EABCN Training School: Monetary-Fiscal Policy Interactions

Lecture 4. Generalizing Policy Interactions (A)

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The Messages

- Draws heavily from “Generalizing the Taylor Principle,” with Troy Davig (*AER*, June 2007)
- We do see policy rules—or regimes—change
  - to study the implications of recurring changes, need to model them coherently
- Before studying monetary-fiscal interactions when policy regimes can change, need some preliminary analysis when only MP can switch
- This allows simple analytical derivations that build intuition and understanding
- Many of our inferences are monetary policy effects change in subtle ways once we allow recurring regime change
- Subsequent work will allow both monetary and fiscal regime to undergo recurring change

SIMPLIFYING POLICY

- Monetary policy is complex
- For descriptive & prescriptive reasons, seek to simplify
- Most successful simplification due to Taylor

$$i_t = \bar{i} + \alpha(\pi_t - \pi^*) + \gamma x_t + \varepsilon_t$$

- **Taylor principle:** $\alpha > 1$
  - necessary & sufficient for unique bounded eqm (w/ bounded shocks)
- Unique & stable eqm necessary for good policy
  - rules out arbitrarily large fluctuations

The Taylor Rule & Principle

- Central banks can stabilize economy by adjusting nominal interest rate more than one-for-one with inflation
  - approximates Federal Reserve behavior since 1982
  - nearly optimal in workhorse class of monetary models
  - used by central banks as a benchmark
- Maintains two key assumptions
  - fiscal policy is perpetually passive
  - policy rule permanent & agents believe change impossible
- Here we relax this second assumption
  - rule evolves according to a Markov chain
  - consider two conventional monetary models

GENERALIZING THE TAYLOR RULE & PRINCIPLE

- $\alpha(s_t)$, $\gamma(s_t)$ $s_t \sim$ Markov chain
- s_t: "rule," "regime," "state"
- s_t exogenous (for now)
- Can believe actual policy rule time invariant
  - but Taylor rule is a gross simplification of reality
  - paper shows that a particular form of non-linearity can change predictions of models

In the Fisherian Model . . .

- Derive *long-run Taylor principle*
  - imposes much weaker conditions on MP for uniqueness
  - departures from short-run Taylor principle can be substantial—but brief—or modest—and prolonged
  - the more "hawkish" one regime is, the more "dovish" the other can be and still deliver uniqueness
  - "expectations formation effects"—beliefs about possible future regimes affect current eqm, increasing volatility even in a regime that satisfies **TP**

In the New-Keynesian Model . . .

- Derive *long-run Taylor principle*: dramatically expands region of determinacy
- Inference that inflation of the 70's due to failure to obey TP does not hold up when expectations embed possibility of regime change
- Occasional large departures from TP—due to worries about financial instability or economic weakness—can have quantitatively important impacts even in a regime that satisfies TP
- Misleading inferences can arise from dividing data into regime-specific periods to interpret estimates as arising from distinct fixed regimes

Why Regime Change?

- Evidence that monetary policy regime changed
- Institutional or policy reforms
  - adoption of inflation targeting by over 20 countries
  - Fed's "just trust us" approach
- Logical consistency
  - if regime *has* changed, regime *can* change
  - expectations depend on prob. distn. over possible regimes
- Recurring: in US, no legislated change installed Volcker or Greenspan
  - confluence of economic/political conditions allowed US to dodge a bullet and get Bernanke (coulda' been a FOG)

A Modeling Choice

- Because Taylor rule a gross simplification, deviations occur
  - can be large and serially correlated
  - are systematic responses to state of economy
- How should we model these deviations?
  - shuffled into the ε's?
  - time-varying feedback coefficients, α_t & γ_t?
- ε's affect conditional expectations
- α_t & γ_t affect expectations *functions*
- A substantive choice

MODEL OF INFLATION DETERMINATION

- A simple Fisherian economy

$$\begin{aligned} i_t &= E_t \pi_{t+1} + r_t \\ r_t &= \rho r_{t-1} + \nu_t, \quad \nu \text{ bounded support} \\ i_t &= \alpha(s_t)\pi_t, \quad s_t \text{ Markov; } s_t = 1, 2 \end{aligned}$$

$$p_{ij} = P[s_t = j \,|s_{t-1} = i]$$

$$\alpha(s_t) = \begin{cases} \alpha_1 \text{ for } s_t = 1 \\ \alpha_2 \text{ for } s_t = 2 \end{cases}$$

  - a *monetary policy regime*: realization of $\alpha(s_t)$
  - a *monetary policy process*: collection $(\alpha_1, \alpha_2, p_{11}, p_{22})$
  - policy is *active* if $\alpha_i > 1$; *passive* if $\alpha_i < 1$

Determinacy: Definition

- Seek generalization of Taylor principle
  - necessary & sufficient condition for existence of unique bounded eqm
- Why boundedness?
  - consistent w/ standard definition under fixed regime
  - corresponds to locally unique eqm
    - can analyze small perturbations
  - considering log-linearized models
    - boundedness ensures approximations are good

Determinacy: Formalism

Model: $\alpha(s_t)\pi_t = E_t\pi_{t+1} + r_t$

- Let $\Omega_t^{-s} = \{r_t, r_{t-1}, \ldots, s_{t-1}, s_{t-2}, \ldots\}$ and $\Omega_t = \Omega_t^{-s} \cup \{s_t\}$
- Integrating over s_t, for $s_t = 1$ and $s_t = 2$

$$\begin{aligned} E_t\pi_{t+1} &= E[\pi_{t+1} \,|\, s_t = i, \Omega_t^{-s}] \\ &= p_{i1}E[\pi_{1t+1} \,|\, \Omega_t^{-s}] + p_{i2}E[\pi_{2t+1} \,|\, \Omega_t^{-s}] \end{aligned}$$

  where $\pi_{it} = \pi_t(s_t = i, r_t)$, the solution when $s_t = i$
- The system is

$$\begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix} \begin{bmatrix} \pi_{1t} \\ \pi_{2t} \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \begin{bmatrix} E_t\pi_{1t+1} \\ E_t\pi_{2t+1} \end{bmatrix} + \begin{bmatrix} r_t \\ r_t \end{bmatrix}$$

  where $E_t\pi_{it+1}$ denotes $E[\pi_{it+1} \,|\, \Omega_t^{-s}]$

Determinacy: Formalism (con't)

- Write system as

$$\pi_t = ME_t\pi_{t+1} + \alpha^{-1}r_t$$

- MSV solution: π_t function only of (r_t, s_t)
- Define $x_t = \pi_t - \pi_t^{MSV}(r_t, s_t)$
- Bounded soln for $\{x_t\} \Longleftrightarrow$ bounded soln for $\{\pi_t\}$
- We study: $x_t = ME_t x_{t+1}$
- Proof of determinacy shows that under certain conditions on the policy process, $x_t = 0$ is the only solution

Determinacy: Formalism (con't)

- **Prop. 1** When $\alpha_i > 0$, a unique bounded solution exists iff all the eigenvalues of M lie inside the unit circle
- Sufficiency: the usual proof in linear RE models
  - intuition: boundedness requires that $\lim_{n \to \infty} M^n = 0$, so $x_t = 0$ the only solution
  - delivered by eigenvalue condition

Determinacy: Formalism (con't)

- Necessity: Suppose $\lambda_1 \geq 1$, $\lambda_2 < 1$
  - diagonalize M, let $y_t = V^{-1}x_t$, then

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} \lambda_1 & 0 \\ 0 & \lambda_2 \end{bmatrix} \begin{bmatrix} E_t y_{1t+1} \\ E_t y_{2t+1} \end{bmatrix}$$

  bounded solutions $y_{1t+1} = \lambda_1^{-1} y_{1t} + \phi_{t+1}$, so

$$\begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} = \begin{bmatrix} \gamma v_{11} \lambda_1^{-t} \\ \gamma v_{21} \lambda_1^{-t} \end{bmatrix}$$

  - also exist bounded sunspot solutions: $y_{1t+1} = \lambda_1^{-1} y_{1t} + \phi_{t+1}$, $y_{2t+1} = 0$, $E_t \phi_{t+1} = 0$, bounded
  - multiple eq & sunspots possible w/ more stringent det defn

LONG-RUN TAYLOR PRINCIPLE

- **Prop. 2** Given $\alpha_i > p_{ii}$ for $i = 1, 2$, the following statements are equivalent:
  (A) All the eigenvalues of M lie inside the unit circle.
  (B) $\alpha_i > 1$, for some $i = 1, 2$, and the *long-run Taylor principle (LRTP)*

$$(1 - \alpha_2)\, p_{11} + (1 - \alpha_1)\, p_{22} + \alpha_1 \alpha_2 > 1$$

  is satisfied.
- Premise $\alpha_i > p_{ii}$ all i unfamiliar
  - fixed regime: MP always obeys TP
  - LRTP is hyperbola w/ asymptotes $\alpha_1 = p_{11}$ & $\alpha_2 = p_{22}$
  - restricts α's to economically interesting portion of hyperbola

A Range of Policies Deliver Uniqueness

$$\alpha_1 > 1\text{: } p_{11}(1-\alpha_2) + p_{22}(1-\alpha_1) + \alpha_1\alpha_2 > 1$$

- Some policy processes that deliver unique equilibria

  $$\alpha_1 \to \infty \Rightarrow \alpha_2 > p_{22}$$

  or

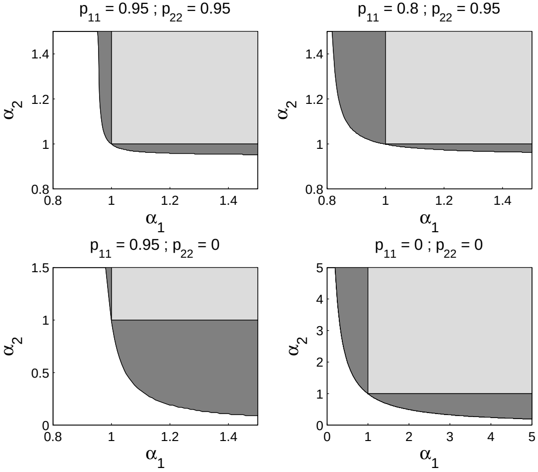
  $p_{11} = 1 \Rightarrow$ need $\alpha_1 > 1$ and $\alpha_2 > p_{22}$

  - more active is one regime, more passive the other can be

    $p_{22} \to 1$ OK if $\alpha_2 \approx 1$ (but < 1)
  - ergodic prob of passive regime can be ≈ 1 (but < 1)

    $p_{11} = p_{22} = 0$ need $\alpha_2 > 1/\alpha_1$
  - more active in one regime, less active in the other
- Figure illustrates these points

Determinacy Region: Fisherian Model



Fisherian Model: Solution

- Define state as (r_t, s_t) & find MSV solutions
  - posit regime-dependent rules:

$$\pi_t = a(s_t = i) r_t$$

$$a(s_t) = \begin{cases} a_1 \text{ for } s_t = 1 \\ a_2 \text{ for } s_t = 2 \end{cases}$$

  - expectations functions:

$$E[\pi_{t+1} \,|s_t = 1, r_t] = [p_{11} a_1 + (1 - p_{11}) a_2] \rho r_t$$

$$E[\pi_{t+1} \,|s_t = 2, r_t] = [(1 - p_{22}) a_1 + p_{22} a_2] \rho r_t$$

  - solve simple 2×2 system to get a_1 and a_2

Solution

- Solutions are:

$$a_1 = a_1^F \left(\frac{1 + \rho p_{12} a_2^F}{1 - \rho^2 p_{12} a_2^F p_{21} a_1^F} \right)$$

and

$$a_2 = a_2^F \left(\frac{1 + \rho p_{21} a_1^F}{1 - \rho^2 p_{12} a_2^F p_{21} a_1^F} \right)$$

$p_{12} = 1 - p_{11}$, $p_{21} = 1 - p_{22}$ & “fixed-regime” coefficients

$$a_i^F = \frac{1}{\alpha_i - \rho p_{ii}}, \qquad i = 1, 2$$

- $\alpha_1 > \alpha_2 \Leftrightarrow a_1 < a_2$

EXPECTATIONS-FORMATION EFFECTS

- Solutions are:

$$a_1 = a_1^F \left(\frac{1 + \rho p_{12} a_2^F}{1 - \rho^2 p_{12} a_2^F p_{21} a_1^F} \right)$$

  and

$$a_2 = a_2^F \left(\frac{1 + \rho p_{21} a_1^F}{1 - \rho^2 p_{12} a_2^F p_{21} a_1^F} \right)$$

- Expectations-formation effects from regime 2 to regime 1
  - through $p_{12} a_2^F$
  - large if p_{12} large, p_{22} large, α_2 small

Special Case

- Real interest rate serially uncorrelated $(\rho = 0)$, solution is

$$a_1 = \frac{1}{\alpha_1}$$

  and

$$a_2 = \frac{1}{\alpha_2}$$

- Looks like fixed-regime solution, BUT
  - determinacy in FR: $\alpha_i > 1$ all i
  - switching allows determinacy w/ some $\alpha_i < 1$
  - if $p_{22} < \alpha_2 < 1$, regime 2 *amplifies* shocks
  - possible to fit volatile data with determinate eqm?

A New-Keynesian Model

- Bare-bones model with nominal rigidities
  - from class in wide use for monetary policy analysis
  - general insights extend to more complex models now confronting data
- With recurring regime change and rational expectations:
  - How does the Taylor principle change?
  - How do impacts of demand and supply shocks change?
- Expectations-formation effects can be large

A New-Keynesian Model

- Consumption-Euler equation and AS relations

$$\begin{aligned} x_t &= E_t x_{t+1} - \sigma^{-1}(i_t - E_t \pi_{t+1}) + u_t^D \\ \pi_t &= \beta E_t \pi_{t+1} + \kappa x_t + u_t^S \end{aligned}$$

- Disturbances: bounded, autoregressive, mutually uncorrelated

$$\begin{aligned} u_t^D &= \rho_D u_{t-1}^D + \varepsilon_t^D \\ u_t^S &= \rho_S u_{t-1}^S + \varepsilon_t^S \end{aligned}$$

- A Taylor rule for $s_t = 1, 2$

$$i_t = \alpha(s_t)\pi_t + \gamma(s_t)x_t$$

New-Keynesian Model: Determinacy

- Let $\pi_{it} = \pi_t(s_t = i)$ & $x_{it} = x_t(s_t = i)$, $i = 1, 2$
- Define forecast errors

$$\eta^{\pi}_{1t+1} = \pi_{1t+1} - E_t\pi_{1t+1} \qquad \eta^{\pi}_{2t+1} = \pi_{2t+1} - E_t\pi_{2t+1}$$
$$\eta^{x}_{1t+1} = x_{1t+1} - E_t x_{1t+1} \qquad \eta^{x}_{2t+1} = x_{2t+1} - E_t x_{2t+1}$$

- Model is

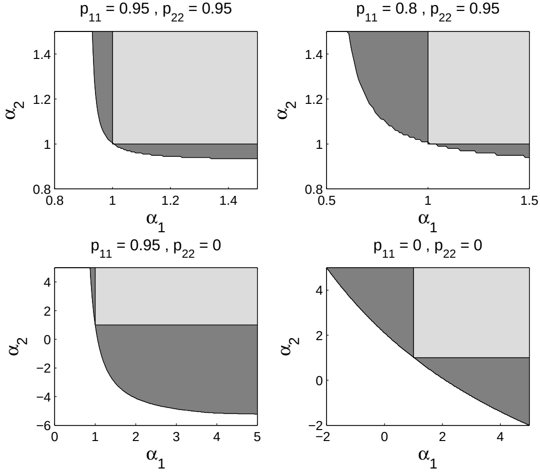
$$AY_t = BY_{t-1} + A\eta_t + Cu_t$$

- Unique bounded eqm requires the 4 generalized eigenvalues of (B, A) to lie inside unit circle
- Derive *long-run Taylor principle*

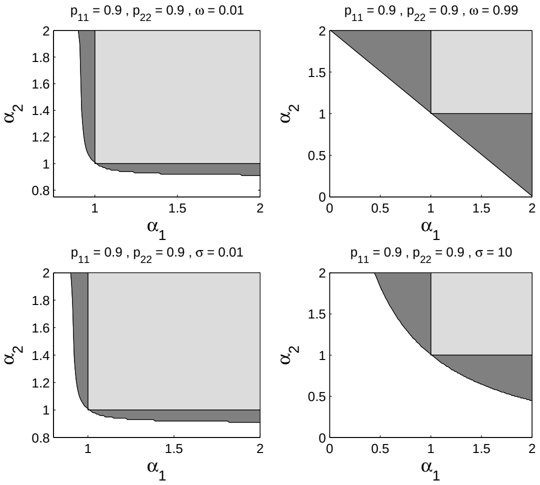
NEW-KEYNESIAN MODEL: DETERMINACY

- Set $\gamma(s_t) = 0$
- Intertemporal margins interact w/ expected policy to affect determinacy
- Determinacy regions expand w/ parameters that reduce ability to substitute away from future policy
    - increase degree of stickiness (κ)
    - reduce intertemporal elasticity of substitution (σ)

DETERMINACY REGIONS EXPAND



DET. REGIONS & PRIVATE PARAMETERS



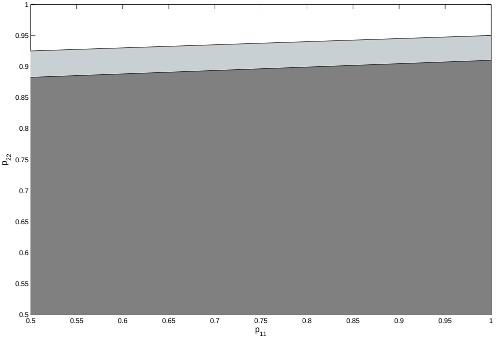
New-Keynesian Model: Solutions

- MSV solution is straightforward to compute
- Easiest to consider numerical examples
- For inflation, intuition from fixed regimes carries through
    - more active MP process reduces inflation volatility
- For output, switching introduces non-monotonicity
    - more active MP process can raise or lower output volatility, depending on source of shock

A Return to the 1970s?

- Studies find Fed passive 1960-79; active since 1982
- Fears of reverting to 1970s behind calls for IT
- Fiscal policy may be an impetus for switching to passive MP
- Embed estimates of Lubik-Schorfheide in switching setup
  - compute set of (p_{11}, p_{22}) that deliver uniqueness
- Implications
  - inference that US switched from indeterminate to determinate eqm requires current state be absorbing
  - fixed regime badly mispredicts impacts of supply & demand shocks

DETERMINACY REGIONS: L-S ESTIMATES



LS: $\alpha_1 = 2.19, \gamma_1 = .30, \alpha_2 = .89, \gamma_2 = .15$

Dark: high flexibility $(\sigma = 1.04, \kappa = 1.07)$

Light: low flexibility $(\sigma = 2.84, \kappa = .27)$

Financial Crises & Business Cycles

- MP shifts focus from inflation to other concerns
  - financial stability & job creation
  - shift can last few months or more than year
  - during Greenspan era: 2 market crashes, 2 foreign financial crises, 2 jobless recoveries
  - documented by Marshall and Rabanal
- Take normal times to be $\alpha_1 = 1.5$, $\gamma_1 = .25$, and persistent
  - other regime: $\gamma_2 = .5$, α_2 and p_{22} vary
  - a crude characterization of those events
- Spillovers from demand shocks can make inflation much more volatile and output much less volatile than if the active regime were permanent

Financial Crises & Business Cycles

	$p_{11} = .95$			
	Demand		**Supply**	
	Inflation	Output	Inflation	Output
$p_{22} = 0$				
$\alpha_2 = .25$	1.060	1.011	1.092	.994
$\alpha_2 = 0$	1.073	1.014	1.110	.992
$p_{22} = .75$				
$\alpha_2 = .25$	1.268	.886	1.412	1.066
$\alpha_2 = 0$	1.454	.807	1.653	1.104

Standard Deviation Active Regime Relative to Fixed Regime

Active and fixed regimes set $\alpha_1 = \alpha = 1.5$, $\gamma_1 = \gamma = .25$; $\gamma_2 = .5$

Empirical Implications of Switching

- Commonplace for empirical work to split data into regime-dependent sub-periods
- Estimates then interpreted in fixed-regime theoretical model
- We simulate switching eqm, estimate correctly-specified (fixed-regime) identified VARs
  - assume econometrician knows when regime changed
- Estimated model

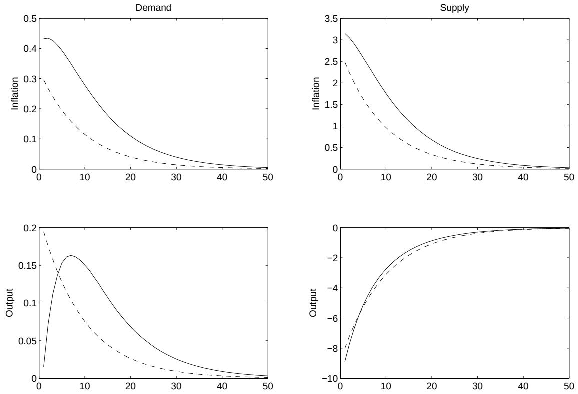
$$\begin{aligned} x_t &= \delta i_t + u_t^D + lags \\ \pi_t &= \theta x_t + u_t^S + lags \\ i_t &= \alpha \pi_t + \bar{\gamma} x_t + u_t^{MP} + lags \end{aligned}$$

Empirical Implications of Switching

	α	$\bar{\gamma}$	δ	θ
Regime 1	2.182	0.30	-1.690	0.409
Regime 2	0.885	0.15	-0.750	1.675
Full Sample	1.375	0.225	-1.476	0.657

Estimates from an identified VAR using simulated data.
Regime 1 is conditional on remaining in regime with $\alpha_1 = 2.19$
Regime 2 is conditional on remaining in regime with $\alpha_2 = 0.89$.
Full sample is recurring changes from regime 1 to regime 2.
α is the estimated response of monetary policy to inflation.
$\bar{\gamma}$ is the policy response to output, held fixed in estimation.

Demand & Supply Shocks: Lubik-Schorfheide Parameters



$\alpha_1 = 2.19, \gamma_1 = .30, \alpha_2 = .89, \gamma_2 = .15, p_{11} = .95, p_{22} = .93$

Dashed: fixed regime; Solid: active, switching

SUMMARY

- A broader perspective on Taylor principle and range of unique bounded equilibria it supports
- Endowing conventional models with empirically relevant MP switching processes
  - drastically alters conditions for a unique bounded eqm
  - generates important expectations-formation effects
- Developed a two-step solution method to get determinacy conditions and solutions
- Conventional models extremely sensitive to deviation from usual assumption that policy is permanent
- The possibility of regime change should be the default assumption in theoretical models

WRAP UP

- Many potential applications
  - any purely forward-looking model
  - exchange rate determination: switch between fixed & floating
  - term structure: policy switching
  - technology: switch between high- and low-growth periods
  - terms of trade: persistent & transitory changes
- Need to develop methods to allow analytical solutions with endogenous state variables