Competition and the Phillips Curve

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Flattening of the Phillips curve

- Federal Reserve Vice Chair: Richard Clarida, on Sept. 26, 2019

  "Another key development in recent decades is that price inflation appears less responsive to resource slack. That is, the short-run price Phillips curve—if not the wage Phillips curve—appears to have flattened, implying a change in the dynamic relationship between inflation and employment"

- San Francisco Fed President: Mary Daly, on Aug. 29, 2019

  "As for the Phillips curve… most arguments today center around whether it's dead or just gravely ill. Either way, the relationship between unemployment and inflation has become very difficult to spot"

- New York Fed President: John Williams, on Feb. 22, 2019

  "The Phillips curve is the connective tissue between the Federal Reserve's dual mandate goals of maximum employment and price stability. Despite regular declarations of its demise, the Phillips curve has endured. It is useful, both as an empirical basis for forecasting and for monetary policy analysis"

Market concentration

- Covarrubias, Gutierrez and Philippon (2019)

  "After 2000, however, the evidence suggests inefficient concentration, decreasing competition and increasing barriers to entry, as leaders become more entrenched and concentration is associated with lower investment, higher prices and lower productivity growth"

- De Loecker, Eeckhout and Unger (2020)

  "In 1980, aggregate markups start to rise from 21% above marginal cost to 61% now. ... We also find an increase in the average profit rate from 1% to 8%. Although there is also an increase in overhead costs, the markup increase is in excess of overhead"

- Autor, Dorn, Katz, Patterson and Reenen (2020)

  "sales concentration is rising across a large set of industries. ... aggregate markups have been rising"

What we do

- Argue that market concentration affects the slope of the Phillips curve and the transmission of monetary policy
- Extend the New Keynesian model under CES monopolistic competition
  - Introduce entry and exit as in Bilbiie, Ghironi and Melitz (2008) and Bilbiie, Fujiwara and Ghironi (2014)
  - Replace CES by HSA (*Homothetic Single Aggregator*) demand system proposed by Matsuyama and Ushchev (2017, 2020a,b, 2022)
    - Robustness check with two alternative homothetic demand systems proposed by Matsuyama and Ushchev (2017, 2020a,b)

HSA

- HSA demand system is *flexible* and *tractable*
  - CES and Translog are special cases
  - HSA can accommodate
    - *Marshall's Second law* : the price elasticity of demand goes up with its price $\Rightarrow$ Concentration causes higher markup rate
    - *The Third law* (Matsuyama and Ushchev, 2022) : the speed of the price elasticity change slows down with its price $\Rightarrow$ Concentration causes lower pass-through rate
  - Its single aggregator summarizes all the impacts of market concentration on the price elasticity, the pass-through rate, and hence the flattening of the Phillips curve
  - The impact of concentration to the Phillips curve is summarized by two sufficient statistics, both functions of $z = p/A(\mathbf{p})$, the price divided by the single aggregator
    1. the price elasticity: $\zeta(z)$
    2. the pass-through rate: $\rho(z)$

Key takeaways

- *Steady-state effect* of concentration
  - Gross substitutes: $s(z) \Uparrow \Leftrightarrow z \Downarrow$
  - Under Rotemberg pricing, *the Second law* $\Rightarrow$ lower price elasticity $\Rightarrow$ higher markup rate $\Rightarrow$ *structurally* flattening the Phillips curve
  - Under Calvo pricing, *the Third law* $\Rightarrow$ lower pass-through rate $\Rightarrow$ *structurally* flattening the Phillips curve
- *Dynamic effect* of endogenous entry
  - Concentration affects price setting dynamically through strategic complementarity - endogenous cost-push shock
    - The supply side effects of monetary policy through the entry of firms
  - Pass-through rate plays an important role in cyclicality of markup
- *Observational* implications of concentration and endogenous cost-push shock under *the Second law*
  - A *naive* regression of the inflation rate on the real marginal cost $\Rightarrow$ the *negative* omitted variable bias (OVB): underestimating the slope
  - Under Rotemberg, *the Third law* matters for the *magnitude*
  - Under Calvo, both *Second and Third laws* matter for the *magnitude*

NKPC under HSA

- Concentration: $s(z) \Uparrow \Leftrightarrow z \Downarrow$
  - The Second law: $\zeta'(z) > 0$
  - The Third law: $\rho'(z) > 0$
- Rotemberg pricing

$$\hat{\pi}_t = \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} + \overbrace{\frac{\zeta(z)-1}{\chi}}^{\text{steady-state effect}}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \overbrace{\frac{1}{\chi}\frac{1-\rho(z)}{\rho(z)}\hat{N}_t}^{\text{dynamic effect}}$$

- Calvo pricing: $\tilde{z}$ is the average of z

$$\begin{aligned}\hat{\pi}_{t+1} \quad &= \quad \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} + \overbrace{\frac{(1-\phi)\left[1-\phi\beta(1-\delta)\right]}{\phi}\rho(\tilde{z})}^{\text{steady-state effect}}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{\tilde{p}}_t\right) \\ &\quad - \overbrace{\frac{(1-\phi)\left[1-\phi\beta(1-\delta)\right]}{\phi}\frac{1-\rho(\tilde{z})}{\zeta(\tilde{z})-1}\hat{N}_t}^{\text{dynamic effect}}\end{aligned}$$

Related literature

- Flattening of the Phillips curve

  Mis-measurement (Goolsbee and Klenow, 2018; Crump et al., 2019); Labor market (Daly and Hobijn, 2014); Policy regime (McLeay and Tenreyro, 2019; L'Huillier et al., 2022); Inflation expectation (Coibion and Gorodnichenko, 2015; Hazell et al., 2022); Structural (Sbordone, 2010; Wang and Werning, 2022; Del Negro et al., 2020; Baqaee et al., 2021; L'Huillier et al., 2022; Harding et al., 2022; Rubbo, 2022)

- Competition and monetary policy (more on the next page)

  Wang and Werning (2022), Baqaee, Farhi and Sangani (2021)

- Business cycle model with entry and exit under monopolistic competition

  Bilbiie, Ghironi and Melitz (2012, 2019), Bilbiie, Ghironi and Melitz (2008), Bilbiie, Fujiwara and Ghironi (2014), Bilbiie (2021)

- Equivalence/nonequivalence between Rotemberg and Calvo

  Roberts (1995), Nistico (2007), Lombardo and Vestin (2008), Ascari and Rossi (2012)

- HSA

  Matsuyama and Ushchev (2017, 2020a,b, 2022, 2023), Kasahara and Sugita (2020), Grossman, Helpman and Lhuillier (2021), Baqaee, Farhi and Sangani (2023)

Competition and monetary policy

- CES New Keynesian model, irrespective of entry and exit
    - Competition is irrelevant to the Phillips curve
- Wang and Werning (2022)
    - In an oligopoly model with the strategic interaction
        - $\Uparrow$ concentration $\Rightarrow$ the Phillips curve with inflation persistence + endogenous cost-push shock
- Baqaee, Farhi and Sangani (2021)
    - $\Uparrow$ concentration $\Rightarrow$ $\Downarrow$ slope of the Phillips curve + endogenous cost-push shock
    - The supply side effects of monetary policy through the misallocation channel

	comp.	entry	pref.	nominal friction
Wang and Werning (2022)	oligo.	exo.	CES / Kimball	Calvo
Baqaee et al. (2021)	mono.	exo.	Kimball	Calvo
our paper	mono.	end.	HSA	Rotemberg / Calvo

- Simple to endogenize entry under HSA; difficult under Kimball

Structure of presentation

HSA

- A continuum of varieties ($\omega \in \Omega$), gross substitutes and symmetry

- Market share of $\omega = \frac{p_t(\omega)c_t(\omega)}{P(\mathbf{p}_t)C_t} = s\left(\frac{p_t(\omega)}{A(\mathbf{p}_t)}\right)$ where $\int_{\Omega_t} s\left(\frac{p_t(\omega)}{A(\mathbf{p}_t)}\right) \mathrm{d}\omega \equiv 1$
  - Gross substitutes $\Rightarrow s(z)$ is decreasing in z
  - $A(\mathbf{p}_t)$ implicitly defined by the adding-up constraint: $\int_{\Omega_t} s\left(\frac{p_t(\omega)}{A(\mathbf{p}_t)}\right) \mathrm{d}\omega \equiv 1$

- $A(\mathbf{p}_t) \neq \text{constant} \times P(\mathbf{p}_t)$
  - $A(\mathbf{p}_t)$: *single aggregator*, the inverse measure of *competitive pressures*, fully captures cross price effects in the demand system
  - $P(\mathbf{p}_t)$: theoretical price index, the inverse measure of TFP, captures the *productivity consequences* of price changes

P vs A

CES as a special case of HSA: $s\left(\frac{p_t(\omega)}{A_t}\right) = \gamma_{CES}\left(\frac{p_t(\omega)}{A_t}\right)^{1-\theta}, \theta > 1$

- Production function

$$C_t = Z_C \left[\int_{\Omega_t} c_t(\omega)^{1-\frac{1}{\theta}} \, \mathrm{d}\omega\right]^{\frac{\theta}{\theta-1}}$$

- Hicksian demand function

$$c_t(\omega) = Z_C^{\theta-1}\left(\frac{p_t(\omega)}{P_t}\right)^{-\theta} C_t$$

- The market share function

$$s\left(\frac{p_t(\omega)}{A_t}\right) = \gamma_{CES}\left(\frac{p_t(\omega)}{A_t}\right)^{1-\theta} = \frac{p_t(\omega)\, c_t(\omega)}{P_t C_t} = Z_C^{\theta-1}\left(\frac{p_t(\omega)}{P_t}\right)^{1-\theta}$$

  - $P_t = \text{constant} \times A_t$, *iff* CES, proved by Matsuyama and Ushchev (2017)

Three price indices

- P_t: the final goods price (CPI), which captures the productivity effects of entry – the reference price for consumers

$$\int_{\Omega_t} \frac{p_t(\omega) c_t(\omega)}{P_t C_t} \mathrm{d}\omega \equiv 1$$

- A_t: the single price aggregator, which captures the competitive effects of entry – the reference price for firms

$$\int_{\Omega_t} s\left(\frac{p_t(\omega)}{A_t}\right) \mathrm{d}\omega \equiv 1$$

- p_t: the average price index (PPI) – the measured price index (without entry effects)

$$p_t = \int_{\Omega_t} s\left(\frac{p_t(\omega)}{A_t}\right) p_t(\omega)\, \mathrm{d}\omega$$

Model

- Bilbiie, Ghironi and Melitz (2008) and Bilbiie, Fujiwara and Ghironi (2014) under HSA
  - 4 agents
    1. Consumer
    2. Intermediate goods producer
    3. Final goods producer
    4. Central bank
  - Symmetric equilibrium under *monopolistic competition*
  - Rotemberg price adjustment cost – Calvo pricing in Section 7
  - Endogenous entry but exogenous exit

Timing

- In every period, there is an unbounded mass of prospective entrants
- One-period time-to-build lag: entrants at time t only start producing at time $t+1$
- Exogenous destruction: all firms are subject to identical probability δ of exogenous firm destruction at the end of each period, after production and entry
  - A proportion δ of new entrants will never produce

Consumer

- A representative household maximizes

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(u\left(C_t\right) - v\left(L_t\right) \right)$$

subject to the budget constraint

$$\frac{B_{t+1}}{P_t} + x_{t+1} \int_{\Omega_t + \Omega_{E,t}} \frac{V_t\left(\omega\right)}{P_t} \mathrm{d}\omega + C_t = \frac{\left(1 + i_{t-1}\right) B_t}{P_t} + x_t \int_{\Omega_t} \frac{D_t\left(\omega\right) + V_t\left(\omega\right)}{P_t} \mathrm{d}\omega + \frac{W_t}{P_t} L_t$$

- The final good is produced with intermediate inputs under HSA technology, which leads to the HSA demand for intermediate inputs

MC intermediate inputs producers

- Intermediate inputs producer ω maximizes the value of the firm

$$\frac{V_t(\omega)}{P_t} = \mathbb{E}_0 \sum_{t=0}^{\infty} m_{t,t+1} \left(\frac{D_{t+1}(\omega)}{P_{t+1}} \right)$$

subject to the profit

$$\frac{D_t(\omega)}{P_t} = \frac{p_t(\omega)}{P_t} y_t(\omega) - \frac{W_t}{P_t} l_t(\omega) - \frac{\chi}{2} \left(\frac{p_t(\omega)}{p_{t-1}(\omega)} - 1 \right)^2 \frac{p_t(\omega)}{P_t} y_t(\omega)$$

the linear production technology

$$y_t(\omega) = Z_{P,t} l_t(\omega)$$

the HSA demand curve

$$y_t(\omega) = c_t(\omega) = s\left(\frac{p_t(\omega)}{A_t} \right) \frac{P_t C_t}{p_t(\omega)}$$

Central bank

- A simple feedback rule

$$(1+i_t) = (1+i_{t-1})^{\alpha_i} \left(\frac{p_t}{p_{t-1}} - 1 \right)^{(1-\alpha_i)\alpha_\pi} u_t$$

Aggregate conditions

- Free entry condition

$$\frac{W_t}{P_t}\frac{f_{E,t}}{Z_{E,t}} = \frac{V_t}{P_t}$$

- Labor market clearing

$$L_t = N_t l_t + N_{E,t}\frac{f_{E,t}}{Z_{E,t}}$$

- Firm dynamics

$$N_t = (1-\delta)(N_{t-1} + N_{E,t-1}) = (1-\delta) N_{H,t-1}$$

- Aggregate accounting

$$\frac{V_t}{P_t}N_{E,t} + C_t = \frac{D_t}{P_t}N_t + \frac{W_t}{P_t}L_t$$

- Adding up constraint

$$s\left(\frac{p_t}{A_t}\right) = s(z_t) = \frac{1}{N_t}$$

- Final goods price

$$\ln\left(\frac{P_t}{A_t}\right) = \ln\left(\frac{z_t}{\bar{p}_t}\right) = \bar{K} - \frac{1}{s(z_t)}\left[\int_{z_t}^{\bar{z}} \frac{s(\xi)}{\xi} d\xi\right]$$

where

$$z_t := \frac{p_t}{A_t},\ \bar{p}_t := \frac{p_t}{P_t}$$

Equilibrium

- An *equilibrium* in this economy is
  - a collection of sequence of aggregate prices $\{P_t, A_t, W_t, i_t\}$ and the price of intermediate goods $\{p_t\}$
  - a collection of sequences of aggregate quantities $\{Y_t, C_t, L_t\}$ and quantities of intermediate goods $\{y_t, l_t\}$
  - a collection of sequences of firm-value functions and profit $\{V_t, D_t\}$ together with measures of operating firms and entering firms $\{N_t, N_{E,t}\}$
- These equilibrium objects satisfy the following conditions
  - households maximize their utility subject to their budget constraints
  - intermediate-good firms maximize the net present value of their per-period profits
  - final-good firms maximize profits
  - all of the feasibility constraints are satisfied

Preference and detrending

- Preference

$$u\left(C_t\right) := \frac{C_t^{1-\sigma}-1}{1-\sigma},\ v(L_t) := \frac{L_t^{1+\psi}}{1+\psi}$$

- Nominal variables are detrended

$$w_t := \frac{W_t}{P_t}, d_t := \frac{D_t}{P_t}, v_t := \frac{V_t}{P_t}, z_t := \frac{p_t}{A_t}, \bar{p}_t := \frac{p_t}{P_t}, \pi_t := \frac{p_t}{p_{t-1}}$$

System of equations

1. Taylor rule

$$(1+i_t) = \left(1+i_{t-1}\right)^{\alpha_i} (\pi_t - 1)^{(1-\alpha_i)\alpha\pi} u_t$$

2. Euler equation for bonds

$$C_t^{-\sigma} = \beta \mathbb{E}_t C_{t+1}^{-\sigma} \frac{1+i_t}{\pi_{t+1}} \frac{\bar{p}_{t+1}}{\bar{p}_t}$$

3. New Keynesian Phillips curve (hereafter, NKPC)

$$\left[1 - \frac{\chi}{2}(\pi_t - 1)^2\right] \frac{s'(z_t) z_t}{s(z_t)} + \left[1 - \frac{s'(z_t) z_t}{s(z_t)}\right] \frac{L_t^{\psi} C_t^{\sigma}}{Z_{P,t}\bar{p}_t} - \chi(\pi_t - 1)\pi_t + \beta(1-\delta)\mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \chi\left(\pi_{t+1} - 1\right)\pi_{t+1}^2 \frac{s\left(z_{t+1}\right)}{s(z_t)} \frac{\bar{p}_t}{\bar{p}_{t+1}} \frac{A_{t+1}}{A_{t+1}} \frac{Y_{t+1}}{Y_t} = 0$$

4. Euler equation for equity

$$L_t^{\psi} C_t^{\sigma} \frac{f_{E,t}}{Z_{E,t}} = \beta(1-\delta)\mathbb{E}_t \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \left\{ \left[1 - \frac{L_{t+1}^{\psi} C_{t+1}^{\sigma}}{Z_{P,t+1}\bar{p}_{t+1}} - \frac{\chi}{2}\left(\pi_{t+1} - 1\right)^2\right] s\left(z_{t+1}\right) Y_{t+1} + L_{t+1}^{\psi} C_{t+1}^{\sigma} \frac{f_{E,t+1}}{Z_{E,t+1}} \right\}$$

5. Firm dynamics

$$\frac{1}{s(z_t)} = (1-\delta)\left[\frac{1}{s\left(z_{t-1}\right)} + \frac{Z_{E,t-1}}{f_{E,t-1}}\left(L_{t-1} - \frac{Y_{t-1}}{\bar{p}_{t-1} Z_{t-1}}\right)\right]$$

6. P_t / A_t

$$\ln\left(\frac{P_t}{A_t}\right) = \ln\left(\frac{z_t}{\bar{p}_t}\right) = \bar{K} - \frac{1}{s(z_t)}\left[\int_{z_t}^{\bar{z}} \frac{s(\xi)}{\xi} d\xi\right]$$

7. Resource constraint

$$C_t = \left[1 - \frac{\chi}{2}(\pi_t - 1)^2\right] Y_t$$

Steady state

1. Taylor rule
$$\pi = 1$$
2. Euler equation for bonds
$$i = \frac{1-\beta}{\beta}$$
3. NKPC
$$L^{\psi} Y^{\sigma} = \frac{\bar{p}}{1 - \frac{s(z)}{s'(z)z}} Z_P$$
4. Euler equation for equity
$$L = \frac{1}{1-\delta} \frac{f_E}{Z_E} \left[\delta - \frac{1-\beta(1-\delta)}{\beta} \frac{s'(z)z}{s(z)} \right] \frac{1}{s(z)}$$
5. Firm dynamics
$$Y = -\frac{1-\beta(1-\delta)}{\beta(1-\delta)} Z_P \frac{f_E}{Z_E} \frac{\frac{s'(z)z}{s(z)} \frac{z}{s(z)}}{\exp\left(\bar{K} - \frac{\int_z^{\bar{z}} \frac{s(\xi)}{\xi} d\xi}{s(z)} \right)}$$
6. P/A
$$\frac{P}{A} = \frac{z}{\bar{p}} = \exp\left(\bar{K} - \frac{\int_z^{\bar{z}} \frac{s(\xi)}{\xi} d\xi}{s(z)} \right)$$

Linearized system of equations

1. Taylor rule

$$i_t = \alpha_i i_{t-1} + (1-\alpha_i)\,\alpha_\pi \hat{\pi}_t + u_t$$

2. Euler equation for bonds

$$\hat{Y}_t = \mathbb{E}_t \hat{Y}_{t+1} - \frac{1}{\sigma}\left[i_t - \left(\hat{p}_t - \mathbb{E}_t \hat{p}_{t+1}\right) - \mathbb{E}_t \hat{\pi}_{t+1}\right]$$

3. NKPC

$$\hat{\pi}_t = \frac{1}{\chi}\left[-\frac{s'(z)\,z}{s(z)}\right]\left(\psi \hat{L}_t + \sigma \hat{Y}_t - \hat{Z}_{P,t} - \hat{p}_t\right) + \frac{1}{\chi}\left[\frac{s'(z)\,z}{s(z)} - \frac{\frac{s''(z)z}{s'(z)}}{1-\frac{s(z)}{s'(z)z}}\right]\hat{z}_t + \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1}$$

4. Euler equation for equity

$$\begin{aligned}\psi \hat{L}_t \quad = \quad & \left\{[1-\beta(1-\delta)]\frac{s'(z)\,z}{s(z)} + \beta(1-\delta)\right\}\psi \mathbb{E}_t \hat{L}_{t+1} + [1-\beta(1-\delta)]\left[\sigma \frac{s'(z)\,z}{s(z)} + (1-\sigma)\right]\mathbb{E}_t \hat{Y}_{t+1} \\ & -\left(\hat{f}_{E,t} - \hat{Z}_{E,t}\right) + \beta(1-\delta)\,\mathbb{E}_t\left(\hat{f}_{E,t+1} - \hat{Z}_{E,t+1}\right) - [1-\beta(1-\delta)]\frac{s'(z)\,z}{s(z)}\mathbb{E}_t \hat{Z}_{P,t+1}\end{aligned}$$

5. Firm dynamics

$$\hat{z}_t = (1-\delta)\,\hat{z}_{t-1} - \left\{\left[\delta \frac{s(z)}{s'(z)\,z} - \frac{1-\beta(1-\delta)}{\beta}\right]\hat{L}_t - \hat{Y}_t + \hat{p}_t + \hat{Z}_{P,t}\right\} + \delta \frac{s(z)}{s'(z)\,z}\left(\hat{f}_{E,t} - \hat{Z}_{E,t}\right)$$

6. $\hat{P}_t - \hat{A}_t$

$$\hat{P}_t - \hat{A}_t = \hat{z}_t - \hat{p}_t = \left[1 + \frac{\int_z^{\bar{z}} \frac{s(\xi)}{\xi}\,d\xi}{s(z)}\,\frac{s'(z)\,z}{s(z)}\right]\hat{z}_t$$

NKPC under HSA

- How does market concentration affect the slope of the Phillips curve?
- How does the entry cost f_E affect the number of firms N in the steady state, and then the slope of NKPC?

$$
\begin{aligned}
\hat{\pi}_t &= \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} + \frac{1}{\chi}\left[-\frac{s'(z)z}{s(z)}\right]\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) + \frac{1}{\chi}\left[\frac{s'(z)z}{s(z)} - \frac{\frac{s''(z)z}{s'(z)}}{1-\frac{s(z)}{s'(z)z}}\right]\left[-\frac{s'(z)z}{s(z)}\right]\hat{z}_t \\
&= \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} + \overbrace{\frac{\zeta(z)-1}{\chi}}^{\text{steady-state effect}}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \overbrace{\frac{1}{\chi}\frac{1-\rho(z)}{\rho(z)}\hat{N}_t}^{\text{dynamic effect}}
\end{aligned}
$$

- Price elasticity: $\zeta(z) := -\frac{\partial \ln(c_t(\omega))}{\partial \ln(p_t)} = 1 - \frac{s'(z)z}{s(z)} > 1$
  - Markup rate under flexible price: $\mu^f(z) = \zeta(z)/(\zeta(z)-1)$
- Pass-through rate under flexible price: $\rho(z) := \frac{\partial \ln(p_t)}{\partial \ln(W_t/Z_{P,t})} = \left[1 - \frac{d\ln\left(\frac{\zeta(z)}{\zeta(z)-1}\right)}{d\ln(z)}\right]^{-1}$
  - The role of pass-through rate in NKPC: Baqaee et al. (2021), Auclert et al. (2022) Super-elasticity

NKPC under CES

- Under CES

$$s(z) = \gamma_{CES} z^{1-\theta}$$

- No effect from competition – the entry cost $f_{E,t}$ – on parameters in NKPC

$$\hat{\pi}_t = \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} + \frac{\theta-1}{\chi}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right)$$

- Due to constant price elasticity under CES
  - no effect to the slope of the Phillips curve
  - no dynamic effect of endogenous entry

Implications of the Second law $\zeta'(z) > 0$

$$\hat{\pi}_t = \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} + \overbrace{\frac{\zeta(z)-1}{\chi}}^{\text{steady-state effect}}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \overbrace{\frac{1}{\chi}\frac{1-\rho(z)}{\rho(z)}\hat{N}_t}^{\text{dynamic effect}}$$

1. Steady-state effect of concentration - flattening of the Phillips curve
   - More concentration $\Leftrightarrow$ higher market share: $s(z) \Uparrow \Leftrightarrow z \Downarrow$
   - $\zeta'(z) > 0 \Rightarrow \zeta(z) \Downarrow$, flattening of the Phillips curve
2. Dynamic effect of endogenous entry - endogenous cost-push shock

$$\hat{\mu}_t^f = -\frac{1-\rho(z)}{\rho(z)}\hat{z}_t = -\frac{1-\rho(z)}{\rho(z)}\left(\hat{p}_t - \hat{A}_t\right)$$

   - $\zeta'(z) > 0 \Leftrightarrow$ incomplete pass-through: $\rho(z) < 1 \Leftrightarrow$ *strategic complementarity*
     - The firm reduces its price and markup rate in response to more competitive pressure, a lower A_t, when other firms reduce their prices
     - If $\hat{\mu}_t^f = -\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right)$ and $\hat{N}_t$ move to the opposite directions to a structural shock, its impact on inflation is muted

Flexible price by entry Output gap

Supply side effects of monetary policy

- Dynamic effect of endogenous entry $\Rightarrow$ the supply side effects of monetary policy
- Misallocation across heterogenous firms in Baqaee, Farhi and Sangani (2021)
  - Monetary easing $\Rightarrow$ production shifts to more efficient firms $\Uparrow$ $\Rightarrow$ aggregate TFP $\Uparrow$ $\Rightarrow$ inflation-stimulating effect $\Downarrow$
- Entry of firms in our model
  - Monetary easing $\Rightarrow$ number of firms $\Uparrow$ $\Rightarrow$ markup rate via the Second law $\Downarrow$ $\Rightarrow$ inflation-stimulating effect $\Downarrow$

HDIA and HIIA

- Matsuyama and Ushchev (2017) characterize three classes of homothetic demand systems
  1. HSA
  2. HDIA (Homothetic with Direct Implicit Additivity): Without endogenous entry, this would be equivalent to Kimball (1995)

$$\int_{\Omega_t} \varphi\left(\frac{y_t(\omega)}{Y_t(\mathbf{y}_t)}\right) d\omega = 1$$

$$y_t(\omega) = \varphi'^{-1}\left(\frac{p_t(\omega)}{A_{\text{HDIA}}(\mathbf{p}_t)}\right) Y_t(\mathbf{y}_t)$$

  3. HIIA (Homothetic with Indirect Implicit Additivity)

$$\int_{\Omega_t} \vartheta\left(\frac{p_t(\omega)}{P(\mathbf{p}_t)}\right) d\omega = 1$$

$$y_t(\omega) = -\vartheta'^{-1}\left(\frac{p_t(\omega)}{P(\mathbf{p}_t)}\right) B_{\text{HIIA}}(\mathbf{y}_t)$$

NKPC under HSA, HDIA and HIIA

- The same implications on NKPC can be derived by appropriately re-defining z_t

$$\hat{\pi}_t = \beta (1-\delta) \hat{\pi}_{t+1} + \frac{\zeta (z) - 1}{\chi} \left[\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t \right) - \frac{1 - \rho (z)}{\rho (z)} \hat{z}_t \right]$$

  - Under HSA
$$z_t = \frac{p_t}{A_t}$$
  - Under HDIA
$$z_t = \frac{p_t}{A_{\text{HDIA},t}}$$
  - Under HIIA
$$z_t = \frac{p_t}{P_t}$$

- GE implications, such as entry, productivity, and welfare, can be very different across the three classes

Cyclicality of markup to the technology shock

	Flexible price	Sticky price
CES	constant	procyclical
The Second law	countercyclical	procyclical / countercyclical

- In a flexible price equilibrium under CES, constant
- In a sticky price equilibrium under CES, procyclical
  - The marginal cost decreases but the price does not change
- In a flexible price equilibrium under the Second law, countercyclical
  - A positive technology shock increases the number of firms, which causes the markup rate to decline
- In a sticky price equilibrium under the Second law, generally ambiguous and depends on the tension between nominal rigidities and the pass-through rate

$$\hat{\mu}_t = \frac{1}{\zeta(z) - 1}\{\overbrace{\chi\left[\beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} - \pi_t\right]}^{\text{nominal rigidity}} - \overbrace{\frac{1-\rho(z)}{\rho(z)}}^{\text{pass-through}}\hat{N}_t\}$$

- Disagreement about the cyclicality of the markup in the literature as surveyed by Nekarda and Ramey (2020)

Parametric families of HSA

	Share	Price elasticity	Pass-through
CES	$s(z) = \gamma_{CES} z^{1-\theta}$	$\zeta(z) = \theta$	$\rho(z) = 1$
Translog	$s(z) = \gamma_{TL} \ln\left(\frac{\bar{z}}{z}\right)$	$\zeta(z) = 1 + \frac{1}{\ln\left(\frac{\bar{z}}{z}\right)}$	$\rho(z) = \frac{1+\ln\left(\frac{\bar{z}}{z}\right)}{2+\ln\left(\frac{\bar{z}}{z}\right)}$
Co-PaTh	$s(z) = \gamma_{CP} \theta^{\frac{\rho}{1-\rho}} \left[1 - \left(\frac{z}{\bar{z}}\right)^{\frac{1-\rho}{\rho}}\right]^{\frac{\rho}{1-\rho}}$	$\zeta(z) = \frac{1}{1-\left(\frac{z}{\bar{z}}\right)^{\frac{1-\rho}{\rho}}}$	$\rho(z) = \rho < 1$

- $\bar{z} := \inf\{z > 0 | s(z) = 0\}$: if $\bar{z} < \infty$, $\bar{z} A_t$ is the choke price

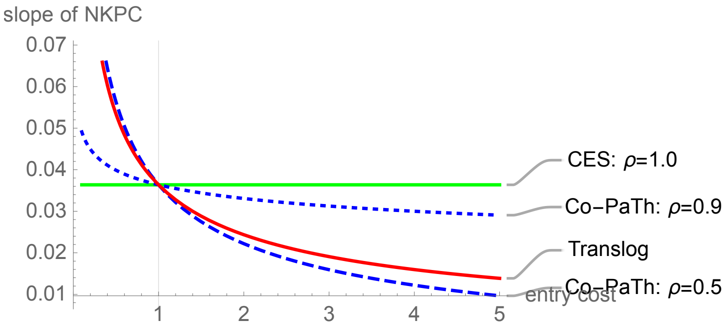
$$\bar{z} = \left(\frac{\theta}{\theta - 1}\right)^{\frac{\rho}{1-\rho}}$$

Calibration

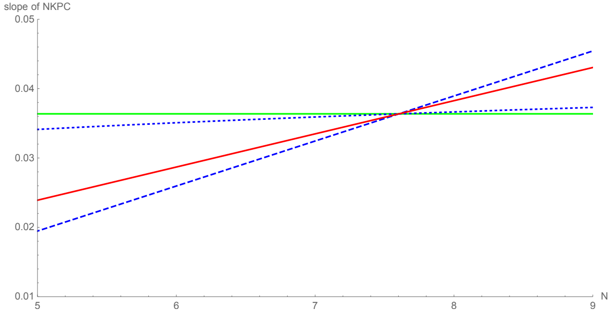
parameter	definition	value
β	subjective discount factor	0.99
σ	relative risk aversion	1
δ	exit rate	0.025
ψ	inverse of labor supply elasticity	1
f_E, Z_E, Z_P	technologies	1
θ	price elasticity under CES	3.8
χ	Rotemberg adj. cost	77
α_i	policy inertia	0.9
α_π	policy reaction to π	1.1 or ∞
ρ	pass-through rate	1, 0.9 or 0.5

- Most are taken from Bilbiie, Fujiwara and Ghironi (2014)
- $\bar{K} = 1/(\theta - 1) \Leftrightarrow Z_C = \gamma_{CES}^{1/(\theta-1)} \Leftrightarrow P_t = A_t$ under CES
- γ_{TL} and γ_{CP} are calibrated so that $\zeta(z) = \theta$ when $f_E = 1$

Entry cost and the slope of NKPC (Fig. 2)



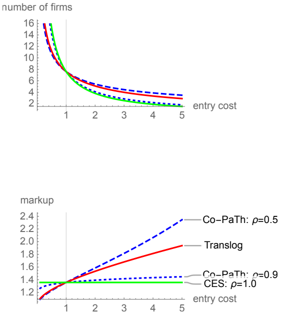
Concentration and the slope of NKPC (Fig. 2)



- The slope of NKPC: $\frac{\zeta(z)-1}{\chi}$, where $\frac{dz}{dN} > 0$,
- The Second law

$$\zeta'(z) > 0, \quad \frac{d \ln\left(\frac{\zeta(z)}{\zeta(z)-1}\right)}{d \ln(z)} = 1 - \frac{1}{\rho(z)} < 0$$

SS with varying entry cost (Fig. 1)

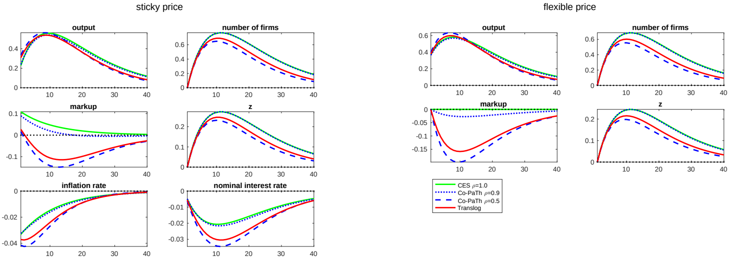


- Increasing barriers to entry: higher entry cost
  - Market concentration: fewer number of firms
    - More concentration $\Leftrightarrow$ high market share (concentration), $s(z) \Uparrow \Leftrightarrow z \Downarrow$
    - The Second law: $\zeta'(z) > 0 \Rightarrow \zeta(z) \Downarrow$
  - Higher markup, $\mu(z) = \frac{\zeta(z)}{\zeta(z)-1} \Uparrow$: higher profit

Impulse responses

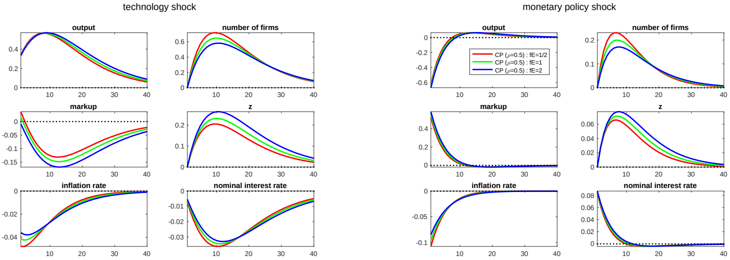
- Two shocks
  1. Technology shock: $Z_{P,t}$, $Z_{E,t}$
  2. Monetary policy shock: u_t
- Two scenarios
  1. Around the same steady state markup
  2. Around the different market concentration reflecting difference in the entry cost
     - Two countries
     - Two regulatory regimes

Technology shock by pass-through rate (Fig. 3)



- Under both sticky and flexible prices
  - Higher return $\Rightarrow C_t = Y_t \Uparrow$ and $N_{E,t} \Uparrow$ for intertemporal smoothing, but gradual increase in $N_t \Rightarrow z_t \Uparrow \Rightarrow y_t \Downarrow \Rightarrow d_t \Downarrow$
  - Smaller pass-through $\Rightarrow$ lower markup $\Rightarrow$ lower profits $\Rightarrow$ weaker incentive for creation $\Rightarrow$ muted increase in N_t
- Sticky vs Flex
  - Countercyclical (procyclical) markup under flexible (sticky) price
    - Cyclicality of markup depends on the pass-through and nominal rigidities
    - The dynamic effect of endogenous entry $\Rightarrow$ deflation with small $\rho(z)$

Technology and monetary policy shocks by entry cost (Fig. 4)



- Higher entry cost $\Rightarrow$ higher market concentration
    - Response of π_t becomes smaller
        - The Second law $\Rightarrow$ flatter NKPC

NKPC under Calvo pricing

$$\hat{\tilde{\pi}}_t = \beta(1-\delta)\mathbb{E}_t\hat{\tilde{\pi}}_{t+1} + \frac{(1-\phi)[1-\phi\beta(1-\delta)]}{\phi}\left[\rho(\tilde{z})\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{\tilde{p}}_t\right) - \frac{1-\rho(\tilde{z})}{\zeta(\tilde{z})-1}\hat{N}_t\right]$$

where $\tilde{\pi}_t := \tilde{p}_t/\tilde{p}_{t-1}$, $\tilde{z}_t := \tilde{p}_t/A_t$ and $\tilde{p}_t$ is implicitly given by
$\int_{\Omega_t} s(p_t(\omega)/A_t)\,\mathrm{d}\omega = 1 = N_t s(\tilde{p}_t/A_t)$

- Concentration leads to flattening of NKPC under the Third law (Matsuyama and Ushchev, 2023; Baqaee et al., 2023)
    - A higher price leads to a smaller rate of change in the price elasticity
    - A higher entry cost leads to less competitive pressures and lowers the pass-through rate
    - Translog cannot accommodate the Third law
- Strategic complementarity ⇒ real rigidity

Power elasticity of markup rate

- Power Elasticity of Markup rate (hereafter, PEM) proposed by Matsuyama and Ushchev (2023) accommodates the third law
- The market share function: either $\bar{z} = \infty$ and $c \leq 1$ or $\bar{z} < \infty$ and $c = 1$, $\kappa > 0$ and $\lambda > 0 \Rightarrow$ the Second law and the strong Third law

$$s(z) = \exp\left[\int_{z_0}^{z} \frac{c}{c - \exp\left(-\frac{\kappa \bar{z}^{-\lambda}}{\lambda}\right)\exp\left(\frac{\kappa \xi^{-\lambda}}{\lambda}\right)} \frac{d\xi}{\xi}\right]$$

  - Price elasticity

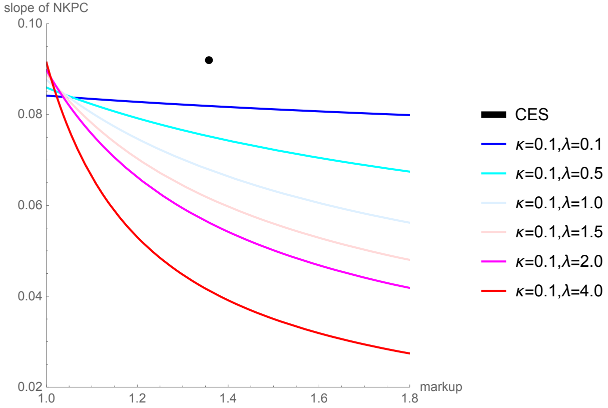
$$\zeta(z) = \frac{1}{1 - c\exp\left(\frac{\kappa \bar{z}^{-\lambda}}{\lambda}\right)\exp\left(-\frac{\kappa z^{-\lambda}}{\lambda}\right)}$$

  - Pass-through

$$\rho(z) = \frac{1}{1 + \kappa z^{-\lambda}}$$

- PEM collapses to
  - CES with $\kappa = 0$, $c = 1 - 1/\theta$ and $\bar{z} = \infty$
  - Co-PaTh with $\lambda = 0$, $\kappa = (1-\rho)/\rho$, $c = 1$ and $\bar{z} < \infty$

The markup rate and the slope of NKPC under Calvo



- Each locus traces the markup rate $\zeta(\tilde{z}) / [\zeta(\tilde{z}) - 1]$ and the slope of NKPC $(1-\phi)[1-\phi\beta(1-\delta)]\rho(\tilde{z})/\phi$ by changing $\tilde{z}$ under several λ with the reset probability $1-\phi = 0.25$

Omitted variable bias

- We now show that under the Second law
  - Concentration affects price setting dynamically through strategic complementarity - endogenous cost-push shock
  - A *naive* regression of the inflation rate on the real marginal cost $\Rightarrow$ the omitted variable bias (OVB): underestimating the slope
- Under Rotemberg pricing, the Third law matters for the magnitude of negative bias
- Under Calvo pricing, both Second and Third laws matter for the magnitude of negative bias

OVB: Rotemberg pricing

- NKPC under Rotemberg pricing

$$\begin{aligned}\hat{\pi}_t - \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} &= \frac{\zeta(z)-1}{\chi}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \frac{1-\rho(z)}{\chi\rho(z)}\hat{N}_t \\ &= \kappa^R\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \frac{1-\rho(z)}{\chi\rho(z)}\hat{N}_t\end{aligned}$$

- Estimation of NKPC

$$\hat{\pi}_t - \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} = \tilde{\kappa}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) + \varepsilon_t$$

- The estimated slope coefficient is biased

$$\begin{aligned}\tilde{\kappa} &= \kappa^R - \frac{1-\rho(z)}{\chi\rho(z)}\frac{\operatorname{cov}\left(\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right),\hat{N}_t\right)}{\sigma_x^2} \\ &= \kappa^R + \frac{1-\rho(z)}{\chi\rho(z)}\frac{\operatorname{cov}\left(\hat{\mu}_t,\hat{N}_t\right)}{\sigma_x^2}\end{aligned}$$

- The Second law
  - countercyclical markup $\Leftrightarrow \operatorname{cov}\left(\hat{\mu}_t,\hat{N}_t\right) < 0 \Rightarrow$ negative bias
- The Third law
  - $\Uparrow$ market concentration $\Rightarrow \Uparrow [1-\rho(z)]/\rho(z)/\chi \Rightarrow \Uparrow$ negative bias

OVB: Calvo pricing

- NKPC under Calvo pricing

$$\hat{\pi}_t - \beta(1-\delta)\mathbb{E}_t\hat{\pi}_{t+1} = \frac{(1-\phi)[1-\phi\beta(1-\delta)]}{\phi}\left[\rho(\tilde{z})\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \frac{1-\rho(\tilde{z})}{\zeta(z)-1}\hat{N}_t\right]$$
$$= \kappa^C\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \frac{(1-\phi)[1-\phi\beta(1-\delta)]}{\phi}\frac{1-\rho(\tilde{z})}{\zeta(z)-1}\hat{N}_t$$

- The estimated slope coefficient is biased

$$\tilde{\kappa} = \kappa^C - \frac{(1-\phi)[1-\phi\beta(1-\delta)]}{\phi}\frac{\rho(\tilde{z})[1-\rho(z)]}{\zeta(\tilde{z})-1}\frac{\operatorname{cov}\left(\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right), \hat{N}_t\right)}{\sigma_x^2}$$
$$= \kappa^C + \frac{(1-\phi)[1-\phi\beta(1-\delta)]}{\phi}\frac{\rho(\tilde{z})[1-\rho(\tilde{z})]}{\zeta(\tilde{z})-1}\frac{\operatorname{cov}\left(\hat{\mu}_t, \hat{N}_t\right)}{\sigma_x^2}$$

- The Second law
  - countercyclical markup $\Leftrightarrow \operatorname{cov}\left(\hat{\mu}_t, \hat{N}_t\right) < 0 \Rightarrow$ negative bias
- The Second and Third laws
  - $\Uparrow$ market concentration $\Rightarrow \Downarrow$ the price elasticity (the Second law) + $\Downarrow$ the pass-through rate (the Third law) $\Rightarrow \Uparrow \rho(\tilde{z})[1-\rho(\tilde{z})]/[\zeta(\tilde{z})-1] \Rightarrow \Uparrow$ negative bias

Key takeaways

- *Steady-state effect* of concentration
  - Gross substitutes: $s(z) \Uparrow \Leftrightarrow z \Downarrow$
  - Under Rotemberg pricing, *the Second law* $\Rightarrow$ lower price elasticity $\Rightarrow$ higher markup rate $\Rightarrow$ *structurally* flattening the Phillips curve
  - Under Calvo pricing, *the Third law* $\Rightarrow$ lower pass-through rate $\Rightarrow$ *structurally* flattening the Phillips curve
- *Dynamic effect* of endogenous entry
  - Concentration affects price setting dynamically through strategic complementarity - endogenous cost-push shock
    - The *supply side effects of monetary policy* through the entry of firms
  - Pass-through rate plays an important role in cyclicality of markup
- *Observational* implications of concentration and endogenous cost-push shock under *the Second law*
  - A *naive* regression of the real marginal cost on the inflation rate $\Rightarrow$ the *negative* OVB: underestimating the slope
  - Under Rotemberg, *the Third law* matters for the *magnitude*
  - Under Calvo, both *Second and Third laws* matter for the *magnitude*

Future studies

- Future studies include
  - Optimal policy
  - Wage Phillips curve
  - More general price setting mechanisms such as menu cost
    - We conjecture that results would be a hybrid of Rotemberg and Calvo
  - Heterogeneous firm

Ascari, Guido and Lorenza Rossi, "Trend Inflation and Firms Price-Setting: Rotemberg Versus Calvo," *Economic Journal*, September 2012, *122* (563), 1115–1141.

Auclert, Adrien, Rodolfo D. Rigato, Matthew Rognlie, and Ludwig Straub, "New Pricing Models, Same Old Phillips Curves?," NBER Working Papers 30264 July 2022.

Autor, David, David Dorn, Lawrence F Katz, Christina Patterson, and John Van Reenen, "The Fall of the Labor Share and the Rise of Superstar Firms," *The Quarterly Journal of Economics*, 2020, *135* (2), 645–709.

Baqaee, David, Emmanuel Farhi, and Kunal Sangani, "The Supply-Side Effects of Monetary Policy," NBER Working Papers 28345, National Bureau of Economic Research, Inc January 2021.

Baqaee, David Rezza, Emmanuel Farhi, and Kunal Sangani, "The Darwinian Returns to Scale," *The Review of Economic Studies*, 2023.

Bilbiie, Florin O., "Monetary Neutrality with Sticky Prices and Free Entry," *The Review of Economics and Statistics*, July 2021, *103* (3), 492–504.

—, Fabio Ghironi, and Marc J. Melitz, "Monetary Policy and Business Cycles with Endogenous Entry and Product Variety," in "NBER Macroeconomics Annual 2007, Volume 22" NBER Chapters, National Bureau of Economic Research, Inc, February 2008, pp. 299–353.

—, —, and —, "Endogenous Entry, Product Variety, and Business Cycles," *Journal of Political Economy*, 2012, *120* (2), 304–345.

—, —, and —, "Monopoly Power and Endogenous Product Variety: Distortions and Remedies," *American Economic Journal: Macroeconomics*, October 2019, *11* (4), 140–174.

—, Ippei Fujiwara, and Fabio Ghironi, "Optimal monetary policy with endogenous entry and product variety," *Journal of Monetary Economics*, 2014, *64* (C), 1–20.

Coibion, Olivier and Yuriy Gorodnichenko, "Is the Phillips Curve Alive and Well after All? Inflation Expectations and the Missing Disinflation," *American Economic Journal: Macroeconomics*, January 2015, *7* (1), 197–232.

Covarrubias, Matias, German Gutierrez, and Thomas Philippon, "From Good to Bad Concentration? US Industries over the Past 30 Years," in "NBER Macroeconomics Annual 2019, volume 34" NBER Chapters, National Bureau of Economic Research, Inc, February 2019, pp. 1–46.

Crump, Richard K., Stefano Eusepi, Marc Giannoni, and Aysegul Sahin, "A unified approach to measuring u*," *Brookings Papers on Economic Activity*, 2019, (Spring).

Daly, Mary C. and Bart Hobijn, "Downward Nominal Wage Rigidities Bend the Phillips Curve," *Journal of Money, Credit and Banking*, October 2014, *46* (S2), 51–93.

De Loecker, Jan, Jan Eeckhout, and Gabriel Unger, "The Rise of Market Power and the Macroeconomic Implications," *The Quarterly Journal of Economics*, 2020, *135* (2), 561–644.

Del Negro, Marco, Michele Lenza, Giorgio E. Primiceri, and Andrea Tambalotti, "What's up with the Phillips Curve?," *Brookings Papers on Economic Activity*, 2020, (Spring), 301–373.

Goolsbee, Austan D. and Peter J. Klenow, "Internet Rising, Prices Falling: Measuring Inflation in a World of E-Commerce," *AEA Papers and Proceedings*, May 2018, *108*, 488–92.

Grossman, Gene M., Elhanan Helpman, and Hugo Lhuillier, "Supply Chain Resilience: Should Policy Promote Diversification or Reshoring?," NBER Working Papers 29330, National Bureau of Economic Research, Inc October 2021.

Harding, Martin, Jesper Linde, and Mathias Trabandt, "Resolving the missing deflation puzzle," *Journal of Monetary Economics*, 2022, *126* (C), 15–34.

Hazell, Jonathon, Juan Herreno, Emi Nakamura, and Jon Steinsson, "The Slope of the Phillips Curve: Evidence from U.S. States*," *The Quarterly Journal of Economics*, 02 2022, *137* (3), 1299–1344.

Kasahara, Hiroyuki and Yoichi Sugita, "Nonparametric Identification of Production Function, TotalFactor Productivity, and Markup from Revenue Data," Technical Report, University of British Columbia 2020.

Kimball, Miles S, "The Quantitative Analytics of the Basic Neomonetarist Model," *Journal of Money, Credit and Banking*, November 1995, *27* (4), 1241–1277.

Klenow, Peter J. and Jonathan L. Willis, "Real Rigidities and Nominal Price Changes," *Economica*, July 2016, *83* (331), 443–472.

L'Huillier, Jean-Paul, Gregory Phelan, and William R. Zame, "Flattening of the Phillips Curve and the Mandate of the Central Bank," Technical Report, Federal Reserve Bank of Cleveland and Brandeis University, Williams College, and UCLA December 2022.

Lombardo, Giovanni and David Vestin, "Welfare implications of Calvo vs. Rotemberg-pricing assumptions," *Economics Letters*, August 2008, *100* (2), 275–279.

Matsuyama, Kiminori and Philip Ushchev, "Beyond CES: Three Alternative Classes of Flexible Homothetic Demand Systems," CEPR Discussion Papers 12210, C.E.P.R. Discussion Papers August 2017.

— **and** — , "Constant Pass-Through," CEPR Discussion Papers 15475, C.E.P.R. Discussion Papers November 2020.

— **and** — , "When Does Procompetitive Entry Imply Excessive Entry?," CEPR Discussion Papers 14991, C.E.P.R. Discussion Papers July 2020.

— **and** — , "Destabilizing effects of market size in the dynamics of innovation," *Journal of Economic Theory*, 2022, *200*, 105415.

— **and** — , "Selection and Sorting of Heterogeneous Firms through Competitive Pressures," CEPR Discussion Papers 17092-2, C.E.P.R. Discussion Papers 2023.

McLeay, Michael and Silvana Tenreyro, "Optimal Inflation and the Identification of the Phillips Curve," in "NBER Macroeconomics Annual 2019, volume 34" NBER Chapters, National Bureau of Economic Research, Inc, December 2019, pp. 199–255.

Nekarda, Christopher J. and Valerie A. Ramey, "The Cyclical Behavior of the Price-Cost Markup," *Journal of Money, Credit and Banking*, December 2020, *52* (S2), 319–353.

Nistico, Salvatore, “The welfare loss from unstable inflation,” *Economics Letters*, July 2007, *96* (1), 51–57.

Roberts, John M, “New Keynesian Economics and the Phillips Curve,” *Journal of Money, Credit and Banking*, November 1995, *27* (4), 975–984.

Rubbo, Elisa, “Networks, Phillips curves, and monetary policy,” *manuscript, Harvard University*, 2022.

Sbordone, Argia M., “Globalization and Inflation Dynamics: The Impact of Increased Competition,” in “International Dimensions of Monetary Policy” NBER Chapters, National Bureau of Economic Research, Inc, December 2010, pp. 547–579.

Wang, Olivier and Ivan Werning, “Dynamic Oligopoly and Price Stickiness,” *American Economic Review*, August 2022, *112* (8), 2815–49.

$P(\mathbf{p}_t)$ vs $A(\mathbf{p}_t)$

- Under HSA

$$\frac{\partial P(\mathbf{p}_t)/\partial p_t(\omega)}{P(\mathbf{p}_t)/p_t(\omega)} = s\left(\frac{p_t(\omega)}{A(\mathbf{p}_t)}\right) \Rightarrow \frac{\partial\left(P(\mathbf{p}_t)/A(\mathbf{p}_t)\right)}{P(\mathbf{p}_t)/A(\mathbf{p}_t)} = \frac{s(z_t(\omega))}{z_t(\omega)}\partial z_t(\omega)$$

- By integrating

$$\ln\left(\frac{P(\mathbf{p}_t)}{A(\mathbf{p}_t)}\right) = \bar{K} - \int_{\Omega_t}\left[\int_{\frac{p_t(\omega)}{A_t}}^{\bar{z}} \frac{s(\xi)}{\xi}d\xi\right]\mathrm{d}\omega$$

  - $\bar{z} := \inf\{z > 0 | s(z) = 0\}$: if $\bar{z} < \infty$, $\bar{z}A_t$ is the choke price
  - $\bar{K}$: a constant

- $P(\mathbf{p}_t) = \text{constant} \times A(\mathbf{p}_t)$ *iff* CES, because, by differentiating the adding-up constraint

$$\frac{\partial \ln(A(\mathbf{p}_t))}{\partial \ln(p_t(\omega))} = \frac{\frac{p_t(\omega)}{A(\mathbf{p}_t)}s'\left(\frac{p_t(\omega)}{A(\mathbf{p}_t)}\right)}{\int_{\Omega_t}\frac{p_t(\omega')}{A(\mathbf{p}_t)}s'\left(\frac{p_t(\omega')}{A(\mathbf{p}_t)}\right)\mathrm{d}\omega'} \neq s\left(\frac{p_t(\omega)}{A(\mathbf{p}_t)}\right) = \frac{\partial \ln(P(\mathbf{p}_t))}{\partial \ln(p_t(\omega))}$$

  unless $s(z)$ is a power function

HSA

Super-elasticity

- Super-elasticity (Klenow and Willis, 2016)

$$\xi(z) := \frac{\zeta'(z)\, z}{\zeta(z)}$$

- The relationship between the super-elasiticty and the pass-through rate is given by

$$\xi(z) = \left[\frac{1}{\rho(z)} - 1\right][\zeta(z) - 1]$$

- NKPC under Rotemberg

$$\hat{\pi}_t = \beta(1-\delta)\,\mathbb{E}_t\hat{\pi}_{t+1} + \frac{\zeta(z)-1}{\chi}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \frac{1}{\chi}\frac{\xi(z)}{\zeta(z)-1}\hat{N}_t$$

- NKPC under Calvo

$$\hat{\tilde{\pi}}_t = \beta(1-\delta)\,\mathbb{E}_t\hat{\tilde{\pi}}_{t+1} + \frac{(1-\phi)[1-\phi\beta(1-\delta)]}{\phi[\zeta(z)-1+\xi(z)]}\left\{[\zeta(z)-1]\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{\tilde{p}}_t\right) - \frac{\xi(z)}{\zeta(\tilde{z})-1}\hat{N}_t\right\}$$

NKPC

Flexible price by entry

- When entry firms face no nominal frictions, NKPC is given by

$$\begin{aligned}\hat{\pi}_t^* &= \beta(1-\delta)\hat{\pi}_{t+1}^* + \frac{\zeta(z)-1}{\chi}\frac{1}{1-\delta}\left[1-\delta\rho(z)\right]\left(\hat{w}_t + \hat{\bar{p}}_t - \hat{Z}_{P,t}\right) \\ &\quad -\frac{1}{\chi}\frac{1-\rho(z)}{\rho(z)}\frac{1}{1-\delta}\hat{N}_t\end{aligned}$$

where the average inflation rate is implicitly given by

$$\sum_{\tau=2}^{\infty}(1-\delta)^{\tau-1}\hat{\pi}_{t,t-\tau} = \sum_{\tau=2}^{\infty}(1-\delta)^{\tau-1}\hat{\pi}_t^* = \frac{1-\delta}{\delta}\hat{\pi}_t^*$$

NKPC

NKP with output gap

- To transform the real marginal cost (reciprocal of the markup rate) into the output gap, we extend Bilbiie (2021)'s static entry model to include sticky prices and HSA

$$\begin{aligned}\hat{\pi}_t &= \beta \mathbb{E}_t \hat{\pi}_{t+1} + \frac{\zeta(z) - 1}{\chi}\left(\hat{W}_t - \hat{Z}_{P,t} - \hat{p}_t\right) - \frac{\zeta(z) - 1}{\chi}\frac{1 - \rho(z)}{\rho(z)}\hat{z}_t \\ &= \beta \mathbb{E}_t \hat{\pi}_{t+1} + \kappa(z)\hat{Y}_t - \frac{\zeta(z) - 1}{\chi}\frac{1 - \rho(z)}{\rho(z)}\hat{z}_t\end{aligned}$$

where

$$\kappa(z) := \frac{1}{\chi}\frac{\frac{\sigma+\psi}{1+\psi}\left[\zeta(z) - 1\right] - \frac{1-\sigma}{1+\psi}\frac{\zeta(z)-1}{s(z)}\int_z^{\bar{z}}\frac{s(\xi)}{\xi}d\xi}{1 - \frac{\zeta(z)-1}{s(z)}\int_z^{\bar{z}}\frac{s(\xi)}{\xi}d\xi}$$

- Flattening of NKP with concentration under benchmark calibration

$$\frac{d\kappa(z)}{dz} > 0$$

NKPC

Computation of z

- Steady state of z is pinned down by
  1. Pricing formula: $f(L(z), Y(z), z) = 0$

$$\overbrace{L(z)^{\psi} Y(z)^{\sigma}}^{\text{MRS}} = \overbrace{\overbrace{\frac{z}{\left[1 - \frac{s(z)}{s'(z)z}\right] \exp\left(\text{const.} - \frac{\int_z^{\bar{z}} \frac{s(\xi)}{\xi} d\xi}{s(z)}\right)}}^{\text{markup}} \overbrace{Z_P}^{\text{MPL}}}^{\text{w}}$$

  2. Firm dynamics: $Y = Y(z)$

$$Y(z) = -\frac{1-\beta(1-\delta)}{\beta(1-\delta)} Z_P \frac{f_E}{Z_E} \frac{\frac{s'(z)z}{s(z)} \frac{z}{s(z)}}{\exp\left(\text{const.} - \frac{\int_z^{\bar{z}} \frac{s(\xi)}{\xi} d\xi}{s(z)}\right)}$$

  3. Value of the firm: $L = L(z)$

$$L(z) = \frac{1}{1-\delta} \frac{f_E}{Z_E} \left[\delta - \frac{1-\beta(1-\delta)}{\beta} \frac{s'(z)z}{s(z)}\right] \frac{1}{s(z)}$$

Computation of z under CES

- Steady state of z is pinned down by
  1. Pricing formula: $f(L(z), Y(z)) = \text{constant}$

$$\overbrace{L(z)^{\psi} Y(z)^{\sigma}}^{\text{MRS}} = \overbrace{\overbrace{\frac{\theta-1}{\theta}}^{\text{markup}} \overbrace{Z_P}^{\text{MPL}}}^{\text{w}}$$

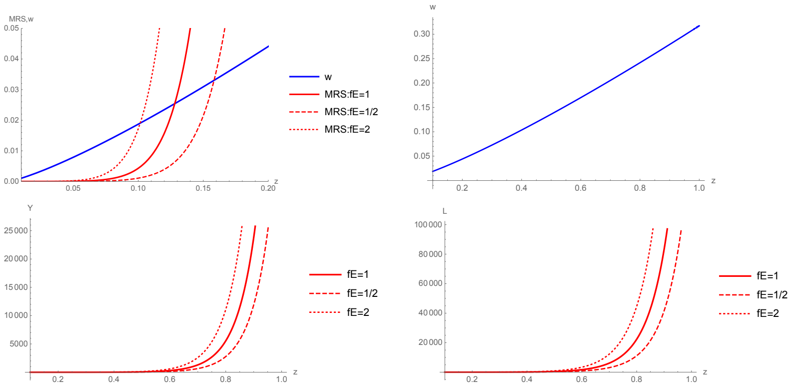
  2. Firm dynamics: $Y = Y(z)$: $\frac{\partial Y}{\partial z} > 0$, $\frac{\partial^2 Y}{\partial z \partial f_E} > 0$

$$Y(z) = \frac{1-\beta(1-\delta)}{\beta(1-\delta)} Z_P \frac{f_E}{Z_E} (\theta-1) z^{\theta-1}$$

  3. Value of the firm: $L = L(z)$: $\frac{\partial L}{\partial z} > 0$, $\frac{\partial^2 L}{\partial z \partial f_E} > 0$

$$L(z) = \frac{1}{1-\delta} \frac{f_E}{Z_E} \left[\delta + \frac{1-\beta(1-\delta)}{\beta}(\theta-1)\right] z^{\theta-1}$$

Labor market equilibrium with f_E: Co-PaTh, $\rho = 0.9$



Analytical integration

- For some special cases, we can obtain an analytical expression for the integral, $\int_{z}^{\bar{z}} \frac{s(\xi)}{\xi} d\xi$
- Under Co-PaTh, the integral is given by the hypergeometric function

$$\int \frac{\left[1-\left(\frac{\xi}{\bar{z}}\right)^{\frac{1}{\nu}}\right]^{\nu}}{\xi} d\xi = \frac{\nu\left[1-\left(\frac{\zeta}{\bar{z}}\right)^{\frac{1}{\nu}}\right]^{1+\nu}}{1+\nu} \sum_{n=0}^{\infty} \frac{(1)_n (1+\nu)_n}{(2+\nu)_n n!} \left[1-\left(\frac{\zeta}{\bar{z}}\right)^{\frac{1}{\nu}}\right]^{n}$$

- Under Translog

$$\int \frac{\gamma_{TL} \ln\left(\frac{\bar{z}}{\xi}\right)}{\xi} d\xi = -\frac{\gamma_{TL}}{2}\left[\ln\left(\frac{\bar{z}}{\xi}\right)\right]^2$$