Myopia and Anchoring

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This Paper

incomplete info \ = \ myopia + anchoring
Theory

- **Starting point:** representative-agent model of the form

\[ a_t = \varphi \xi_t + \delta E_t[a_{t+1}] \]

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

- **Add: “noise”**
  - imperfect knowledge of, or attention to, fundamentals
  - imperfect reasoning about behavior of others
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- **Add**: “noise”
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- **Main result**: under conditions, observational equivalence with
  \[ a_t = \varphi \xi_t + \omega_f \delta E_t [a_{t+1}] + \omega_b a_{t-1} \]

  - \( \omega_f < 1 \) (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

- But: frictions endogenous to GE and policy
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- Relate to other forms of bounded rationality
  - e.g., Level-k Thinking maps to $\omega_f < 1$ but $\omega_b = 0$
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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) ...
- **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

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

- \( a_t \) is endogenous outcome (\( \pi_t, C_t, I_t \), asset price ...)
- \( \xi_t \) 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

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

- Stylizes fixed point between actual and expected outcomes
Example 1: Dynamic IS Curve

- Removing CK/RE from Dynamic IS Curve:

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

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

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

- In this context: \( \gamma = GE = \text{Keynesian cross} \)
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- In this context: \( \gamma = GE = \text{Keynesian cross} \)
Example 2: NKPC

- Removing CK/RE from NKPC:

\[ \pi_t = E_t[\kappa_m c_t + \beta \pi_{t+1}] \quad \rightarrow \]

\[ \pi_t = \kappa \sum_{k=0}^{\infty} (\beta \theta)^k E_t[m c_{t+k}] + \chi (1 - \theta) \sum_{k=0}^{\infty} (\beta \theta)^k E_t[\pi_{t+k+1}] \]

nested with \( a_t = \pi_t, \xi_t = m c_t, \varphi = \kappa, \beta = \beta \theta \) and \( \gamma = \beta (1 - \theta) \)

- In this context: \( \gamma = GE = \text{feedback from expected to actual inflation} \)
Benchmark: Complete Information

- Back to abstract setting:

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

- Complete (common) information \(\Rightarrow\) a representative agent with

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

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

- 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 ⇒ curse of dimensionality

- E.g., with $\beta = 0$, an infinity of HOB matter:

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

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

- 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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○ 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 ($\sigma = 0$):
  \[ a_t = \varphi \xi_t + \delta \mathbb{E}_t[a_{t+1}] \quad \Rightarrow \quad a_t = a^*_t \equiv \frac{\varphi}{1 - \delta \rho} \xi_t \]
  outcome (e.g., $\pi$) 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 $AR(2)$!
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:

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

- \(\vartheta\) 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

\[ a_t = \varphi \xi_t + \delta \omega_f E_t [a_{t+1}] + \omega_b a_{t-1} \]

for a unique pair of \((\omega_f, \omega_b)\) 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 \(t = 1\)

\[
\pi_0 = \kappa \delta \theta \, \mathbb{E}_0[\xi_1] + \delta (1-\theta) \delta \theta \, \mathbb{E}_0[\pi_1] \\
= \kappa \delta \theta \, \mathbb{E}_0[\xi_1] + \delta (1-\theta) \delta \theta \, \mathbb{E}_0 \left[ \kappa \mathbb{E}_1[\xi_1] \right]
\]
Understanding Myopia ($\omega_f < 1$)

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

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

  \[ \pi_0 = \kappa \delta \theta \bar{E}_0[\xi_1] + \delta (1 - \theta) \delta \theta \bar{E}_0[\pi_1] = \kappa \delta \theta \bar{E}_0[\xi_1] + \delta (1 - \theta) \delta \theta \bar{E}_0 [\kappa \bar{E}_1[\xi_1]] \]

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

- Implied beliefs:

  \[
  \bar{E}_{i,0}[\xi_1] = \bar{E}_{i,1}[\xi_1] = \lambda x_i \\
  \bar{E}_0[\xi_1] = \bar{E}_1[\xi_1] = \lambda \xi_1 \\
  \bar{E}_0[\bar{E}_1[\xi_1]] = \lambda^2 \xi_1
  \]

  \[ \Rightarrow \text{as if the news is discounted, more discounting with HOB} \]
Understanding Anchoring ($\omega_b > 0$)

- Anchoring, or momentum, hinges on learning

- Basic intuition: in Kalman filter, past belief shows up as a state variable

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

- 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

\[
c_t = -\sum_{k=0}^{\infty} \beta^k E_t[r_{t+k}] + (1 - \beta) \sum_{k=0}^{\infty} \theta^k E_t[c_{t+k+1}]
\]

○ Reduces to \(c_t = -r_t + E_t[c_{t+1}]\) with complete info, but not without

○ Applying our result \(\Rightarrow\) myopia toward future MP + habit

\[
c_t = -r_t + \omega_f E_t[c_{t+1}] + \omega_b c_{t-1}
\]

○ both distortions increase with slope of Keynesian cross (captured by \(\gamma\))
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

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

○ \( \omega_b > 0 \) → momentum, predictability

○ \( \omega_f < 1 \) → little response to long-term earnings (or long-run risks?)

○ Distortions larger at aggregate level → 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
  - \( \pi \): 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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- That said, interesting to combine incomplete info + mis-specification
  - preserve observational equivalence, but with different $(\omega_f, \omega_b)$
  - 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:
  \[ \pi_t = \kappa m c_t + \beta E_t[\pi_{t+1}] \]

- NKPC with incomplete info:
  \[ \pi_t = \kappa \sum_{k=0}^{\infty} (\beta \theta)^k E_t [mc_{t+k}] + \beta (1 - \theta) \sum_{k=1}^{\infty} (\beta \theta)^k E_t [\pi_{t+k}] \]

- Impossible to take the above to the data
  - missing data about all the relevant expectations
  - invalid to use \( \pi_t = \kappa m c_t + \beta E_t[\pi_{t+1}] \)

- But, our observational-equivalence result \( \Rightarrow \)

  \[ \pi_t = \kappa m c_t + \omega_f \beta E_t[\pi_{t+1}] + \omega_b \pi_{t-1} \]

- Notable implications:
  - \( \gamma \) increases with \( \theta \) \( \Rightarrow \) distortions increase with price flexibility
  - testable restriction on \( (\omega_f, \omega_b) \)
  - plus, both distortions tied to dynamics of expected inflation
Test 1: Matching Estimates of Hybrid NKPC

- $\omega_f$ and $\omega_b$ move together as $\sigma$ varies $\Rightarrow$ testable restriction

- Gali and Gertler (1999), Gali et al (2005) provide estimates of $(\omega_f, \omega_b)$

- Test whether these estimates satisfy our theory’s restriction
  - use standard value for $\delta$ and $\theta$, estimate $\rho$ 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
  \[
  \pi_{t+k} - \mathbb{E}_t[\pi_{t+k}] = K \left( \mathbb{E}_t[\pi_{t+k}] - \mathbb{E}_{t-1}[\pi_{t+k}] \right) + v_{t+k,t}
  \]
  - \(K = 0\) with complete information
  - \(K > 0\) indicates correlated forecast errors

- **That paper**: treat \(\pi\) as exogenous

- **Here**: solve fixed point between \(\mathbb{E}[\pi]\) and \(\pi\)
  - use theory to map moment \(K\) to parameter \(\sigma\)
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:

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

where $\pi_t^{\text{fundamental}}$ obeys our Hybrid NKPC but $\pi_t^{\text{noise}}$ 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