Optimal Monetary Policy in Production Networks

Jennifer La'O Alireza Tahbaz-Salehi

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Optimal Monetary Policy

- In the canonical NK model, it is optimal to stabilize the aggregate price level
- Why? price stability preserves productive efficiency and implements the first best
- "Divine Coincidence" Blanchard and Gali (2007)
  - price stability minimizes both inflation and the "output gap"
- target is straightforward in the model: aggregate price level = average price across firms

But the real world is much more complex.

- multiple, heterogeneous sectors that interact in a network of intermediate good trade
- in theory, how should the aggregate price level depend on:
  - whether sectors produce final goods or intermediate inputs?
  - heterogeneity in the price flexibility of sectors?
  - changes in the relative size of sectors? e.g. healthcare and services
- in policy debates: there are numerous measures of the price level; which is the most appropriate?
  - overall measures of consumer prices? e.g. CPI, HICP
  - consumer price indices that exclude food and energy categories? e.g. Core measures
  - measures of producer prices? e.g. PPI

This paper

How does the multi-sector, input-output structure of the economy

affect the optimal conduct of monetary policy?

Three Model Ingredients

1. multi-sector economy with heterogeneous production technologies
2. input-output network of intermediate good trade across sectors
3. sectoral heterogeneity in nominal rigidities

Main Results

- optimal policy stabilizes an optimal price index with greater weight on:
  - larger sectors as measured by Domar weights, i.e. sales shares of GDP
  - stickier sectors
  - more upstream sectors, sectors with stickier customers, sectors with more flexible suppliers
- quantitative illustration:
  - we calibrate the model to the US input-output tables + US data on price stickiness
  - we find modest welfare improvements from adopting the optimal policy
  - optimal price index: largest weights on service sectors, healthcare, and manufacturing

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Baseline Framework

The Environment

- static environment
- production: n sectors indexed by $i \in I \equiv \{1, \ldots, n\}$
  - continuum of identical firms within a sector, indexed by $k \in [0,1]$
  - firms produce differentiated goods $\rightarrow$ monopolistic competitors
  - firm managers make nominal pricing decision under incomplete info
- for every $i \in I$, perfectly-competitive sectoral CES aggregator firm
  - output may be either consumed or used as an intermediate good
- representative household
  - consumes sectoral goods, supplies labor

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Technology

- CRS Cobb-Douglas production function of firm k in sector i

$$y_{ik} = z_i \ell_{ik}^{\alpha_i} \prod_{j \in I} x_{ij,k}^{a_{ij}}$$

  - input-output matrix $A = [a_{ij}]$
  - vector of labor income shares $\alpha = (\alpha_1, \dots, \alpha_n)'$

- nominal profits

$$\pi_{ik} = (1 - \tau_i) p_{ik} y_{ik} - w \ell_{ik} - \sum_{j=1}^{n} p_j x_{ij,k}$$

Sectoral Aggregator firm

$$y_i = \left(\int_0^1 y_{ik}^{\frac{\theta_i - 1}{\theta_i}} dk \right)^{\frac{\theta_i}{\theta_i - 1}}$$

- perfectly competitive, takes prices as given
- nominal profits

$$\pi_i = p_i y_i - \int_0^1 p_{ik} y_{ik} dk$$

Household

- homothetic preferences

$$U(C) - V(L) = \frac{C^{1-\gamma}}{1-\gamma} - \frac{L^{1+1/\eta}}{1+1/\eta}$$

- Cobb-Douglas consumption basket

$$C = \mathcal{C}(c_1, \ldots, c_n) = \prod_{i \in I} (c_i/\beta_i)^{\beta_i}$$

- budget set

$$\sum_{i \in I} p_i c_i \leq wL + \sum_{i \in I} \int_0^1 \pi_{ik} dk + T$$

The Government and Market Clearing

- government has full commitment, balanced budget
- monetary authority controls aggregate nominal demand

$$m = PC = \sum_{i \in I} p_i c_i$$

- markets clear

$$y_j = c_j + \sum_{i \in I} \int x_{ij,k} dk \quad \forall j \in I, \qquad \text{and} \qquad L = \sum_{i \in I} \int \ell_{ik} dk$$

Nominal Rigidity = Informational Friction

- uncertainty over fundamentals: vector of sectoral productivity shocks

$$z = (z_1, \ldots, z_n)$$

- manager of firm k in sector i receives signal ω_{ik}

$$\omega_{ik} = \begin{cases} \emptyset & \text{with prob } 1 - \phi_i \\ z & \text{with prob } \phi_i \end{cases}$$

  - managers make their nominal pricing decision under incomplete info

- $\phi_i \in [0, 1]$ is the *degree of price flexibility* of industry i
  - $\phi_i = 1$ is full price flexibility
  - lower ϕ_i is greater price stickiness

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Nominal Rigidity and Market Clearing

1. Nature draws the aggregate state

$$s = (z, \omega) \in S$$

2. Firms make their nominal pricing decisions

$$p_{ik}(\omega_{ik})$$

   - nominal rigidity = measurability constraint on the nominal price

3. All other market outcomes, allocations adjust to the aggregate state

   - given prices, household chooses consumption
   - inputs must adjust so that supply = demand (but input mix chosen optimally)
   - monetary policy state-contingent, but sectoral taxes are non-state-contingent

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Flexible-Price Firm Optimality

- flexible-price firm: price equals mark-up over marginal cost

$$p_{ik}(s) = \left[(1-\tau_i)\,\frac{\theta_i - 1}{\theta_i}\right]^{-1} \mathrm{mc}_i(s)$$

- marginal cost solves cost minimization problem

$$\min w(s)\ell_{ik}(s) + \sum_{j=1}^{n} p_j(s) x_{ij,k}(s)$$

subject to the firm's technology

Sticky-Price Firm Optimality

- sticky-price firm: price equals mark-up over expected marginal cost

$$p_{ik}(\omega_{ik}) = \left[(1-\tau_i)\frac{\theta_i - 1}{\theta_i}\right]^{-1} \mathbb{E}_{ik}\left[v_{ik}(s)\mathrm{mc}_i(s)\right]$$

with appropriate risk weights $v_{ik}(s)$

The first best is unattainable as an equilibrium

Theorem

The first best efficient allocation cannot generically be implemented under sticky prices for any monetary policy.

- impossible for any monetary policy to simultaneously acheive:
  - productive efficiency within sectors (zero price dispersion within each sector)
  - efficient relative price movement across sectors

When can you implement the first best?

Proposition

If there is a single sticky-price industry i, then the first-best can be attained under sticky prices with a monetary policy that stabilizes the price of sector i.

- nests special cases:
  - canonical NK model
  - Aoki (2001): two-sector model with one flex-price sector, one sticky-price sector
  - Erceg, Henderson, Levin (1999): either wage flexibility or price flexibility
- but away from this *very* special case, what is optimal monetary policy?

To answer this,

consider Flexible-Price Allocations

Flexible-Price Allocations

- for a moment abstract from nominal rigidities:

$$\phi_i = 1, \qquad \forall i \in I$$

- all firms know the state perfectly when setting nominal prices

$$p_{ik}(s) = \left[(1-\tau_i) \frac{\theta_i - 1}{\theta_i} \right]^{-1} \mathrm{mc}_{ik}(s)$$

- under flexible prices, we have the typical production network model:
  - efficient economies: Long and Plosser (1983), Acemoglu et al (2012), Baqaee and Farhi (2019), ...
  - markups and misallocation: Jones (2013), Baqaee and Farhi (2020), Bigio and La'O (2020), ...

Domar Weights = sales shares

- set taxes such that

$$(1-\tau_i)\frac{\theta_i - 1}{\theta_i} = 1, \qquad \forall i \in I$$

- define the equilibrium Domar weight of sector i as:

$$\lambda_i \equiv \frac{p_i y_i}{PC}$$

  - Domar weights are equilibrium sales shares of GDP

Productivity Shocks in Production Networks

Theorem

(Hulten, 1978) To a first-order approximation, aggregate TFP satisfies

$$d\log TFP \approx \sum_{i\in N} \lambda_i d\log z_i$$

- λ_i: sufficient statistic for the first-order effect of a sectoral productivity shock on aggregate TFP
- with Cobb-Douglas technology, this is both exact and global:

$$\log TFP = \sum_{i\in N} \lambda_i \log z_i$$

- see Baqaee and Farhi (2019, 2020) for non-negligible second-order effects/when Hulten's theorem fails

Distortionary Shocks in Production Networks

- Consider now shocks to equilibrium markups (distortions)

$$\mu_i = (1 - \tau_i)\frac{\theta_i - 1}{\theta_i}$$

Theorem

(Bigio La'O, 2020) To a first-order around efficiency, the aggregate output gap satisfies

$$d\log C - d\log C^* \approx \sum_{i \in N} \lambda_i d\log \mu_i$$

- λ_i: sufficient statistic for the first-order effect of a sectoral distortion on the output gap

Full network model with sticky prices

Finally, consider the full model:

- input-output linkages

$$y_{ik} = z_i \ell_{ik}^{\alpha_i} \prod_{j \in I} x_{ij,k}^{a_{ij}}$$

- all sectors face some nominal rigidity

$$\phi_i \in (0,1), \qquad \forall i \in I$$

Our Main Result

Theorem

(La'O and Tahbaz-Salehi, 2022) The optimal monetary policy is a price index stabilization policy:

$$\sum_{i \in I} \psi_i^* \log p_i = 0 \qquad \textit{with} \qquad \sum_{i \in I} \psi_i^* = 1,$$

with optimal weights $(\psi_1^*, \ldots, \psi_n^*)$ that satisfy:

- ψ_i^* *is increasing in* λ_i *(Domar weight)*
- ψ_i^* *is decreasing in* ϕ_i *(price flexibility)*

Optimal Monetary Policy in Production Networks

- optimal monetary policy stabilizes an aggregate price index
- the optimal price index places greater weight on:
  - larger sectors as measured by their Domar weights
  - stickier sectors
  - also: more upstream sectors, sectors with stickier customers, sectors with more flexible suppliers

Why stickier sectors?

- recall that if only one sector is sticky, it is optimal to stabilize price of that one sector
- stickier sectors: greater potential for larger pricing errors and greater price dispersion
- principle of "sticky-price stabilization," first proposed by Goodfriend and King (1997)
- later formalized in multi-sector models without IO linkages: Erceg, Henderson, Levin (2000), Aoki (2001), Mankiw Reis (2003), Benigno (2004), Woodford (2010), Eusepi, Hobijn, Tambalotti (2011)

Why sectors with greater Domar weights?

- larger sectors: distortions have a greater effect on equilibrium output and welfare
- but "size" is measured not by consumption share, nor value added share, but instead by sales share!
- why? in a network model, the Domar weight is a sufficient statistic for:
  - the first-order effect of a sectoral productivity shock on aggregate TFP
  - the first-order effect of a sectoral distortion on the aggregate output gap
- Domar weight = sectoral "importance"
  - takes into account not just value added effects, but also equilibrium network effects

Conclusion and Policy Implications

- Optimal policy is a price index stabilization with greater weight on:
  - larger (in Domar weights) & stickier sectors
- Real world policy implications:
  - price index should place greater weight on services (because large and sticky)
  - less weight on oil, gas, energy (because these are fairly flexible)

Thank You!