Myopia and Anchoring

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NBER Summer Institute, EFCE group, July 2018

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- Take a forward-looking, representative-agent, GE model of the form

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- Also: distortions intensify with strength of GE feedback
  - distortions more prevalent at macro level

What We Do: Applications

- Evaluate quantitative performance in context of inflation/NKPC
  - rationalize evidence on hybrid NKPC (Gali and Gertler)
  - match evidence on inflation expectations (Coibion and Gorodnichenko)
  - use the latter evidence plus theory to quantify role of informational friction

- Other applications
  - habit in consumption
  - IAC
  - myopia and momentum in asset prices

Broader Contribution

- Simple window to the effects of incomplete info and HOB
- Micro-foundation of ad hoc adjustment frictions in DSGE
- Resolution to disconnect between micro and macro
- Comparison to recent work on bounded rationality

Literature

- Informational frictions and higher-order uncertainty
  - Morris and Shin (2001, 2002)
  - Sims (2003), Woodford (2003), Mankiw and Reis (2003, 2011)
  - Nimark (2008, 2017), Mackowiak and Wiederholt (2009, 2015), Angeletos and La'O (2009, 2010, 2013), Huo and Takayama (2015a)
  - Angeletos and Lian (2016), Huo and Takayama (2015b)
  - Allen, Morris, and Shin (2006), Bacchetta and van Wincoop (2006), Kasa, Walker, and Whiteman (2014), Nimark (2017)
  - Coibion and Gorodnichenko (2012, 2015),Kumar et al (2015)
- DSGE, Philips Curves, and Micro vs Macro
  - Gali and Gertler (1999), Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2007)
  - Golosov and Lucas (2007), Midrigan (2011), Alvarez and Lippi (2014), Nakamura and Steinsson (2013)
  - Havranek, Rusnak, and Sokolova (2017), Altissimo et al. (2010)
- Bounded rationality
  - Gabaix (2016), Farhi and Werning (2017), Woodford (2018)
  - Sargent (1993), Evans and Honkapohja (2001, 2009), Marcet and Nicolini (2003), Eusepi and Preston (2016), Carvalho et al (2017)

Framework

Framework

- Continuum of infinitely-lived agents with Euler-like best responses given by

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

  - ξ_t: persistent economic fundamental

$$\xi_t = \rho\xi_{t-1} + \eta_t \qquad \text{or} \qquad \xi_t = \sum_{k=0}^{\infty} \varrho_k \eta_{t-k}$$

  - a_t: aggregate action
  - $\beta \geq 0$ parameterizes PE discounting
  - $\gamma \geq 0$ parameterizes GE feedback

- Agents are forward-looking $\rightarrow$ *dynamic* beauty contest

Example: NKPC

- Firms' optimal pricing decision:

$$p_{it}^{*} = (1-\delta\theta)\sum_{k=0}^{\infty}(\delta\theta)^{k}\mathbb{E}_{it}[\xi_{t+k}+p_{t+k}]$$

  - ξ_t = real marginal cost; θ = Calvo parameter; δ = discount factor

- Equilibrium inflation with complete info:

$$\pi_t = \kappa\xi_t + \delta\mathbb{E}_t[\pi_{t+1}]$$

  where $\kappa \equiv \frac{(1-\delta\theta)(1-\theta)}{\theta}$

- Equilibrium inflation with incomplete info:

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

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- Nested in abstract model with

$$\pi_{it} = \kappa\mathbb{E}_{it}[\xi_t] + \underbrace{\delta\theta}_{\beta}\mathbb{E}_{it}[\pi_{it+1}] + \underbrace{\delta(1-\theta)}_{\gamma}\mathbb{E}_{it}[\pi_{t+1}]$$

  - GE effect increases with price flexibility
  - this is irrelevant with complete info but not without
  - alert: invalid to replace NKPC with $\pi_t = \kappa\xi_t + \delta\overline{\mathbb{E}}_t[\pi_{t+1}]$

Frictionless Benchmark

- Back to abstract model

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

- Assume ξ_t perfectly and commonly known
- Model reduces to a representative agent with

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

- PE and GE do not play separate roles, only sum $\beta + \gamma$ matters
  - GE parameter "hidden" and irrelevant conditional on δ

Frictionless Benchmark

- Equilibrium condition:

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

- By forward iteration:

$$a_t = \varphi \sum_{k=0}^{\infty} \delta^k \mathbb{E}_t[\xi_{t+k}]$$

- Under AR(1) specification for the fundamental:

$$\mathbb{E}_t[\xi_{t+k}] = \rho^k \xi_t$$

- Result: outcome follows same AR(1) as fundamental, up to rescaling

$$a_t = a_t^* \equiv \tfrac{\varphi}{1-\rho\delta} \xi_t$$

Adding Incomplete Information

- Why incomplete information?
  - dispersed information (Hayek, Lucas)
  - rational inattention (Sims) and costly cognition (Tirole)
  - capture "bounded rationality" within REE paradigm
  - plus: lack of CK = doubts about others' awareness and response

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- Main specification: AR(1) for ξ_t and sequence of private signals given by

$$x_{it} = \xi_t + u_{it}, \qquad u_{it} \sim \mathcal{N}(0, \sigma^2)$$

  - not only first-order uncertainty (imperfect knowledge of ξ_t)
  - but also higher-order uncertainty (doubts about others)

Higher-Order Beliefs

- To illustrate, consider the case where $\beta = 0$:

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

- Evaluating at $t+1$ and taking the period-t average expectation:

$$\overline{\mathbb{E}}_t[a_{t+1}] = \varphi \underbrace{\overline{\mathbb{E}}_t \left[\overline{\mathbb{E}}_{t+1} [\xi_{t+1}]\right]}_{\text{2nd-order beliefs}} + \gamma \overline{\mathbb{E}}_t \left[\overline{\mathbb{E}}_{t+1} [a_{t+2}]\right]$$

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- Iterating again and again:

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

where $\overline{\mathbb{F}}_t^h [X]$ is an h-th order, forward-looking belief defined by

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

- $\gamma \rightarrow$ GE interaction $\rightarrow$ beliefs of actions of others $\rightarrow$ HOB
- with $\beta > 0$, structure of HOB more involved, but basic insight is the same

Tractability and Solution

- Characterizing the dynamics of HOB can be a computational nightmare!
- This is where our paper comes to rescue
- Baseline: bypass HOB and solve for RE fixed point in closed form
  - under aforementioned specification for ξ_t and signals
  - using methods of Huo and Takayama (2015b)
- Robustness: richer specification, alternate method
  - less sharp results, but same insights

Solution (in Baseline)

Proposition

The equilibrium exists, is unique, and is such that

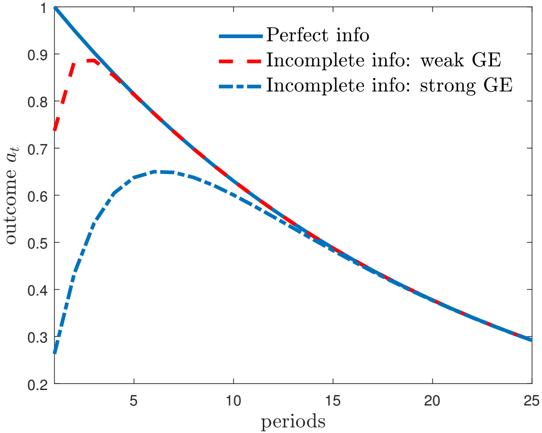
$$a_t = \left(1 - \frac{\vartheta}{\rho}\right)\left(\frac{1}{1-\vartheta L}\right) a_t^*$$

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

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

- Key Property 1: ϑ controls both impact and persistence
- Key Property 2: ϑ increasing in both σ (noise) and γ (GE)

GE and Dynamics



Equivalence Result

Proposition

The incomplete-info economy is replicated by a complete-info economy with

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

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 : $\omega_b > 0$

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Proposition

$\omega_f \downarrow$ *and* $\omega_b \uparrow$ *as either* $\sigma \uparrow$ *or* $\gamma \uparrow$

- both distortions are larger when GE is stronger

Robustness

- Richer stochasticity/information
  - general MA process for fundamental: $\xi_t = \sum \Sigma_k \varrho_k \eta_{t-k}$
  - arbitrary series of independent signals for $\{\eta_{t-k}$ in each period
- Idiosyncratic shocks
- Isolate GE (HOB) from PE (FOB)

Understanding Myopia ($\omega_f < 1$)

- To simplify, let $\beta = 0$:

$$\begin{aligned} \bar{a}_t &= \overline{\mathbb{E}}_t[\xi_t] + \gamma \overline{\mathbb{E}}_t[a_{t+1}] \\ &= \varphi \sum_{h=0}^{\infty} \gamma^h \overline{\mathbb{F}}_t^{h+1}[\xi_{t+h}] \end{aligned}$$

- Consider response of a_t to news about ξ_{t+h}, for some $h \geq 1$
- Response depends on h-th order beliefs
  - thinking about the future path of a is the same as thinking about HOB
- HOB move much less than FOB $\Rightarrow$ *as if* the news is discounted
  - Indeed, in the absence of learning, effective discounting modified

$$\delta = \beta + \gamma \qquad \longrightarrow \qquad \delta' = \beta + \lambda\gamma$$

    for some $\lambda \in (0, 1)$ that is inversely related to σ.

Understanding Anchoring ($\omega_b > 0$)

- Anchoring, or momentum, is product of learning and GE/HOB
- Basic intuition: Kalman filter

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

  - past belief shows up as a state variable
- Similar logic applies in our setting except that
  - relevant state variable is a_{t-1} (the latter summarizes HOB)
  - effective G decreases with γ (persistence increases with GE)

Parenthesis: HOB and Rational Expectations

- For the analyst: understanding HOB = understanding RE
- However, agents themselves need not engage in higher-order reasoning!
  - in Muth/Lucas tradition, agents can still be understood as "statisticians"
  - the literature often misses this elementary point
- Plus: fixed point can be computationally/cognitively easier than iterating
  - our solution itself is an illustration of this point

Relations to the Literature

- Earlier versions of basic insights
  - anchoring/sluggishness: Woodford (2003), Sims (2003), Mankiw & Reis (2003)
  - myopia: Angeletos & Lian (2017a)
  - lack of CK dampens/slows down GE: Angeletos & Lian (2017b)

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- Recent macro literature on bounded rationality
  - Gabaix (2016), Farhi and Werning (2017): offer $\omega_f < 1$ but restrict $\omega_b = 0$.
  - data want both $\omega_f < 1$ and $\omega_b > 0$
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- DSGE literature
  - a unified micro-foundation of ad hoc modifications to Euler, NKPC, Q-theory
  - plus: tie as-if distortions to GE effects and expectations
  - plus: explain why distortions larger at macro level

Macro vs Micro

- Pervasive gap between macro and micro
  - C: estimated habit much smaller in micro data (Havranek et al, 2017)
  - I: models that match plant-level investment dynamics inconsistent with IAC
  - π: models that match price data don't produce hump shapes/hybrid NKPC
  - AP: Samuelson dictum (Jung and Shiller, 2005).

- Our results help merge the gap
  - key: higher-order uncertainty and GE/complementarity
  - distinct from, but complementary to, Mackowiak and Wiederholt (2009)
  - justifies DSGE practice but: as-if distortions not fixed structural params

Applications

NKPC with Incomplete Information

- Firms' optimal pricing decision:

$$p^*_{it} = (1-\delta\theta)\sum_{k=0}^{\infty}(\delta\theta)^k \mathbb{E}_{it}[\xi_{t+k} + p_{t+k}]$$

  - ξ_t = real marginal cost (or gap)
  - θ = probability of not resetting price

- Equilibrium inflation:

$$\pi_t = \frac{(1-\delta\theta)(1-\theta)}{\theta}\sum_{k=0}^{\infty}(\delta\theta)^k \overline{\mathbb{E}}_t\left[\xi_{t+k}\right] + \delta(1-\theta)\sum_{k=1}^{\infty}(\delta\theta)^k \overline{\mathbb{E}}_t\left[\pi_{t+k}\right]$$

- Dynamic beauty contest representation:

$$a_{it} = \underbrace{\frac{(1-\delta\theta)(1-\theta)}{\theta}}_{\varphi}\mathbb{E}_{it}[\xi_t] + \underbrace{\delta\theta}_{\beta}\mathbb{E}_{it}[a_{it+1}] + \underbrace{\delta(1-\theta)}_{\gamma}\mathbb{E}_{it}[a_{t+1}]$$

Test 1: Matching Estimates of Hybrid NKPC

- Our equivalence result ⇒ testable restriction on params of hybrid NKPC
  - incomplete-info dynamics satisfies

$$\pi_t = \kappa\xi_t + \omega_f \delta\mathbb{E}_t[\pi_{t+1}] + \omega_b \pi_{t-1}$$

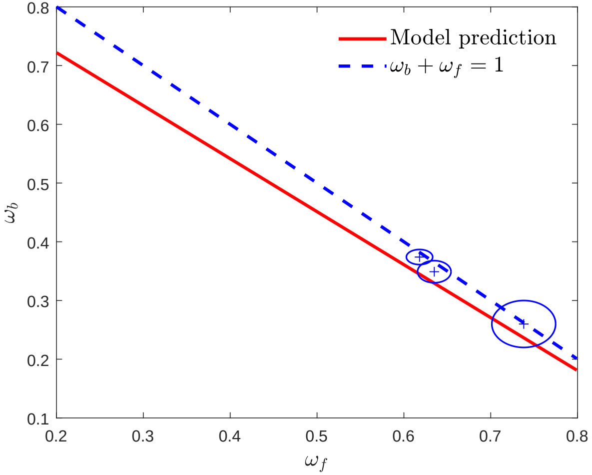
  where (ω_f, ω_b) needs to satisfy the restriction

$$\omega_b = \Omega(\omega_f; \delta, \rho)$$

- 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, 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

- Results suggestive of info friction, but two key limitations"
  - treat π as exogenous $\Rightarrow$ could not quantify effect of info friction on π dynamics
  - mapping from K to σ is endogenous to whole equilibrium

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- Our contribution
  - endogenize π, solve fixed point between $\bar{\mathbb{E}}[\pi]$ and π, use theory to map K to σ
  - quantify importance of info friction
  - connect to estimates of hybrid NKPC

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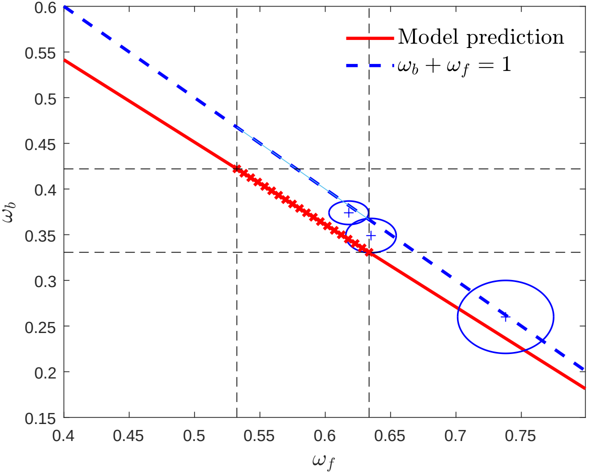
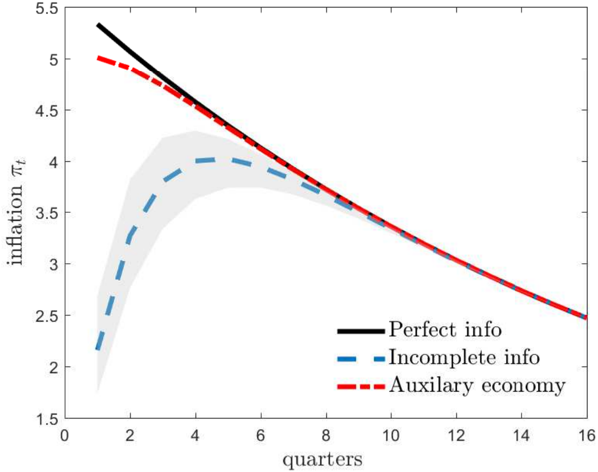


Highlighted segment corresponds to 90% confidence interval in Coibion and Gorodnichenko (2015)

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

Quantitative Role



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

Other Applications

1. Consumption
   - modify standard Euler condition to
     $$c_t = \sigma R_t + \omega_f \mathbb{E}[c_{t+1}] + \omega_b c_{t-1}$$
   - reconcile DSGE with smaller micro estimates of habit (Havranek et al, 2017)
   - both myopia and anchoring increase with discount rate / market incompleteness

2. Investment
   - micro-foundation of IAC
   - reconcile DSGE with empirical literature on plant-level dynamics

3. Asset pricing
   - myopia towards earnings/fundamentals at longer horizons
   - challenges literature on long run risks
   - explains more momentum at aggregate level (Jung and Shiller, 2005)

Conclusion

Conclusion

- A theory of myopia and anchoring
  - recast RI and HOB as behavioral distortions
  - provide micro-foundation of ad hoc DSGE add-ons
  - ease disconnect between micro and macro
  - promising quantitative potential
- Rational Expectations (evil empire?) strikes back