

Can Supply Shocks Be Inflationary with a Flat Phillips Curve?

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Motivation: 2 Empirical Facts

1. Phillips Curve (PC) is very flat

- See Nakamura and Steinsson (2014), Del Negro et al. (2020), Hazell et al. (2022)

2. Supply shocks are inflationary

- See Känzig (2021), Bunn et al. (2022), Ball et al. (2022), and others

→ Demand shocks do not move inflation much
Supply shocks do

This Paper: 2 Parts

1. Observation: **Standard models** struggle to match these facts
 2. Contribution: model with **shock-dependent price stickiness**
 - **Stickiness** with respect to **demand shocks**
 - **Flexibility** with respect to **supply shocks**
- Matches the empirical facts

Observation

- Standard models struggle to match these empirical facts
 - Flat PC implies very **rigid price level**, whatever the friction(s)
 - But rigid prices *also* dampen response to cost-push shocks
 - Must resort to **implausible cost-push shocks** to generate inflation
 - c.f. Chari, Kehoe, McGrattan (2009) and Bilts, Klenow, Malin (2012)
- Taylor, Calvo, Rotemberg, Menu costs—all have same problem

Contribution

- Shock-dependent pricing can match these empirical facts
 1. Flat PC because demand shocks do not change firms' prices
 2. Inflationary supply shocks because prices respond flexibly to costs
 - We provide a candidate microfoundation with shock-dependent pricing
 - Firms pass on cost increases to consumers
 - But they avoid increasing prices when demand increases
- The reason for price stickiness is intrinsically demand-based
- Equilibrium in game among rational consumers and firms
 - see Blinder et al. (1998)

Intuition for Shock-Dependent Stickiness

- Firms are better informed than consumers about aggregate conditions
 - Sticky prices arise from the strategic decision of firms
 - c.f. L'Huillier (2020), L'Huillier and Zame (2022)
- But shock type matters
 - Firms find it optimal to set prices that **adjust to supply** (costs)
 - Firms may find it optimal to set prices that **do not adjust to demand**
- **Firm incentives** are source of pricing friction

Demand Shock

- Discount factor shock: today is a good time to buy
 - Consumers willing to buy more at the same price
 - Shock is **payoff-relevant** for consumers
 - With perfect info, firms would charge higher prices when demand is high
 - But some consumers are uninformed, don't know "times are good"
 - Could uninformed consumers learn "times are good" from high prices? No.
 - If high prices stimulated consumers' demand ("good time to buy"), then firms would *always* like to charge high prices if enough consumers uninformed
 - That is not credible! **Strategic friction**
 - Higher prices simply lower demand and profits
- Firms do not change prices

Supply Shock

- Supply: firms' marginal costs increase
 - Not Payoff-relevant for consumers: just care about price and own demand
 - *Whether or not consumers know the costs:*
 - When costs are high, firms earn higher profits by charging **higher prices**
 - When costs are low, firms earn higher profits by charging **lower prices**
 - Profit-maximizing prices do not depend on consumers knowing firms' costs
 - No strategic friction
 - Consumers demand less, but higher prices necessary because of costs
- Firms change prices

Summary of Results

- With demand, firms' incentives create a strategic friction to adjusting
- With cost shocks, firms' incentives create no strategic friction to adjusting
- Shock-dependent pricing produces a flat PC with inflation from cost shocks
- Prices adjust to supply while still sticky with respect to demand
 - Quite distinct from standard pricing frictions
- Important policy implications

Policy Implications

- Inflation from supply shocks is efficient in our model
 - Prices flexible, no price dispersion
- If CB raises rates, creates inefficient output gap
- Absent additional frictions, no need for CB to respond to supply shocks

Outline

- 1 Illustration: NK Model
- 2 Model of Shock-Dependent Stickiness
 - Setup
 - Demand Shocks: Sticky Prices and Flat PC
 - Cost Shocks: Flexibility and Inflation
 - Shock-Dependent Stickiness with Demand and Supply Shocks
- 3 Quantification and Empirical Evidence
 - Calibration
 - VAR exercise
- 4 Conclusion

Illustration: New Keynesian PC

- We can write structural NKPC as

$$\hat{\pi}_t = \beta \mathbb{E}_t[\hat{\pi}_{t+1}] + \underbrace{(\lambda \cdot e)}_{\kappa} \hat{x}_t + \lambda \hat{z}_t,$$

- Standard models get flat PC (low κ) with a low λ
 - $\lambda \approx 0.0020$
 - c.f. Del Negro et al. 2020, Hazell et al. 2022
- Standard cost-push shock normalization $\nu_t \equiv \lambda \hat{z}_t$

$$\hat{\pi}_t = \beta \mathbb{E}_t[\hat{\pi}_{t+1}] + \kappa \hat{x}_t + \nu_t$$

Standard NK shock normalization

- Standard normalization $\nu_t \equiv \lambda \hat{z}_t$

$$\hat{\pi}_t = \beta \mathbb{E}_t[\hat{\pi}_{t+1}] + \kappa \hat{x}_t + \nu_t$$

- ν_t main driver of inflation dynamics in estimated NKDSGE models
- Need **structural** cost shock $\hat{z}_t = 500\%$ to get $\nu_t = 1\%$
 - If steady-state markup is 12.5%, desired markup increases to **75%**
 - Unrealistic.
 - To generate 5% inflation increase requires desired markups of **325%**
 - Unrealistic.
- Implausible cross-sectional implications

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2 Model of Shock-Dependent Stickiness

Setup

Demand Shocks: Sticky Prices and Flat PC

Cost Shocks: Flexibility and Inflation

Shock-Dependent Stickiness with Demand and Supply Shocks

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VAR exercise

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Model Overview

- Two agents, consumers and firms (CB in background)
- Two periods, present and future
- In present (short run), trade is decentralized at continuum of islands
 - Each island has a monopolistic firm and a continuum of consumers
 - Each firm picks a nominal price p (potentially different across islands)
- In future (long run), all trade is centralized, frictionless
 - Consumers trade endowments (a simplification)
 - Price normalized to 1 (w.l.o.g.)

Aggregate State and Information

- Aggregate state $s = \{\theta, z\}$
 - θ is demand shock (discount factor shock)
 - z is supply shock (shock to firms' marginal cost)
- Firms: informed, know the state
- Consumers:
 - Fraction α "Insiders": know the state directly
 - Fraction $1 - \alpha$ "Outsiders": do not know the state directly, might learn through prices
 - $\alpha \in [\alpha_0, \alpha_1]$ differs across islands

Central Bank

- CB sets interest rate i using interest rate rule

Consumers

- Agents have linear-quadratic utility (simplification)

$$\mathbb{E}_j [(c - c^2/2) + (\beta\theta)C]$$

- c is present consumption, C is future consumption
 - $\beta\theta \equiv \frac{1}{1+\rho}$ is discount rate, ρ is natural rate of interest
- The budget constraint is

$$pc + QC = \text{Income}$$

- p is current nominal price at the island
- C is numeraire
- $Q \equiv \frac{1}{1+i}$ is the bond price

Demand Shocks

- Future marginal utility could be high or low with $\mathbb{E}[\theta] = 1$
 - High ρ increases demand today
- Optimal consumption c^* depends on price p and **expectation** of θ
 - Insiders know θ exactly
 - Outsiders might not, form expectation

Firms

In present:

- Each island served by a monopolistic firm
- Firm produces with real marginal cost z
- Sets price p , may choose to condition on s

Perfect Bayesian Equilibrium

- Consumer demand c^* depends on price p and **expectation** of θ
- Firm problem depends on:
 - Fraction of Insiders
 - Outsiders' expectations

⇒ Solution concept is a **Perfect Bayesian Equilibrium** (PBE)

- First consider demand shocks only, $s = \{\theta, z_0\}$ with z_0 fixed
- Then consider supply shocks only, $s = \{\theta_0, z\}$ with $\theta_0 = 1$ fixed
- Then both shocks together

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PBE: Demand Shocks Only

- The **full information** equilibrium is a PBE if there are enough Insiders
- There exists $\bar{\alpha}$ such that the full-information equilibrium is a PBE iff $\alpha > \bar{\alpha}$
- We refer to this as **flexible price** equilibrium
 - Firms choose a price p_s that responds to the demand shock
 - Outsiders learn θ
 - Output is constant (demand shock is neutral)

PBE: Firm IC Constraint

- Why isn't this a PBE if $\alpha < \bar{\alpha}$? Firms subject to an IC constraint
 - In flex-price PBE, high price corresponds to high-demand (“times are good”)
 - Can PBE beliefs be “high price = high state” always? No.
 - Strategic friction
 - Firms tempted to charge a high price to stimulate demand from Outsiders
 - Without discipline, firms would always charge a high price
- Outsiders won't believe “high price = high state” PBE \implies lower demand

PBE: Firm IC Constraint

- Insiders provide discipline and credibility
 - a high price credibly reflects a high state
- Without many Insiders, changing prices entails a cost (profit loss)
- Alternative equilibrium? **Sticky price**
 - Price that would prevail in the absence of shocks (e.g., steady state)

Sticky Price PBE

- In **sticky price** equilibrium, firms choose same price p_0 in each state
 - Profit-maximizing price if $\theta = 1$
 - $p_0 = \frac{1+z_0}{2}$
 - Price does not respond to the demand shock
- Insiders know θ
 - Demand c^* moves with state
- Outsiders do not learn θ
 - Demand c^* is constant $x = \frac{1-z_0}{2}$
- Output fluctuates with θ due to Insiders' demand

Equilibrium Short-Run Prices

- For islands with $\alpha > \bar{\alpha}$, firms choose flexible price p_s
- For islands with $\alpha < \bar{\alpha}$, firms choose sticky price p_0

Phillips Curve

- Let κ denote the slope of the Phillips Curve
 - Average output moves with shocks if some firms choose sticky price
 - Average price moves with shocks if some firms choose flexible price
 - κ depends on $\bar{\alpha}$
- There exists conditions on shocks such that **all firms choose sticky price**
 - Demand shocks not so big or MP is sufficiently hawkish
 - c.f. L'Huillier, Phelan, Zame (2022)
 - Call the condition C1

Flat Phillips Curve

Proposition 1 (Flat Phillips Curve).

The PC slope $\kappa = 0$ whenever condition C1 holds.

- PC is flat if demand shocks are not so big or MP is sufficiently hawkish

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Cost Shocks

- Demand shocks can lead to sticky prices
- Results **very different** with supply/cost-push shock to z_s
- Consider shocks to z (e.g., productivity shocks)
 - For now, fix $\theta = 1$ (no demand shock)

Cost Shocks and Flexible Prices

Proposition 2 (Flexible Prices with Cost Shocks).

When the economy features a supply shock to z_s , all firms choose a flexible price $p_s = \frac{1+z_s}{2}$, output is at potential.

- Firms always adjust price to cost shock
- We get inflation when z changes
- Price elasticity w.r.t. z is 1

Cost Shocks and Flexible Prices

- Intuition? c^* depends on *observed price* and *expectation of demand shock*
- Marginal cost z is not payoff-relevant to consumers
- No strategic friction

Cost Shocks and Flexible Prices

- Cost shocks always lead to change in prices (flexible price) with respect to z_s
- Productivity shocks lead to flexible prices, no output gap
- No reason *in this model* for monetary policy to respond to supply shocks

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Supply and Demand Shocks

- What if we have independent shocks to supply and to demand?
 - Demand shocks **move along PC**
 - Supply shocks **shift PC**
- Flex and sticky prices $p_{s,z}$ and $p_{0,z}$ depend on z , as do $\bar{\alpha}$ and PC slope κ
 - $p_{0,z} = \frac{1+z}{2}$
 - Sticky price moves with z but not with θ
- Exists condition C2 such that all firms choose sticky price for all z
 - sticky price w.r.t. demand always PBE
 - Price reflects supply shock alone

PC with Supply and Demand Shocks

Proposition 3 (Inflation with Supply and Demand Shocks).

Suppose C2 holds. Aggregate prices are flexible with respect to supply shocks but sticky with respect to demand shocks. The Phillips Curve is perfectly flat with respect to demand shocks but supply shocks create inflation.

- $\kappa = 0$ for all z but price elasticity w.r.t. z is 1
- The PC is perfectly flat but supply shocks can meaningfully shift the PC

Supply and Demand Shocks

- Prices can credibly reflect change in costs even if both demand and supply shocks are simultaneously unknown to Outsiders
- Intuition? Higher prices are a credible signal of higher costs z but not θ
 - In equilibrium Outsiders do not increase their demand if prices rise
 - Outsiders interpret high prices as reflecting high costs, not θ
 - Demand **decreases** with a **higher price**
- Firms increase prices iff costs increase (penalized with lower demand)
 - Higher price lowers demand but maximizes profits (cover costs)

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Quantification

- Calibrate firm heterogeneity in productivity/cost z , not Insiders α
 - Use empirical distribution of marginal costs
- MP follows interest rate rule $\phi_\pi = 1.5, \phi_x = 0.22$
 - Determine i in eqm
- Choose $\alpha = 0.88$ to match PC slope given Taylor rule and firms' costs
- Repeated model with constant α
- Consider dynamics in response to supply and demand shocks

Quantification

Demand Shock

- First consider a 1% demand shock
- Economy behaves as you expect, with almost no inflation (flat PC!)
- Output gap is sufficient statistic for welfare losses

Quantification

Demand Shock: Inflation

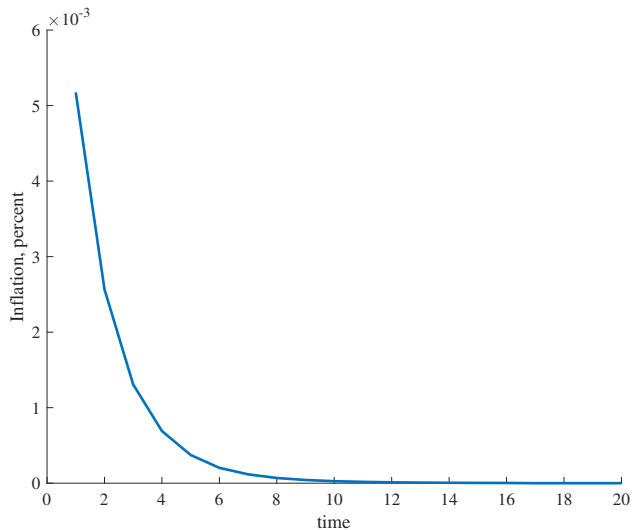
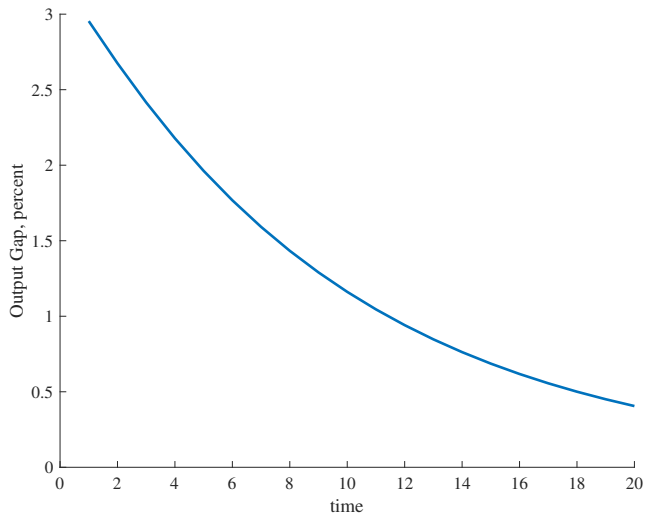


Figure: Almost no inflation (flat PC)

Quantification

Demand Shock: Output Gap



Quantification

Supply Shock varying Hawkishness

- Now consider supply shock (negative productivity shock)
- Now we vary inflation hawkishness ϕ_π
 - Inflation barely affected by MP rule (flat PC)
 - With $\phi_\pi > 0$ MP just creates output gaps (bad)
 - With $\phi_\pi = 0$ there is no MP response, no output gap, no welfare loss

Quantification

Supply Shock varying Hawkishness: Inflation

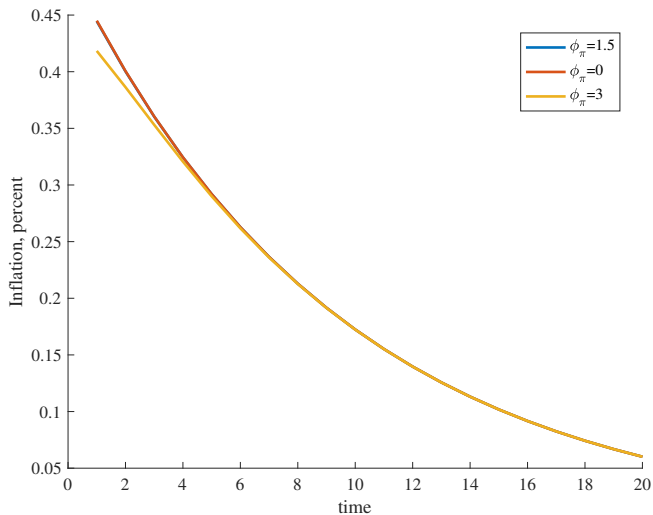


Figure: Inflation: $\approx 50\%$ passthrough, very hawkish stance barely dampens inflation

Quantification

Supply Shock varying Hawkishness: Output Gap

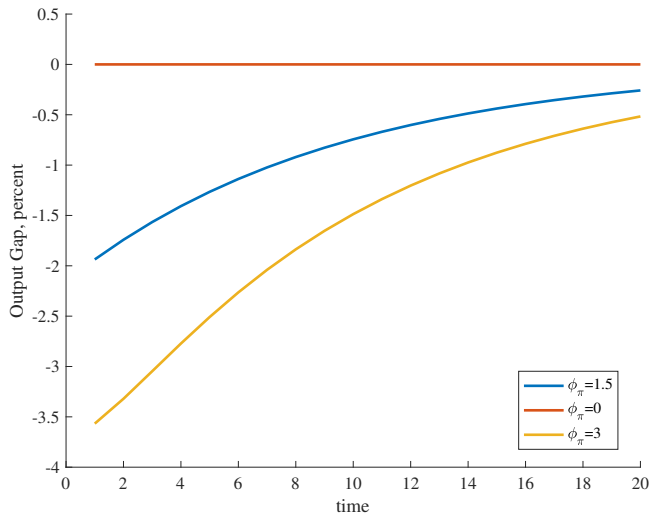


Figure: MP creates negative output gap—but doesn't need to

Quantification

Supply Shock varying Hawkishness

- With shock-dependent stickiness, inflation from supply shock is efficient
- Prices are flexible, no price dispersion creating welfare losses
- No welfare loss *unless* MP creates an output gap

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Empirical Evidence

Is there empirical evidence for asymmetric sensitivity?

- Look for VAR **evidence of shock-dependent sensitivity** of inflation
- Use two off-the-shelf models of well-identified instrumental variables for supply and demand shocks
 - **Demand**: monetary policy surprises from Gertler-Karadi (2015)
 - **Supply**: oil supply news from Känzig (2021)
- Run their VARs with inflationary shocks
 - scale shocks to have same magnitude impact on output (IP)
 - compare IRFs for inflation
- Is there a shock-dependent inflation response?

Empirical Evidence

IRFs for Output (Industrial Production)

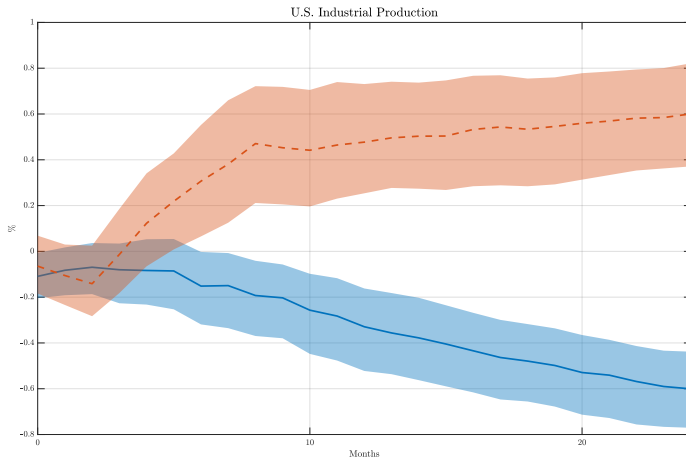


Figure: IP. Red is demand (monetary policy) shock. Blue is supply (oil news) shock.

Empirical Evidence

IRFs for Inflation (CPI)

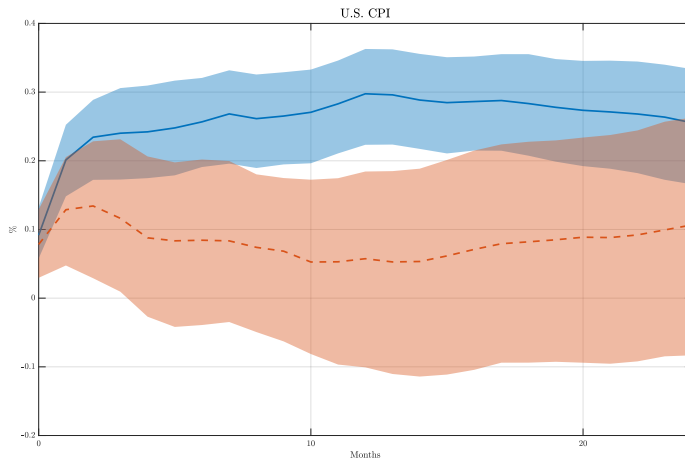


Figure: CPI. Red is demand (monetary policy) shock. Blue is supply (oil news) shock.

Empirical Evidence

VAR Results

- Nearly identical IRFs for output (flipped by construction)
- Compared to demand shock, supply shock has
 - 2.5 times the effect on CPI over 24 months
 - 5 times the effect over 12 months
- In standard NK models, $\lambda < \kappa$, should expect reverse
- Suggestive evidence that **inflation moves more in response to supply shocks**
 - Certainly more than NK model predicts

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Conclusion

- Two empirical facts: PC is very flat and supply shocks create inflation
 - But standard models cannot plausibly deliver both
- Shock-dependent price stickiness can match these facts
 - The reason for price stickiness is intrinsically demand-based
 - Cost shocks very different from demand shocks
- Our model can generate significant inflation with completely flat PC

Thank you!