Production Networks and the Flattening of the Phillips Curve

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Motivation

The relationship between the slack in the economy or unemployment and inflation was a strong one 50 years ago ... and has gone away.
(Jerome Powell, 2019)

- The Phillips curve has become flatter in recent decades.
  (Ball & Mazumder 2014, Kiley 2000, 2015)
- Implications for central banks ability to control and predict inflation.
- Potential explanations:
  1. Success of monetary policy in anchoring expectations (Bernanke, 2010),
  2. Credibility of the central bank (McLeay & Tenreyro, 2019),
  3. Global forces (Jordá et al., 2019),
  4. Measurement problems (Coibin & Gorodnichenko 2015, Stock & Watson, 2019).
- This paper proposes a novel explanation based on **changes in the production network** structure of the economy.

Has the structure of the U.S. network changed?

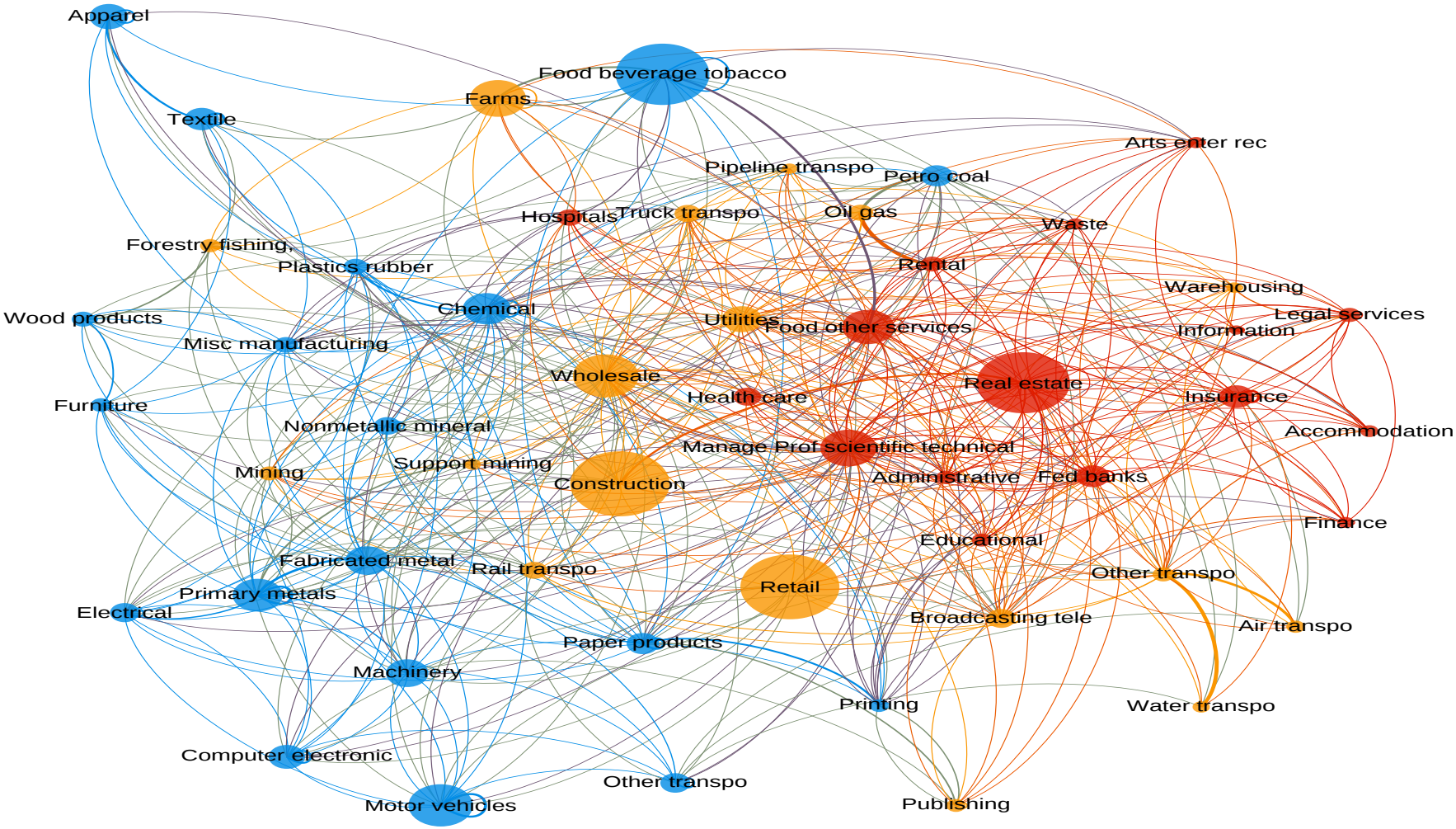


Figure: US Input-Output network in 1963. Manufacturing Services Other

Has the structure of the U.S. network changed? YES

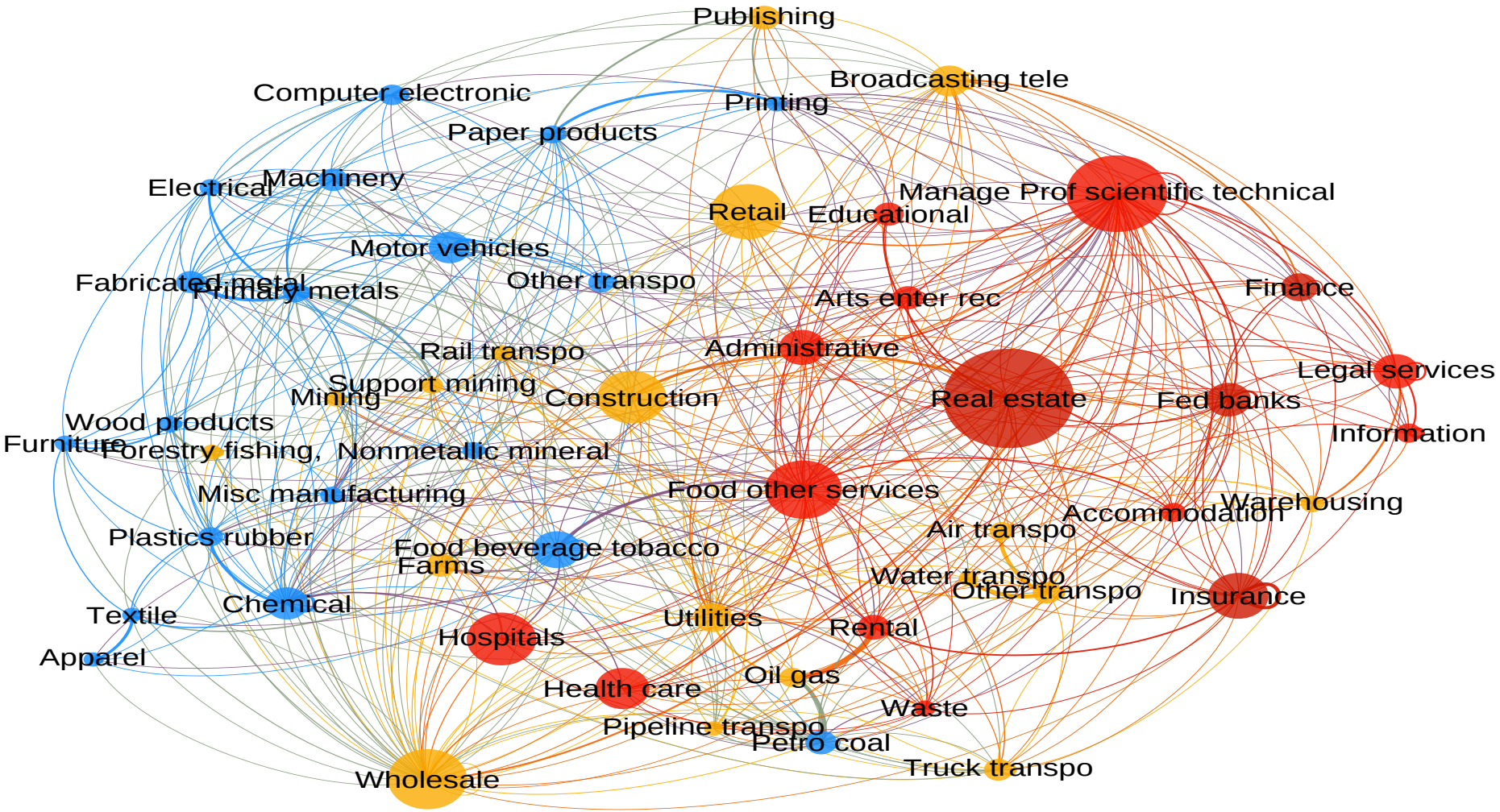


Figure: US Input-Output network in 2017. Manufacturing Services Other

Contribution

Could a change in the U.S. production network account for the flattening of the Phillips curve?

- I combine a multi-sector New Keynesian model with production networks & historical data on input-output relations in the U.S.
- Main findings:
  1. Inflation dynamics depend on the network structure: generalized NK Phillips curve.
  2. Change to production structure can account for a decrease in the slope of up to a quarter of total flattening.
  3. Ignoring the network channel, i.e. allowing only for compositional changes, we would miss half of this change.

Mechanism

- Increase in the importance of sectors that change prices less often.
  $\Rightarrow$ Aggregate degree of nominal rigidity in the economy increases.

Relationship to the Literature

1. Evidence and Explanations for Flattening of the Phillips Curve:
   - Kiley (2000, 2015), Ball & Mazumder (2011, 2013), Hall (2013), Daly & Hobijn (2014), Bryan & Meyer (2010), Blanchard, Cerutti & Summers (2015), Coibion & Gorodnichenko (2015), Galí & Gambetti (2019), Hooper, Mishkin & Sufi (2019)
   - **This paper:** structural approach.
2. Multi-Sector Models with Production Networks:
   - Horvath (1998, 2000), Acemoglu et al., (2012), Carvalho (2014), Tahbaz-Salehi et al. (2017), Atalay (2017), Bigio & La'O (2019), Herskovic (2018), Choi & Foerster (2017)
   - **This paper:** two (endogenous) network statistics.
3. New Keynesian Models with Production Networks:
   - Basu (1995), Pasten, Schoenle & Weber, (2018,2019), Galesi & Rachedi (2016), Cienfuegos (2018), Bouakez, Rachedi & Santoro (2019), Rubbo (2019)
   - **This paper:** studies effects on Phillips curve.

The Model

Model Environment

1. A representative HH makes consumption and labor supply decisions.
2. Firms are within a Nested CES structure: Within sectors firms face monopolistic competition and prices are sticky a la Calvo.
3. The key: intermediate good production
   $\Rightarrow$ Technology: an Extension of the Basic NK Model

Household

Household's problem and budget constraint

$$\max_{C_t, L_t, B_t} E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\varphi}}{1+\varphi} \right]$$

$$P_t C_t + Q_t B_t = \sum_k W_{k,t} L_{k,t} + B_{t-1} + \sum_k \int_i D_{k,t}(i) di$$

Total consumption

$$C_t = \prod_{k=1}^{K} C_{k,t}^{\vartheta_k}$$

and $C_{k,t} = CES(C_{k,t}(i), \varepsilon_k)$. Imperfect labor mobility, $L_t = CES(L_{k,t}, \nu)$.

Technology: an Extension of the Basic NK Model

Firm i of sector k produces with technology

$$Q_{k,t}(i) = L_{k,t}(i)^{1-\gamma_k} X_{k,t}(i)^{\gamma_k}$$

where

$$X_{k,t}(i) = \left(\prod_{j=1}^{K} X_{k,t}(i,j)^{\omega_{k,j}} \right)$$

Network ingredients:

- $X_{k,t}(i,j) = CES(X_{k,t}(i,j,h), \varepsilon_k)$: intermediate input use of firm (k,i) from sector j.
- γ_k: intermediate input share.
- $\omega_{k,j}$: expenditure on sectoral intermediate goods.

Putting Things Together: Sectoral Inflation Dynamics

Generalized Sectoral New Keynesian Phillips Curves

$$\hat{\pi}_{k,t} = \beta E\hat{\pi}_{k,t+1} + \frac{(1-\gamma_k)}{1+\gamma_k\varphi}\Phi_k^{Std}\hat{y}_t + \Psi_{k,t}$$

$$\Psi_{k,t} = \underbrace{\kappa_k \frac{\varphi(1-\gamma_k)}{1+\gamma_k\varphi}(\hat{\delta}_{k,t} + \hat{\Phi}_t^{NM})}_{\text{network component}} + \underbrace{\kappa_k \frac{(1+\varphi)}{1+\gamma_k\varphi}(\gamma_k\hat{p}_t^k - \hat{p}_{k,t})}_{\text{strategic complementarities}}$$

- $\Phi_k^{Std} = \kappa_k(\sigma+\varphi)$: slope standard NK model.
- $\Psi_{k,t}$: endogenous term.

The Role of two Network Statistics

- Network Multiplier, $\Phi_t^{NM} = \frac{Q_t}{Y_t}$: A measure of the importance of the network in this economy.
- Sectoral (Gross) Output share, $\delta_{k,t} = \frac{P_{k,t}Q_{k,t}}{P_t Q_t}$: A measure of the importance of the sector in the network (Katz, 1953).
- Both are endogenous and depend on (countercyclical) markups.

Aggregate Inflation Dynamics and Estimation Bias

Generalized Aggregate New Keynesian Phillips Curve

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \tilde{\Phi}^{Std} \hat{y}_t + \Psi_t$$

Implications:

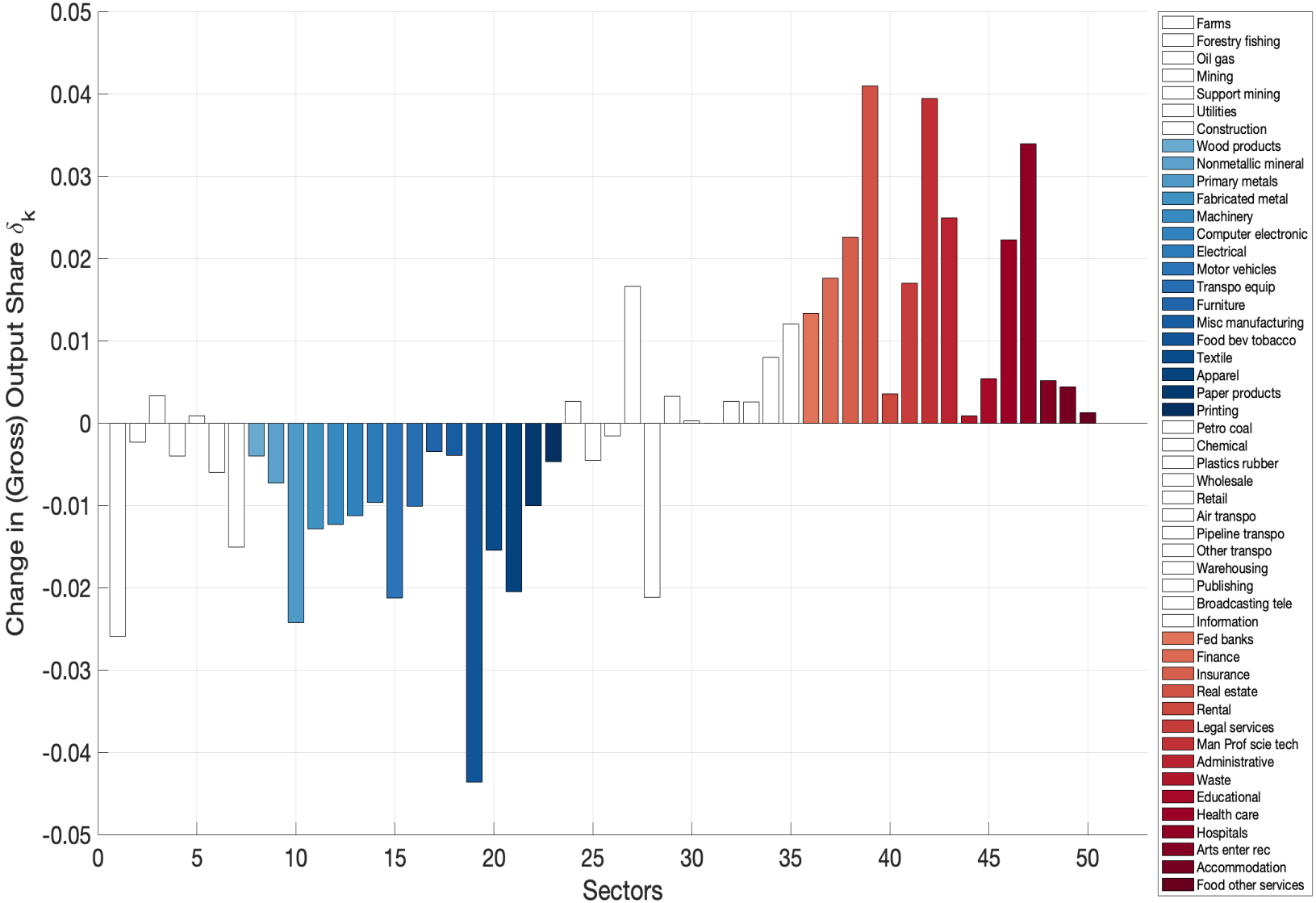
- Ψ_t depends on the network structure of the economy.
- Ψ_t introduces bias in estimate of slope of standard NKPC because correlated with $\hat{y}_t$, i.e $Corr(\hat{y}_t, \Psi_t) \neq 0$.
- Flattening of PC either because of (i) decline in standard slope or (ii) change in bias.

How to Derive Evolution of Slope over time?

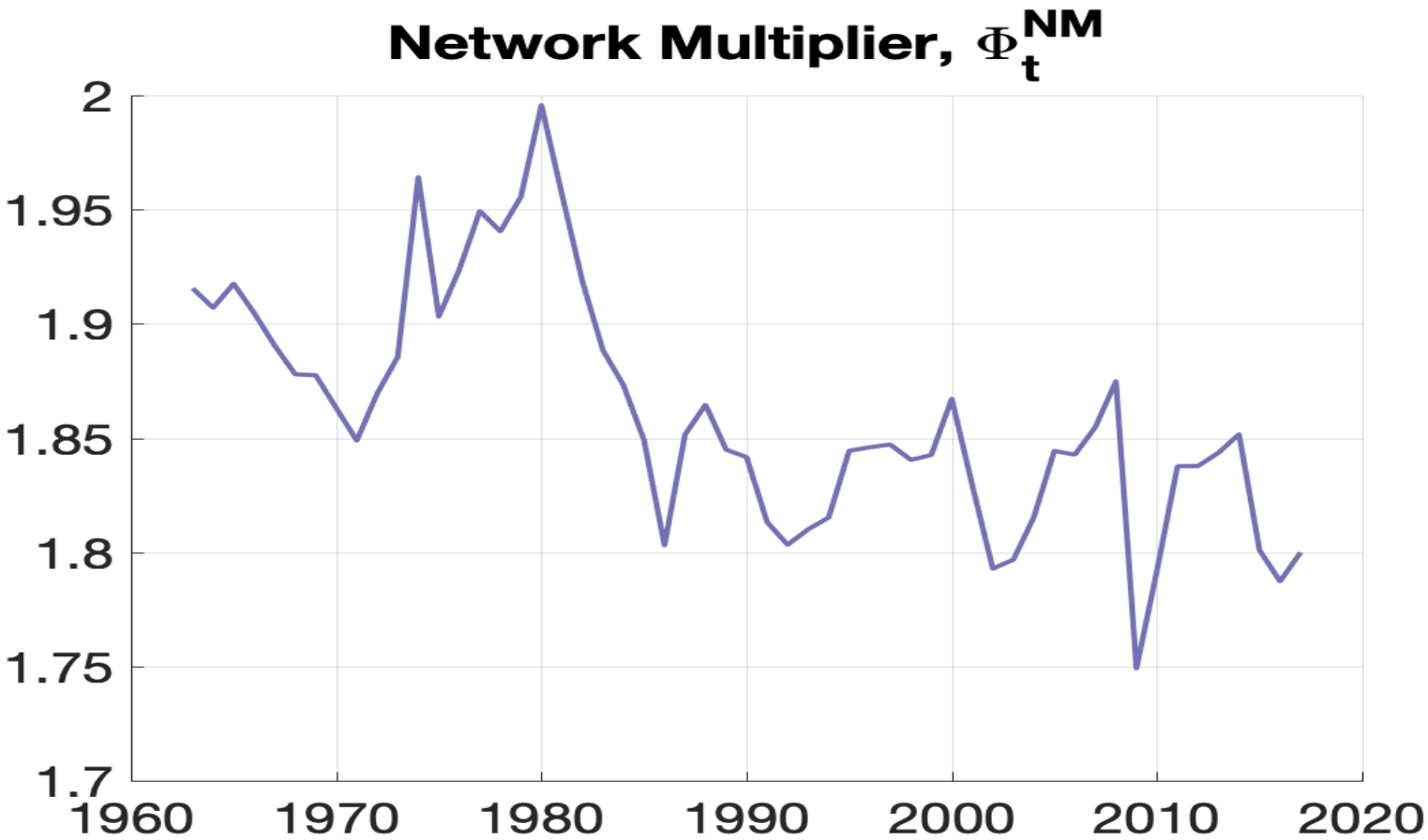
- **Identification strategy:** Changes in the network structure will be reflected as changes to the technology of firms.
- Match parameters of the production function in the model to changes in expenditure shares in the data.
- Use historical U.S. data on Input-Output linkages from 1963 - 2017 to calibrate technology parameters.
  - Intermediate input share, γ_k,
  - Expenditure on sectoral intermediate goods, $\omega_{k,j}$
  - Consumption shares: ϑ_k.
- Simulate data from model for series of shocks and estimate slope of Phillips curve.

Change to Network in U.S.

Change in centrality $\delta_{k,t}$ from 1963 to 2017



No trend in network multiplier over time



Findings and Counterfactuals

Decrease of model implied slope

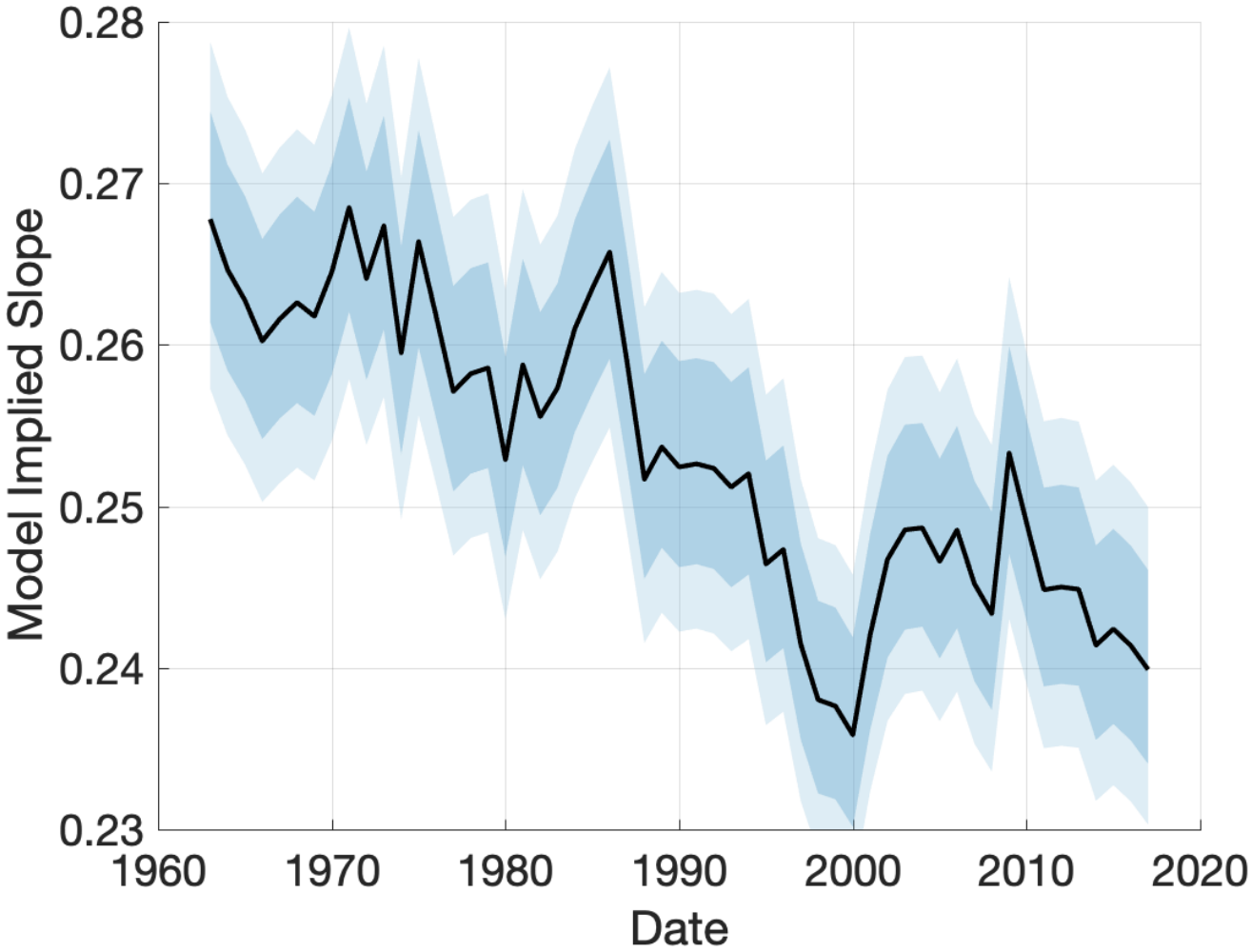


Figure: The shaded regions report point-wise 68% and 90% credible sets.

Mechanism and Importance of Network

- Main channel: Increase importance of more rigid sectors.

Increase in Aggregate Rigidity

- Network channel is important:
  1. Importance of sectors measured by centrality.
  2. Compositional changes in consumption shares capture only half of the flattening.

Increase in Agg Rigidity | What if no change in size?

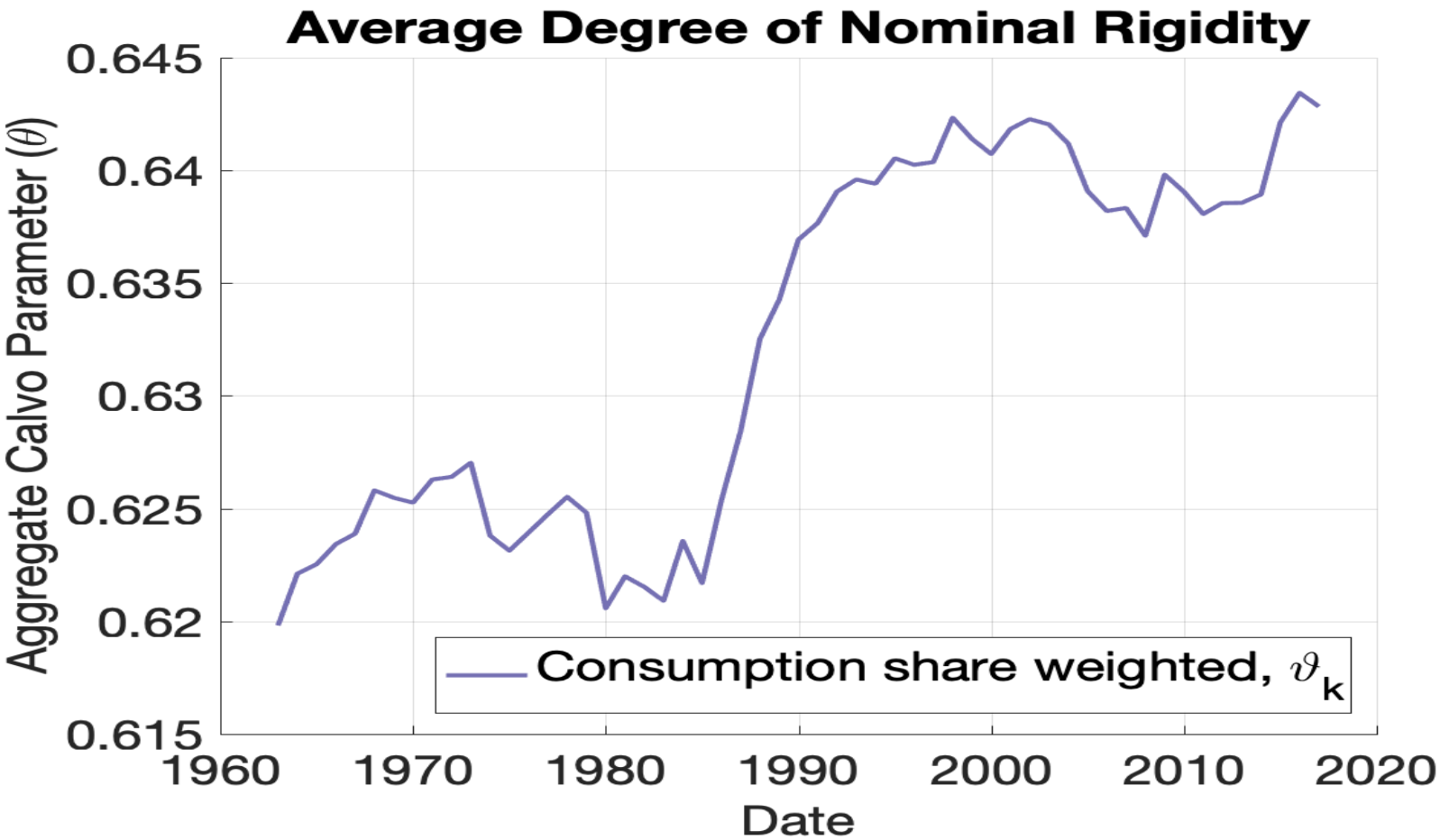
Conclusion

1. Do inflation dynamics depend on the network structure of the economy?
   - Yes, a NK model with production networks predicts
     - a generalized NK Phillips curve that depends on two network statistics,
     - the importance of sectors is measured by its (gross) output share.
2. Could a change in the U.S. production network account for the flattening of the Phillips curve?
   - Yes, structural transformation in the network structure can explain a flattening of about 15%.
   - Other dimension of production chains potentially also contribute: (i) global value chains (ii) rise in markups.

$\Rightarrow$ Accounting for production networks has important implications on inflation dynamics.

Appendix

Increase in Aggregate Degree of Rigidity



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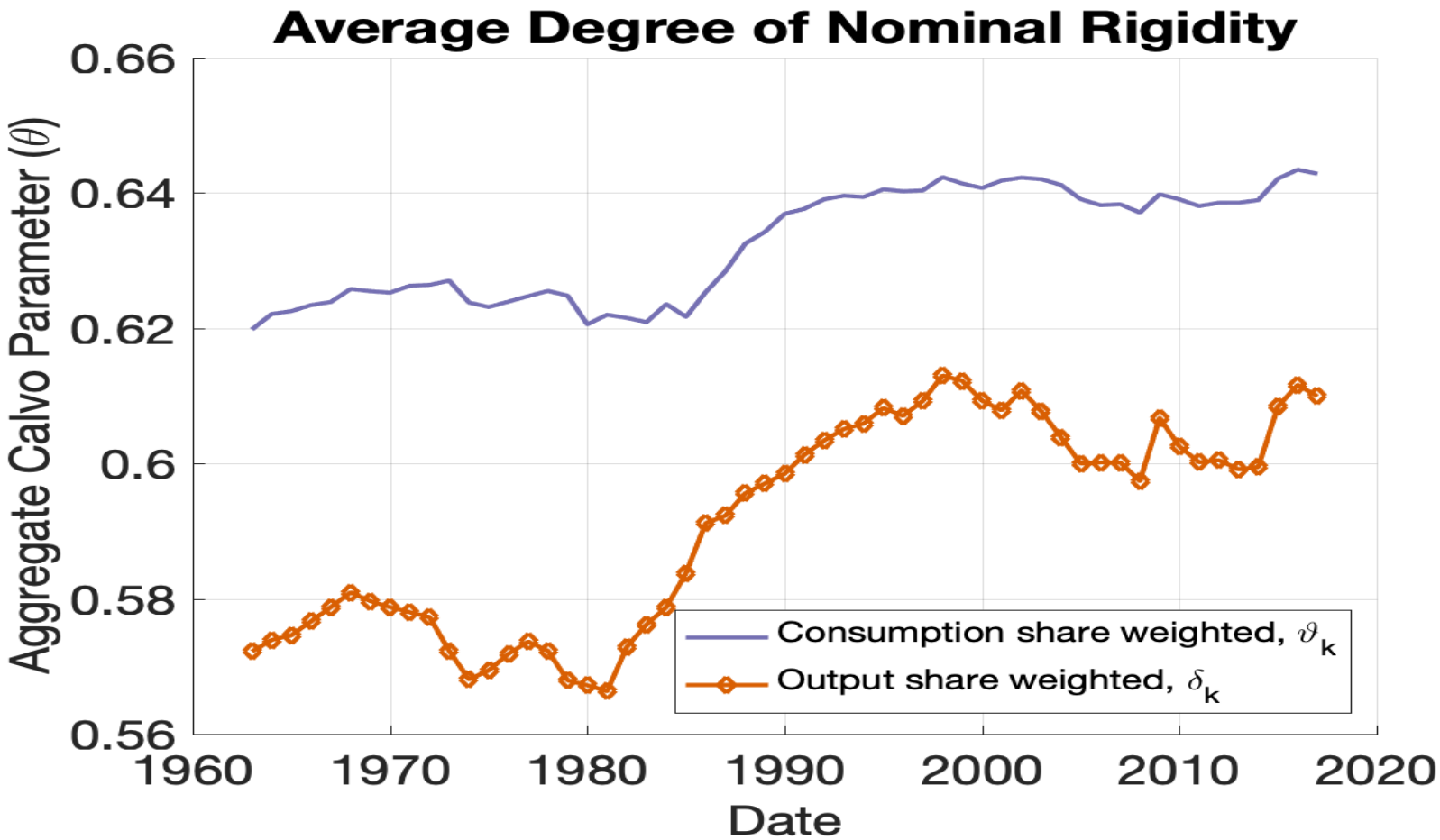
Larger Increase in centrality weighted Rigidity



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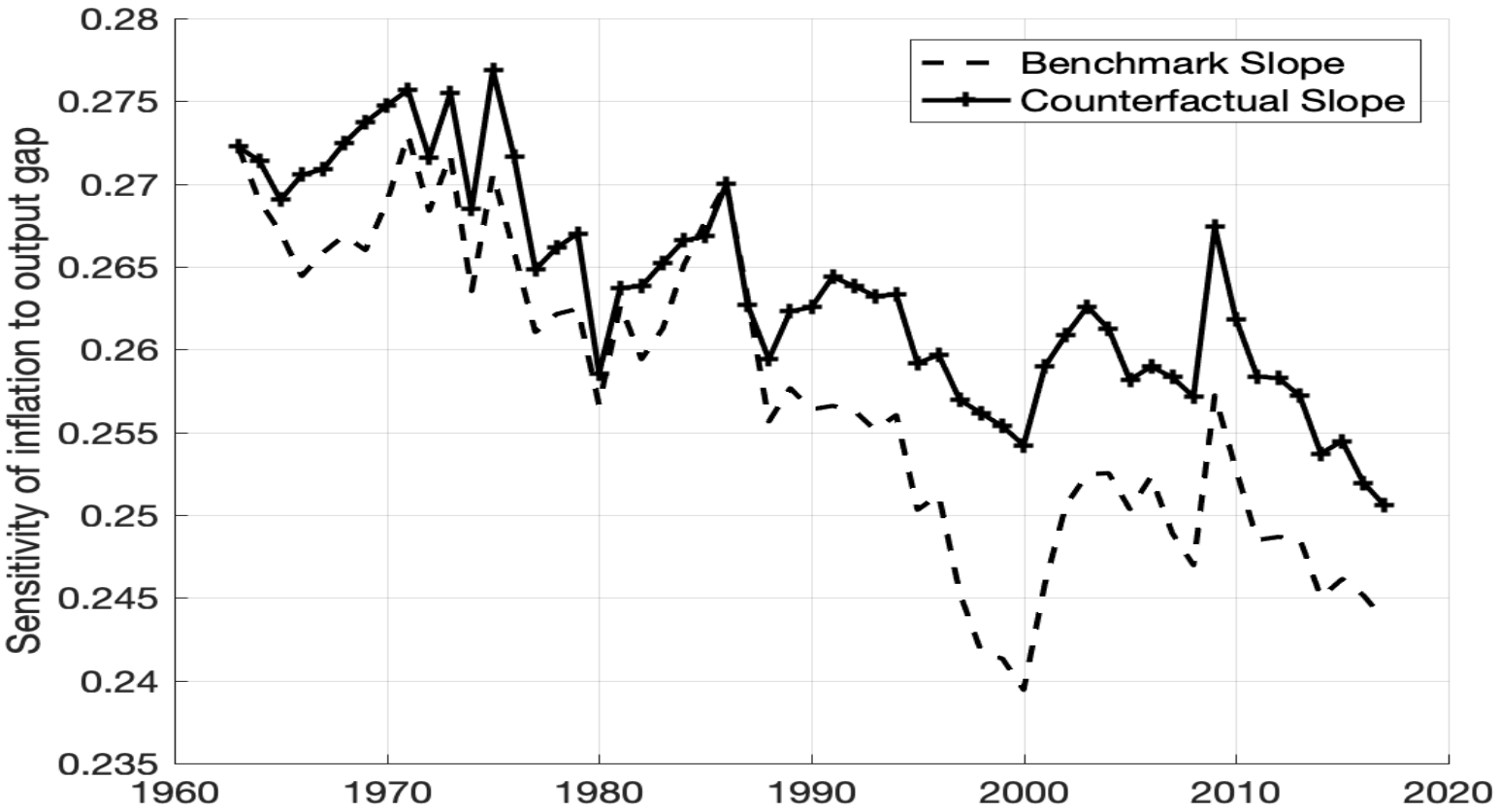
Channel: Role of Network

Counterfactual: No change in consumption shares from 1963



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