Monetary Policy when the Phillips Curve is Quite Flat

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Introduction : Inflation

- US and EZ situation with low unemployment *and* low inflation was puzzling just before the COVID-19 outbreak.
- This is one in a set of puzzles in the behaviour of inflation over the last 20 years, when observed through the lens of a New Keynesian model
  - × missing deflation in the Great Recession
  - × missing volatility of inflation at the ZLB
  - × price puzzle following a monetary shock
  - × missing inflation in 2020 given supply shock and lax monetary policy
- We propose to revive an old idea (cost channel of monetary policy), and show that it can solve those puzzles and be empirically relevant.

1. Theoretical exploration of a "3-equation" model in which the Phillips curve of the type

$$\pi_t = \beta E_t[\pi_{t+1}] + \underbrace{\left(\gamma_y y_t + \gamma_r (i_t - E_t[\pi_{t+1}])\right)}_{\text{marginal cost}} + \mu_t$$

- Nothing new!
- We find interesting theoretical results when *"γ_y is small as compared to γ_r"* (new)...
- ... but is that empirically relevant?

2. Careful limited information estimation of a Phillips curve of the type

$$\pi_t = \beta E_t[\pi_{t+1}] + \left(\gamma_y y_t + \gamma_r (i_t - E_t[\pi_{t+1}])\right) + \mu_t$$

Result: $\gamma_y \approx 0$, $\gamma_r > 0$

3. Full information estimation of a 3-equation NK model with a Phillips curve of the type

$$\pi_t = \beta E_t[\pi_{t+1}] + \left(\gamma_y y_t + \gamma_r(i_t - E_t[\pi_{t+1}])\right) + \mu_t$$

Result: $\gamma_y \approx 0$ and $\gamma_r > 0$

Roadmap

1. Theory
2. Phillips Curve Estimation
3. Full Information Estimation

Roadmap

1. Theory
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Theory

- I don't want to spend time on microfoundations (nothing deep there)

$$y_t = \quad E_t[y_{t+1}] - \alpha_r \underbrace{(i_t - E_t[\pi_{t+1}])}_{r_t} + d_t \qquad \text{Euler Equation (EE)}$$

$$\pi_t = \beta E_t[\pi_{t+1}] + \underbrace{\left(\gamma_y y_t + \color{red}{\gamma_r (i_t - E_t \pi_{t+1})}\right)}_{\text{“marginal cost”}} + \mu_t \qquad \text{Phillips Curve (PC)}$$

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- α_y can be arbitrarily close to 1.

A Condition on parameters

- Let's define a condition on parameters that has simple interpretation and that happens to be key (and not fully studied previously)

The Patman condition

- Let $r_t = i_t - E_t\pi_{t+1}$.

$$y_t = \alpha_y E_t[y_{t+1}] - \alpha_r r_t + d_t \qquad \text{Euler Equation (EE)}$$
$$\pi_t = \beta E_t[\pi_{t+1}] + \gamma_y y_t + \gamma_r r_t + \mu_t \qquad \text{Phillips Curve (PC)}$$

- Let's compute the effect on inflation of an increase in r (set by policy) keeping expectations fixed.
  - × direct positive effect: γ_r
  - × indirect negative effect $-\alpha_r\gamma_y$

The Patman condition

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- Let's compute the effect on inflation of a small increase in r (set by policy) keeping expectations fixed.
  - × direct positive effect: γ_r
  - × indirect negative effect $-\alpha_r\gamma_y$

(Temporary Equilibrium) Patman condition :
An increase in r will increase π, keeping expectations fixed, if $\gamma_r > \alpha_r\gamma_y$

The Patman condition

$$y_t = \alpha_y E_t[y_{t+1}] - \alpha_r r_t + d_t \qquad \text{Euler Equation (EE)}$$
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- $\gamma_r > \alpha_r \gamma_y$
- Congressman Wright Patman's critique of the Fed in the 70's: high interest rates cause inflation because they put pressure on firms financial costs.
- He pointed out " *...the senselessness of trying to fight inflation by raising interest rates. Throwing gasoline on fire to put out the flames would be as logical.*" [1970]
- Tobin [1980] : " *More fundamentally, heretics from the populist Texas Congressman, Wright Patman, to John Kenneth Galbraith have disputed the orthodox view that tight money policies are anti-inflationary, claiming that borrowers mark up interest charges like other cost.*"

The Patman condition

$$y_t = \alpha_y E_t[y_{t+1}] - \alpha_r r_t + d_t \qquad \text{Euler Equation (EE)}$$
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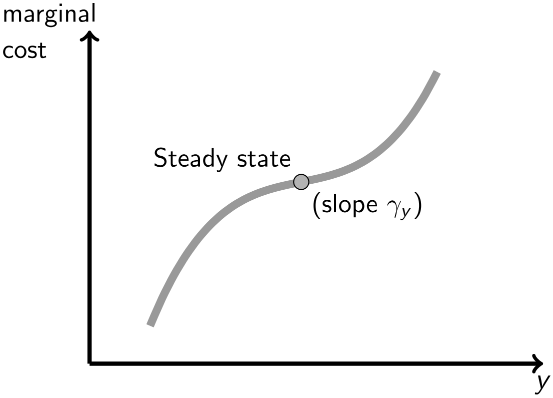
(Temporary Equilibrium) Patman condition :
An increase in r will increase π*, keeping expectations fixed, if* $\gamma_r > \alpha_r \gamma_y$

- Note: this condition also describes what happens in equilibrium if shocks are iid ...
- ... because $E_t[\pi_{t+1}] = 0$ and $E_t[y_{t+1}] = 0$.
- In that case also a *General Equilibrium Patman Condition*

Remark: The Patman condition cannot hold globally

- Unlikely that the Phillips curve is flat for very positive or negative output gaps.
- Most likely,
  marginal cost $= \Gamma(y) + \gamma_r r$
  - × $\Gamma'(y)$ minimum at zero
  - × $\Gamma'(0) = \gamma_y$
- The Patman condition is in essence a local condition.
- How local? Does it hold on average? Empirical work will tell us.
- We will mostly keep a linear approximation



The Patman condition

- In analytical models of the cost channel (e.g. Ravenna and Walsh, Surico, etc...), the model specification always implies that the Patman condition cannot hold.

Demand and markup shocks

- The response of the economy to demand and markup shocks, for standard Taylor rules, is qualitatively similar regardless of the Patman condition holding or not
- Patman condition matters for monetary policy and monetary shocks

Implication for monetary policy

- A lot of results that counter the intuition of the NK model, but not the facts
  - × How to stabilize inflation?
  - × ZLB trap and Lowflation
  - × Price puzzle
- (more in the paper)

How to stabilize inflation?

$$y_t = \alpha_y E_t[y_{t+1}] - \alpha_r r_t + d_t \qquad \text{Euler Equation (EE)}$$
$$\pi_t = \beta E_t[\pi_{t+1}] + \left(\gamma_y y_t + \gamma_r r_t\right) + \mu_t \qquad \text{Phillips Curve (PC)}$$

- Start at steady state
- Consider a permanent $d > 0$ or a $\mu > 0$
- Monetary policy increases the real interest rate to r on impact, with persistence ρ_r
- We derive can the relation $\pi_t(r)$ in equilibrium:

$$\begin{aligned}\pi_t =& \frac{\rho_r^t}{1-\rho_r\beta}\left((\gamma_r - \alpha_r\gamma_y) - \frac{\rho_r}{1-\rho_r\alpha_y}\alpha_y\alpha_r\gamma_y\right) r \\ &+\gamma_y \sum_{j=0}^{\infty}\beta^j\left(E_t\sum_{k=0}^{\infty}\alpha_y^k E_{t+j} d_{t+j+k}\right) + \sum_{j=0}^{\infty}\beta^j E_t \mu_{t+j}.\end{aligned}$$

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$$+\gamma_y \sum_{j=0}^{\infty} \beta^j \left(E_t \sum_{k=0}^{\infty} \alpha_y^k E_{t+j} d_{t+j+k}\right) + \sum_{j=0}^{\infty} \beta^j E_t \mu_{t+j}.$$

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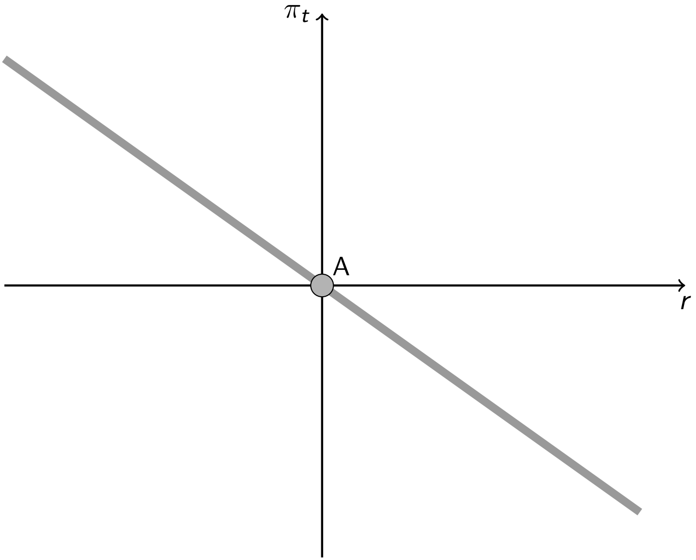
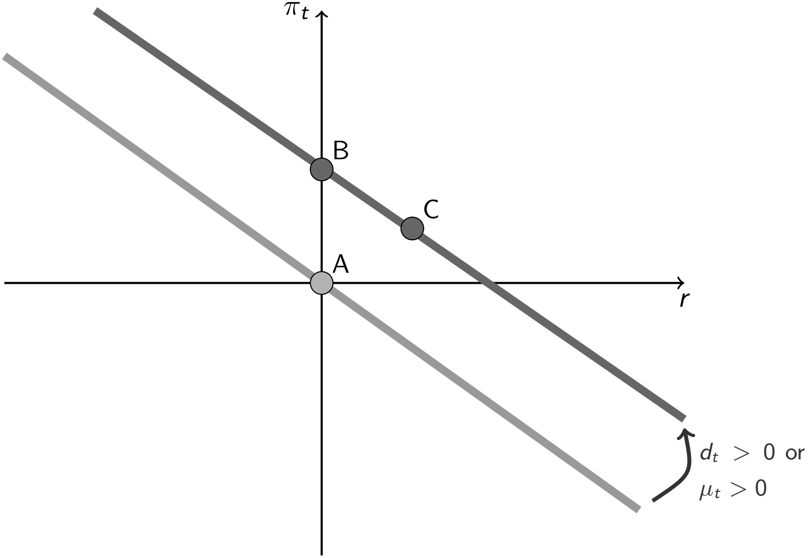
- Start at steady state
- Consider a permanent $d > 0$ or a $\mu > 0$
- Monetary policy increases the real interest rate to r on impact, with persistence ρ_r
- We derive can the relation $\pi_t(r)$ in equilibrium: (G.E. Patman condition)

$$\pi_t = \frac{\rho_r^t}{1-\rho_r\beta}\left((\gamma_r - \alpha_r\gamma_y) - \frac{\rho_r}{1-\rho_r\alpha_y}\alpha_y\alpha_r\gamma_y\right) r$$
$$+\gamma_y \sum_{j=0}^{\infty} \beta^j \left(E_t \sum_{k=0}^{\infty} \alpha_y^k E_{t+j} d_{t+j+k}\right) + \sum_{j=0}^{\infty} \beta^j E_t \mu_{t+j}.$$

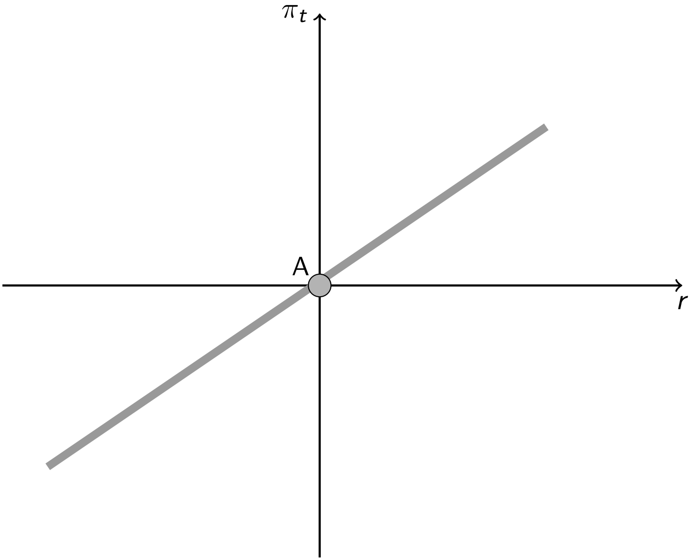
π_t as a Function of r when the Patman Condition is Not Met



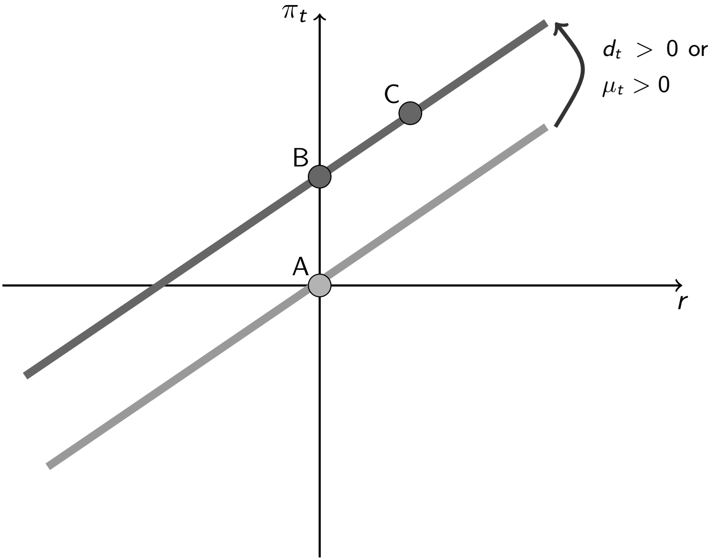
π_t as a Function of r when the Patman Condition is Not Met



π_t as a Function of r_t when the Patman Condition Holds



π_t as a Function of r_t when the Patman Condition Holds



The ZLB Trap and Lowflation

The ZLB Trap and Lowflation

- Under Patman condition, the ZLB is almost inevitable following a persistent fall in demand.
  - Initial negative demand shock (*say a discount factor shock*) $\rightsquigarrow$
  - Low activity and low inflation $\rightsquigarrow$
  - Monetary expansion $\rightsquigarrow$
  - Lower i and lower inflation $\rightsquigarrow$
  - Calls for more monetary expansion $\rightsquigarrow$
  - Even lower i $\rightsquigarrow$
  - Very likely to hit the zero lower bound.
- Typically what will happen under price level targeting

"To be more concrete on how the temporary price-level target would be communicated, suppose that, at some moment when the economy is away from the ZLB, the Fed were to make an announcement something like the following:

- (...)

- The FOMC (...) agrees that, in future situations in which the funds rate is at or near zero, a necessary condition for raising the funds rate will be that average inflation <u>since the date at which the federal funds rate first hit zero be at least 2 percent</u>."

Bernanke *[2017] (underlined by* Bernanke*)*

The ZLB Trap and Lowflation

iid + Flat PC

$$
\begin{aligned}
\pi_t &= \beta E_t \pi_{t+1} + \gamma_y y_t + \gamma_r (i_t - E_t \pi_{t+1}), \\
y_t &= \alpha_y E_t y_{t+1} - \alpha_r (i_t - E_t \pi_{t+1}) + d_t
\end{aligned}
$$

- Assume iid shocks and flat Phillips Curve ($\gamma_y = 0$).

$$
\begin{aligned}
\pi_t &= \gamma_r i_t, \\
y_t &= -\alpha_r i_t + d_t
\end{aligned}
$$

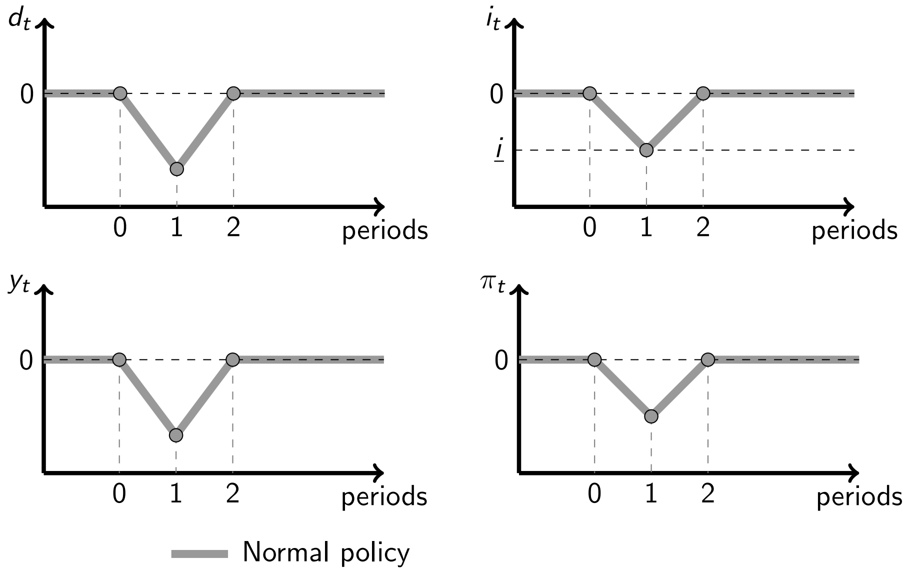
- Normal Policy

$$i_t = \max\left\{\psi d_t, \underline{i}\right\}$$

- Aggressive Policy (Bernanke)

$$i_t = \begin{cases} \max\left\{\psi d_t, \underline{i}\right\} & \text{in normal times – i.e., when } [i_{t-1} > \underline{i}] \text{ or } [i_{t-1} = \underline{i} \text{ and } \pi_{t-1} \geq 0], \\ \underline{i} & \text{if } [i_{t-1} = \underline{i} \text{ and } \pi_{t-1} < 0]. \end{cases}$$

The ZLB Trap and Lowflation



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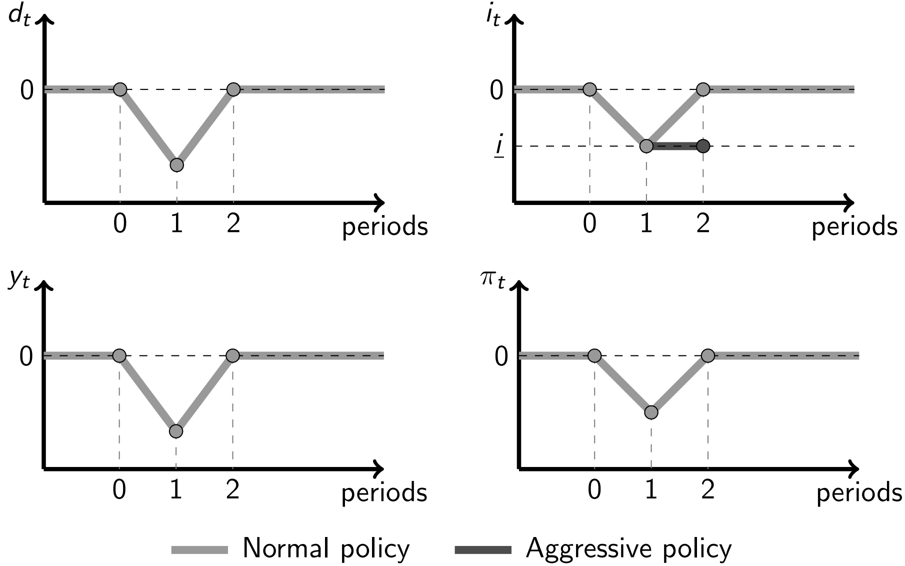

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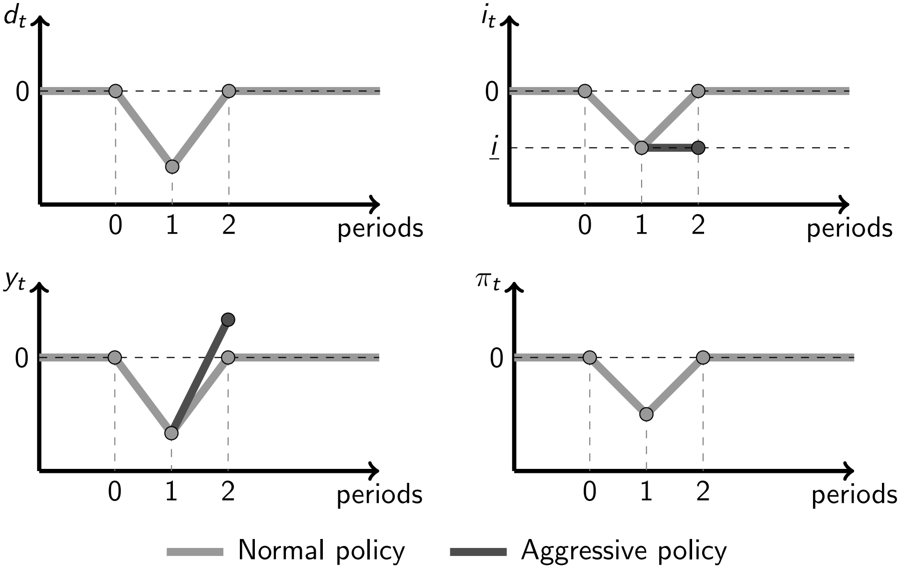

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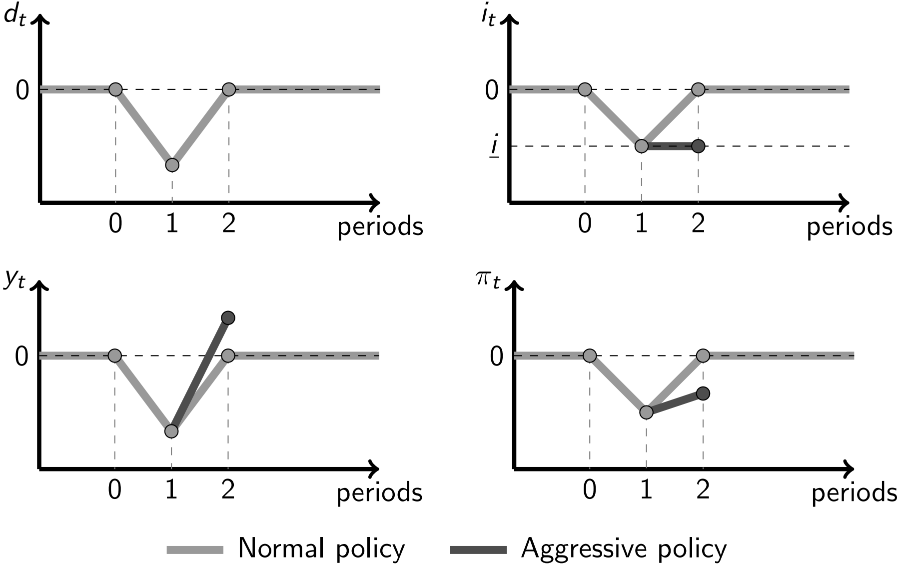
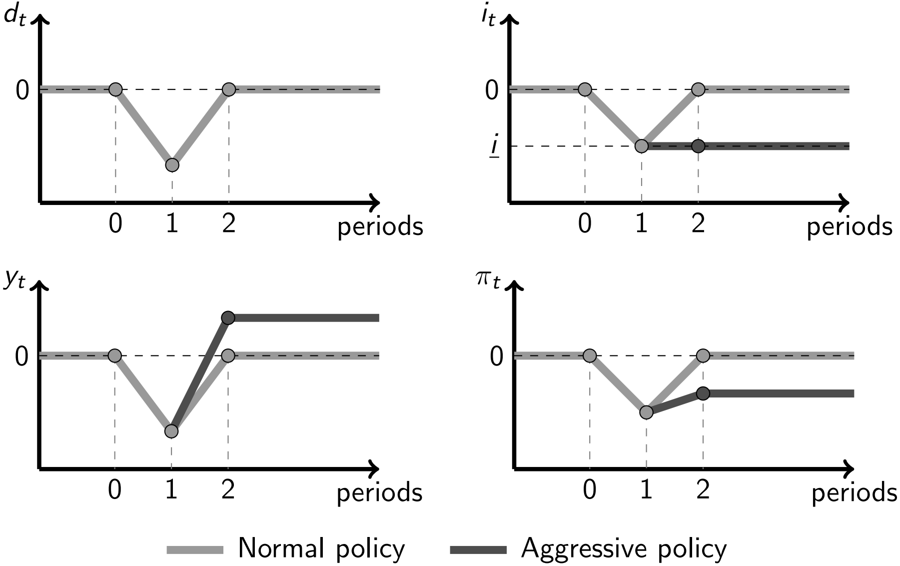


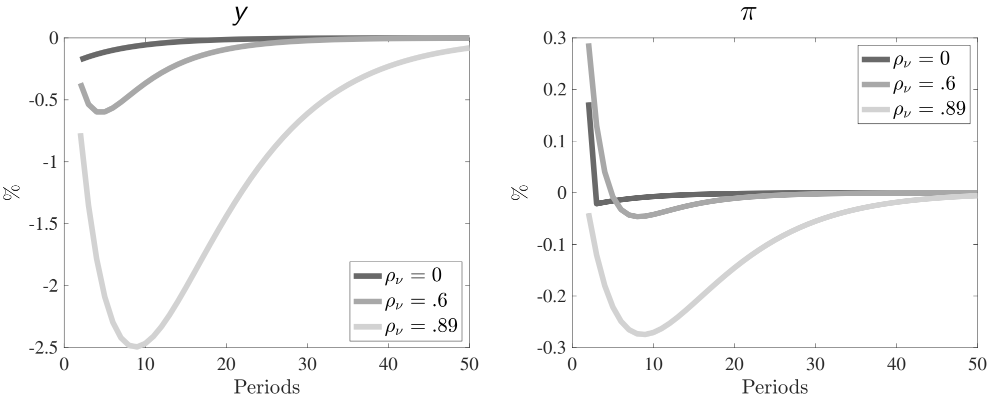
The ZLB Trap and Lowflation



Price puzzle

- If the Patman condition holds, we have a price “puzzle”.
- Only in the short run in a model with some endogenous propagation (habit persistence).

Impulse Responses to a Contractionary Monetary Shock



Roadmap

1. Theory
2. Phillips Curve Estimation
3. Full Information Estimation

- Here we build on the large literature that estimate single equation Phillips curves.

Phillips Curve Estimation
Measurement

$$\pi_t = \beta E_t \pi_{t+1} + \gamma_y y_t + \gamma_r (i_t - E_t \pi_{t+1}) + \theta z_t + \mu_t$$

Phillips Curve Estimation
Measurement

$$\pi_t = \beta E_t \pi_{t+1} + \gamma_y y_t + \gamma_r (i_t - E_t \pi_{t+1}) + \theta z_t + \mu_t$$

Phillips Curve Estimation

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Phillips Curve Estimation

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Phillips Curve Estimation
Measurement

$$\pi_t = \beta \quad \pi^e_{t+1} + \gamma_y x_t + \gamma_r(i_t - \quad \pi^e_{t+1}) + \theta z_t + \mu_t$$

Phillips Curve Estimation
Measurement

$$\pi_t = \beta \quad \pi^e_{t+1} + \gamma_y x_t + \gamma_r (i_t - \quad \pi^e_{t+1}) + \theta z_t + \mu_t$$

- First Pass:
- π_t: Headline CPI
- π^e_t: University of Michigan Survey of Consumers (MSC)
- x_t: *minus* Unemployment gap from U.S. Congressional Budget Office
- z_t: Oil price

Endogenity

$$\pi_t = \beta\pi^e_{t+1} + \gamma_y x_t + \gamma_r(i_t - \pi^e_{t+1}) + \theta z_t + \mu_t$$

- Need to deal with endogeneity and measurement error for
  - x
  - $i_t - \pi^e_{t+1}$
  - π^e_{t+1}
- Instrument: Romer & Romer [2004] monetary shocks (extended by Wieland & Yang [2020]), as suggested by Barnichon & Mesters [2020]

Phillips Curve Estimation: Basic - Headline CPI

$$\pi_t = \beta\pi^e_{t+1} + \gamma_y x_t + \gamma_r(i_t - \pi^e_{t+1}) + \theta z_t + \mu_t$$

π^e	MSC		FIRE	
	(1)	(2)	(3)	(4)
β	1.12	1.18	0.81	0.98
	(0.079)	(0.074)	(0.098)	(0.106)
γ_y	0.12	0.06	0.08	-0.07
	(0.047)	(0.053)	(0.071)	(0.076)
γ_r		0.14		0.21
		(0.041)		(0.062)

- z: oil price,
- Sample: 1969Q1–2017Q4,
- Newey-West HAC standard errors,
- for the γs: : significant at 1%

Phillips Curve Estimation: Core CPI

$$\pi_t = \beta \pi^e_{t+1} + \gamma_y x_t + \gamma_r (i_t - \pi^e_{t+1}) + \mu_t$$

π^e	MSC	FIRE
	(1)	(2)
β	0.97	0.74
γ_y	-0.05	0.00
γ_r	0.19	0.47

- Sample: 1969Q1–2017Q4
- Newey-West HAC standard errors,
- for the γs: ▢ : significant at 1%

Phillips Curve Estimation: Some subtleties (1)

- Before 1983, the shelter component of the CPI was computed using an index of house prices, and an index of mortgage rates.
- Mortgage rates directly co-move with the effective federal funds rate, and indirectly, through discount rates, house prices do too.
- This would mechanically make CPI inflation reacting to the federal fund rate.
- Since 1983, the BLS adjusted its methodology, and changed the computation of the shelter component of the CPI in favour of a rental equivalence index.
- Core R-CPI does this adjustment retroactively back to 1978Q2

Phillips Curve Estimation: Some subtleties (2)

- The slope of the Phillips curve is notoriously hard do estimate on aggregate data.
- Using monetary shocks as instruments (Barnichon & Mesters [2020]) is a good solution, but there are other ones.
- Hazell, Herreño, Nakamura, and Steinsson [2020] exploit US regional variations to estimate γ_y
- We also repeat our estimations constraining γ_y to take their value.

Phillips Curve Estimation: Core R-CPI

$$\pi_t = \beta\pi^e_{t+1} + \gamma_y x_t + \gamma_r(i_t - \pi^e_{t+1}) + \mu_t$$

π^e	MSC		FIRE	
	(1)	(2)	(3)	(4)
β	0.91	0.95	0.98	1.01
γ_y	-0.08	$0.0138^{\dagger}$	-0.03	$0.0138^{\dagger}$
γ_r	0.12	0.20	0.06	0.10

- × Sample: `1978Q2-2017Q4`,
- × Newey-West HAC standard errors,
- × for the γs: ▢ : significant at 1%

Phillips Curve Estimation: Iterating Forward the Phillips Curve

- In the spirit of Hazell, Herreño, Nakamura, and Steinsson [2020].
- Identification does not rely on the timing of inflation variations.
- Same results

Phillips Curve Estimation: Hybrid

$$\pi_t = \beta_{+1}\pi^e_{t+1} + \beta_{-1}\pi_{t-1} + \gamma_y x_t + \gamma_r(i_t - \pi^e_{t+1}) + \theta z_t + \mu_t$$

- We obtain similar results.

Some Further International Evidence

- Coibion, Gorodnichenko, and Ulate [2019] assemble time series of inflation expectations for 18 countries/regions.

$$\pi_{i,t} - \pi^e_{i,t+1} = \gamma_y y_{i,t} + c_i + \varepsilon_{i,t},$$

- Results "*a robust and negative*" γ_y
- We repeat their exercice with a cost channel.

$$\pi_{i,t} - \pi^e_{i,t+1} = \gamma_y y_{i,t} + \gamma_r \left(i_{i,t} - \pi^e_{i,t+1} \right) + c_i + \varepsilon_{i,t}.$$

γ_y	0.32	.019
	(0.10)	(0.17)
γ_r	–	0.20
	(–)	(0.07)
Adj. R^2	0.63	0.66
Observations	1062	1062

: significant at 1%, : significant at 5%

Phillips Curve Estimation: Nonlinear estimation

$$\pi_t = \beta\pi^e_{t+1} + (\gamma_{y,1}x_t + \gamma_{y,2}x_t^2 + \gamma_{y,3}x_t^3) + \gamma_r(i_t - \pi^e_{t+1}) + \theta z_t + \mu_t$$

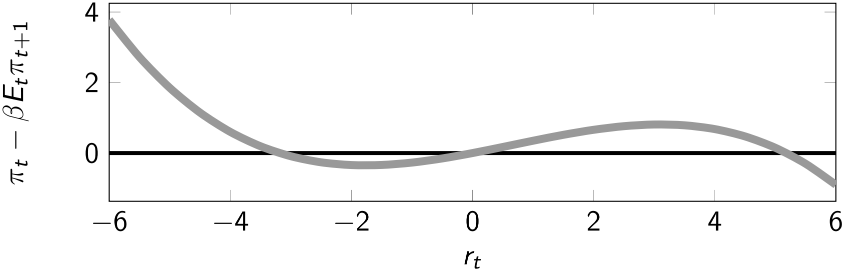
-

-

Phillips Curve Estimation: Nonlinear estimation

$$\pi_t = \beta\pi^e_{t+1} + (\gamma_{y,1}x_t + \gamma_{y,2}x_t^2 + \gamma_{y,3}x_t^3) + \gamma_r(i_t - \pi^e_{t+1}) + \theta z_t + \mu_t$$

- $\pi_t - \beta\pi^e_{t+1}$ as a function of r_t implied by the estimation:



- Patman zone for $r \in [-2\%, +3\%]$ around historical average value

Nominal versus Real Interest Rates in the Marginal Cost

- Both ways are theoretically possible
- It does not change the estimation, just the parameters interpretation

$$\pi_t = \beta\pi^e_{t+1} + \gamma_y y_t + \gamma_r(i_t - \pi^e_{t+1})$$

$$\pi_t = \underbrace{(\beta - \gamma_r)}_{\widehat{\beta}}\pi^e_{t+1} + \gamma_y y_t + \gamma_r i_t$$

- We estimate $\beta = .91$ and $\gamma_r = .12$ with the real interest rate model interpretation.
- $\beta = .99$ in calibrated models
- With the nominal interest rate model, one would estimate a smaller (too small) discount factor $\widehat{\beta} = \beta - \gamma_r = .79$

Nominal versus Real Interest Rates in the Marginal Cost

- We can also directly compare the real and nominal rate specification if we set $\beta = .99$ and $\gamma_y = 0.0138$ and estimate the two following equations:

$$\begin{aligned}\pi_t &= .99\pi^e_{t+1} + 0.0138x_t + \gamma_r(i_t - \pi^e_{t+1}) + \mu_t,\\ \pi_t &= .99\pi^e_{t+1} + 0.0138x_t + \gamma_r i_t + \mu_t.\end{aligned}$$

	With real interest rate	With nominal interest rate
β	$.99^{\dagger}$	$.99^{\dagger}$
γ_y	$0.0138^{\dagger}$	$0.0138^{\dagger}$
γ_r	0.20	0.09
R^2	0.250	0.022

Roadmap

1. Theory
2. Phillips Curve Estimation
3. <u>Full Information Estimation</u>

Simple Model

- To compare to existing literature, we estimate a local approximation of the model.

$$y_t = \alpha_y E_t[y_{t+1}] - \alpha_r(i_t - E_t[\pi_{t+1}]) + d_t, \tag{EE}$$

$$\pi_t = \beta E_t[\pi_{t+1}] + \big(\gamma_y y_t + \gamma_r(i_t - E_t[\pi_{t+1}])\big) + \mu_t, \tag{PC}$$

-

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- To compare to existing literature, we estimate a local approximation of the model.

$$y_t = \alpha_y E_t[y_{t+1}] - \alpha_r(i_t - E_t[\pi_{t+1}]) + d_t, \tag{EE}$$

$$\pi_t = \beta E_t[\pi_{t+1}] + \big(\gamma_y y_t + \gamma_r(i_t - E_t[\pi_{t+1}])\big) + \mu_t, \tag{PC}$$

$$i_t = E_t[\pi_{t+1}] + \phi_d d_t + \phi_\mu \mu_t + \nu_t. \tag{Policy}$$

- We prove in the paper that such a real interest rate rule encompasses the traditional Taylor rule.

Simple Model

$$y_t = \alpha_y E_t[y_{t+1}] - \alpha_r(i_t - E_t[\pi_{t+1}]) + d_t, \tag{EE}$$

$$\pi_t = \beta E_t[\pi_{t+1}] + \big(\gamma_y y_t + \gamma_r(i_t - E_t[\pi_{t+1}])\big) + \mu_t, \tag{PC}$$

$$i_t = E_t[\pi_{t+1}] + \phi_d d_t + \phi_\mu \mu_t + \nu_t. \tag{Policy}$$

Quasi-No Euler Discounting

$$y_t = .99 E_t[y_{t+1}] - \alpha_r(i_t - E_t[\pi_{t+1}]) + d_t, \tag{EE}$$

$$\pi_t = .99 E_t[\pi_{t+1}] + \big(\gamma_y y_t + \gamma_r(i_t - E_t[\pi_{t+1}])\big) + \mu_t, \tag{PC}$$

$$i_t = E_t[\pi_{t+1}] + \phi_d d_t + \phi_\mu \mu_t + \nu_t. \tag{Policy}$$

Estimated Parameters, Simple Model, ML

γ_y	0.013	γ_r	0.034
	(0.03)		(0.016)

Temp. Eq. Patman condition	0.034	(0.016)
Gen. Eq. Patman condition	0.089	(0.030)

Figure 1: Impulse Responses to Shocks, Simple Model, Baseline

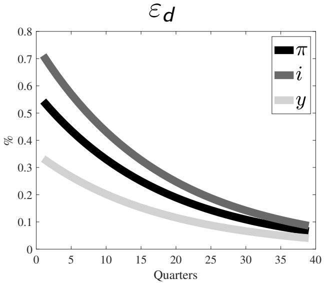


Figure 1: Impulse Responses to Shocks, Simple Model, Baseline

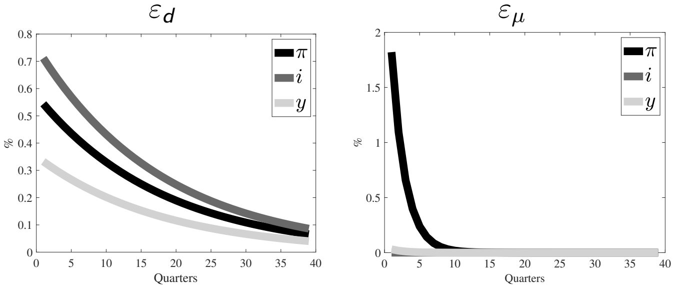
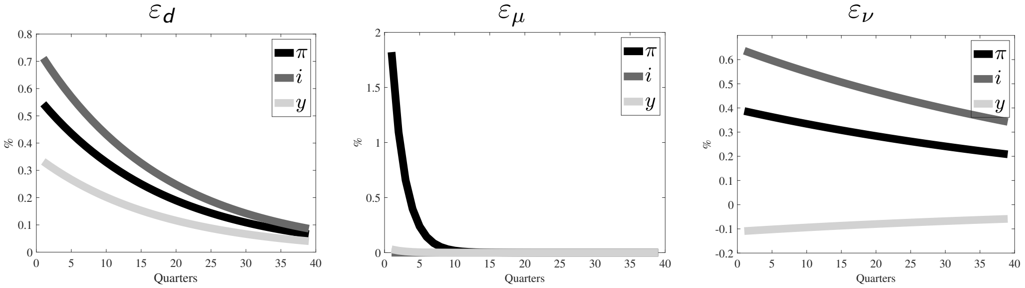


Figure 1: Impulse Responses to Shocks, Simple Model, Baseline



Extended Model

- We add habit persistence, hybrid Phillips curve and persistence in policy rule.
- Estimation using Bayesian technique.

$$y_t = \alpha_y\left(\alpha_{y,+1}E_t[y_{t+1}] + (1-\alpha_{y,+1})y_{t-1}\right) - \alpha_r(i_t - E_t[\pi_{t+1}]) + \alpha_\mu \mu_t + d_t, \quad \text{(EE')}$$

$$\pi_t = \beta\left((1-\beta_{-1})E_t[\pi_{t+1}] + \beta_{-1}\pi_{t-1}\right) + \left(\gamma_y y_t + \gamma_r(i_t - E_t[\pi_{t+1}])\right) + \mu_t, \quad \text{(PC')}$$

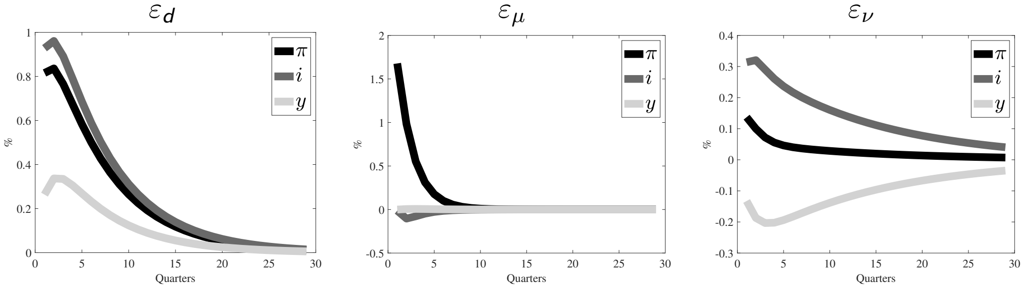
$$i_t = E_t[\pi_{t+1}] + \phi_{r,-1}\left(i_{t-1} - E_{t-1}[\pi_t]\right) + \phi_{\pi,-1}\pi_{t-1} + \phi_{y,-1}y_{t-1} + \phi_d d_t + \phi_\mu \mu_t + \nu_t. \quad \text{(Policy')}$$

Estimated Parameters, Extended Model

γ_y	-0.03	γ_r	0.07
	[-0.11, 0.04]		[0.03, 0.11]

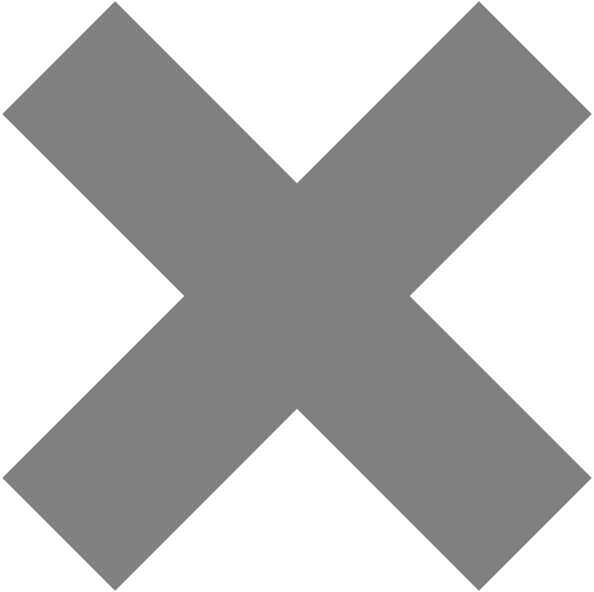
Temp. Eq. Patman condition	0.07	[0.03, 0.11]
Gen. Eq. Patman condition	0.10	[0.07, 0.13]

Figure 2: Impulse Responses to Shocks, Extended Model, Baseline



To conclude

- The cost channel is strong as compared to the slope of the Phillips curve (Patman condition holds)
- This is shown estimating simple DSGE-like models or Phillips curve alone.
- This has implications for the effect of monetary policy aiming at stabilizing inflation.



Coibion, Gorodnichenko, and Ulate [2019]

- Australia, Canada, Chile, Czechia, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, South Korea, Sweden, Turkey, United Kingdom, United States, as well as the entire eurozone

Iterating forward the Phillips Curve

- Hazell, Herreño, Nakamura, and Steinsson [2020]
- Take the Phillips curve

$$\pi_t = \beta\pi^e_{t+1} + \gamma_y x_t + \gamma_r(i_t - \pi^e_{t+1}) + \mu_t$$

- and solve forward

$$\pi_t = \sum_{j=0}^{\infty} \beta^j(\gamma_y E_t x_{t+j} + \gamma_r E_t r_{t+j} + E_t \mu_{t+j}) + \underbrace{\lim_{j\to\infty} \beta^j E_t \pi_{t+j}}_{=0}$$

- Assume that x_t and r_t have a long-run and a transitory component so that $x_t = \widetilde{x}_t + x_\infty$ and $r_t = \widetilde{r}_t + r_\infty$.
- When $t \to \infty$ we have $E_t\pi_\infty = \frac{1}{1-\beta}(\gamma_y E_t x_\infty + \gamma_r E_t r_\infty)$.

Iterating forward the Phillips Curve

- Then the Phillips curve rewrites

$$\pi_t = \gamma_y \sum_{j=0}^{\infty} \beta^j E_t \widetilde{x}_{t+j} + \gamma_r \sum_{j=0}^{\infty} \beta^j E_t \widetilde{r}_{t+j} + \frac{1}{1-\beta}(\gamma_y E_t x_\infty + \gamma_r E_t r_\infty) + \sum_{j=0}^{\infty} \beta^j E_t \mu_{t+j}$$

$$= \gamma_y \sum_{j=0}^{\infty} \beta^j E_t \widetilde{x}_{t+j} + \gamma_r \sum_{j=0}^{\infty} \beta^j E_t \widetilde{r}_{t+j} + E_t \pi_\infty + \sum_{j=0}^{\infty} \beta^j E_t \mu_{t+j}$$

- Truncate the infinite time horizon at $T = 40$, and use the ten-year ahead CPI forecast from Cleveland Fed as a measure of $E_t \pi_\infty$.
- Replace $\sum_{j=0}^{\infty} \beta^j E_t \widetilde{x}_{t+j}$ and $\sum_{j=0}^{\infty} \beta^j E_t \widetilde{r}_{t+j}$ with $\sum_{j=0}^{T} \beta^j \widetilde{x}_{t+j}$ and $\sum_{j=0}^{T} \beta^j \widetilde{r}_{t+j}$
- Instrument with monetary shocks prior to time t.

Iterating forward the Phillips Curve

γ_y	0.0138†
	(–)
γ_r	0.11
	(0.020)

- Sample: 1982Q1–2017Q4,
- Newey-West HAC standard errors,
- : significant at 1%