“Supply Chain Constraints and Inflation”

NBER EFG FALL MEETING

Discussion by **Şebnem Kalemli-Özcan**

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Summary of the Paper

- Develops a multi-sector (two) small open economy NK model to match U.S. inflation and explain its drivers.
- Key innovation: Occasionally binding **capacity constraints** on sector output $\Rightarrow$ cost-push/mark-up shock.
  - Constraints on domestic producers $\Rightarrow$ mark-up shock on domestic prices (greed-inflation).
  - Constraints on foreign producers of intermediate goods $\Rightarrow$ mark-up shock on import prices.
  - No constraint on foreign producers of final goods.
- **Capacity constraints** bind due to $\uparrow$ aggregate demand.
  - No fiscal shock (increase in expenditures via resource constraint)
  - Impulse is a large monetary shock: FED inaction
  - Also discount rate shock via Euler equation

My Discussion

- Pedagogical.
- Alternative explanations
  $\Rightarrow$ draw out pluses and minuses of different approaches for carrying to data
  $\Rightarrow$ to understand which model/s can match reality of 2020–2023.
- Discuss features of the CJJ model for its success in matching inflation
  $\Rightarrow$ to explain persistence in inflation.

One Sector Approaches—Dynamics

- Gagliardone-Gertler (2023): Matches dynamics of **un-targeted inflation and wages.**
  $\Rightarrow$ Interaction between oil shocks and labor markets via complementarities in production.
- Benigno-Eggertsson (2023): Model predicts inflation dynamics close to actual.
  $\Rightarrow$ Non-linear Philips curve; slope linked to labor market tightness.
- Blanchard- Bernanke (2023): Model predicts inflation dynamics close to actual.
  $\Rightarrow$ Importance of oil shocks and labor market tightness.
- Harding, Linde, Trabant (2023, JME): Illustrative
  $\Rightarrow$ Quasi-kinked demand for goods ($\uparrow$ demand elasticity in price); non-linear Philips curve.
- Fornaro and Wolf (2023, JME): Illustrative
  $\Rightarrow$ Permanent productivity shock (energy).

Multi-Sector Approaches—Inflation and Supply Chains

- Baqaee-Farhi'22 AER: 66 U.S. sectors I-O; data ends May 2020
  $\Rightarrow$ Sector supply shocks explain lack of deflation in 2020.

- di Giovanni, Kalemli-Ozcan, Silva, Yildirim'22 ECB Sintra: Multi-country-multi-sector I-O; data ends December 2021
  $\Rightarrow 1/3$ of 2021 inflation is from sector supply shocks; supply constraints on intermediates bind via complementarity with factors w/$\uparrow$ demand.

- di Giovanni, Kalemli-Ozcan, Silva, Yildirim'23b: Multi-country-multi-sector I-O; Data up to 2023q1
  $\Rightarrow$ Time-varying role for sectoral supply, reallocation of demand, aggregate demand and energy shocks.

- Rubbo'23: 66 U.S. sectors I-O; data up to 2023q1
  $\Rightarrow 1/3$ of 2021–2022 U.S. inflation is from sector supply shocks; quantification via sectoral prices with linear heterogenous sector supply elasticities; prices shoot up before wages, wages and quantities catch up later.

- Ferrante, Graves, Iacoviello'22 JME 66 U.S. sector I-O; focus on 2021
  $\Rightarrow$ Aggregate labor supply shock so labor cannot relocate according to sectoral shifts in consumption.

- Amiti, Heise, Karahan, Sahin'23 NBER MA: 2 U.S. sectors; focus on 2021
  Supply shocks to imported goods explain inflation only w/labor dis-utility shock.

- Lorenzoni-Werning'23 BPEA: Illustrative
  $\Rightarrow$ Supply constraints on intermediates explain increase in prices before wages.

Authors Difference from the Multi-Sector Literature

1. Supply issues in factor markets (cannot go to work (or not want to), limited machines/factories—real life is mostly about labor given the health shock)

2. Supply issues in good markets (cannot get your laptop, home office desk, exercise bike—show up as bottlenecks in real life)

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Supply issues for intermediates (construction cannot get the imported/domestic steel, lumber; tech cannot get chips)

Goes under (1) if input to production
Goes under (2) if bunched with final consumption goods

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- Both approaches give you cost-push shocks, aggregate inflation $\uparrow$
- Sector supply shocks/constraints are important—Models w/only $\uparrow$ aggregate demand cannot predict/match inflation
- Modeling choice: constraint is on output $(\bar{Y}, \bar{M})$ rather than factors producing the output $(\bar{L}, \bar{K}, \bar{M})$
  - **Pros:** Mark-up does not have to be about changing elasticity of demand but rather firms are changing behavior to price to demand with the constraint.
  - **Cons:** Log-linearization
    - Second order-terms have an important impact on inflation, especially with strong complementarities (Baqaee-Farhi'19 ECMA)
    - The authors take into account complementarities but given extreme convexity, maybe missing second-order terms might still be an issue? $\Rightarrow$ How accurate is local approximation?

Capacity constraints vs fully inelastic factor supply

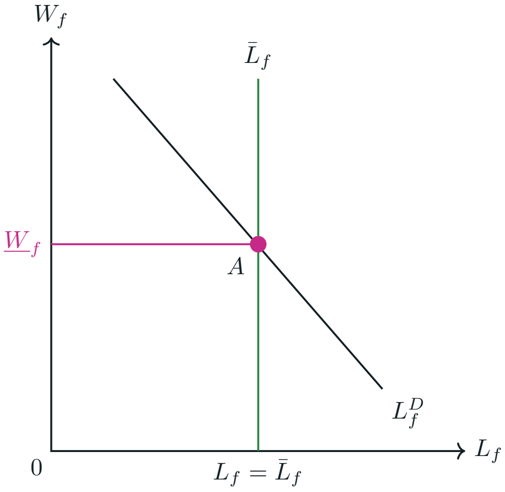
Data cannot tell you if the marginal cost increase is due to fixed factor supply vs firm greed (mark-up). User cost of capital changes show up as mark-ups in data.

Segmented factor markets + nominal wage rigidity: All factors (K, L) are inelastically supplied.

- di Giovanni et al, (2022, 2023):
  - Instead of exogenous capacity constraints, factor market friction: Sector L/K cannot reallocate
  - Non-linear response to shocks
  - Demand shocks amplify supply constraints via interaction of factor (labor) shortages and complementarity in production
  - Amplified in open economy via global supply chains and network complementarities
  - Can explain early rise in goods inflation, and slowly rising services inflation. Linkages between goods and services are important; services employment cannot adjust quickly enough.

Factor Markets—Segmented w/inelastic supply

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



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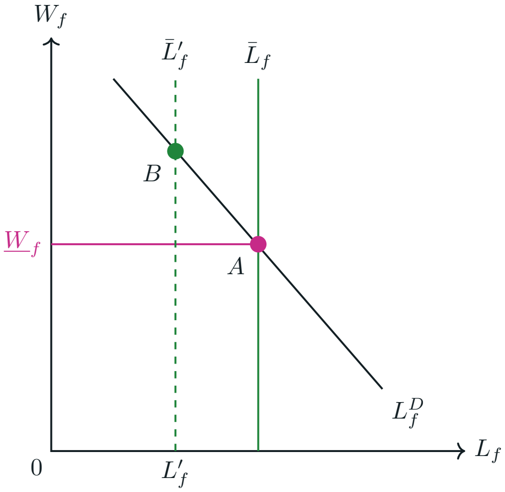

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- $\bar{L}_f$: Potential level for factor f. Decrease due to workers getting sick, shutdowns, etc.
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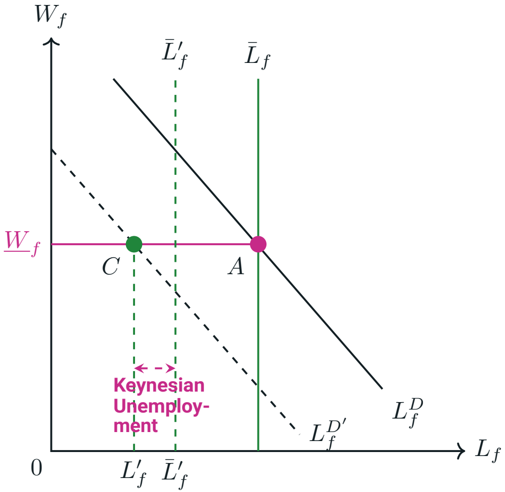
  - Demand effects+downward wage rigidity $\Rightarrow$ workers employed might be lower than *potential*
- Difference between $\bar{L}_f$ and L_f: Keynesian unemployment



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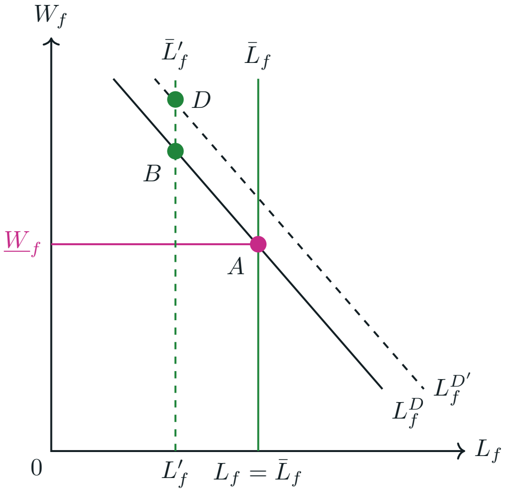
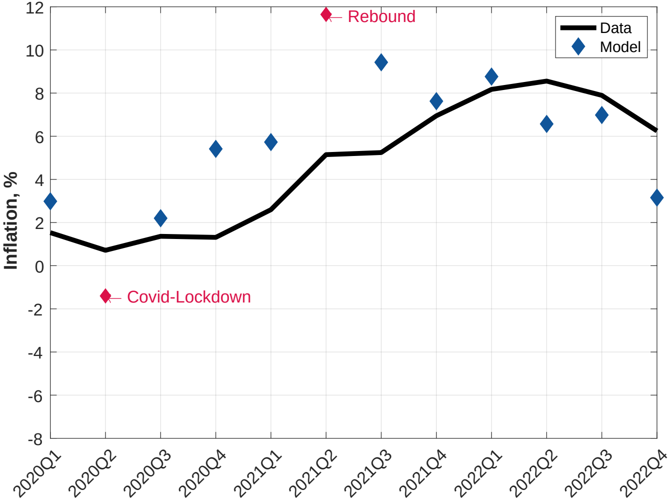
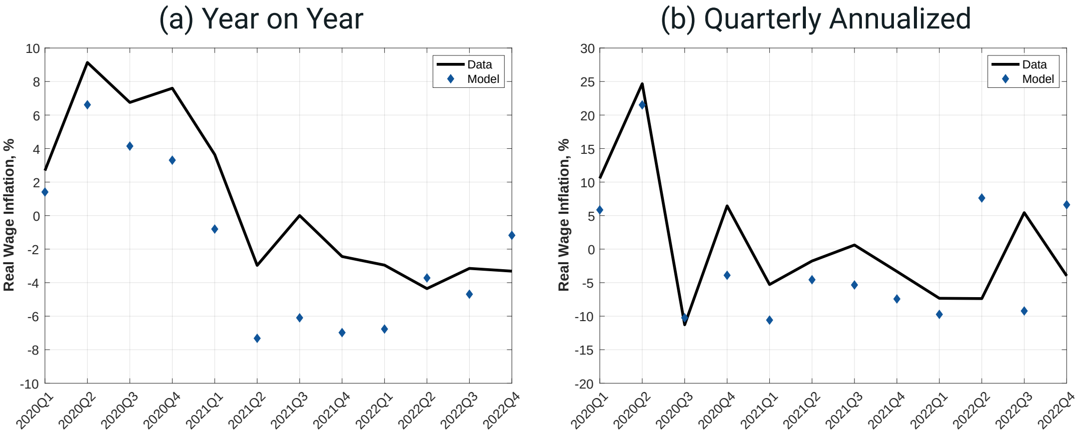
- During recovery – point D: where these unemployment gaps are closed (heterogeneous across sectors, may not be back to 2019 but still inflationary).



Model w/fully inelastic factors and demand and supply shocks can match inflation...



..and wages and sectoral prices



First-order approximation of domestic CPI inflation

Factor shares by $\boldsymbol{\Omega}^F$. Country-level Domar weights for all factors globally:

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

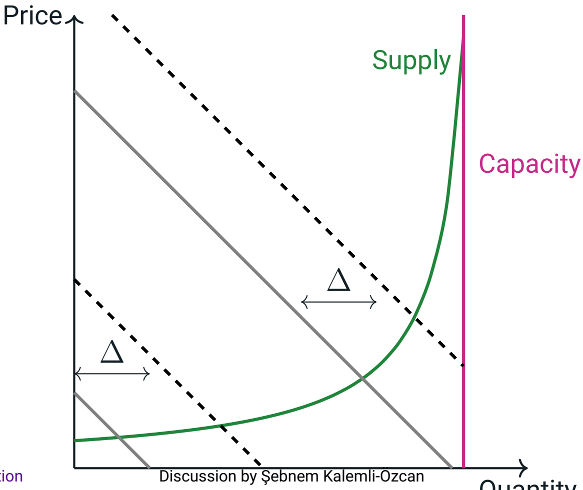
Then the (local currency) CPI in country n can be written as:

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

- 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 adjusted foreign demand shocks

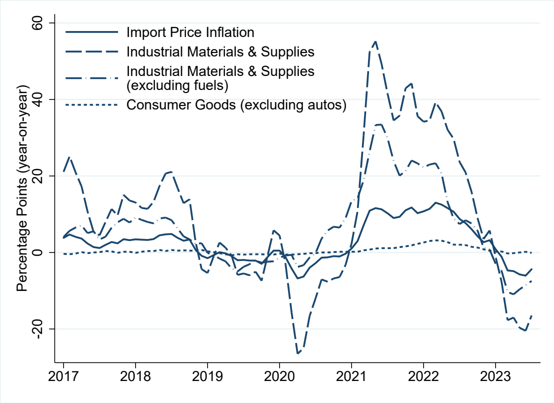
Capacity Constraints at Plants ⇒ Convex Sector Supply Curves (Boehm-Pandalai-Nayar'22 AER)

- Supply becomes more inelastic as quantities increase—do we need such a harsh jump?
- Quantification is difficult−derivative wrt quantities—need post pandemic data, cannot in 2021.



Authors' Supporting Evidence

Figure 2: Import Price Inflation by End Use



Note: Import price indexes are obtained from the US Bureau of Labor Statistics (series identifiers: IR for total imports, EIUIR1 for industrial materials, EUIIR1EXFUEL for industrial materials excluding fuels, and EIUIR4 for consumer goods).

Which sectors are important for this evidence?

	All commodities	All imports exc. fuels	Consumer goods, exc. automotives	Industrial supplies and materials (ISM)	ISM exc. fuels	ISM Durable	ISM nondurable exc. petroleum	Fuels and lubricants	Paper and paper base stocks	Agri. prod, textile sup. and chemicals	Selected building mat., exc. metals	Unfinished metals ass. w/ durables	Finished metals ass. w/ durables	Nonmetals ass. w/ durables
Month	**EIUIR**	**EIUIREXFUELS**	**EIUIR4**	**EIUIR1**	**EIUIR1EXFUEL**	**EIUIR1DUR**	**EIUIR1NONDUR**	**EIUIR10**	**EIUIR11**	**EIUIR12**	**EIUIR13**	**EIUIR14**	**EIUIR15**	**EIUIR16**
2021 Jan	1%	3%	0%	2%	13%	20%	3%	-13%	-1%	3%	39%	29%	6%	1%
2021 Feb	3%	3%	0%	11%	14%	20%	8%	6%	1%	6%	37%	26%	9%	1%
2021 Mar	7%	4%	1%	31%	19%	25%	13%	56%	4%	9%	43%	34%	14%	2%
2021 Apr	11%	5%	1%	52%	26%	34%	17%	131%	7%	14%	59%	48%	17%	3%
2021 May	12%	6%	1%	55%	33%	42%	21%	113%	10%	19%	80%	58%	18%	5%
2021 Jun	11%	6%	1%	49%	33%	41%	23%	85%	10%	21%	79%	54%	21%	5%
2021 Jul	10%	6%	1%	41%	30%	34%	28%	66%	15%	23%	44%	49%	24%	6%
2021 Aug	9%	6%	1%	35%	24%	24%	28%	56%	17%	24%	11%	39%	24%	6%
2021 Sep	9%	5%	1%	36%	20%	17%	28%	70%	18%	26%	-9%	33%	25%	7%
2021 Oct	11%	6%	2%	43%	21%	18%	35%	91%	18%	29%	-4%	30%	27%	7%
2021 Nov	12%	6%	2%	44%	24%	21%	36%	87%	14%	32%	8%	30%	28%	8%
2021 Dec	10%	6%	2%	36%	23%	20%	35%	61%	14%	32%	13%	24%	28%	8%

- Other sub-indices of Industrial supplied and materials (ISM)
- Highlighted cells: more than %25 change

How to interpret the capacity constraint?

- The authors present capacity constraints on output as conceptually distinct from factor supply shocks/shortages although they are very similar
- One can add any factor in fixed supply to production function and assume Leontieff production function between that factor and rest of variable inputs

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- One can add any factor in fixed supply to production function and assume Leontieff production function between that factor and rest of variable inputs

Why they do not do this? If assume Leontieff between fixed supply factor and rest of inputs then firms will be exactly at constraint in steady state, preventing local approximation around SS w/slack constraint

Puzzling Question 1: Why constraint would not bind? Leaving a fixed factor "idle"?

Puzzling Question 2: Why any factor would jump from being idle (flat part) to being fully constrained (vertical part)?

Capacity Constraints vs semi-inelastic heterogenous factor supply

- Rubbo'22 ECMA,'23:
  - Multiple factors, elastically supplied with different Frish elasticities
  - Wage rigidity is symmetric; Linear solution
  - Cost-push shocks when demand for inelastic factors is inefficiently high due to interaction with supply elasticity
  - Prices shoot up before wages when inelastic factor gets a worse shock (higher relative demand)

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CJJ: Capacity constraints on sector output: Can be reframed as elastic labor factor + occasionally inelastic capital factor

The authors approach is isomorphic to sector-specific factors that are in fixed quantity and Leontieff with labor

Essential ingredient in CJJ—based on Rubbo (2023)

A very inelastic factor modeled here as an exogenous constraint on max output.

Convex supply is not a necessary condition for “greed-inflation”; sticky wage/sticky price settings with DRS can produce this

- 2 sectors (goods, services), CES preferences, goods-sector more capital intensive and services

$$Y_G = K_G, Y_S = L_s$$

- Labor supply from consumption-leisure tradeoff, and capacity utilization

$$\left(\frac{L}{\mathcal{E}_L}\right)^{\varphi_L} = \frac{W}{P_G^{\frac{1}{2}} P_S^{\frac{1}{2}}}; \left(\frac{K}{\mathcal{E}_K}\right)^{\varphi_K} = \frac{R}{P_G^{\frac{1}{2}} P_S^{\frac{1}{2}}}$$

- Capital is less elastic than labor,

$$\varphi_L << \varphi_K; \varphi_K \to \infty \text{ (full inelastic)}$$

Log-Linearized Equilibrium

Aggregate output in the flex-price economy:

$$y^{nat} = \log \bar{\mathcal{E}} - \frac{Cov\left(\frac{1}{\varphi}, \log \mathcal{E} - \log \eta\right)}{\theta + \mathbb{E}\left(\frac{1}{\varphi}\right)}$$

Output declines when demand increases more than supply in the inelastically supplied sector.

$$y^{nat} = \log \bar{\mathcal{E}} - \frac{1}{4} \frac{\left(\frac{1}{\varphi_G} - \frac{1}{\varphi_S}\right)\left[(\log \mathcal{E}_G - \log \eta_G) - (\log \mathcal{E}_S - \log \eta_S)\right]}{\theta + \mathbb{E}\left(\frac{1}{\varphi}\right)}$$

The second term < 0 when the increase in demand relative to supply is larger in the good sector than in the service sector:

$$(\log \mathcal{E}_G - \log \eta_G) < (\log \mathcal{E}_S - \log \eta_S)$$

The covariance effect (demand and supply shock correlation) is largest when goods and services are strong complements

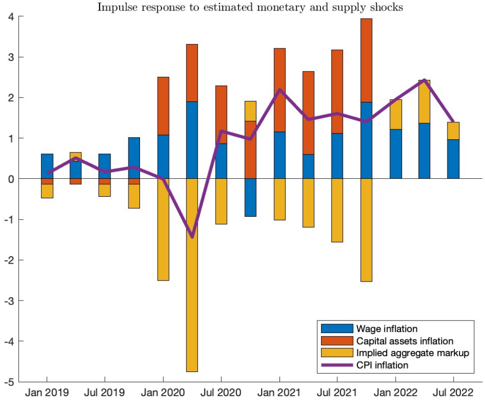
CPI inflation in sticky-price economy:

$$\pi^{CPI} = \kappa^{CPI}\left(y - y^{nat}\right) + \frac{1}{4} \frac{\theta\delta\bar{\varphi}}{1 + \theta\delta\bar{\varphi}} \frac{\varphi_G - \varphi_S}{\bar{\varphi}} \left[(\log \eta_G - \log \mathcal{E}_G) - (\log \eta_S - \log \mathcal{E}_S)\right]$$

- Inflation $\uparrow$ when $D_G \uparrow > S_G$, and goods are more inelastically supplied than services (y at potential)
- Inflation in services lower when K is more inelastic and output above potential (scaling up with $\uparrow$ AD is more costly in goods sector)
- Inflation in services lower when $D_G \uparrow > S_G$ relative to $D_S \uparrow > S_S$

2021: Wage growth $<$ Price growth; Mark-ups $\downarrow$ due to higher price of inelastic K factor

- Back out monetary shocks and supply shocks to match the actual behavior of sectoral inflation rates
- Fed the shocks to compute impulse-responses of wages, prices of fixed factors, and a residual equal to the implied change in aggregate markups.



Source: Rubbo'23

Micro-Foundations for Capacity Constraints and Persistence in Inflation

- Boehm and Pandala-i-Nayar'22 micro-founded the capacity constraints as firms choose some maximum processing capacity for variable inputs (number of workstations)
- Aggregate to industry; industry output NOT subject to a maximum capacity but industry supply curves are convex.
- Show alternatives where marginal costs of inputs/labor increases as you use them more intensively (doctors 24 hours): gives upward sloping supply curve.

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Why does this matter? For dynamic response to shocks.

- If firms foresee a persistent increase in demand (pandemic recovery), should optimally respond by increasing their maximum processing capacity of variable inputs.
  $\Rightarrow$ industry supply curve shifts outward, and this dampens price response to shocks.
- Survey data on capacity utilization has questions on why utilization is low.
  $\Rightarrow$ Before 2020, insufficient demand.
  $\Rightarrow$ During pandemic: Unable to hire labor.

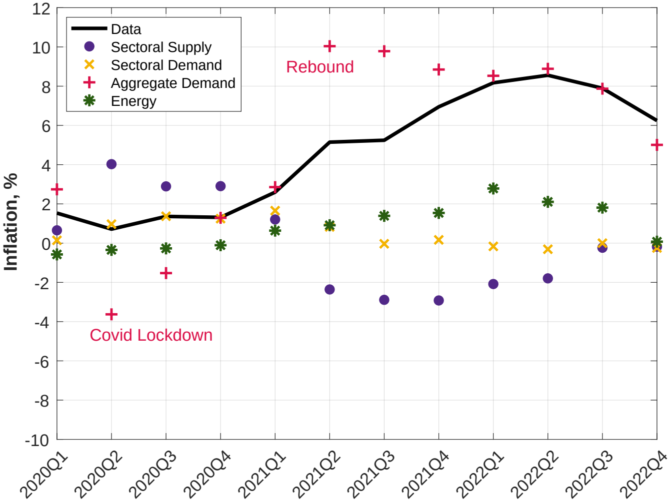
Even though firms will know demand will be high for goods during lockdown and services during recovery, there is no need to expand production capacity as they cannot hire workers.
$\Rightarrow$ Until you get some slack in the labor market there will be inflationary pressure.

Conclusion

- Interesting and ambitious paper trying to match the entire dynamics of inflation in 2020–2023.
- A successful model in matching data; will be useful to understand persistence in inflation.
- Not fully clear which approach is better to match real-life experience:
  - Complicated nature of the COVID shock: aggregate and sectoral, demand and supply, global but not synchronized
  - Capacity constraints for output as a structural feature and they bind under easy monetary policy
- Important to know for policy implications: <u>which shock hits which sector?</u>
  As asymmetric shocks require adjustments in relative prices across sectors, a more expansionary monetary policy can be optimal (Guerrieri, Lorenzoni, Straub, Werning'21 JH)
  - If easy monetary policy can improve employment prospects in the declining sector, then labor reallocation slows down. (Fernald and Li'21 JH).
  - If easy monetary policy affects relative wages, than labor reallocation is accelerated.

Appendix

..via both sectoral and aggregate demand and supply shocks



Sectoral Prices US