A BEHAVIORAL NEW KEYNESIAN MODEL

Xavier Gabaix
Harvard, CEPR and NBER

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Introduction

- I write a theory of monetary and fiscal policy with behavioral agents
- I use the workhorse framework of monetary policy, the New Keynesian model – and write a behavioral version of it
- Agents are patient, but they're partially myopic to future disturbances
- The rational model is a particular case
- Motivation
    - If people aren't fully rational, our models and policies should incorporate that
    - A number of empirical issues with New Keynesian framework
    - The economy (e.g. Japan, US) looks stable at the ZLB, even though that contradicts the Taylor principle, so that in principle the economy could jump from one equilibrium to the next (Cochrane '15),

Related literature

- Inattention: Sims 03, Gabaix and Laibson 02, 06, Caballero 95, Mankiw Reis 02, Reis 06, Abel, Eberly and Panageas 09, Chetty, Kroft Looney 09, Angeletos La'O 10, Maćkowiak and Wiederholt 10, 16, Masatlioglu and Ok 10, Veldkamp 11, Matejka and Sims 11, Caplin, Dean and Martin 11, Woodford 12, Alvarez Lippi, Paciello 13, Greenwood Hanson 14, Croce, Lettau Ludvigson 15
- Behavioral macro: Gabaix '14, '16, Garcia-Schmidt and Woodford '15
- Further explorations of behavioral NK: Farhi and Werning (in prep.), Angeletos and Lian (in prep.)
- New NK thinking: Michaillat and Saez '15, Auclert '15, Kaplan, Moll, Violante '16
- Monetary policy and ZLB: many, including Eggertsson and Woodford 03, Evans, Fisher, Gourio, Krane 16, Werning 12
- Forward Guidance puzzle: Piergallini 06, Nistico 12, Del Negro, Giannoni, Patterson 15, McKay, Nakamura and Steinsson 15, Chung Herbst and Kiley 15, Caballero Farhi 15, Garcia-Schmidt and Woodford 15, Werning 15, Kiley 16, Campbell, Fisher, Justiniano, Melosi 16, Angeletos and Lian 16

Individual problem

$$\max_{(c_t, N_t)_{t\geq 0}} \mathbb{E} \sum_{t=0}^{\infty} \beta^t u(c_t, N_t), \qquad u(c, N) = \frac{c^{1-\gamma}}{1-\gamma} - \frac{N^{1+\phi}}{1+\phi}$$

$$\begin{aligned} k_{t+1} &= (1 + \bar{r} + \hat{r}_t)(k_t + \bar{y} + \hat{y}_t - c_t) \\ X_{t+1} &= G(X_t, \varepsilon_{t+1}) \end{aligned}$$

with $(\widehat{r}_t, \widehat{y}_t) = bX_t$, X_t =(de-meaned) state vector.

- Agent maximizes in a simplifiable subjective model:

$$\begin{aligned} k_{t+1} &= (1 + \bar{r} + m_r \widehat{r}_t)(k_t + \bar{y} + m_y \hat{y}_t - c_t) \\ X_{t+1} &= \bar{m} G(X_t, \varepsilon_{t+1}) \end{aligned}$$

  so "cognitive discounting":

$$\mathbb{E}_t^{BR}[\widehat{y}_{t+k}] = m_y \bar{m}^k \mathbb{E}_t^{rat}[\widehat{y}_{t+k}]$$

  with $m_r, m_y, \bar{m} \in [0, 1]$.

- Rational case: $\bar{m} = m_r = m_y = 1$

BR permanent income

- With $b_r(k_t) := \frac{\frac{r}{R}k_t - \psi c^d}{R^2}$, $b_y = \frac{\bar{r}}{\bar{R}}$
- **Proposition**: In this behavioral model (up to 2nd order terms)

$$c_t = \bar{y} + \frac{\bar{r}}{\bar{R}}k_t + \mathbb{E}_t\left[\sum_{\tau \geq t}\frac{\bar{m}^{\tau-t}}{R^{\tau-t}}\left(b_r(k_t)\, m_r \hat{r}_t + b_y m_y \hat{y}_\tau\right)\right]$$

- Then, I put these agents in general equilibrium, with $y_t = c_t$
- Define $x_t = \ln y_t - \ln y_t^*$ the output gap
- Define d_t=deficit after payment of interest rate on debt. I.e., active "transfers" by government to agents.

Behavioral firms' problem

- Dixit-Stiglitz firms with Calvo pricing frictions
- They pay limited attention m^f to future (macro) markup values
- Hence, with ψ_t=nom. marginal cost, the reset price p_t^* is:

$$p_t^* - p_t = (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \bar{m}^k m^f \mathbb{E}_t [\psi_{t+k} - p_t]$$

- I put those firms and agents in general equilibrium, work out resulting dynamics

Behavioral NK model

- **Proposition:** with $\hat{r}_t = i_t - \mathbb{E}_t \pi_{t+1} - r_t^n$

$$x_t = M \mathbb{E}_t \left[x_{t+1} \right] + b_d d_t - \sigma \hat{r}_t \text{ (IS curve)}$$

$$\pi_t = \beta M^f \mathbb{E}_t \left[\pi_{t+1} \right] + \kappa x_t \text{ (Phillips curve)}$$

with

$$M := \frac{\bar{m}}{R - r m_y}, \qquad \sigma := \frac{m_r \psi}{R \left(R - r m_y \right)}, \qquad b_d = \frac{r m_y}{R - m_y r} \frac{R \left(1 - \bar{m} \right)}{R - \bar{m}}$$

$$M^f = \bar{m} \left[\theta + \left(1 - \theta \right) \frac{1 - \beta \theta}{1 - \beta \theta \bar{m}} m^f \right], \qquad \kappa = \bar{\kappa} m^f.$$

- Rational model: $M = M^f = 1, b^d = 0$. Behavioral: $M, M^f \in \left[0, 1 \right], b^d \geq 0$
- Empirical support for main features of model:
  1. Phillips curve: Gali and Gertler '99: need $\beta M^f = 0.75$, so $M^f \simeq 0.8$
  2. Fwd guidance puzzle lit.: Need $M < 1$, perhaps $M = 0.8$
  3. Evidence that Ricardian equivalence doesn't fully hold: e.g. tax rebates etc. literature: $b^d > 0$.

Multiplicity of equilibria under the traditional model

- Consider a Taylor rule

$$i_t = \phi_\pi \pi_t + \phi_x x_t + j_t$$

With $z_t' = (x_t, \pi_t)$, $D = 1 + \sigma\phi_x + \kappa\sigma\phi_\pi$,
$b_t' = -\frac{\sigma}{D}(1, \kappa)(i_t - r_t^n)$

$$z_t = A\mathbb{E}_t[z_{t+1}] + b_t$$
$$A = \frac{1}{D}\begin{pmatrix} M & \sigma\left(1 - \beta^f \phi_\pi\right) \\ M\kappa & \sigma\kappa + \beta^f\left(1 + \sigma\phi_x\right) \end{pmatrix}$$

- We have equilibrium uniqueness ("Blanchard-Kahn determinacy") iff the eigenvalues of A are less than 1 in modulus.
- Then, we can write: $z_t = \mathbb{E}_t[\sum_{\tau \geq t} A^{\tau - t} b_\tau]$
- Otherwise, there are other equilibria $z_{t+s} = \Lambda_2^{-s} v_1 \delta_t$ with $\mathbb{E}_{t-1}[\delta_t] = 0$

Taylor principle reconsidered

- Consider a Taylor rule

$$i_t = \phi_\pi \pi_t + j_t$$

- Traditional model: determinacy iff $\phi_\pi > 1$
- **Proposition** We have equilibrium determinacy iff

$$\phi_\pi + \frac{\left(1 - \beta M^f\right)(1 - M)}{\kappa\sigma} > 1$$

- In particular, if monetary policy is passive (e.g. stuck at ZLB, $\phi_\pi = 0$), uniqueness with strong enough BR:

$$\frac{\left(1 - \beta M^f\right)(1 - M)}{\kappa\sigma} > 1$$

- Need enough BR (low M) and price stickiness (low κ). (cf. Kocherlakota '16)
- Paper works out full Taylor rule $i_t = \phi_\pi \pi_t + \phi_x x_t + j_t$

In the trad. model, the economy should be much more volatile at the ZLB

- With $z_t' = (x_t, \pi_t), b_t' = -\frac{\sigma}{D}(1, \kappa)(i_t - r_t^n)$

$$z_t = A_t \mathbb{E}_t [z_{t+1}] + b_t$$

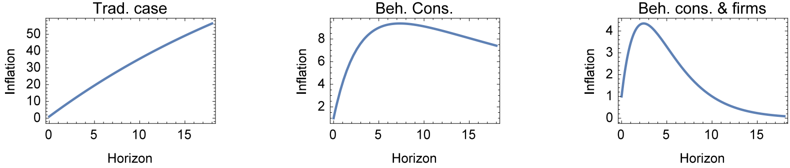
- Suppose we're at the ZLB for $t \leq T$: $A_t = A_{ZLT}$ for $t \leq T$, $A_t = A_{normal}$ for $t > T$. Then,

$$z_0 = A_{ZLB}^T \mathbb{E}_0 [z_T] + \mathbb{E}_0 \left[\sum_{t=0}^{T-1} A_{ZLB}^t b_t \right]$$

- As (in the trad. model) $||A_{ZLB}|| > 1$, the economy should be extremely sensitive to forecasts about the future, so very unstable.
- In this behavioral model$||A_{ZLB}|| < 1$, so no high volatility.

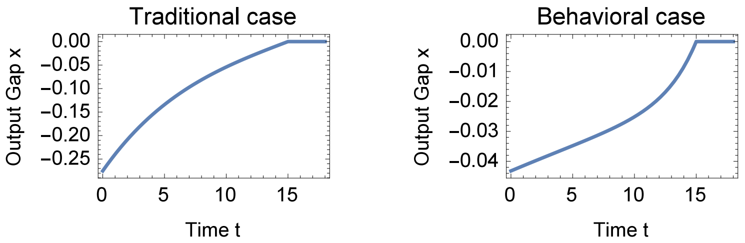
Announcement of future rate cut

- Central bank announces today that it will cut the rate later, at horizon T (as McKay-Nakamura-Steinsson (2015)).
- What's the impact today on inflation today?



Impact of a ZLB for T periods

- Werning (2012), but with behavioral agents. Take $r_t = \underline{r}$ for $t \leq T$, and $r_t = \bar{r} < 0$ for $t > T$. For $t > T$, the CB sets $i_t = \bar{r} > 0$, $x_t = \pi_t = 0$.
- **Proposition**. When $\frac{\left(1-\beta M^f\right)(1-M)}{\kappa\sigma} < 1$, the recession is unbounded. But if $\frac{\left(1-\beta M^f\right)(1-M)}{\kappa\sigma} > 1$, then the recession is bounded)



Optimal Monetary and Fiscal Policy

- Welfare: $\widetilde{W} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, N_t)$
- $\widetilde{W} = W^{FB} + W$

$$W = -K \mathbb{E}_0 \sum_{t=0}^{\infty} \frac{1}{2} \beta^t \left(\pi_t^2 + \vartheta x_t^2 \right) + W_-$$

with

$$\vartheta = \frac{\kappa}{m^f \varepsilon}$$

and $K = u_c c (\gamma + \phi) \frac{\epsilon}{\kappa} m^f$, and W_- is a constant

- Controlling forκ, the relative weight on the output gap (ϑ) is higher when firms are more behavioral (when m^f is lower).
- Intuition: inflation creates less between-firm price dispersion, because firms react less today to future inflation.
- First best: zero output gap and inflation, $x_t = \pi_t = 0$

Optimal policy with supply and demand shocks

First best via "helicopter drops of money"

- You get the first best iff:

$$i_t - \frac{b_d}{\sigma} d_t = r_t^n$$

- *When the ZLB doesn't bind*. To obtain the first best, set (with Taylor rule around it)

  $$i_t = r_t^n \text{ and zero deficit: } d_t = 0$$

  Like in the traditional model.
- *If we hit the ZLB*. Rational agents: Very complex, second best
- Behavioral agents: the right "helicopter drops of money" give First Best;

  $$i_t = 0 \text{ and deficit: } d_t = \frac{-\sigma}{b_d} r_t^n$$

- Because agents are not Ricardian, they spend the transfers you give them, hence output goes up

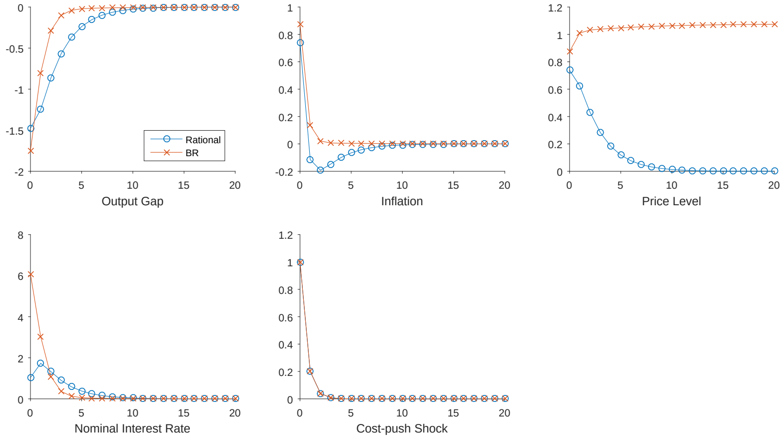
Optimal policy with complex tradeoffs

- Cost-push shocks: with ν_t AR(1)

$$\pi_t = \beta M^f \mathbb{E}_t [\pi_{t+1}] + \kappa x_t + \nu_t$$

- Then first best cannot be achieved.
- Optimal policy with commitment:
  - Traditional model: Optimal policy gives "price level targeting", "nominal GDP" targeting
  - With behavioral firms: this is not true any more
- Without commitment: the optimal policy under rational vs behavioral economy are close.

Optimal policy with commitment



Extending the model: partially backward-looking firms

- Motivation: so far, no permanent changes to inflation etc.
- Why is inflation stable? "Because agents' expectations are anchored at 2% inflation"
- Augment micromodel:

$$
\begin{aligned}
\mathbb{E}_t^{BR}\left[\pi_{t+k}\right] &= \bar{m}^k m_f \left(f\,\mathbb{E}_t\left[\pi_{t+k}\right] + (1-f)\,\mathbb{E}_t\left[\pi_{t+k}^d\right]\right) \\
\pi_{t+1}^d &= (1-\gamma)\,\pi_t^d + \gamma\zeta\pi_t^{CB} + \gamma\,(1-\zeta)\,\pi_t
\end{aligned}
$$

- Firms have two noisy signals: noisy rational expectations, and "default inflation"
- π_t^d=default inflation, which comes "for free" to the mind
- π_t^{CB}= central bank guidance.

Extending the model: partially backward-looking firms

- Extra microfoundation: firms use "default inflation" π_t^d to forecast future inflation
- Augmented model: with $\hat{r}_t = i_t - \mathbb{E}_t \pi_{t+1} - r_t^n$

$$x_t = M \mathbb{E}_t \left[x_{t+1} \right] + b_d d_t - \sigma \hat{r}_t \text{ (IS curve)}$$
$$\pi_t = \beta M^f \mathbb{E}_t \left[\pi_{t+1} \right] + \alpha \pi_t^d + \kappa x_t \text{ (Phillips curve)}$$
$$\pi_{t+1}^d = (1-\gamma)\, \pi_t^d + \gamma \zeta \pi_t^{CB} + \gamma (1-\zeta)\, \pi_t$$

with $M^f = \bar{m} \left(\theta + f m^f (1-\theta) \right)$,$\alpha = \beta \bar{m} m^f (1-f)(1-\theta)$

- π_t^d=default inflation, which comes "for free" to the mind
- π_t^{CB}= inflation guidance by central bank guidance.
- Embeds trad. model ($\alpha = 0$, $M = 1$), old Keynesian Taylor model ($M = \beta^f = 0$, $\alpha = 1, \zeta = 0$), basic behavioral model ($\alpha = 0$,$M < 1$).

Payoffs from this model

- The data wants some backward looking inflation in the Phillips curve (Gali and Gertler '99)
- Inflation dynamics are more inert, via "default" inflation π_t^d
- Notion of "the central bank raises rates to combat the past inflation", like in the old Keynesian model.
- To get Fisher sign neutrality (higher inflation $\rightarrow$ higher interest rate in long term) and stable economy, need large enough importance of "central bank guidance" ($\alpha\zeta$ big enough)
- Then, allows to see why the economy is stable at the ZLB: that's true iff there's enough bounded rationality and inflation guidance

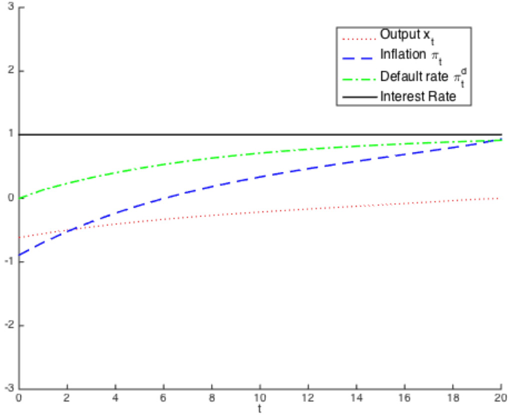
$$\frac{\left(\alpha\zeta + 1 - \alpha - \beta^f\right)}{\kappa\sigma}(1 - M) > 1$$

- ... something impossible in the NK model ($M = 1$) and Old Keynesian model ($\alpha + \beta^f = 1, \zeta = 0$)

Model is Keynesian in Short run, Fisherian in Long Run

Fed raises the nominal rate by 1%, permanently. No Taylor rule, but $\pi_t^{CB} = 1\%$.

Conclusion: the economy is Neo-Fisherian in long run, but Keynesian in run short. Solution to Cochrane's challenge.



Comparision with other models

$$x_t = M\mathbb{E}_t\left[x_{t+1}\right] + b_d d_t - \sigma\hat{r}_t \text{ (IS curve)}$$

$$\pi_t = \beta M^f \mathbb{E}_t\left[\pi_{t+1}\right] + \kappa x_t \text{ (Phillips curve)}$$

- Hand-to-mouth: keeps $M = M^f = 1$, though give (something like) $b_d > 0$
- Sticky information (Mankiw-Reis): keeps $M = 1$, $b_d = 0$
- Rational discounted Euler equation: Del Negro, Giannoni, Patterson ('15), McKay, Nakamura and Steinnsson ('15), Piergallini ('06), Nistico ('12), Caballero and Farhi ('15), Werning ('15): Keeps $M^f = 1$, and silent about b_d. In calibrations gives $M \simeq 1-$(small liquidity spread) or $M \simeq 1-$(small probability of death)
- Misperception of GE (Angeletos and Liu '16) without credit constraints: gives $M \geq \beta$, $b^d = 0$.
- Heterogeneity (McKay, Nakamura Steinsson '16, Farhi Werning '16): don't get $M^f < 1$; lose rep. agent framework

Conclusion: Monetary and Fiscal

1. Behavioral version of the work-horse model used for policy
2. Monetary policy is less powerful (esp. forward guidance)
3. Fiscal policy is more powerful (agents not Ricardian)
4. Optimal joint fiscal+monetary policy.
5. Taylor principle strongly modified. Equilibrium is determinate (even with rigid monetary policy): stable economy at the ZLB.
6. The ZLB is much less costly.
7. Optimal policy
   7.1 Do "helicopter drops of money" at the ZLB→First Best
   7.2 "Nominal GDP targeting" is not optimal any more
8. Resolution of neo-Fisherian paradoxes: Model is "neo-Fisherian" in long run, but Keynesian in short run.

- Empirical support for main features of model:
  1. Phillips curve: Gali and Gerler '99: need $\beta M^f = 0.8$, so $M^f \simeq 0.8$
  2. Need $M < 1$, perhaps $M = 0.8$ (fwd guidance puzzle lit.)
  3. Evidence that Ricardian equivalence doesn't fully hold: e.g. tax rebates etc. literature: $b^d > 0$.
  4. Point 8 conjectured to be correct empirically

Ongoing work: Bounded Rationality in economics

1. Micro: "A sparsity-based model of bounded rationality" (2014): Fairly general and simple device,

   $$\underset{a}{\operatorname{smax}}\, u(a, x) \text{ subject to } b(a, x) \geq 0$$

   Basic consumer theory: Walrasian demand, Hicksian demand, Slutsky matrix. Competitive equilibrium: Arrow-Debreu, Edgeworth boxes...
2. Macro: "Behavioral Macroeconomics via Sparse Dynamic programming": Life-cycle, RBC
3. "A Behavioral New Keynesian model": monetary and fiscal
4. Public economics: "Optimal Taxation with Behavioral Agents" (with E. Farhi)

   Ongoing work:
5. Finance: in the works. Merton problem...
6. Game theory: "Some game theory with sparsity-based bounded rationality". Sparse *Nash equilibrium*