Discouraging Deviant Behavior in Monetary Economics

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Multiple Equilibria Standard NK Model

- Standard, New Keynesian (NK) Monetary Model:
  - Interest rate rule with big coefficient on inflation (‘Taylor rule’) and passive fiscal policy:
    - Big coefficient on inflation: ‘Taylor Principle’.
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- Message from models: Taylor rule not sufficient to stabilize inflation globally.
Implementation of Desired Equilibrium by Escape Clause

Intuitive motivation used in Taylor (1996), Christiano-Rostagno (2001), and BSGU.

▶ In high inflation, money growth high.
▶ Just declare 'we refuse to allow high money growth'.
▶ In deflation, money growth slow.
▶ Just declare 'we refuse to allow slow (negative) money growth'.
▶ While inside an inflation monitoring range, follow Taylor rule.

There exists a unique equilibrium under this policy.

Practical examples of escape clauses:
▶ Exigent circumstances clause 13.3 in Federal Reserve Act.
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Push Back Against Dramatic Conclusions in Two Papers

  ▶ Uniqueness proof with the escape clause is correct.
  ▶ Undesired equilibria ruled out by govt. commitment to do something impossible.
  ▶ Commitment to 'blow up the economy.'
  ▶ The policy delivering uniqueness is of no economic interest.

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  ▶ While correct in his endowment economy.
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Push Back Against Dramatic Conclusions in Two Papers (See paper)

• ACK suggest shrinking the monitoring range to a singleton and letting the escape clause do all the work to uniquely implement desired equilibrium.

• ACK conclude: Taylor principle irrelevant to implement desired equilibrium.

• Equilibrium with ACK policy is knife-edge:
  ▶ Lacks robustness to trembles.
  ▶ Tiny trembles activate escape clause,
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Bigger Question

• What makes agents to think that other allocations don't realize under a certain policy?
  ◀ Competitive equilibrium concept is silent about these types of questions.

• We approach this question by reformulating economy as game.
  ◀ We can formally ask "what makes you think other equilibria do not arise?".

• We use a refinement of rationalizability to answer the big question.
  ◀ Rationalizable implementation is more desirable for policy design.

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Roadmap

- Model

Background results:

▶ Multiple equilibria with Taylor rule, uniqueness when escape clause is added.

▶ How does the escape clause eliminate the non-desired equilibria?

▶ How does it discourage deviant behavior?
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• Conclusion
Government

• Government levies taxes, provides monetary transfers:

\[ \bar{\mu}_t - 1 \bar{M}_{t-1}, \bar{\mu}_t = \bar{M}_t / \bar{M}_{t-1}, \]

and balances budget in each period.

• Monetary policy:

\[ \{\bar{\mu}_t\}_{t=0}^{\infty} \]

selected so that, in equilibrium,

\[ \bar{R}_t = \bar{R}^* (\bar{\pi}_t \bar{\pi}^*) \phi, \quad \bar{\pi}_{t+1} = P_{t+1} / P_t, \]

\[ \bar{R}^* = \bar{\pi}^* / \beta, \]

where \( \bar{\pi}^* \geq 1 \) and \( \bar{R}^* \) are desired inflation and interest rate.
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where \(\bar{\pi}^* = \bar{\mu}^* \geq 1\) and \(\bar{R}^*\) are desired inflation and interest rate.
Representative Household

• A version of 'Limited participation model':
  ▶ Household gets wage at start of $t$, in time to satisfy cash in advance constraint.

• Household first order conditions:
  \[ W_t P_t = c\gamma_t l\psi_t, \]
  \[ c - \gamma_t = \beta c - \gamma_{t+1}\bar{R}_t \bar{\pi}_{t+1}, \]
  'Euler equation' plus transversality and cash in advance conditions.
Representative Household

- A version of ‘Limited participation model’:

\[
W_t P_t = c_t \gamma t L \psi_t, \\
\gamma t - c_t = \beta c_t - \gamma t + 1 \bar{R}_t \bar{\pi}_t + 1, \\
\text{‘Euler equation’ plus transversality and cash in advance conditions.}
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\frac{W_t}{P_t} = \frac{c_t^{\gamma} \psi_t}{\psi_t}, \quad c_t^{1-\gamma} = \beta c_{t+1}^{1-\gamma} \frac{\bar{R}_t}{\bar{\pi}_{t+1}}, \quad \text{‘Euler equation’}
\]

plus transversality and cash in advance conditions.
Firms

- Competitive, final good firm production and profits:

\[ Y_t = \left[ \int_0^1 Y_{i,t}^{\frac{\varepsilon - 1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon - 1}}, \quad \varepsilon > 1. \]
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- Demand curve:

\[
Y_{i,t} = Y_t \left( \frac{p_{i,t}}{P_t} \right)^{-\varepsilon}, \quad P_t \triangleq \left[ \int_0^1 p_{i,t}^{1-\varepsilon} \, di \right]^{\frac{1}{1-\varepsilon}}.
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• Optimizing price:
Firms

• Competitive, final good firm production and profits:

\[ Y_t = \left[ \int_0^1 Y_{i,t} \frac{1}{(1 - \varepsilon)} \, di \right]^{1/(1 - \varepsilon)}, \quad \varepsilon > 1. \]

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- Optimizing price:
  \[ p_{i,t} = \frac{\varepsilon}{\varepsilon - 1} \times \tilde{R}_t \times W_t \times (1 - \tau_t). \]
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Market Clearing and other Equilibrium Conditions

- Labor/goods market clearing and firm optimality:

\[ 1 = \frac{W_t}{P_t} = \frac{c_t^\gamma l_t^\psi}{MRS} \]
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- In equilibrium, the Euler equation is the Fisher equation:

\[
c_t^{-\gamma} = \beta c_{t+1}^{-\gamma} \frac{\tilde{R}_t}{\bar{\pi}_{t+1}} \implies 1 = \beta \frac{\tilde{R}_t}{\bar{\pi}_{t+1}}.
\]
Scaling

• Scaled, logged Fisher equation

\[ \bar{R}_t = \bar{\pi}_{t+1} + 1 \]

\[ \bar{R}_t \equiv \ln(\bar{R}_t \bar{R}^*_t) \]

\[ \bar{\pi}_{t+1} \equiv \ln(\bar{\pi}_{t+1} \bar{\pi}^*_t) \]

• Monetary policy in scaled terms:

\[ \bar{R}_t = \bar{R}^* \left( \bar{\pi}_t \bar{\pi}^*_t \right)^\phi \rightarrow \bar{R}_t \bar{R}^*_t = \left( \bar{\pi}_t \bar{\pi}^*_t \right)^\phi \rightarrow R_t = \phi \pi_{t+1} \]

• Combining (\( \ast \)) and (\( \ast \ast \)), yields equilibrium difference equation:

\[ \pi_{t+1} = \phi \pi_t \]

• Scaled money growth:

\[ \mu_t = \ln(\bar{\mu}_t \bar{\pi}^*_t) \]
Scaling

- Scaled, logged Fisher equation $\beta \bar{R}_t = \bar{\pi}_{t+1}$:

\[
\bar{R}_t = \bar{\pi}_{t+1}^{\phi}, \quad (\ast\ast)
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Scaling

- Scaled, logged Fisher equation $\beta \tilde{R}_t = \bar{\pi}_{t+1}$:

\[
\frac{\beta \tilde{R}_t}{\beta \tilde{R}^*} = \frac{\bar{\pi}_{t+1}}{\bar{\pi}^*}
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Scaling

- Scaled, logged Fisher equation $\beta \bar{R}_t = \bar{\pi}_{t+1}$:

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  \[
  \frac{\beta \tilde{R}_t}{\beta \tilde{R}^*} = \frac{\tilde{\pi}_{t+1}}{\tilde{\pi}^*} \rightarrow R_t = \pi_{t+1}, \quad (*) \text{ where } \quad R_t \equiv \ln \left( \frac{\tilde{R}_t}{\tilde{R}^*} \right), \quad \pi_{t+1} \equiv \ln \left( \frac{\tilde{\pi}_{t+1}}{\tilde{\pi}^*} \right).
  \]

- Monetary policy in scaled terms:
  \[
  \tilde{R}_t = \tilde{R}^* \left( \frac{\tilde{\pi}_t}{\tilde{\pi}^*} \right)^\phi \rightarrow \frac{\tilde{R}_t}{\tilde{R}^*} = \left( \frac{\tilde{\pi}_t}{\tilde{\pi}^*} \right)^\phi \rightarrow R_t = \phi \pi_t \quad (**) \]

- Combining \((*)\) and \((**)\), yields equilibrium difference equation:
  \[
  \pi_{t+1} = \phi \pi_t.
  \]
Scaling

• Scaled, logged Fisher equation $\beta \tilde{R}_t = \bar{\pi}_{t+1}$:

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• Combining (*) and (**), yields equilibrium difference equation:

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• Scaled money growth: \( \mu_t = \ln \left( \frac{\tilde{\mu}_t}{\tilde{\pi}^*} \right) \)
Properties of Taylor Rule Equilibrium
Multiplicty and Local Uniqueness of Desired Equilibrium

- Multiple equilibria, \( \{\pi_t\} \), each indexed by \( \pi_0 \).
- Desired equilibrium is unique equilibrium that never violates monitoring range, \([\pi_l, \pi_u]\).
  - If \( \pi_0 \neq 0 \), then \( |\pi_t| \to \infty \).
Taylor rule with Escape Clause

• Keep using Taylor rule while inflation remains inside monitoring range, \( \pi_t \in [\pi_l, \pi_u] \), \( \pi_l \leq 0 \leq \pi_u < \infty \).

• Activate escape clause: if for some \( t \), \( \pi_t / \in [\pi_l, \pi_u] \), then, in \( t + 1 \) switch forever to constant money growth, \( \mu = 0 \).

▶ Equilibrium is unique after the activation of the escape clause. (See paper)

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Uniqueness of Equilibrium Under Escape Clause

- If $\pi_0 \neq 0$, then $|\pi_t| \to \infty$.

- Activation of escape clause is not consistent with the equilibrium conditions.

- Unique equilibrium associated with $\pi_0 = 0$. 

\[ \pi_t = \phi \pi_{t+1} \]

\[ \pi_l \leq \pi_u \leq \pi_t \]
Activation of Escape Clause Not an Equilibrium

Suppose $\pi_T > \pi_u$. Then, Taylor rule: $R_T = \phi \pi_T > \pi_u$, because $\phi > 1$.

Fisher equation: $R_T = \pi_T + 1 = 0$.

Escape clause $\leq \pi_u$.

So, $R_T > \pi_u$ and $R_T \leq \pi_u$, contradiction!
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• Suppose $\pi_T > \pi_u$. Then,

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Activation of Escape Clause Not an Equilibrium

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\[ \pi_l \quad \pi_u \]

\[ \pi_t \quad \pi_t+1 \]

\[ 45^\circ \]
Cochrane’s Critique of Implementation Result

Cochrane concludes uniqueness is achieved by “blow-up-the-economy threat.”

Reaches this conclusion by studying the question: ‘what would happen if the out-of-equilibrium event, $\pi_T > \pi_u$ occurred?'

In his endowment economy, $c_t = y_t$ always, in and out of equilibrium.

Household Euler equation reduces to Fisher equation in and out of equilibrium.

Concludes that under escape clause monetary policy commits to setting $R_T$ to two different values: Impossible!!!

$R_T$ implied by Fisher equation and $R_T$ implied by Taylor rule.

No equilibrium exists if $\pi_T > \pi_u$.

Cochrane’s answer: Escape clause achieves uniqueness by blowing up the economy if $\pi_T / \in [\pi_l, \pi_u]$.

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Uniqueness by Threatening to Blowing up Economy Not Interesting

• Diamond and Dybvig (1983) model of bank runs.
  ▶ In absence of regulation, two equilibria: run, no-run.

• Implementation problem:
  ▶ Design policy that rules out run equilibrium and keeps no-run equilibrium.

• Answer to the problem: deposit insurance.
  ▶ Everyone's dominant strategy is no-run.

• The answer is uninteresting if govt.'s deposit insurance is not feasible.
  ▶ Then no one would believe the insurance, and they might run.

• Cochrane calls such implementation Blowing up the Economy.
  ▶ In the monetary model, no one would believe such policy, and hyperinflation is not excluded!
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Cochrane’s Critique in Our Production Economy
Euler Equation in our Production Economy

• Euler Equation in our model:

\[ \frac{R}{T} = \pi_T + 1 + \gamma \log \left( \frac{c_T + 1}{c_T} \right) \]

▶ In equilibrium, our Euler equation reduces to Fisher equation because \( c_t = 1 \) all \( t \geq 0 \).

▶ Out of equilibrium, our Euler equation depends on the value of \( \frac{c_T + 1}{c_T} \).

• Euler equation in Cochrane's endowment economy:

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▶ in and out of equilibrium because \( c_t = Y \) for all \( t \geq 0 \) (Cochrane (2010, p.574)).
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Cochrane’s Critique in our Production Economy

• The critique is only valid in Cochrane’s endowment model.

• Suppose $\pi_T > \pi_u$ in our production economy. Then, Taylor rule: $R_T = \phi \pi_T > \pi_u$, because $\phi > 1$.

− Euler equation: $R_T = \pi_T + 1 \frac{1}{c_T} \log \left( \frac{c_T + 1}{c_T} \right)$ endogenously determined.

− Apparently consistent with a familiar and coherent narrative:
  ▶ if $\pi_T > \pi_u$, then real rate, $R_T - \pi_T + 1$, is very high and $c_T$ very low.
  ▶ looks like a stylized Volcker recession.
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How Do We Answer Cochrane’s Question?

What is it about the escape clause that implies $\pi^T > \pi_u$ cannot occur in equilibrium?

We need an equilibrium concept which allows for out-of-equilibrium.
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Exit Ramp Off Equilibrium
Equilibrium Concept that Allows for Out-of-Equilibrium Events

  - Reinterpret rational expectations equilibrium as a fixed point of a best response function.
  - Nash Equilibrium.
- Then we can understand the economics of why a non-fixed point fails to be an equilibrium.

- Best response analysis goes back at least to Diamond and Dybvig (1983)
  - Describe what would happen, off-equilibrium paths, and discourage undesirable actions.
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  - Reinterpret rational expectations equilibrium as a fixed point of a best response function.
    - Nash Equilibrium.
  - Then we can understand the economics of why a non-fixed point fails to be an equilibrium.
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• Best response analysis goes back at least to Diamond and Dybvig (1983)
  ▶ Describe what would happen, off-equilibrium paths, and discourage undesirable actions.
Introduce Firms’ Best Response Function

To set a price, intermediate firms need a belief about $W_t$. Why?

▶ $W_t$ is jointly determined in labor market and labor supply depends on $P_t$.

▶ So, intermediate firms need a conjecture, $P_{ct}$, about aggregate prices, $P_t$.

\[
p_{it} = P_{ct} \times W_t P_{ct}.
\]

We divide the period into morning and afternoon.

▶ In the morning, intermediate firms set $p_{it}$ simultaneously given conjecture $P_{ct}$.

▶ In the afternoon, the rest happens so $W_t/P_{ct}$ is determined as a function of "history," $(h_{t-1}, P_{ct})$.

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p_{it} = P_{ct}(c_{bt}(h_{t-1}, P_{ct}))^{\gamma} + \psi = P_{ct}(c_{bt}(h_{t-1}, P_{ct}))^{\gamma} + \psi.
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$$p_{i,t} = P_t^c \times \frac{W_t}{P_t^c}.$$
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Best Response Function

\[
\ln p_i \left( t \right) - \bar{\mu}^* \times \left( c_{bt} \left( h_{t-1}, P_{ct} \right) \right)^\gamma + \psi \equiv F(h_{t-1}, \pi_{ct}).
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Best Response Function

- Scaling and logging, we get the individual best response $F$.

$$
\ln \frac{p_{i,t}}{P_{t-1}\bar{\mu}^*} = \ln \left[ \frac{P_t}{P_{t-1}\bar{\mu}^*} \times \left( c_t^b (h_{t-1}, P_t^c) \right)^{\gamma+\psi} \right] \equiv F\left(h_{t-1}, \pi_t^c\right).
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$F (h_{t-1}, \pi_t^c)$ is the best response function

$$x_{i,t} = F (h_{t-1}, \pi_t^c).$$
Continuation Equilibrium

- Let

\[ a_t = (l_t, \pi_t, c_t, R_t, W_t, \mu, \bar{M}_t) \]

\[ h_{t-1} = (a_0, a_1, ..., a_{t-1}) . \]
Continuation Equilibrium

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**Definition**

A *continuation equilibrium* conditional on \( (h_{t-1}, \pi^c_t) \) is a sequence, \( a_{t+s} \), for \( s \geq 0 \), with two properties:

(a) \( a_{t+s}, s > 0 \) satisfies all \( t + s \) equilibrium conditions.

(b) \( a_t \) satisfies all time \( t \) equilibrium conditions except intermediate good firm optimality.
Strategy Equilibrium

**Definition**

A strategy equilibrium is a competitive equilibrium with the property that for each possible history $h_{t-1}$: (i) there is a well-defined continuation equilibrium corresponding to any value of $\pi^c_t$ and (ii) there exists a $\pi^c_t$ that is a fixed point:

$$\pi^c_t = F(h_{t-1}, \pi^c_t).$$

Comment:

- Property: for on-path $h_{t-1}$ and when competitive equilibrium unique, then $\pi^c_t$ equals competitive $\pi_t$.
- Part (i) provides an exit-ramp from the competitive equilibrium in each $t$.
  - Allows us to think coherently about why people privately choose not to take the exit ramp.
  - Can ask 'why does the escape strategy' trim non-desired equilibria?
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Why is $\pi^c_T > \pi_u$ not an Equilibrium Under Escape Clause?

- Easy to show that actual inflation would be:

$$F(h_{T-1}, \pi^c_T) = \pi^c_T + (\gamma + \psi) \left[ \frac{\phi}{1 - \gamma} \pi^c_T \right].$$

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- With low output, labor demand is low $\rightarrow W_T/P_T$ low.
- So, intermediate firms post lower prices, and actual inflation is low,

$$\pi^c_T > F(\pi^c_T)$$

- No fixed points.
Why Can Agents Come Up with a Rational Expectation?

• We use a refinement of "rationalizability" for a theory of expectation.

▶ Pick an arbitrary big compact set $\Pi \subset \mathbb{R}$ for firms' action space.

▶ Firms are certain that other firms only choose their action from $F(\Pi)$.

▶ A firm knows others are rational.

▶ Then firms are now certain that other firms only choose from $F(F(\Pi))$.

▶ A firm knows others know firms are rational.

▶ Keep continuing this forward induction...

▶ Firms only play an action from $F^\infty(\Pi)$.

Proposition

If $\gamma > 1$ and $1 < \phi \leq 2\gamma - \frac{1}{\gamma} + \psi$, then for any large compact set $\Pi$, $F^\infty(\Pi) = \{0\}$.

• Rational firms convince themselves that desired equilibrium occurs!

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Put Simply

• Escape clause prevents undesired inflation by a feasible threat to crash the economy (like Volcker did) if it happened.

• Logic by which it works looks like an 'Out-of-equilibrium Taylor Principle'.

• Common knowledge of rationality is enough to ensure that firms spontaneously come up with the rational expectation.
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Concluding Observations

- Taylor Principle: When inflation is high, raise $R_t$ sharply and (hopefully) this will slow down the economy and stabilize inflation around desired rate.

- Often, $\phi > 1$ is referred to as the 'Taylor Principle'.
  - But, only seems to deliver on its promise in neighborhood of desired equilibrium.
  - Does not rule out other, non-desired, equilibria.

- We showed that the Taylor rule with $\phi > 1$ and an escape clause:
  - Rules out non-desired equilibria by an off-equilibrium version of Taylor Principle.
  - Caveat: regime-shift to constant money rule does not always work when money demand is interest elastic.
  - Need to revisit New Keynesian canon that thinking about money demand is unnecessary.
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