Myopia and Anchoring

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This Paper

incomplete info $=$ myopia $+$ anchoring

Theory

- Starting point: representative-agent model of the form

$$a_t = \varphi \xi_t + \delta \mathbb{E}_t[a_{t+1}]$$

  - nests: AP, Dynamic IS, NKPC...

- Add: **"noise"**
  - imperfect knowledge of, or attention to, fundamentals
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- Main result: under conditions, observational equivalence with

$$a_t = \varphi \xi_t + \omega_f \delta \mathbb{E}_t\left[a_{t+1}\right] + \omega_b a_{t-1}$$

  - $\omega_f < 1$ (myopia) and $\omega_b > 0$ (anchoring)
  - both distortions increase with strategic complementarity/GE

Applied Contribution

- Unifying explanation to multiple facts and bridge to DSGE
  - hybrid NKPC, habit, IAC ...
  - asset price momentum

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- Relate to other forms of bounded rationality
  - e.g., Level-k Thinking maps to $\omega_f < 1$ but $\omega_b = 0$
- Empirical evaluation in the context of inflation
  - a "sufficient statistics" approach
  - connect Hybrid NKPC to evidence on expectations

Literature*

- higher-order beliefs: Morris and Shin (1998, 2001, 2006), Woodford (2003) ...
- myopia: Angeletos & Lian (2018)
- anchoring: Sims (2003), Woodford (2003), Mankiw & Reis (2003), Wiederholt (2015) ...
- micro to macro: Mackowiak & Wiederholt (2009), Havranek et al (2017), Zorn (2017) ...
- NKPC with incomplete info: Nimark (2008) ...
- behavioral: Gabaix (2017) Garcia-Schmidt & Woodford (2018) Farhi & Werning (2017)
- evidence on expectations: Coibion & Gorodnichenko (2012, 2015) ...
- solution method: Huo & Takayama (2018)

* in paper: more references plus connections to other strands of the literature

Roadmap

- Framework
- Equivalence Result
- Robustness and Main Insights
- Applications
- Bounded Rationality
- Empirical Evaluation
- Conclusion and ongoing work

Framework

Framework

- Game with continuum of long-lived players and best responses

$$a_{it} = \mathbb{E}_{it}\left[\varphi\xi_t + \beta a_{it+1} + \gamma a_{t+1}\right]$$

  - a_t is endogenous outcome (π_t, C_t, I_t, asset price ...)
  - ξ_t is exogenous fundamental (marginal cost, dividend ...)
  - $\beta > 0$ regulates PE considerations (direct effect)
  - $\gamma > 0$ regulates GE considerations (strategic complementarity)

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- Equivalently: aggregate outcome satisfies

$$a_t = \overline{\mathbb{E}}_t\left[\sum_{k\geq 0}\beta^k\varphi\xi_{t+k}\right] + \gamma\overline{\mathbb{E}}_t\left[\sum_{k\geq 0}\beta^k a_{t+k+1}\right]$$

  - Stylizes fixed point between actual and expected outcomes

Example 1: Dynamic IS Curve

- Removing CK/RE from Dynamic IS Curve:

$$c_t = \mathbb{E}_t[-\varsigma r_t + c_{t+1}] \quad \longrightarrow$$

$$c_t = -\varsigma \sum_{k=0}^{\infty} \beta^k \overline{\mathbb{E}}_t[r_{t+k}] + (1-\beta) \sum_{k=1}^{\infty} \beta^{k-1} \overline{\mathbb{E}}_t[c_{t+k}]$$

  nested with $a_t = c_t$, $\xi_t = r_t$, $\varphi = -\varsigma$, $\beta = \beta$, and $\gamma = 1 - \beta$

- In this context: γ = GE = Keynesian cross

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Example 2: NKPC

- Removing CK/RE from NKPC:

$$\pi_t = \mathbb{E}_t[\kappa \mathtt{mc}_t + \beta\pi_{t+1}] \quad \longrightarrow$$

$$\pi_t = \kappa \sum_{k=0}^{\infty} (\beta\theta)^k \overline{\mathbb{E}}_t \left[\mathtt{mc}_{t+k}\right] + \chi(1-\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \overline{\mathbb{E}}_t \left[\pi_{t+k+1}\right]$$

nested with $a_t = \pi_t$, $\xi_t = \mathtt{mc}_t$, $\varphi = \kappa$, $\beta = \beta\theta$ and $\gamma = \beta(1-\theta)$

- In this context: γ = GE = feedback from expected to actual inflation

Benchmark: Complete Information

- Back to abstract setting:

$$a_{it} = \mathbb{E}_{it}\left[\varphi\xi_t + \beta a_{it+1} + \gamma a_{t+1}\right]$$

- Complete (common) information ⇒ a representative agent with

$$a_t = \varphi\mathbb{E}_t[\xi_t] + \underbrace{(\beta + \gamma)}_{\delta}\mathbb{E}_t[a_{t+1}]$$

$$\Rightarrow a_t = \varphi\mathbb{E}_t\left[\sum_{k\geq 0}(\beta+\gamma)^k\xi_{t+k}\right]$$

- Key implications:
  - outcome pinned down by FOB (first-order beliefs)
  - decomposition between PE and GE is inconsequential (only sum $\beta + \gamma$ matters)

- Why? Reasoning about others same as reasoning about one's self

Adding Incomplete Info: The Essence

- "Noise" =

  (1) imperfect knowledge of, or inattention to, fundamentals

  $+$

  (2) imperfect reasoning about the behavior of others, or GE effects

- Formally:

  (1) = first-order uncertainty

  (2) = higher-order uncertainty

Adding Incomplete Info: The Bug

- Higher-Order Beliefs (HOB) can be very complex $\Rightarrow$ curse of dimensionality
- E.g., with $\beta = 0$, an infinity of HOB matter:

$$a_t = \varphi \sum_{h=0}^{\infty} \gamma^h \overline{\mathbb{F}}_t^{h+1} [\xi_{t+h}],$$

where $\overline{\mathbb{F}}_t^1 [X] \equiv \overline{\mathbb{E}}_t [X]$ and $\overline{\mathbb{F}}_t^h [X] \equiv \overline{\mathbb{E}}_t \left[\overline{\mathbb{F}}_{t+1}^{h-1} [X] \right] \ \forall h \geq 2$

- With $\beta > 0$, immensely more complex!
  - e.g., even if we focus at $h = 4$ and $k = 10$, there 210 beliefs of the 4-th order that matter when trying to predict outcome 10 periods later
  - and we have to do this for all h and all k!

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  - and we have to do this for all h and all k!
- This paper: cut the Gordian Knot!
  - make assumptions that kill complexity and reveal essence
  - solve directly RE fixed point

Equivalence Result

Baseline Specification

- Fundamental follows AR(1)

$$\xi_t = \rho \xi_{t-1} + \eta_t = \frac{1}{1-\rho L}\eta_t$$

where $\eta_t \sim \mathcal{N}(0,1)$ and $\rho \in (0,1)$

- Information given by history of private signals:

$$x_{it} = \xi_t + u_{it},$$

where $u_{it} \sim_{\text{iid}} \mathcal{N}(0,\sigma^2)$ and $\sigma \geq 0$ parameterizes the friction

Complete vs Incomplete Info

- Complete-info benchmark ($\sigma = 0$):

$$a_t = \varphi \xi_t + \delta \mathbb{E}_t[a_{t+1}] \qquad \Rightarrow \qquad a_t = a_t^* \equiv \frac{\varphi}{1 - \delta\rho}\xi_t$$

outcome (e.g., π) follows same $AR(1)$ as fundamental (real MC), rescaled

- What about incomplete info ($\sigma > 0$)?
  - looks taunting: h-th order belief follows $ARMA(h+1, h-1)$, plus all h matter
  - yet, some REE magic: the fixed point is merely an $AR(2)$!
  - proof: using methods of Huo and Takayama (2018)

Solution of RE Fixed Point

Proposition

The equilibrium exists, is unique, and follows an $AR(2)$ given by

$$a_t = \left(1 - \frac{\vartheta}{\rho}\right)\left(\frac{1}{1-\vartheta L}\right) a_t^*$$

where a_t^* is the complete-information outcome and $\vartheta \in (0, \rho)$ is the reciprocal of the largest root of the following cubic:

$$C(z) \equiv -z^3 + \left(\rho + \frac{1}{\rho} + \frac{1}{\rho\sigma^2} + \beta\right) z^2 - \left(1 + \beta\left(\rho + \frac{1}{\rho}\right) + \frac{\beta+\gamma}{\rho\sigma^2}\right) z + \beta$$

- ϑ controls both amplitude and persistence, embeds effects of HOB
- fixed point tractable although hard to interpret at first glance
- still, no higher-order reasoning involved (unlike, e.g., level-k thinking)
  - agents need to be good statisticians, not good game theorists

Equivalence Result

Proposition (*Observational Equivalence*)

Incomplete-info outcome is replicated by a complete-info economy in which

$$a_t = \varphi\xi_t + \delta\omega_f \mathbb{E}_t [a_{t+1}] + \omega_b a_{t-1}$$

for a unique pair of (ω_f, ω_b) *which is such that* $\omega_f < 1$ *and* $\omega_b > 0$.

- myopia : $\omega_f < 1$
- anchoring : $\omega_b > 0$
- both encompass HOB

Understanding Myopia ($\omega_f < 1$)

- To illustrate: think of NKPC, fix $\xi_t = 0$ for $t \neq 1$, and let $\xi_1 \sim \mathcal{N}(0, \sigma_\xi^2)$

- Response of inflation at $t = 0$ to news about MC at $t = 1$

$$\begin{aligned}\pi_0 &= \kappa\delta\theta\, \overline{\mathbb{E}}_0[\xi_1] + \delta(1-\theta)\delta\theta\, \overline{\mathbb{E}}_0[\pi_1] \\ &= \kappa\delta\theta\, \overline{\mathbb{E}}_0[\xi_1] + \delta(1-\theta)\delta\theta\, \overline{\mathbb{E}}_0\left[\kappa\overline{\mathbb{E}}_1[\xi_1]\right]\end{aligned}$$

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- Information:
  - firm i observes $x_i = \xi_1 + \epsilon_i$ at $t = 0$;
  - no learning at $t = 1$
- Implied beliefs:

$$\begin{aligned} \mathbb{E}_{i,0}[\xi_1] = \mathbb{E}_{i,1}[\xi_1] &= \lambda x_i \\ \overline{\mathbb{E}}_0[\xi_1] = \overline{\mathbb{E}}_1[\xi_1] &= \lambda \xi_1 \qquad \lambda \equiv \frac{\sigma_\xi^2}{\sigma_\xi^2 + \sigma_\epsilon^2} \\ \overline{\mathbb{E}}_0[\overline{\mathbb{E}}_1[\xi_1]] &= \lambda^2 \xi_1 \end{aligned}$$

$\Rightarrow$ as if the news is discounted, more discounting with HOB

Understanding Anchoring ($\omega_b > 0$)

- Anchoring, or momentum, hinges on learning
- Basic intuition: in Kalman filter, past belief shows up as a state variable

$$\overline{\mathbb{E}}_t[\xi_t] = (1 - G)\overline{\mathbb{E}}_{t-1}[\xi_t] + G\xi_t$$

- Similar logic in our setting except that
  - anchoring reinforced by higher-order uncertainty
  - relevant state variable is a_{t-1} (magic: a_{t-1} is a summary statistic of HOB)

The Role of GE Feedback

Proposition (*GE*)

Both distortions intensify ($\omega_f \downarrow$, $\omega_b \uparrow$) with stronger complementarity/GE

- Higher price flexibility $\rightarrow$ more backward-looking inflation
- Larger Keynesian multiplier $\rightarrow$ more discounting and habit in Euler condition

Robustness (in paper)

- Multi-variate systems
- Endogenous signals
- Arbitrary process for fundamental and arbitrary learning dynamics
- Belief mis-specification about fundamental or precision of info

Applications

Monetary Policy and Aggregate Demand

- Question: How does aggregate demand respond to monetary policy
- Answer in baseline New Keynesian model:

$$c_t = -r_t + \mathbb{E}_t[c_{t+1}] = -\sum_{k\geq 0} \mathbb{E}_t[r_{t+k}] \quad (*)$$

- Implication: lower rates now = promising lower rates in 10 years!
- Reason: horizon has offsetting PE and GE effects
- Next: unearth the game beneath $(*)$, revisit answer under incomplete info

Monetary Policy and Aggregate Demand

- Consumption function (PIH) plus market clearing $(y = c)$ give

$$c_t = -\sum_{k=0}^{\infty} \beta^k \overline{\mathbb{E}}_t[r_{t+k}] + \underbrace{(1-\beta)}_{\gamma} \sum_{k=0}^{\infty} \theta^k \overline{\mathbb{E}}_t[c_{t+k+1}]$$

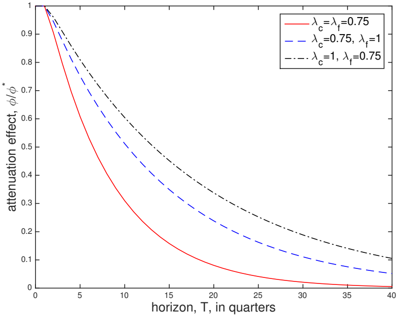
- Reduces to $c_t = -r_t + \mathbb{E}_t[c_{t+1}]$ with complete info, but not without
- Applying our result $\Rightarrow$ myopia toward future MP + habit

$$c_t = -r_t + \omega_f \mathbb{E}_t[c_{t+1}] + \omega_b c_{t-1}$$

  - both distortions increase with slope of Keynesian cross (captured by γ)

Parenthesis: Forward Guidance (Angeletos and Lian, AER 2018)

- Application: ZLB up to $t = T - 1$, response to news about R_t at $t = T$
- Full NK model: additional feedback between AD and AS (multi-layer game)



- Even a tiny perturbation can have huge effects as $T \to \infty$
- Front-loading fiscal stimuli, paradox of flexibility, neo-Fisherian effects...

Asset Pricing

- Basic asset pricing model, with OLG traders

$$p_t = \mathbb{E}_t[d_{t+1}] + \delta \mathbb{E}_t[p_{t+1}]$$

- Adding incomplete info and applying our result

$$p_t = \mathbb{E}_t[d_{t+1}] + \delta \omega_f \mathbb{E}_t[p_{t+1}] + \omega_b p_{t-1}$$

- $\omega_b > 0 \;\rightarrow\;$ momentum, predictability
- $\omega_f < 1 \;\rightarrow\;$ little response to long-term earnings (or long-run risks?)
- Distortions larger at aggregate level $\;\rightarrow\;$ Samuelson dictum

Bridge to DSGE

- Our equivalence result offers a micro-foundation of DSGE add ons
  - habit in consumption
  - adjustment cost to investment (IAC)
  - hybrid NKPC

- But not a panacea: distortions endogenous to GE and thereby to
  - markets (e.g., liquidity constraints, IO structure)
  - policy (e.g., redistributive effects of FP, aggressiveness of MP)

Macro vs Micro

- Pervasive gap between macro and micro
  - C: estimated habit much smaller in micro data (Havranek et al, 2017)
  - I: type of IAC used in DSGE inconsistent with standard Q theory as well as with literature that studies plant-level investment dynamics
  - π: menu-cost models that match price data (Golosov & Lucas etc) don't produce backward-looking feature of hybrid NKPC
  - AP: Samuelson dictum (Jung and Shiller, 2005).
- Our results help merge the gap
  - mechanism: GE and HOB
  - distinct from, but complementary to, Mackowiak & Wiederholt (2009)

Belief Mis-specification, or Bounded Rationality

- Recent works on mis-specified beliefs
  - Garcia-Schmidt & Woodford (2018), Farhi & Werning (2017): Level k
  - Gabaix (2017): cognitive discounting
- They produce myopia but not anchoring/habit/momentum
  - i.e., they allow $\omega_f < 1$ but restrict $\omega_b = 0$
- Data demand both
  - inertia and momentum of macro series, forward-guidance puzzle, etc
  - direct evidence on expectations

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- Data demand both
  - inertia and momentum of macro series, forward-guidance puzzle, etc
  - direct evidence on expectations
- That said, interesting to combine incomplete info + mis-specification
  - preserve observational equivalence, but with different (ω_f, ω_b)
  - match additional facts (e.g., Bordalo, Shleifer et al on over-reaction)
  - give more guidance for how to take theory to data

Empirical Evaluation

Application to NKPC

- NKPC with complete info: $\pi_t = \kappa \mathtt{mc}_t + \beta \mathbb{E}_t[\pi_{t+1}]$
- NKPC with incomplete info:

$$\pi_t = \kappa \sum_{k=0}^{\infty} (\beta\theta)^k \overline{\mathbb{E}}_t \left[\mathtt{mc}_{t+k}\right] + \underbrace{\beta(1-\theta)}_{\gamma} \sum_{k=1}^{\infty} (\beta\theta)^k \overline{\mathbb{E}}_t \left[\pi_{t+k}\right]$$

- Impossible to take the above to the data
  - missing data about all the relevant expectations
  - invalid to use $\pi_t = \kappa \mathtt{mc}_t + \beta \overline{\mathbb{E}}_t[\pi_{t+1}]$
- But, our observational-equivalence result $\Rightarrow$

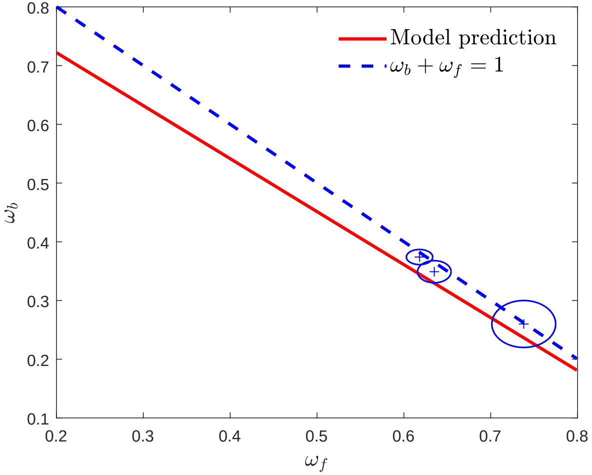
$$\pi_t = \kappa \mathtt{mc}_t + \omega_f \beta \mathbb{E}_t[\pi_{t+1}] + \omega_b \pi_{t-1}$$

- Notable implications:
  - γ increases with θ $\rightarrow$ distortions increase with price flexibility
  - testable restriction on (ω_f, ω_b)
  - plus, both distortions tied to dynamics of expected inflation

Test 1: Matching Estimates of Hybrid NKPC

- ω_f and ω_b move together as σ varies $\Rightarrow$ testable restriction
- Gali and Gertler (1999), Gali et al (2005) provide estimates of (ω_f, ω_b)
- Test whether these estimates satisfy our theory's restriction
  - use standard value for δ and θ, estimate ρ from labor share data

Test 1: Matching Estimates of Hybrid NKPC



Ellipses are 90% confidence regions for various estimates in Gali et al (2005)

Test 2: Matching Evidence on Inflation Expectations

- Coibion and Gorodnichenko (2015) use survey evidence to estimate

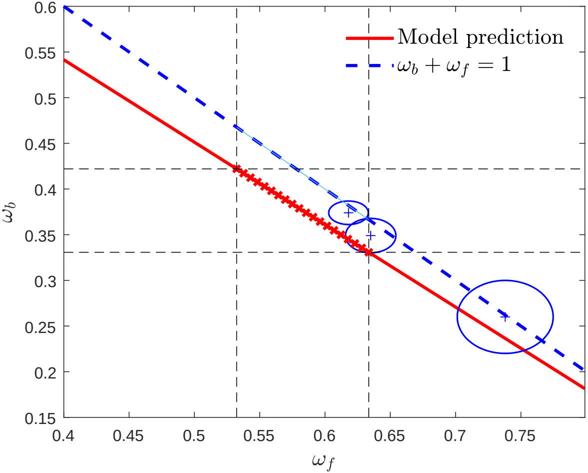
$$\pi_{t+k} - \overline{\mathbb{E}}_t[\pi_{t+k}] = K \left(\overline{\mathbb{E}}_t[\pi_{t+k}] - \overline{\mathbb{E}}_{t-1}[\pi_{t+k}] \right) + v_{t+k,t}$$

  - $K = 0$ with complete information
  - $K > 0$ indicates correlated forecast errors

- That paper: treat π as exogenous

- Here: solve fixed point between $\overline{\mathbb{E}}[\pi]$ and π
  - use theory to map moment K to parameter σ

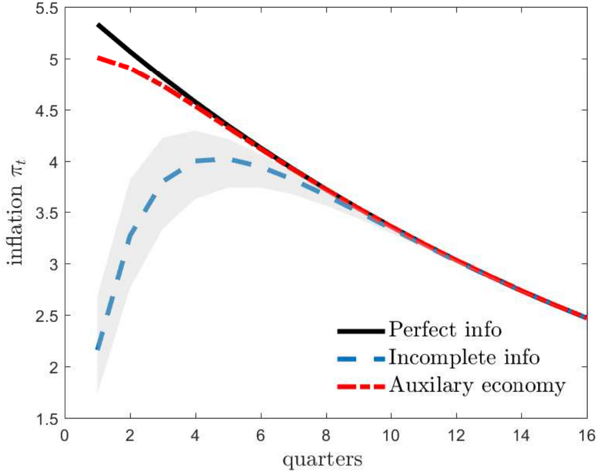
Test 2: Matching Evidence on Inflation Expectations



Highlighted segment corresponds to 90% confidence interval in Coibion and Gorodnichenko (2015)

Parameters: $\rho = 0.95, \theta = 0.6$

Quantitative Bite



Auxiliary economy: incomplete-info $\mathbb{E}[\xi]$ and complete-info $\mathbb{E}[\pi]$

Extension: Correlated Mistakes in Expectations

- Add noisy public signal $\rightarrow$ correlated mistakes
- Result:

$$\pi_t = \pi_t^{fundamental} + \pi_t^{noise}$$

  where $\pi_t^{fundamental}$ obeys our Hybrid NKPC but π_t^{noise} follows AR(1)

- I.e., inertia only vis-a-vis the fundamental, not vis-a-vis the residual
- Unlike DSGE, but exactly as in the data!

Summary

- A window to effects of informational frictions and HOB
- Rationalize both myopia and backward-looking behavior
- Ease disconnect between micro and macro
- Promising quantitative potential
- Important policy implications