Macroeconomic Expectations and Limited Awareness

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Introduction

- **Rational Expectations (RE) is a mainstream tool in macroeconomics**

- **Sizable evidence questioning RE** (e.g., forecast errors are predictable)

  $\Rightarrow$ several theories with departures from RE [learning, level-k, diagnostic expectations, limited-memory, etc.]

  $\Rightarrow$ different implications for macro variables and policies

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  ⇒ several theories with departures from RE [learning, level-k, diagnostic expectations, limited-memory, etc.]

  ⇒ different implications for macro variables and policies
- Most evidence about expectations of different variables considered in isolation

Question: What about coherence of expectations across macro variables?

⇒ important to discipline alternative theories

This paper

Focus on two classical macro variables: **inflation** (π_t) and **unemployment** (u_t)

1. Do agents understand the **"trade-off"** between these two variables?
2. If not, what are the **potential sources** of their "mistake"?
3. **What are the implications for monetary policy?** (in progress)

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1. Do agents understand the **"trade-off"** between these two variables?

   we document **two facts** on expectations

   - **"over-reaction"** for inflation, but **"under-reaction"** for unemployment
   - A **misperceived** Phillips Curve: downward bias in perceived slope

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   - "excessive" weight on demand shocks $\Rightarrow$ over-reaction of inflation
   - downplayed persistence of shock $\Rightarrow$ under-reaction of output
   - omitted variable problem $\Rightarrow$ downward bias on perceived slope of Phillips curve

3. **What are the implications for monetary policy?** (in progress)

Related Literature

- **Subjective expectations in macroeconomics**

  Carroll (2003); Mankiw-Reis-Wolfers (2003); Pesaran-Weale (2006); Coibion-Gorodnichenko (2012, 2015); Bordalo et al. (2020); D'Acunto-Malmendier-Weber (2022)

  $\Rightarrow$ look at relationship across variables

- **Subjective expectations across macroeconomic variables**

  Carvalho and Necchio (2014); Drager-Lamla-Pfajar (2016); Link-Peichl-Roth-Wohlfart (2021); Hou (2022)

  $\Rightarrow$ incoherence between inflation and unemployment forecasts errors

- **Macroeconomic models with departures from RE**

  Marcet and Sargent (1989); Branch and Evans (2003); Adam and Marcet (2011); Garcia-Schmidt and Woodford (2015); Gabaix (2016); Farhi and Werning (2017); Iovino and Sergeyev (2022); Molavi (2019); Angeletos, Huo and Sastry (2020); Molavi, Tahbaz-Salehi and Vedolin (2022); Hansen-Sargent (2022); da Silveira-Sung-Woodford (2023), etc.

  $\Rightarrow$ a simple model of misspecification to rationalize our evidence

Outline

1. Empirical Evidence
2. A Model with Limited Aware Agents
3. Implications for Monetary Policy

Empirical Evidence

Data: Survey of Professional Forecasters (SPF)

✓ Professional forecasters are informed agents

✓ Quarterly survey of approx. 30-40 professionals on

- GDP deflator and CPI forecasts
- Real GDP and unemployment rate forecasts

✓ Run by the Philly-Fed, available since 1968:IV (we end in 2020:I)

✓ Forecasting Horizons from $h = 1$ to $h = 4$ quarters

Question #1: Predictability of Forecast Errors?

based on Cobion and Gorodnichenko (2015) and Bordalo et al. (2020)

- For a generic variable x, and individual i, let's define

$$FE_t^i(x_{t+h}) \equiv x_{t+h} - \mathbb{E}_t^i\{x_{t+h}\} \qquad \text{(Forecast Error)}$$

$$FR_t^i(x_{t+h}) \equiv \mathbb{E}_t^i\{x_{t+h}\} - \mathbb{E}_{t-1}^i\{x_{t+h}\} \qquad \text{(Forecast Revision)}$$

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	Interpretation	Example
$\beta_x > 0$	"under-reaction"	insufficient forecast increase $\rightarrow$ positive forecast error
$\beta_x < 0$	"over-reaction"	excessive forecast increase $\rightarrow$ negative forecast error

Evidence #1: Predictability of Forecast Errors

Table 1: Predictability of Forecast Errors: Forecaster Level Data

	(1)	(2)	(3)	(4)	(5)
	h=1	h=2	h=3	All	1981-2008
Inflation					
β_π	-0.36***	-0.36***	-0.40***	-0.37***	-0.45***
	(0.06)	(0.06)	(0.06)	(0.04)	(0.02)
obs.	4826	4054	3764	12644	5753

Notes: *Driscoll and Kraay (1998) standard errors are in parentheses. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively*

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Unemployment					
β_y	0.28*	0.34**	0.27	0.30*	0.14
	(0.14)	(0.15)	(0.20)	(0.16)	(0.10)
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Question #2: A Missperceived Phillips Curve?

- Suppose that inflation (π_t) and unemployment (u_t) are linked by the following relationship

$$\pi_t = -\kappa u_t + \text{controls}_t + \eta_t \tag{PC}$$

where controls_t may include expectations, lagged variables, etc.

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- Consider now a "perceived" Phillips curve

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Empirical Specification: Taking the difference between (PC) and (perceived PC)

$$\pi_t - \mathbb{E}^i_{t-1}\{\pi_t\} = -\kappa\left[u_t - \mathbb{E}^i_{t-1}\{u_t\}\right] - \gamma\mathbb{E}^i_{t-1}\{u_t\} + \widetilde{\text{controls}}_t + \varepsilon_t$$

where $\widetilde{\text{controls}}_t \equiv \text{controls}_t - \mathbb{E}^i_{t-1}\{\text{controls}_t\}$.

Null Hypothesis (RE): $\gamma \equiv (\kappa - \tilde{\kappa}) = 0$

Question #2: A Missperceived Phillips Curve? (cont'd)

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- **Baseline:** no controls, simple test of RE (OLS valid under RE)

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- **Baseline:** no controls, simple test of RE (OLS valid under RE)
- **Alternative:**
  - (1) **NKPC**: control for individual forecast revisions $\mathbb{E}^i_t\{\pi_{t+1}\} - \mathbb{E}^i_{t-1}\{\pi_{t+1}\}$
  - (2) NKPC on subsample 1981-2008
  - (3) **Hybrid**: NKPC + control for lagged inflation: $\pi_{t-1} - \mathbb{E}^i_{t-1}\{\pi_{t-1}\}$
  - (4) **IV**: use high-frequency monetary shocks as instruments

Evidence #2: A Misperceived Phillips Curve

Table 2: OLS Regressions

	Baseline	**(1) NKPC**	**(2) 1981-2008**	**(3) Hybrid**
One-period $(h = 1)$				
γ	0.22**	0.15***	0.12**	0.13**
	(0.07)	(0.05)	(0.06)	(0.05)
obs.	5972	4807	2211	4799
All periods $(h = 1, 2, 3)$				
γ	0.21**	0.12**	0.15**	0.11**
	(0.06)	(0.05)	(0.05)	(0.05)
obs.	13808	11332	5174	11034

Notes: *Driscoll and Kraay (1998) standard errors are in parentheses. ***, **, and * denote significance at the 1, 5 and 10 percent level, respectively*

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Table 3: Instrumental Variables Regressions

	(1) Unemp.	**(2)** y^{gap}(CBO)	**(3)** y^{gap}(HP)
One-period $(h=1)$			
γ	0.15**	0.04***	0.05**
	(0.06)	(0.01)	(0.02)
obs.	1069	1067	1067
First-stage F-stat	13.40	207.64	367.89

Taking Stock

- We find evidence of

  I. over-reaction of inflation forecasts, under-reaction of unemployment forecasts

  II. **downward bias** in the **perceived slope** of the Phillips curve

$\Rightarrow$ Suggest form of misspecification of relationship among variables

- Inconsistent with (most) existing theories. Examples:
  - Rational inattention: no over-/under-reaction (individual expectations)
  - Diagnostic expectations and limited-memory: over-reactions for all variables

$\Rightarrow$ **Next:** propose a simple model to rationalize our evidence

The Model

A Simple Model with Limited Awareness

- A simple macro model ($\rightarrow$ provide microfoundation later)
  - 2 variables: inflation π_t and output y_t
  - 2 exogenous (AR1) shocks: demand (monetary policy) d_t and supply (cost-push) s_t

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  - perfectly observe output (easy to relax) $\Rightarrow$ use it to infer current monetary shock
  - observe inflation with measurement error (e_t)
  - have access to an infinite amount of data (no "learning")

    $\Rightarrow$ used to estimate unknown model parameters, using selected moments

A Simple Model with Limited Awareness

- **True data generating process**

$$\begin{aligned} y_t &= \psi_{yd} d_t + \psi_{ys} s_t \\ \pi_t &= \psi_{\pi d} d_t - \psi_{\pi s} s_t \end{aligned} \tag{DGP}$$

where $d_t = \rho_d d_{t-1} + \varepsilon_t^d$ and $s_t = \rho_s s_{t-1} + \varepsilon_t^s$, and where $\rho_s > \rho_d$.

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- **Perceived data generating process**

$$\begin{aligned} y_t &= \widetilde{\psi}_{yd} \widetilde{d}_t \\ \pi_t &= \widetilde{\psi}_{\pi d} \widetilde{d}_t + e_t \end{aligned} \tag{PDGP}$$

where e_t is an i.i.d. measurement error.

Agents' Forecasts

- Since agents observe y_t, inferred demand shock is

$$\widetilde{d}_t = (\widetilde{\psi}_{yd})^{-1} \overbrace{[\psi_{yd} d_t + \psi_{ys} s_t]}^{y_t}$$

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- One-period ahead forecasts are given by

$$\mathbb{E}_t\{y_{t+1}\} = \widetilde{\rho}_d \, [\psi_{yd} d_t + \psi_{ys} s_t]$$
$$\mathbb{E}_t\{\pi_{t+1}\} = \widetilde{\rho}_d \widetilde{\kappa} [\psi_{yd} d_t + \psi_{ys} s_t]$$

where $\widetilde{\kappa} \equiv \widetilde{\psi}_{\pi d} / \widetilde{\psi}_{yd}$ can be interpreted as the "perceived" slope of the Phillips curve.

- $\widetilde{\kappa}$ can be obtained from

$$\widetilde{\kappa} = \frac{Cov(\pi_t, y_t)}{Var(y_t)}$$

Result #1: Downward Bias in the Perceived Slope of the Phillips Curve

Proposition (Downward Bias in the Slope of the Phillips Curve)

Due to an omitted variable problem, agents get a biased estimate $\tilde{\kappa} < \kappa$

Proof.

$$\widetilde{\kappa} \equiv \frac{\widetilde{\psi}_{\pi d}}{\widetilde{\psi}_{yd}} = \frac{Cov(\pi_t, y_t)}{Var(y_t)} = \frac{\psi_{\pi d}\psi_{yd}\sigma_d^2 - \psi_{\pi s}\psi_{ys}\sigma_s^2}{\psi_{yd}^2\sigma_d^2 + \psi_{ys}^2\sigma_s^2}$$

$$< \frac{\psi_{\pi d}\psi_{yd}\sigma_d^2}{\psi_{yd}^2\sigma_d^2} = \frac{\psi_{\pi d}}{\psi_{yd}} \equiv \kappa$$

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$$FE^{\pi}_{t+1} = \rho_d(\kappa - \widetilde{\kappa})\psi_{yd} d_t - [\rho_s(\psi_{\pi s}/\psi_{ys}) + \rho_d \widetilde{\kappa}]\, \psi_{ys} s_t + \text{shocks}_{t+1}$$

$$FR^{\pi}_t = \rho_d \widetilde{\kappa}\left[(\rho_s - \rho_d)\psi_{ys} s_{t-1} + \psi_{yd}\varepsilon^d_t + \psi_{yd}\varepsilon^s_t\right]$$

conditional on demand shocks $\overset{\kappa > \widetilde{\kappa}}{\Rightarrow}$ positive correlation $\rightarrow$ under-reaction

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conditional on supply shocks $\Rightarrow$ negative correlation $\rightarrow$ over-reaction

Proposition (Over-reaction of Inflation Forecasts)

Inflation forecasts display over-reaction if the relative variance of supply shocks is large enough

Result #3: Under-reaction of Output

$$FE^{y}_{t+1} = (\rho_s - \rho_d)\psi_{ys} s_t + \text{shocks}_{t+1}$$
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conditional on demand shocks $\Rightarrow$ no correlation

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Proposition (Under-reaction of Output Forecasts)

Output forecasts display under-reaction if supply shocks are more persistent than demand shocks

▸ Intuition

Microfoundation

Microfoundation: NK Model

Household i:

- operates firm i, consumes/works with preferences

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right), \qquad C_t \equiv \left(\int (C_t^i)^{\frac{\varepsilon_t^i - 1}{\varepsilon_t^i}} di \right)^{\frac{\varepsilon_t^i}{\varepsilon_t^i - 1}}$$

- trades nominal bonds (zero net supply)

Firm i:

- produces $Y_t^i = N_t^i$, monopolistic competitor, demand $Y_t^i = (P_t / P_t^i)^{\varepsilon_t^i} Y_t$
- ε_t^i is an aggregate elasticity shock, with mean ε
- hires labor, sets price P_t^i subject to (Calvo) nominal rigidities

Central Bank:

- follows Taylor rule with monetary-policy shocks

FIRE Benchmark: Phillips Curve

Agent *i*:

- observes (only) its own Calvo parameter θ^i and shocks $(\varepsilon_t^i)_t$
- knows that all firms are identical

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Proposition (Phillips Curve)

In the log-linearized equilibrium, all firms set the same price and the following Phillips curve holds:

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa y_t + s_t,$$

where $\kappa \equiv (\sigma + \varphi) \frac{(1+\theta)(1-\beta\theta)}{\theta}$ and where the "cost-push" shock s_t is a function of ε_t.

The Perceived Phillips Curve

Agent i:

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- (wrongly) assumes that θ^i is unrelated to $\tilde{\theta}$
- (wrongly) assumes that shocks across firms $(\varepsilon_t^j)_j$ are i.i.d.

  $\Rightarrow$ thinks aggregate variables only driven by demand shocks and **measurement error**

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Firms estimate the common mean $\tilde{\theta}\,(= f(\tilde{\kappa}))$ from

$$\pi_t - \beta \mathbb{E}_t \pi_{t+1} = \tilde{\kappa} y_t + e_t$$

where e_t is (wrongly) interpreted as a pure measurement error

Proposition (Downward Bias in the Slope of the Phillips Curve)

Due to an omitted variable problem, agents obtain a biased estimate

$$\tilde{\kappa} = \frac{Cov\left(\pi_t - \beta \mathbb{E}_t \pi_{t+1}, y_t\right)}{Var\left(y_t\right)} < \kappa$$

The Full Model

Simple NK model with limited aware agents (in log deviations from SS):

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1}{\sigma}(\phi_\pi \pi_t + d_t - \mathbb{E}_t \pi_{t+1}) \tag{AD}$$

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa y_t + s_t \tag{AS}$$

- Under RE: expectations consistent with above equations
- In our model: $\mathbb{E}_t \pi_{t+1} = \beta \mathbb{E}_t \pi_{t+2} + \widetilde{\kappa} \mathbb{E}_t y_{t+1}$
  - assume all parameters but κ are known (for simplicity)
  - expectations based on perceived demand shock, given observed y_t

Monetary Policy Implications

The Effects of Monetary Shocks

We compare our model with the benchmark NK under RE

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Proposition (Effects of Monetary Shocks)

Suppose $\phi_\pi \in (1, 1 + \beta\sigma(1-\rho)/\kappa)$. Then,

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- LA may contribute to the inflation disconnect puzzle
- More costly to control inflation

The Effects of Monetary Policy: Intuition

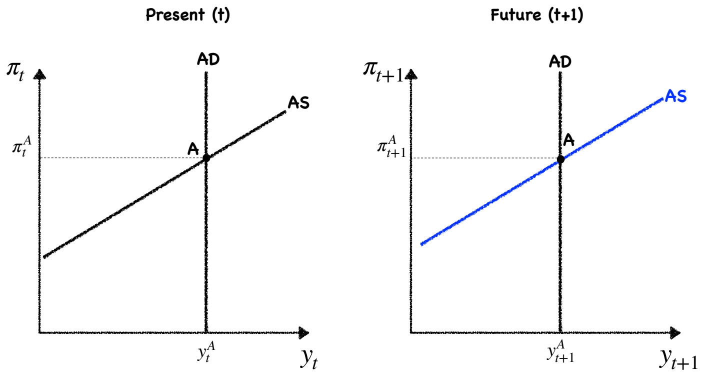
- To get an intuition, suppose the central banks controls the real interest rate

$$r_t = i_t - \mathbb{E}_t\{\pi_{t+1}\} = d_t \tag{1}$$

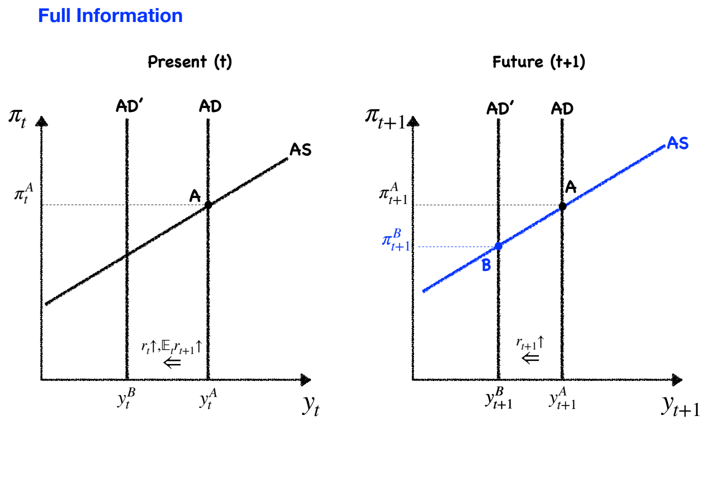
- This means that output is entirely determined by monetary policy (vertical AD equation)

$$y_t = -\frac{1}{\sigma}\sum_{j=0}^{\infty}\mathbb{E}_t\{d_{t+j}\} \tag{2}$$

Graphical Intuition I: Real Rate Rule



Graphical Intuition I: Real Rate Rule



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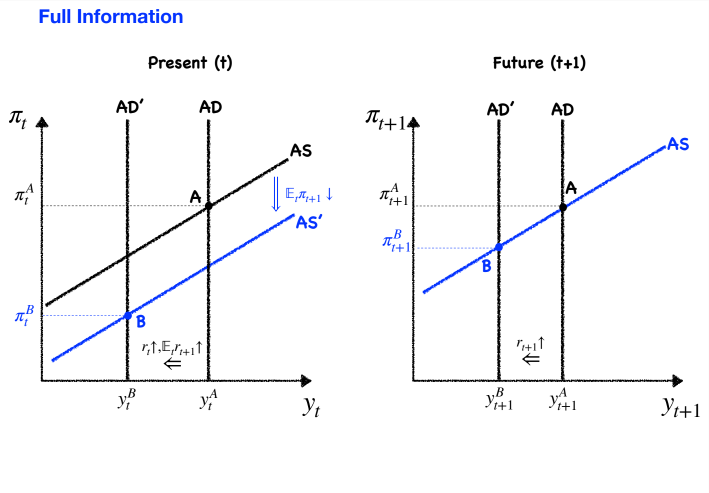

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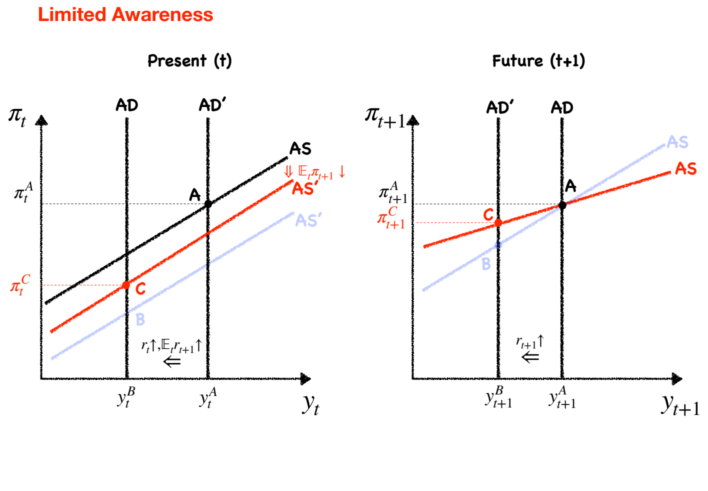
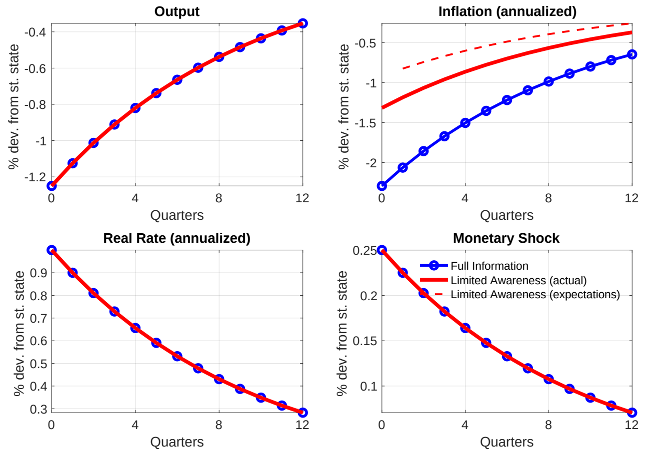
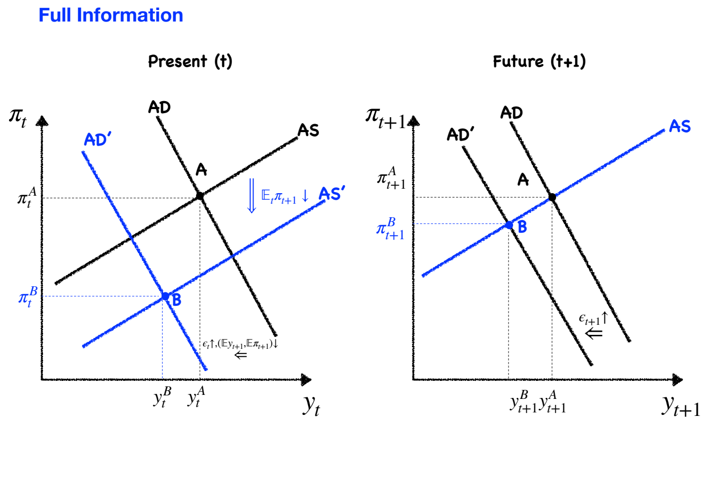


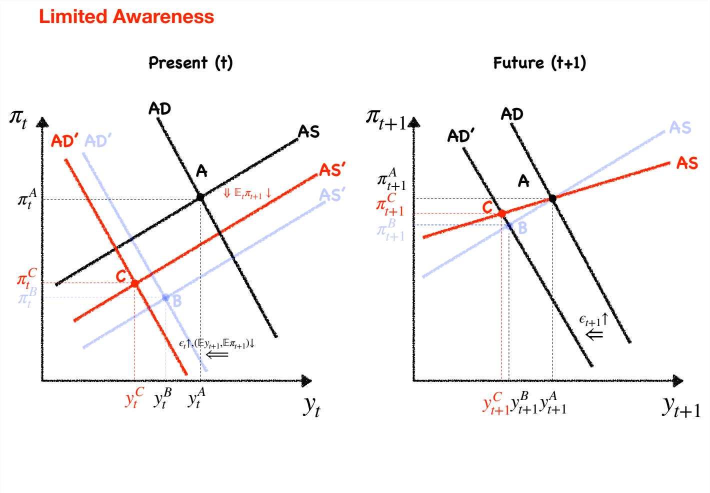
Contractionary Monetary Shock: Real rate rule



Graphical Intuition II: Contractionary, Taylor Rule

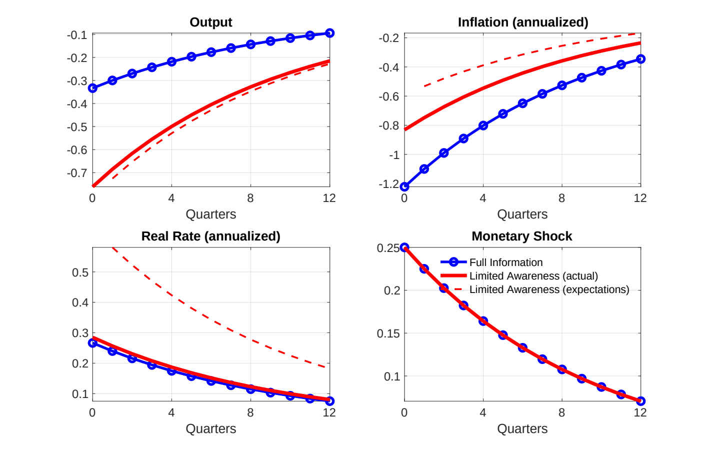


Graphical Intuition II: Contractionary, Taylor Rule

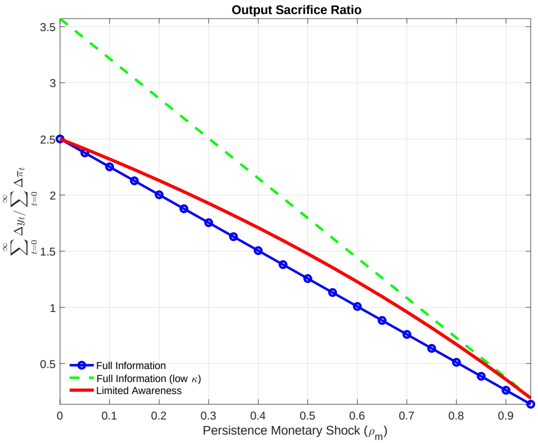


Contractionary Monetary Shock: Taylor rule

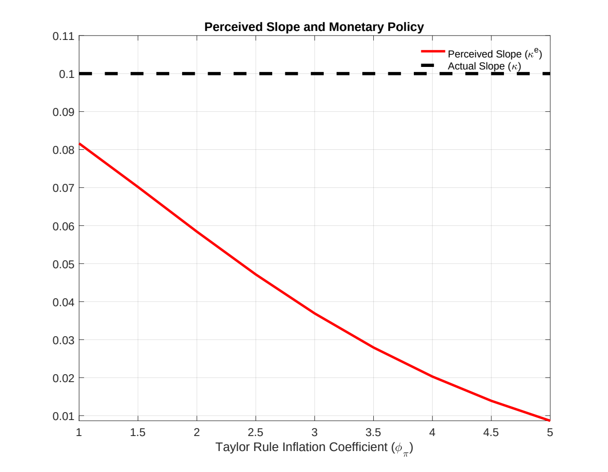
Parameters: $\beta = .99; \sigma = 2; \kappa = .05; \kappa^e = .02; \phi_\pi = 1.5; \rho = .9$



Output Cost of Reducing Inflation



Monetary Policy and the Perceived Slope of the PC



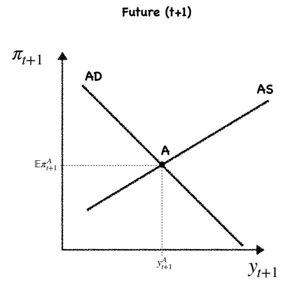
Conclusion

Conclusion

- **Empirical evidence suggests agents misperceive relationship between inflation and output**
- **A model with Limited Awareness rationalizes evidence**
  - Agents are unaware of cost-push shocks
  - Higher cost to lower inflation
  - (Strict) inflation targeting exacerbates the problem
- **Future research: Policy communication (e.g., FG) under LA**

Intuition: Effects of Negative and Persistent Supply Shock

True Data Generating Process



Intuition: Effects of Negative and Persistent Supply Shock

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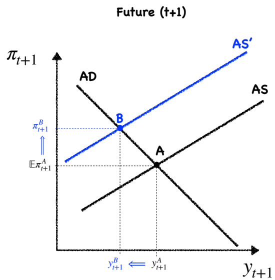
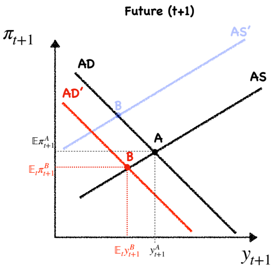


Intuition: Effects of Negative and Persistent Supply Shock

Perceived Data Generating Process: Supply shocks perceived as a (not very persistent) demand shock



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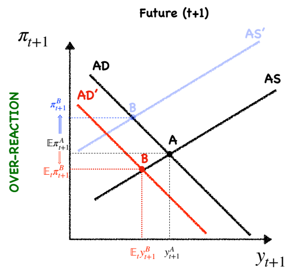

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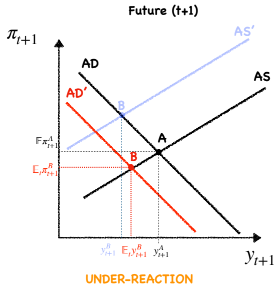

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