CB	L	K	Ric	Fut
C	0	0	0	0	0	Ω^C	0	0	0	0
Y	0	0	Ω^Y_Z	Ω^Y_{VA}	0	0	0	0	0	0
Z	0	0	0	0	Ω^Z	0	0	0	0	0
VA	0	0	0	0	0	0	Ω^{VA}_L	Ω^{VA}_K	0	0
X	0	Ω^X	0	0	0	0	0	0	0	0
CB	0	Ω^{CB}	0	0	0	0	0	0	0	0
L	0	0	0	0	0	0	0	0	0	0
K	0	0	0	0	0	0	0	0	0	0
Ric	$1-\beta$	0	0	0	0	0	0	0	0	β
Fut	0	0	0	0	0	0	0	0	0	0

Index	Description	Size	Elasticity
C	Current Consumption	$\mathcal{N}$	1
Y	Goods / Varieties	$\mathcal{N} \times \mathcal{J}$	θ
Z	Intermediate Bundle	$\mathcal{N} \times \mathcal{J}$	ε
VA	Value-Added	$\mathcal{N} \times \mathcal{J}$	γ
X	Country-Sector Bundles	$\mathcal{N} \times \mathcal{J}$	ξ_i
CB	Consumption Bundles	$\mathcal{N} \times \mathcal{J}$	ξ'_i
L	Sector Specific Labor	$\mathcal{N} \times \mathcal{J}$	
C	Sector Specific Capital	$\mathcal{N} \times \mathcal{J}$	
Ric	Ricardian Consumer	$\mathcal{N}$	1
Fut	Future Consumption	$\mathcal{N}$	

- Rows: Price equations

$$\theta_i \neq 1 \quad \Rightarrow \quad P_i^{1-\theta_i} = \sum_j \Omega_{ij} P_j^{1-\theta_i}$$

$$\theta_i = 1 \quad \Rightarrow \quad \log(P_i) = \sum_j \Omega_{ij} \log(P_j)$$

- Columns: Output (Domar weights)

$$\frac{P_i Y_i}{\text{GDP}_W} \equiv \lambda_i = \sum_j \Omega_{ji} \left(\frac{P_i}{P_j}\right)^{1-\theta_j} \lambda_j$$

Model solution method

- Calibrate the model with ICIO 2018 Table from OECD
  - Final use shares
  - Input shares
  - Value added shares
  - Expenditures
  - Normalize all prices, wages and rents to 1 at steady state
- From this stable equilibrium introduce shocks
- AMPL / Knitro optimizer
- Calculate the relative changes in common currency
- Convert the common currency price changes to local currency by multiplying with the model-consistent exchange rate

First-order approximation of domestic CPI inflation: closed economy

Domar Weights:

$$\lambda_i \equiv \frac{P_i Y_i}{GDP} \quad \text{and} \quad \Lambda_f \equiv \frac{W_f L_f}{GDP}$$

CPI:

$$\mathrm{d}\log CPI = \underbrace{\mathrm{d}\log I}_{\text{Domestic AD shock}} - \boldsymbol{\Lambda}^T \mathrm{d}\log \boldsymbol{L} - \boldsymbol{\lambda}^T \mathrm{d}\log \boldsymbol{A}$$

- Same result as in Baqaee & Farhi (2022)
- Relative strength of sector-level labor or productivity shocks determined by the influence vector of sector-level factor or output shares, respectively

Open-economy Domar weights

- We can relate the final consumption to production via global Leontieff inverse ($\mathbf{\Psi}$). Denote the total output of all industries globally with $\boldsymbol{Y}$, the total consumption of all industries with $\boldsymbol{C}$, then:

$$\boldsymbol{Y} = \mathbf{\Psi}\boldsymbol{C}$$

- Denote the consumption of country n in all industries globally with $\boldsymbol{C}^n$ and assign the portion of production to country n by

$$\boldsymbol{Y}^n = \mathbf{\Psi}\boldsymbol{C}^n$$

- Write the local Domar weights for country n using Y^n_{mi}:

$$\lambda^n_{mi} \equiv \frac{P_{mi}Y^n_{mi}}{I_n}$$

First-order approximation of domestic CPI inflation: open economy

Factor shares are governed by $\boldsymbol{\Omega}^F$. We can define country-level Domar weights for all factors globally as:

$$\boldsymbol{\Lambda^n} \equiv (\boldsymbol{\Omega}^F)^T \boldsymbol{\lambda^n}$$

Then the (local currency) CPI in country n can be written as:

$$\mathrm{d}\log \mathsf{CPI}_n = \underbrace{\mathrm{d}\log I_n}_{\text{AD shock}} - (\boldsymbol{\Lambda^n})^T \mathrm{d}\log \boldsymbol{L} - (\boldsymbol{\lambda^n})^T \mathrm{d}\log \boldsymbol{A}$$

- Labor shortages, at home and abroad, are inflationary domestically
- Positive productivity changes everywhere, $\mathrm{d}\log \boldsymbol{A}$, are deflationary
- Country n's AD shock includes both domestic AD shock and exchange rate change

Quantification Exercises

Mapping data to model shocks

1. Sectoral demand shocks ($\mathrm{d}\Omega_{nj}$): Observed sectoral expenditure shares changes in country n with $\sum_{j \in \mathcal{J}} d\Omega_{nj} = 0$
   - United States: BEA sectoral personal consumption expenditure
   - Euro Area: OECD Quarterly National Accounts
   - Russia & Rest of the world: estimates based on infection levels

Mapping data to model shocks

1. Sectoral demand shocks ($\mathrm{d}\Omega_{nj}$): Observed sectoral expenditure shares changes in country n with $\sum_{j \in \mathcal{J}} d\Omega_{nj} = 0$
   - United States: BEA sectoral personal consumption expenditure
   - Euro Area: OECD Quarterly National Accounts
   - Russia & Rest of the world: estimates based on infection levels

2. Country-sectoral potential supply shocks ($\mathrm{d} \log \overline{L}_{ni}$): Observed changes in total hours worked in country n, sector i
   - United States: BLS tables B1 and B2
   - Russia & Euro Area: EuroStat
   - Rest of the world: estimates based on infection levels

Mapping data to model shocks

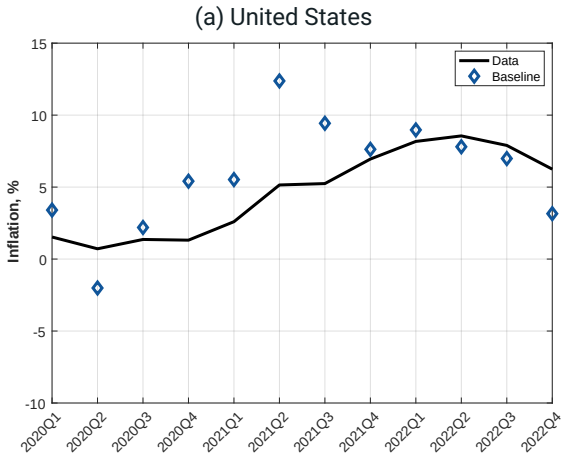
1. Sectoral demand shocks ($\mathrm{d}\Omega_{nj}$): Observed sectoral expenditure shares changes in country n with $\sum_{j \in \mathcal{J}} d\Omega_{nj} = 0$
   - United States: BEA sectoral personal consumption expenditure
   - Euro Area: OECD Quarterly National Accounts
   - Russia & Rest of the world: estimates based on infection levels
2. Country-sectoral potential supply shocks ($\mathrm{d} \log \overline{L}_{ni}$): Observed changes in total hours worked in country n, sector i
   - United States: BLS tables B1 and B2
   - Russia & Euro Area: EuroStat
   - Rest of the world: estimates based on infection levels
3. Country-level aggregate demand shocks ($\mathrm{d} \log \zeta^n$): Nominal (l.c.) expenditure changes
   - United States: Gross national income
   - Euro Area: Gross national income
   - Russia & Rest of the world: country-weighted nominal GDP growth

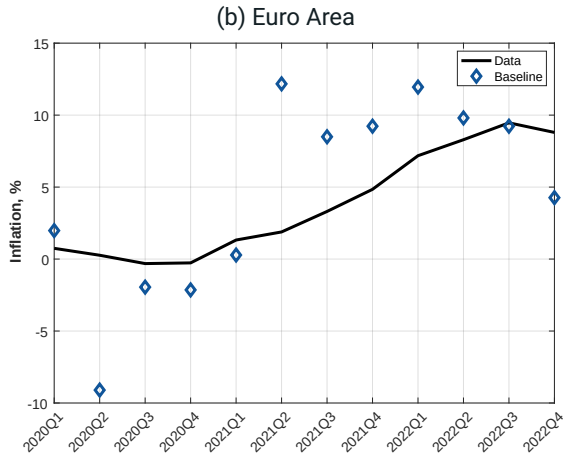
Parametrization

- Model requires initial consumption and input-output shares
  - We use the cross-country input-output database from the OECD year 2018
- Elasticities:
  - Between value added and intermediate inputs: $\theta = 0.6$ (Atalay, 2017; Carvalho et. al, 2021)
  - Between labor and capital: $\gamma = 0.6$ (Raval, 2019; Oberfield and Raval, 2021)
  - Among intermediates: $\varepsilon = 0.2$ (Atalay, 2017; Boehm, Flaaen, and Pandalai-Nayar, 2019)
  - Cross-country Armington: $\xi = 4.55$ (Caliendo & Parro, 2015)
- We set country-sector productivity changes to zero throughout
  - Recent evidence on pandemic suggests little changes in aggregate/sectoral productivity w/no labor reallocation across sectors in the US (Fernald and Li, 2022)
  - Want to give full chance to sectoral labor shocks to mimic the reality of sectoral shortages and demand-supply imbalances

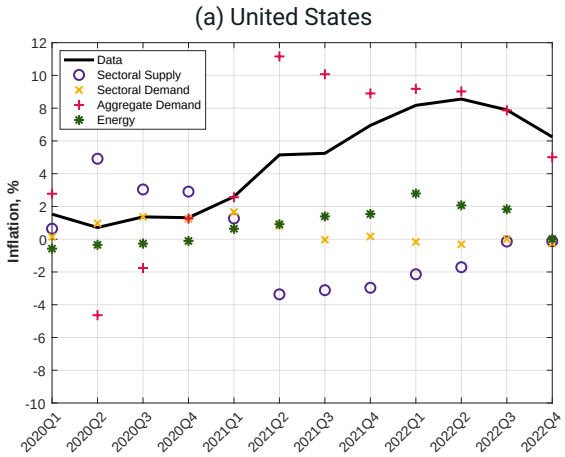
Results

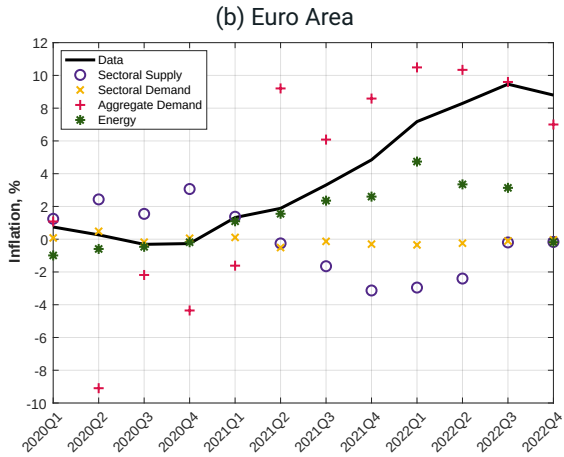
United States and Euro Area Inflation rates: Baseline Model vs. Data



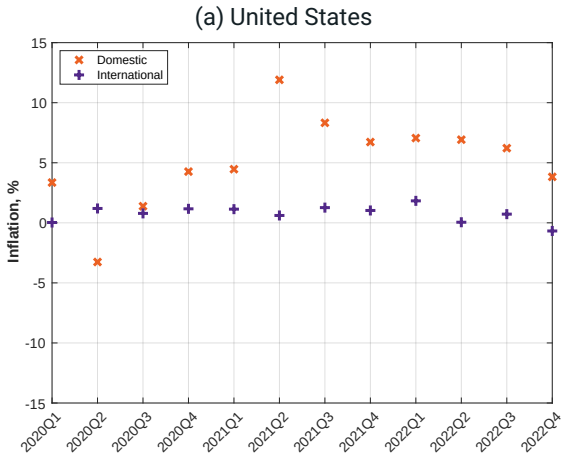


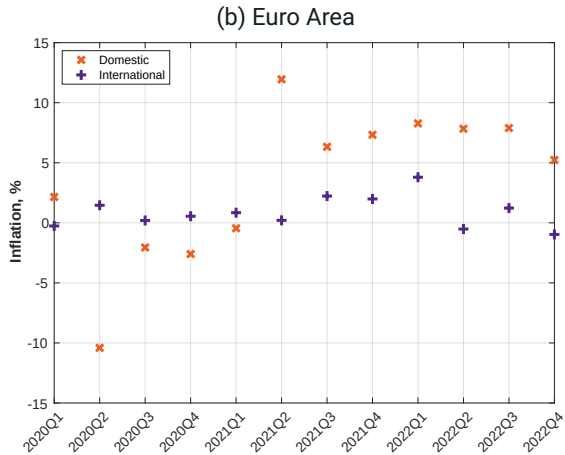
United States and Euro Area Sources of Inflation: Shock Decomposition



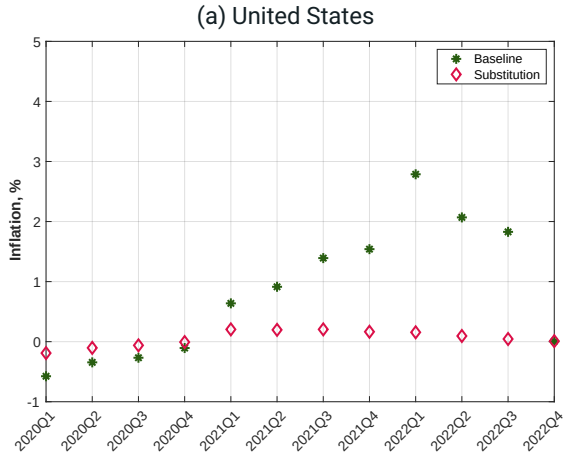


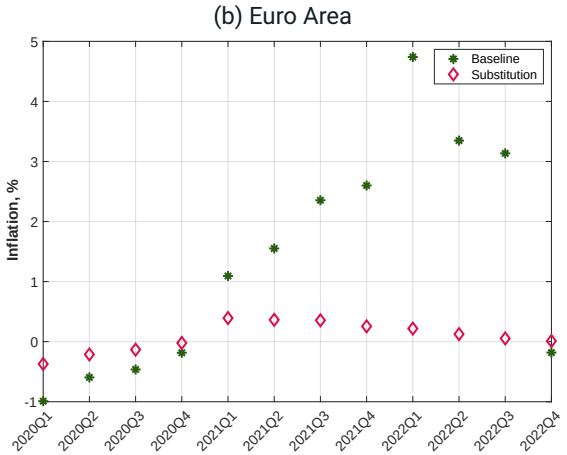
United States and Euro Area Sources of Inflation: Domestic and International Shocks



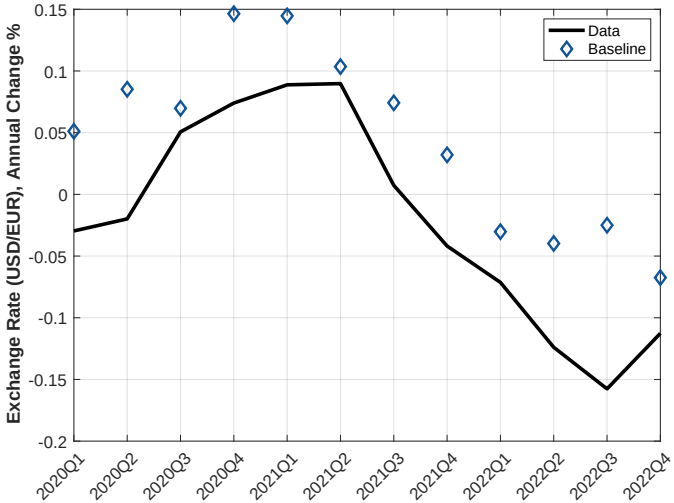


Production Complementarities and Energy Shocks Transmission to Inflation: cannot generate observed inflation without

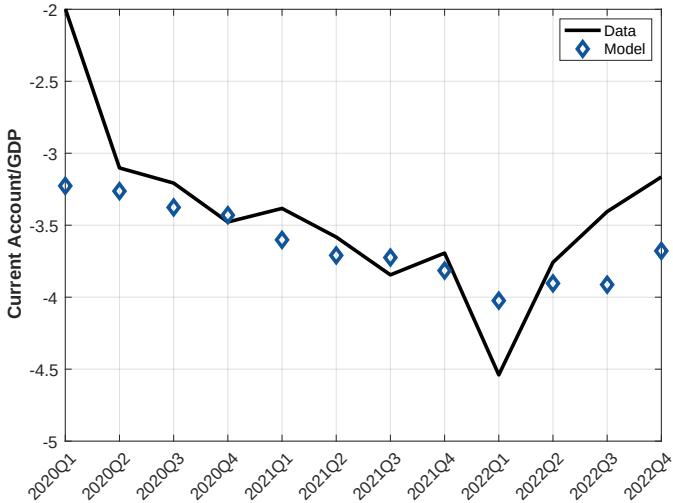




Model implied exchange rate changes and data: USD/Euro



US Current Account



Conclusion

Summary

- Aggregate demand stimulus would not have produced as high an inflation as the one observed in the data without the negative sectoral supply shocks
  - 1/2 of observed EA inflation, 1/3 of observed US inflation driven by sectoral supply shocks

Summary

- Aggregate demand stimulus would not have produced as high an inflation as the one observed in the data without the negative sectoral supply shocks
  - 1/2 of observed EA inflation, 1/3 of observed US inflation driven by sectoral supply shocks

- Limited factor mobility and complementarities in production arose due to the pandemic
  - Global health shock + difficulty for firms to reallocate labor between sectors and/or switch suppliers, domestically or internationally $\Rightarrow$ supply chain bottlenecks $\Rightarrow$ rise in prices

Summary

- Aggregate demand stimulus would not have produced as high an inflation as the one observed in the data without the negative sectoral supply shocks
  - 1/2 of observed EA inflation, 1/3 of observed US inflation driven by sectoral supply shocks
- Limited factor mobility and complementarities in production arose due to the pandemic
  - Global health shock + difficulty for firms to reallocate labor between sectors and/or switch suppliers, domestically or internationally $\Rightarrow$ supply chain bottlenecks $\Rightarrow$ rise in prices
- Monetary policy can tame inflation in a given country by contracting aggregate demand, however, there will remain an upward pressure on price growth as long as global supply bottlenecks persist; frequent sectoral supply shocks happen

Difficult to Quantify 21–23 Inflation: Real Shocks vs Policies?

- **The pandemic temporarily disrupted economies:** Lockdowns and general fear of infection kept many people from working, a shift in demand away from in-person services to goods, supply chain bottlenecks.
- **Russia's invasion of Ukraine:** drove up food and energy prices worldwide, made economies temporarily poorer.
- **Fiscal and Monetary Stimulus:** Governments intervened to help the unemployed, subsidies to firms to maintain their payrolls—The purchasing power was sustained even as economies' abilities to supply goods and services temporarily fell.

  $\Rightarrow$ Inflation was the natural consequence

  $\Rightarrow$ Price increases lead to wage increases.

  $\Rightarrow$ Kept full employment.

- **Temporary/Persistent Inflation:** Labor supply shock (health, great resignation) did not persist in the U.S. but did in the U.K.: permanent reduction in LFP leading to wage-price spirals.

Need a global macro-network model to quantify macro implications of sectoral supply and demand shocks: **will be the case under climate and energy transition.**

Takeaways and open questions

- New multicountry-multisector framework to quantity how supply-demand imbalances that were generated by multiple types of shocks over Covid-19 period spilled over across countries and drove inflation
- Many avenues to further explore with the framework
  - Expanding sample to many more countries/sectors
  - Possible to generate greater spillover effect in a tractable quantifiable framework

  $\Rightarrow$ Common problem in these types of models

  - Incorporate *micro* findings on breakdowns in GVCs into a *macro* framework
  - More generally, how will potential changes in firms' sourcing decisions (fragmentation) impact transmission of shocks and macro volatility?

Thank You

muhammed_yildirim@hks.harvard.edu