Industry Heterogeneity, Production Network and Monetary Policy

Zhesheng Qiu[1] Jianhong Xin[2] Le Xu[23]

[1]City University of Hong Kong

[2]University of Pennsylvania

[3]Federal Reserve of Philadelphia

Introduction

Introduction

- Research on aggregate inflation
- Theoretical work on production network
- We provide the first quantitative study on how monetary policy transmitted through production network ...

Empirical stylized facts

Method: Bayesian Local Projection

1. Consider model

$$y_{t+h} = A' + ... + B^{t-1}S\varepsilon_{t+1} + B^h S\varepsilon_t + B^{h+1}S\varepsilon_{t-1} + ...\nu_{t+h}$$

2. Local projection (Jorda, 2005) estimator is unbiased but inefficient:

$$\hat{\Psi}^{LP}(h) = \left(E'_{t-h}E_{t-h}\right)^{-1} E'_{t-h}Y_t.$$

3. Proxy SVAR estimator is efficient but has mis-specification bias.

$$\hat{\Psi}^{VAR}(h) = \hat{B}^h \hat{S}$$

4. Bayesian Local Projection (BLP) retains the merit of both:

$$\hat{\Psi}^{BLP}(h) = \left(\hat{\Sigma}^{VAR}(h)^{-1} + E'_{t-h}E_{t-h}\right)^{-1} \left(\hat{\Sigma}^{VAR}(h)^{-1}\hat{\Psi}^{VAR}(h) + E'_{t-h}Y_t\right)$$

Method: Identify Monetary Shocks

1. Construct Miranda and Ricco (2018)'s information robust instrument:
   - High-frequency identification (HFI) of Gertler and Karadi (2015)
   - Narrative approach on Romer and Romer (2004)

$$FF4_m = \alpha_0 + \sum_{j=-1}^{2} \theta_j F_m x_{q+j} + \sum_{j=-1}^{2} \vartheta_j \left[F_m x_{q+j} - F_{m-1} x_{q+j}\right] + \Delta FF4_m$$

$$\Delta FF4_t = \phi_0 + \sum_{j=1}^{12} \phi_j \Delta FF4_{t-j} + \varepsilon_t$$

   $F_m x_q$: Greenbook forecast for state variable $x = \{g, \pi, u\}$ for horizon q; $FF4_m$: high-frequency monetary surprise before and after the FOMC m.

2. No confounding anticipated policy shifts in "surprises" with central bank's information controlled.
3. Outcome no output or price puzzles.

Data

1. Industry level
   - Price level P_t and gross output Q_t from the BEA's GDP by industry tables, GDPbyInd_GO_1947-2017.xlsx and value added from
   - Wages W_t from 13 industries (with two-digit SIC code) NIPA Table 6.3 and 6.9.
2. Derive quarterly Q_t and P_t using Chow-Lin's method;
3. Quarterly growth rate γ_t inflation π_t by first order difference.

Data

1. Control variables
   - We construct variables following Christiano, Trabandt and Walentin (2011)

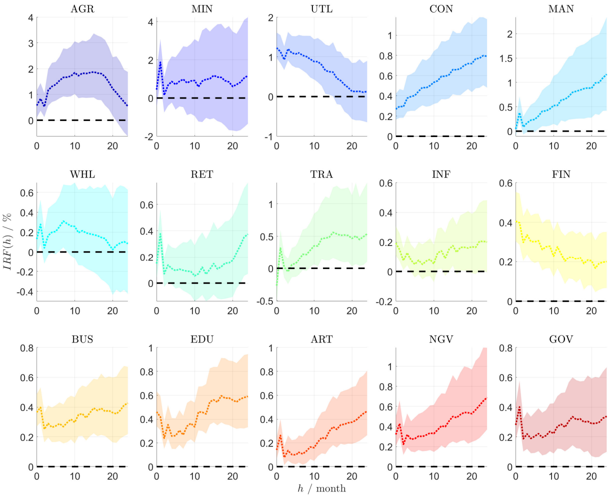
$$w_t = \begin{bmatrix} \Delta \log \text{ (relative price of investment) }_t \\ \Delta \ln (\text{ real } GDP_t / \text{ hours }_t) \\ \text{capacity utilization }_t \\ \text{unemployment rate }_t \end{bmatrix}.$$

   - Use control variables (lag $q = 4$ quarters)

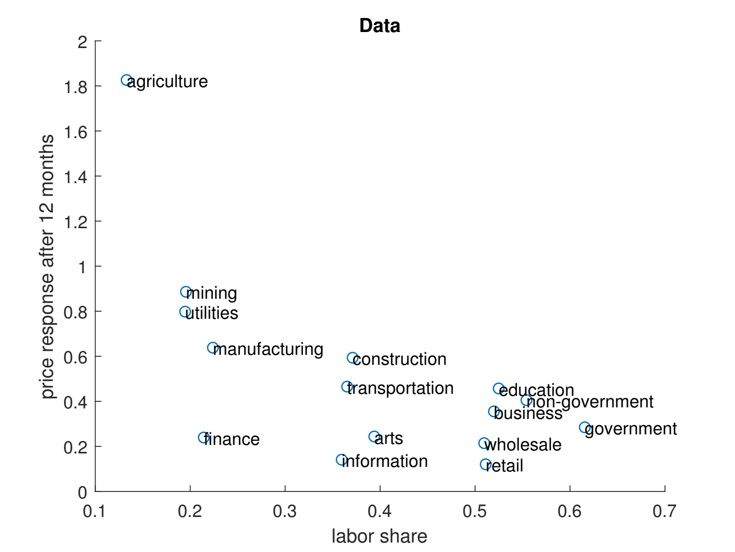
$$X_t = [y_{t-q:t-1}, w_{t-q:t-1}].$$

2. Estimate horizon from 1969:1 to 2008:4.

Price Response Heterogeneity



Puzzling Correlation



Model

Production Network

- CRS variety production function + Dixit-Stiglitz variety aggregator:
  1. asd

- The desired price is

$$\hat{P}^*_{n,t} = \alpha_n \hat{W}_t + (1-\alpha_n) \sum_s \omega_{ns} \hat{P}_{s,t}.$$

- The matrix representation is

$$\hat{\boldsymbol{P}}^*_t = \boldsymbol{\alpha} \hat{\boldsymbol{W}}_t + (\mathbb{I} - \boldsymbol{\alpha}) \boldsymbol{\Omega} \hat{\boldsymbol{P}}_t.$$

Price Rigidities

- Calvo, price aggregator ...
- The industry prices evolve according to

$$\hat{P}_{n,t} = (1 - \theta_n^P)\hat{P}^*_{n,t} + \theta_n^P \hat{P}_{n,t}.$$

- The matrix representation is

$$\hat{\boldsymbol{P}}_t = (\mathbb{I} - \boldsymbol{\Theta}^P)\hat{\boldsymbol{P}}^*_t + \boldsymbol{\Theta}^P \hat{\boldsymbol{P}}_{t-1}.$$

Wage Rigidities

- Assume the following utility function for households.

$$\sum_{t=0}^{+\infty} \mathbb{E}_t \beta^t [\ln(C_t) - L_t].$$

- Under flexible prices, the intra-temporal optimality condition is

$$-\frac{MU_{L_t}}{MU_{C_t}} = \frac{W_t}{P_t} \implies C_t = \frac{W_t}{P_t}.$$

- Consider a myopic labor union that sets nominal wages on behalf of the households, subject to Calvo frictions. When it set wages, following the standard Calvo wage problem with $\beta = 0$, it chooses

$$W_t^* = \frac{\epsilon_W}{\epsilon_W - 1}(C_t + P_t).$$

- Note that we do not need to keep track of labor dynamics.

Wage Rigidities

- Now assume that each household is attached to a job in an industry. As in Calvo wage model, their wage incomes risks due to Calvo friction are full insured and there is no heterogeneity in consumption demand.
- The log deviation of the desired wage in industry n now becomes

$$\hat{W}^*_{n,t} = \hat{C}_t + \hat{P}_t.$$

- The industry nominal wages evolve according to

$$\hat{W}_{n,t} = (1 - \theta^W_n)\hat{W}^*_{n,t} + \theta^W_n \hat{W}_{n,t-1}.$$

- The matrix representation is

$$\hat{\boldsymbol{W}}_t = (\mathbb{I} - \boldsymbol{\Theta}^W)(\mathbf{1}_{N\times 1}\hat{C}_t + \mathbf{1}_{N\times N}\boldsymbol{\xi}\hat{\boldsymbol{P}}_t) + \boldsymbol{\Theta}^W \hat{\boldsymbol{W}}_{t-1}.$$

Monetary Policy

- The data consistent specification of monetary policy should be an interest rate rule. We impose a money supply rule for simplicity.
- Consider a CIA constraint for all households that requires

$$P_t C_t \leq M_t.$$

- As long as the nominal interest rate is positive, this constraint will be binding. For any sequence of $\{M_t\}$, the binding CIA constraint allows us to solve for the equilibrium P_t and C_t.
- The gross nominal interest rate must satisfy the Euler equation

$$C_{t+1} = \beta \frac{R_t P_t}{P_{t+1}} C_t.$$

Monetary Policy

- In order to implement interest rate R_t, which yields the equilibrium P_t and C_t, the monetary authority must provide money supply $\{M_t\}$ that satisfies the binding CIA constraint.
- We could extend households' utility function, such that the model implied interest rate and consumption dynamics can both match data. The consumption dynamics then determines the rest.
- Since the nominal wage and price dynamics can be uniquely pinned down by the aggregate consumption, it is equivalent to simply find a money supply path to replicate consumption dynamics in data.

Monetary Policy

- Binding CIA constraint

$$\hat{M}_t = \hat{C}_t + \hat{P}_t.$$

- The matrix representation is

$$\mathbf{1}_{N\times 1}\hat{M}_t = \mathbf{1}_{N\times 1}\hat{C}_t + \mathbf{1}_{N\times N}\boldsymbol{\xi}\hat{\boldsymbol{P}}_t.$$

- Exogenous surprised money supply increase starting from period 0

$$\hat{M}_t = [1 - e^{-\rho(t+1)}]\hat{M}_{+\infty}.$$

Equilibrium Nominal Wages and Prices

- We only need to consider the following linear system

$$
\begin{aligned}
\hat{\boldsymbol{W}}_t &= (\mathbb{I} - \boldsymbol{\Theta}^W)\mathbf{1}_{N\times 1}\hat{M}_t + \boldsymbol{\Theta}^W \hat{\boldsymbol{W}}_{t-1}, \\
\hat{\boldsymbol{P}}_t &= [\mathbb{I} - (\mathbb{I} - \boldsymbol{\Theta}^P)(\mathbb{I} - \boldsymbol{\alpha})\boldsymbol{\Omega}]^{-1}[(\mathbb{I} - \boldsymbol{\Theta}^P)\boldsymbol{\alpha}\hat{\boldsymbol{W}}_t + \boldsymbol{\Theta}^P \hat{\boldsymbol{P}}_{t-1}], \\
\hat{C}_t &= \hat{M}_t - \mathbf{1}_{1\times N}\boldsymbol{\xi}\hat{\boldsymbol{P}}_t, \\
\hat{M}_t &= [1 - e^{-\rho(t+1)}]\hat{M}_{+\infty}.
\end{aligned}
$$

Characterization

Estimation

Linear System

- Recall the linearized equilibrium conditions

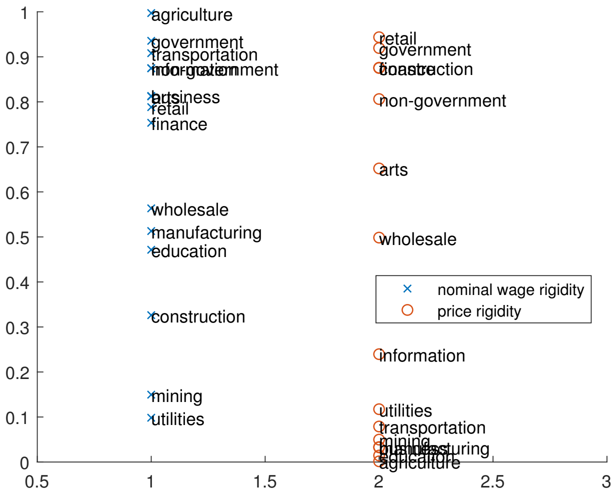
$$\begin{aligned}
\hat{\boldsymbol{W}}_t &= (\mathbb{I} - \boldsymbol{\Theta}^W)\mathbf{1}_{N\times 1}\hat{M}_t + \boldsymbol{\Theta}^W \hat{\boldsymbol{W}}_{t-1}, \\
\hat{\boldsymbol{P}}_t &= [\mathbb{I} - (\mathbb{I} - \boldsymbol{\Theta}^P)(\mathbb{I} - \boldsymbol{\alpha})\boldsymbol{\Omega}]^{-1}[(\mathbb{I} - \boldsymbol{\Theta}^P)\boldsymbol{\alpha}\hat{\boldsymbol{W}}_t + \boldsymbol{\Theta}^P \hat{\boldsymbol{P}}_{t-1}], \\
\hat{C}_t &= \hat{M}_t - \mathbf{1}_{1\times N}\boldsymbol{\xi}\hat{\boldsymbol{P}}_t, \\
\hat{M}_t &= [1 - e^{-\rho(t+1)}]M_{+\infty}.
\end{aligned}$$

- Parameters to calibrate: $\{\boldsymbol{\alpha}, \boldsymbol{\Omega}, \boldsymbol{\xi}\}$.
- Parameters to estimate: $\{\boldsymbol{\Theta}^W, \boldsymbol{\Theta}^P, M_{+\infty}, \rho\}$ (32 parameters).
- Moments to target: $\{\hat{\boldsymbol{W}}_t, \hat{\boldsymbol{P}}_t, \hat{C}_t\}_{t=0}^{24}$ (775 moments).

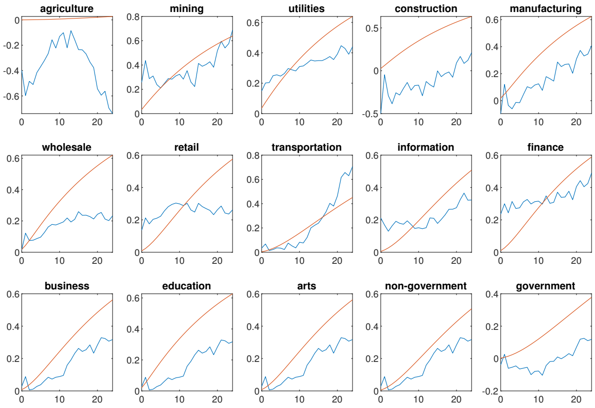
Calibration

- Map to BEA.

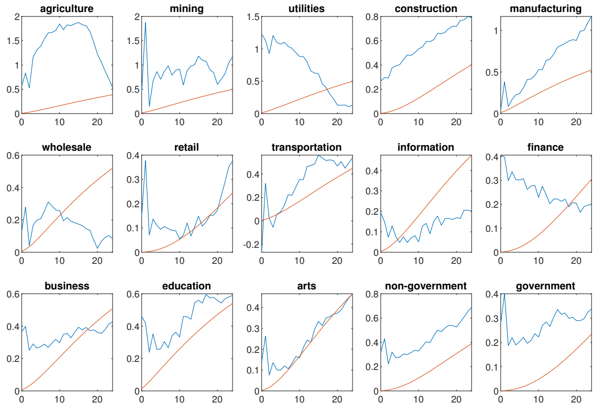
Estimated Parameters



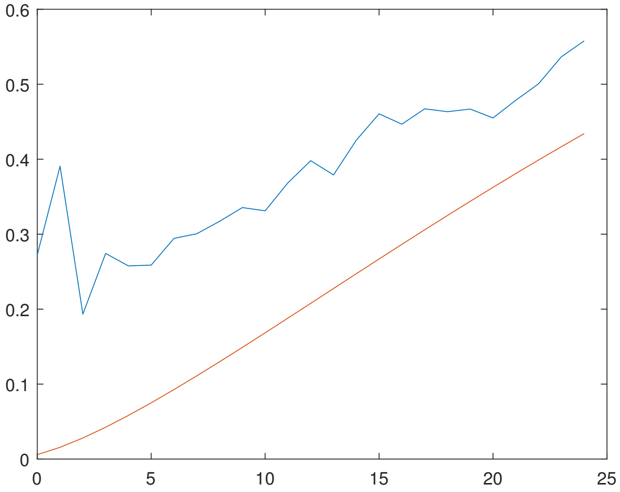
Model vs Data: Industry Nominal Wages



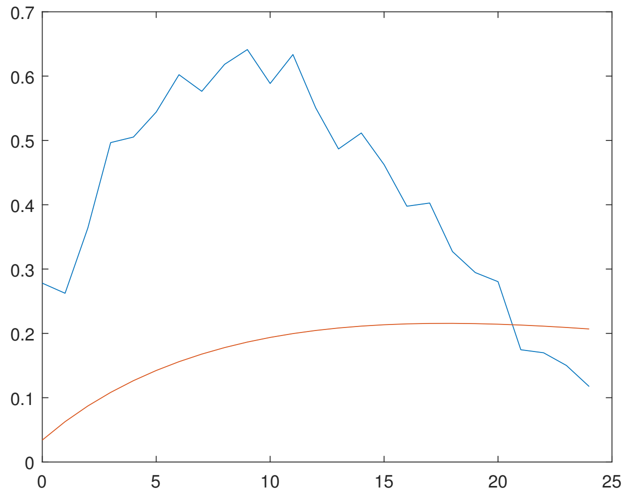
Model vs Data: Industry Prices



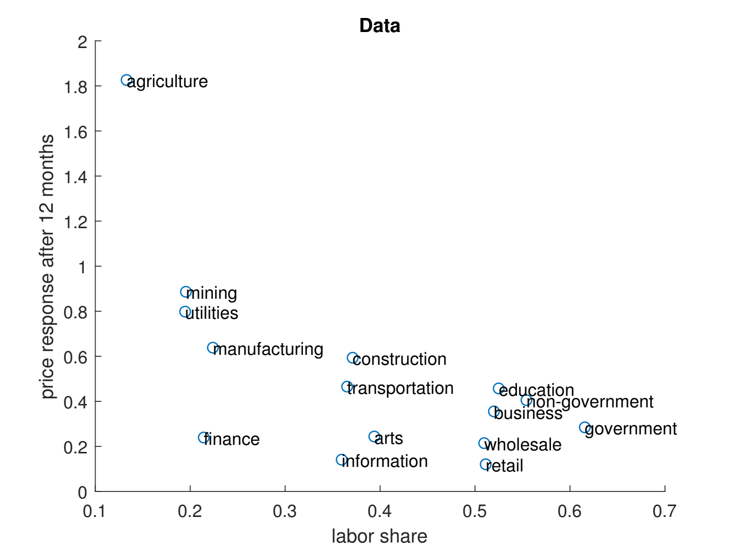
Model vs Data: GDP Deflator



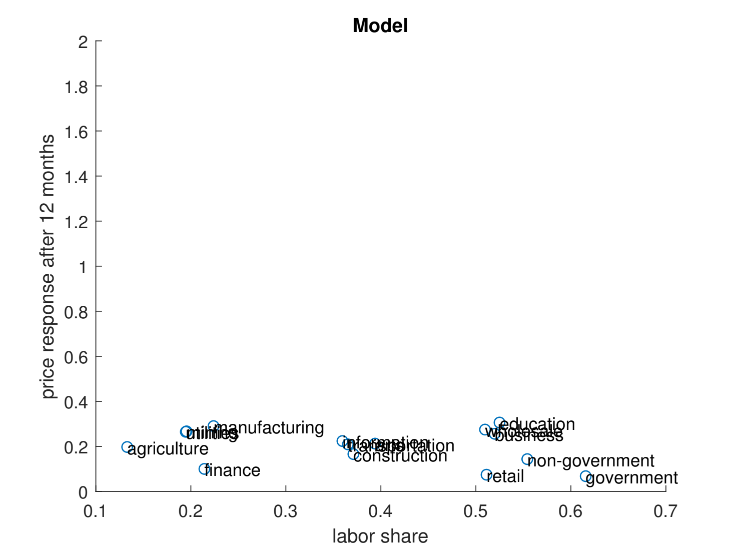
Model vs Data: GDP



Puzzle: Data


Data
price response after 12 months
labor share
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
agriculture
mining
utilities
manufacturing
construction
transportation
education
non-government
business
government
finance
arts
wholesale
information
retail

Puzzle: Model



Analysis

Inflation Pressure and Inflation Decomposition

- Rearranging the law of motion for industry prices yields the following inflation pressure decomposition in all industries

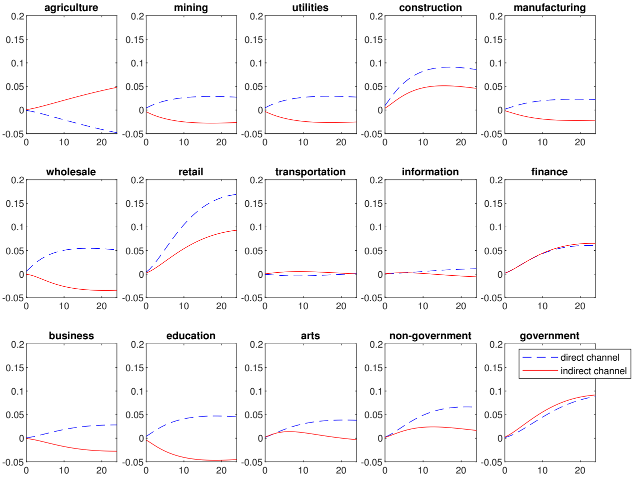
$$\hat{\boldsymbol{P}}_t - \hat{\boldsymbol{P}}_{t-1} = (\boldsymbol{\Theta}^P)^{-1}(\mathbb{I} - \boldsymbol{\Theta}^P)\left[\underbrace{\boldsymbol{\alpha}(\hat{\boldsymbol{W}}_t - \hat{\boldsymbol{P}}_t)}_{\text{direct channel}} + \underbrace{(\mathbb{I} - \boldsymbol{\alpha})(\boldsymbol{\Omega} - \mathbb{I})\hat{\boldsymbol{P}}_t}_{\text{indirect channel}}\right].$$

- The aggregate inflation decomposition is just

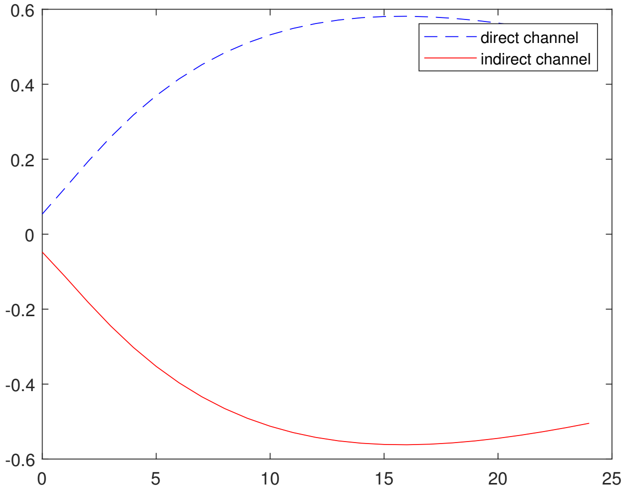
$$\hat{P}_t - \hat{P}_{t-1} = \underbrace{\mathbf{1}_{1\times N}\boldsymbol{\xi}(\boldsymbol{\Theta}^P)^{-1}(\mathbb{I} - \boldsymbol{\Theta}^P)\boldsymbol{\alpha}(\hat{\boldsymbol{W}}_t - \hat{\boldsymbol{P}}_t)}_{\text{direct channel}} + \underbrace{\mathbf{1}_{1\times N}\boldsymbol{\xi}(\boldsymbol{\Theta}^P)^{-1}(\mathbb{I} - \boldsymbol{\Theta}^P)(\mathbb{I} - \boldsymbol{\alpha})(\boldsymbol{\Omega} - \mathbb{I})\hat{\boldsymbol{P}}_t}_{\text{indirect channel}}.$$

- These decompositions are reliable only if we can better match industry specific price dynamics. Yet, we still demonstrate the results.

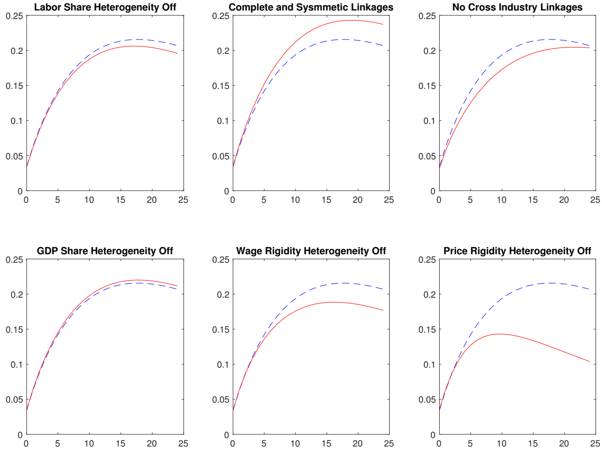
Industry Inflation Pressure Decomposition



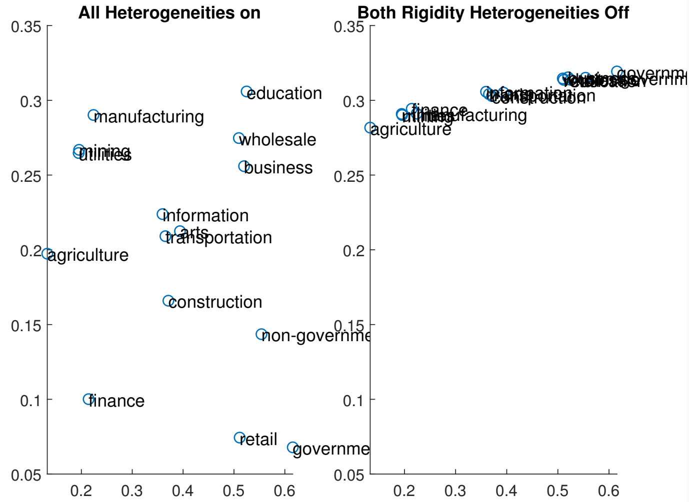
Aggregate Inflation Decomposition



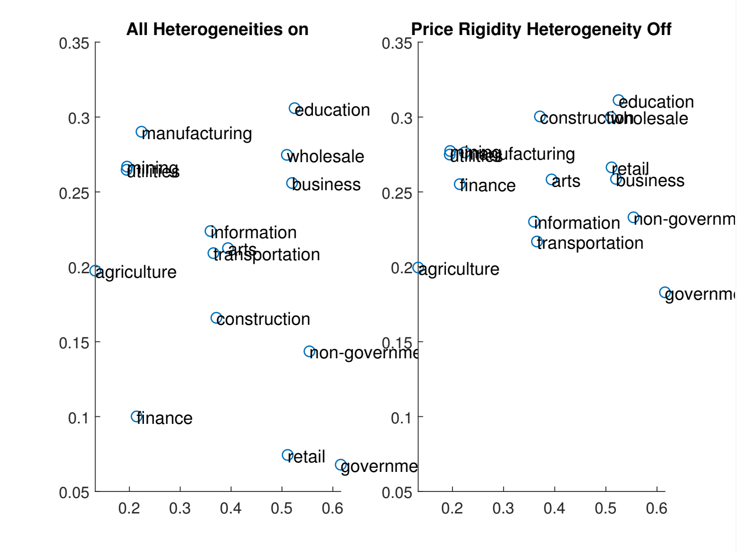
Heterogeneities and the Real Effects of Money



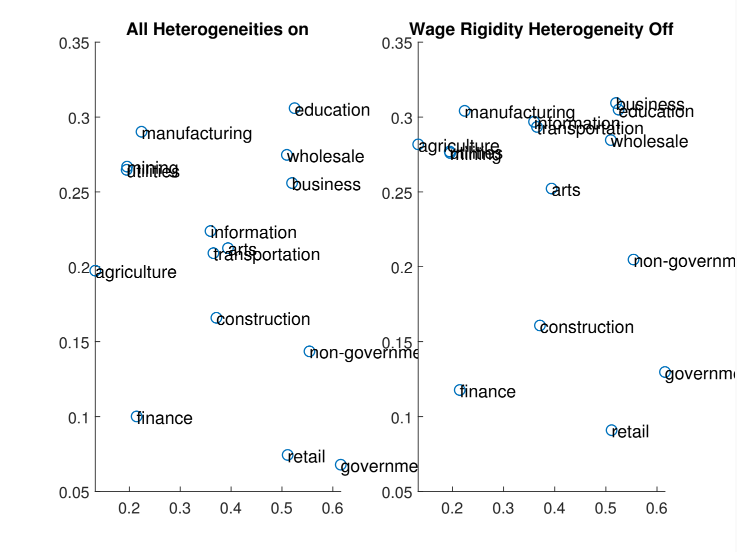
Heterogeneities, Price and Labor Share



Heterogeneities, Price and Labor Share



Heterogeneities, Price and Labor Share



Conclusion

References