Monetary Policy
(Advanced Monetary Economics)

ECON 4325

Nina Larsson Midthjell - Lecture 10 - 8 April 2016

Outline:

NB: Mathematical expressions in Davig and Leeper (2007) which are not discussed at the lecture will **not** be required knowledge on the exam

- Introduction
  - The importance of the Taylor principle
- A Fisherian model of inflation
  - Nec. and suf. for unique eq: The long run Taylor principle holds
  - Expectations of regime change might strongly affect equilibrium dynamics
- Markov (regime) - switching in a New Keynesian Framework
- Practical and empirical implications of regime-switching

Introduction
The Taylor principle 1/6

- The Taylor principle:

Central banks can stabilize the macroeconomy by adjusting the nominal interest rate by more than one for one with inflation ($\phi_\pi > 1$)

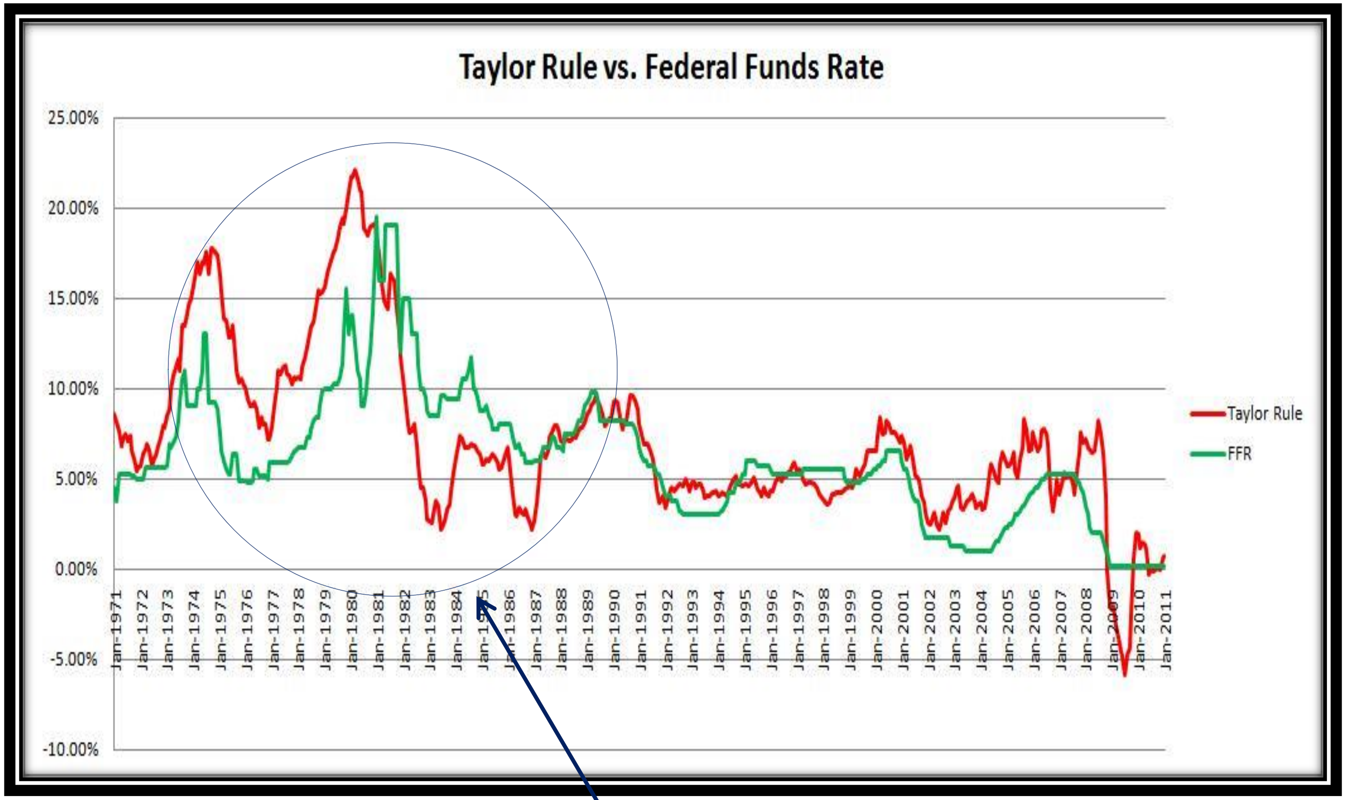
$$i_t = \rho + \phi_\pi(\pi_t - \pi^*) + \phi_{\tilde{y}}\tilde{y}_t + \nu_t \qquad (1)$$

1.5

0.5-1

- A powerful device to simplify modeling behavior – proven extraordinarily useful
- In the NKM described in this course: Necessary and sufficient condition for determinate and unique equilibrium
- What happens if the Taylor principle is not satisfied?

Introduction
The Taylor rule and the Fed Fund's rate 2/6



Taylor principle not fulfilled = source of great macroeconomic instability in the 70s

Source: CGG (2000)

Consequences if Taylor principle not fulfilled:

1. The effects of fundamental shocks are amplified → large fluctuations in π_t $\tilde{y}_t$
2. Multiple equilibria → respond to sunspot shocks as well as fundamental shocks

- Home assignment: Explain why these outcomes are undesirable to an inflation-targeting central bank.

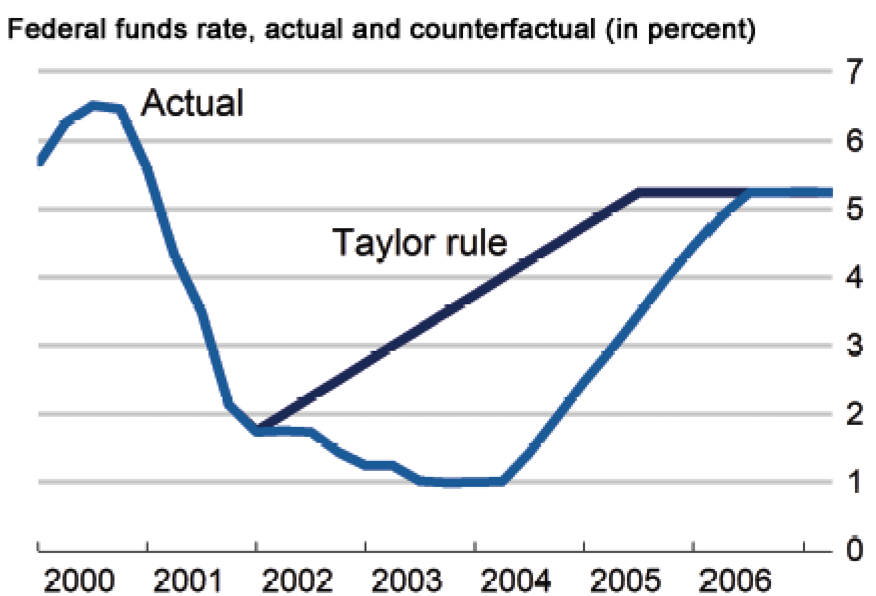


Chart from The Economist, October 18, 2007

all the Fed needed to do was follow "… the kind of policy that had worked well during the period of economic stability called the Great Moderation, which began in the early 1980s."

John Taylor

Introduction
The simple interest rate rule - challenges 4/6

- The simple Taylor rule is heavily used by central banks and in policy research. Why?
  - The rule: $$i_t = \rho + \phi_\pi(\pi_t - \pi^*) + \phi_{\tilde{y}}\tilde{y}_t + \nu_t \qquad (1)$$

- Why is the «true» monetary policy rule not as simple as this one?
  - Central bankers deal with many different sources of information
  - Does not seem plausible that there exists one perfect interest rate response for each macroeconomic variable change which holds for all different states of the economy.
    - **Challenge:** How to model deviations from the rule?
    - Shuffle into the shock component? Affect <u>conditional expectations.</u>
    - **Time-variant CB coefficients?** → **On today's agenda.** Affect <u>expectation functions.</u>
  - The rule is a simplification – masks important aspects of policy behavior.
  - How to determine the «perfect» size of the central bank coefficients ϕ_π and $\phi_{\tilde{y}}$?

Introduction
Generalizing the Taylor principle 5/6

- In the following, the CB coefficients will vary stochastically over time to reflect regime changes.
  ϕ_π and $\phi_{\tilde{y}}$ evolve **exogenously** according to a Markov Chain (as opposed to endogenously)
- To ensure the existence of a determinate equilibrium with regime change: Use a simple dynamic Fisherian model
- Next, we use the NKM to examine the practical consequences of such regime changes

Main results from the Fisherian model:

1. A unique bounded equilibrium does not require the Taylor principle to hold in every period, only that a ***long-run Taylor principle*** is fulfilled.
2. If two possible policy rules: (i) The ***more active***, which reacts aggressively to inflation, and (ii) the ***more passive***, then:
   - Expectations that future policy might be ***more passive*** can strongly affect the equilibrium under the ***more active*** rule (and vice versa)! How can we relate this result till today?

Main results from the NKM:

1. The region of determinacy is dramatically expanded.
2. The effect on expectations: Beliefs about possible future regimes affect current eqm, **increasing inflation volatility** even in a regime that satisfies the Taylor principle!

Introduction

Possible applications of regime switching 6/6

- If allow for the possibility of a regime change in the formation of expectations:
  - Would the CGG (2000) conclusion still hold?

- What are the consequences of the recent departures from the Taylor principle?
  - The too low for too long «regime» in 2003-2005 = ***more passive rule***

- Theoretical consequences of a switch from **active** to **passive**:
  1. If sufficiently passive and persistent → indeterminate equilibrium
  2. Higher inflation volatility (both if switches and if there is a positive probability of switching)
  3. If only brief stay in the passive regime: Less likely that result in indeterminate equilibrium

What type of regime is the current ZLB?
Passive?
Brief or more persistent?

- Empirical evidence: Regime shifts occur.

- Rational agents: Know that regimes occur and form expectations accordingly

- This lecture: Bring theory in line with evidence.

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A Fisherian model of inflation determination
Model set-up

A two-step procedure:

1. Derive **interpretable** analytical conditions on the model parameters that ensure a determinate equilibrium
2. Use the **method of undetermined coefficients** to obtain solutions

In other words: A familiar method☺

- A two-equations economy for inflation determination:

Fisher
$$i_t = E_t \pi_{t+1} + r_t \quad (2)$$

Monetary Policy
$$i_t = \alpha(s_t)\pi_t \quad (3)$$

Real interest rate
$$r_t = \rho r_{t-1} + \nu_t \quad (4)$$

$[\underline{\nu}, \bar{\nu}]$

Two states!
$$\alpha(s_t) = \begin{cases} \alpha_1 & \text{for } s_t = 1 \\ \alpha_2 & \text{for } s_t = 2 \end{cases} \quad (5)$$

ν_t and s_t are independent

A Fisherian model of inflation determination

Definitions and switching probabilities 2/10

A monetary policy **regime** = Realization of s_t

A monetary policy **process** = α_1, α_2 and the probabilities of switching

Active monetary policy = $\alpha_i > 1$, $i = 1,2$ as opposed to **passive** when $\alpha_i < 1$

The switching probabilites:

p_{11} = Staying in regime 1 in period t when regime 1 in period t-1

p_{12} = $= 1 - p_{11}$

p_{22} =

p_{21} = Switching to regime 1 in period t when regime 2 in period t-1 $= 1 - p_{22}$

If $\alpha_1 < \alpha_2$, then monetary policy becomes **more passive** if (circle the correct arrow): α_1 ↑ ↓ α_2 ↑ ↓ p_{11} ↑ ↓ p_{22} ↑ ↓

A Fisherian model of inflation determination

Solving for fixed regime equilibrium 3/10

Inserting for equation (3) in (2), solving for inflation when $\alpha_1 = \alpha_2 = \alpha$:

$$\pi_t = \frac{1}{\alpha} E_t \pi_{t+1} + \frac{1}{\alpha} r_t \qquad (6)$$

How to solve for inflation with one endogenous and one state variable?

$$\xrightarrow{\text{yields}} \pi_t = \left(\frac{1}{\alpha}\right)^T E_t \pi_{t+T} + \frac{1}{\alpha} r_t \left[\frac{1}{1-\frac{\rho}{\alpha}}\right]$$

For which values of α will we have a unique and stable solution and why?

$$\pi_t = r_t \left[\frac{1}{\alpha - \rho}\right] \qquad (7)$$

Interpretation:

Typo corrections on this slide

A Fisherian model of inflation determination

Equilibrium dynamics with regime shifts 4/10

- With switching, there will be one equation like equation (6) per regime, in our case : **Two**

$$\pi_{1t} = \frac{p_{11}}{\alpha_1} E_t\pi_{1t+1} + \frac{p_{12}}{\alpha_1} E_t\pi_{2t+1} + \frac{1}{\alpha_1} r_t \quad (8)$$

$$\pi_{2t} = \frac{p_{21}}{\alpha_2} E_t\pi_{1t+1} + \frac{p_{22}}{\alpha_2} E_t\pi_{2t+1} + \frac{1}{\alpha_2} r_t \quad (9)$$

- Recall the **first step** on how to determine the unique equilibrium in the NKM: **Construct an equation system.** We do the same with our regime-shifting model:

$$\begin{bmatrix} \pi_{1t} \\ \pi_{2t} \end{bmatrix} = \begin{bmatrix} \frac{p_{11}}{\alpha_1} & \frac{p_{12}}{\alpha_1} \\ \frac{p_{21}}{\alpha_2} & \frac{p_{22}}{\alpha_2} \end{bmatrix} \begin{bmatrix} E_t\pi_{1t+1} \\ E_t\pi_{2t+1} \end{bmatrix} + \begin{bmatrix} \frac{1}{\alpha_1} \\ \frac{1}{\alpha_2} \end{bmatrix} [r_t] = \mathbf{M} \begin{bmatrix} E_t\pi_{1t+1} \\ E_t\pi_{2t+1} \end{bmatrix} + \boldsymbol{\alpha}^{-1} [r_t] \quad (10)$$

- Recall the **second step** on how to determine the unique equilibrium in the NKM: **Find the eigenvalues.** Same procedure in this model, we construct: $|\mathbf{M} - \lambda \mathbf{I}| = 0$

Solutions: λ_1 and λ_2 , as given in equation (12) and (13) in Davig and Leeper (2007).

How to find the eigenvalues?

A Fisherian model of inflation determination
The unique bounded equilibrium solution with regime shifts 5/10

- Bounded = bounded fluctuations in the shocks
  - Corresponds to the existence of a locally unique solution
  - Bounded solutions to the linear systems are approximate local solutions to the full nonlinear models when the exogenous shocks are small enough.
  - Recall: log-linearization of nonlinear DSGE-models is what we play with☺
- Recall the **third step** on how to determine the unique equilibrium in the NKM: **Ensure that both eigenvalues lie within the unit circle.** Still the case in this regime shifting model:

> **PROPOSITION 1:** *When* $\alpha_i > 0 \; for \; i = 1,2,$
> *a necessary and sufficient condition for determinacy of equilibrium, defined as the existence of a unique bounded solution for the inflation processes defined in equation (10) is that*
> *all the eigenvalues of* ***M*** *lie* ***inside the unit circle.***

- If not fulfilled: Continuum of bounded solutions
- Do we ***have to*** play around with equations (12) and (13) in Davig and Leeper (2007) to figure out whether proposition 1 is fulfilled? ***Thankfully not.....***

A Fisherian model of inflation determination

The long run Taylor principle 6/10

- Requiring both eigenvalues to lie inside the unit circle $\Leftrightarrow$ ***active* monetary policy in *at least one regime* + the monetary policy process satisfies the *long run* Taylor principle:**

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

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

is satisfied.

- $\alpha_i > p_{ii}$ ⟶ restricts the alphas to the space where monetary policy seeks to stabilize, rather than destabilize, the economy.
- Obviously, a range of monetary policy behavior is consistent with the LRTP.
- Interpret equation (11).

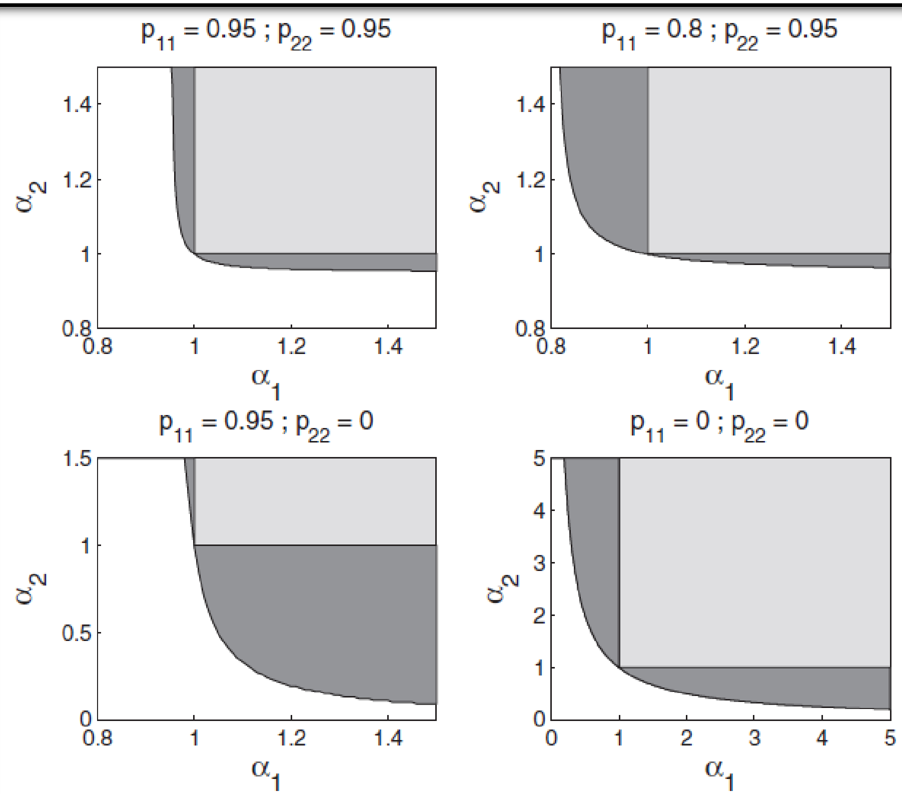

FIGURE 1. DETERMINACY REGIONS: FISHERIAN MODEL

Notes: Parameter combinations in the light-shaded regions imply a unique equilibrium in fixed-regime model; combinations in dark-shaded plus light-shaded regions imply a unique equilibrium in regime-switching model.

- Regions for unique equilibrium expands with regime shifting
- If not likely with regime shifts: Close to the fixed regime region
- If probability of staying within regime 1 slightly drops, opening up for shifts: α_1 can be smaller (but not very small) the larger α_2
- If the probability of staying in regime 2 is zero once you get there whereas the probability is large to stay in regime 1: α_2 may be close to zero if α_1 is sufficiently large
- If mean duration of both regimes approaches 1 period: The regions expand drastically in both directions.
- What does this all mean? Interpret.

A Fisherian model of inflation determination
Solutions for inflation with regime shifts 8/10

- **How is equilibrium inflation affected by a shock in this model with regime shifting?**
- Recall how we study this research question in the NKM: We make a guess and solve the model with the **method of undetermined coefficients**. We do the same in this model with regime shifting:

Recall step 1: Making a guess!

$$\pi_{1t} = a_1 r_t \quad (12)$$

$$\pi_{2t} = a_2 r_t \quad (13)$$

$$E_t \pi_{1t+1} = p_{11} a_1 \rho r_t + p_{12} a_2 \rho r_t = p_{11} a_1 \rho r_t + (1 - p_{11}) a_2 \rho r_t \quad (14)$$

$$E_t \pi_{2t+1} = p_{22} a_2 \rho r_t + p_{21} a_1 \rho r_t = p_{22} a_2 \rho r_t + (1 - p_{22}) a_1 \rho r_t \quad (15)$$

$E_t \pi_{1t+1}$ = Inflation expectations made for period t+1 when in regime **1** in period t

Recall next steps:

Step 2: Insert for the guesses in equation system (10)
Step 3: Get rid of the state variable r_t
Step 4: Solve the equation system of two equations for the two unknowns a_1 and a_2

The two solutions:

$$a_1 = a_1^F\left(\frac{1 + \rho p_{12} a_2^F}{1 - \rho^2 p_{12} a_2^F p_{21} a_1^F}\right), \quad (16)$$

$$a_2 = a_2^F\left(\frac{1 + \rho p_{21} a_1^F}{1 - \rho^2 p_{12} a_2^F p_{21} a_1^F}\right), \quad (17)$$

$$where: {a_i}^F = \frac{1}{\alpha_i - \rho p_{ii}}$$

A Fisherian model of inflation determination
Solutions for inflation with regime shifts 10/10

Interpretation of the solutions (16) and (17):

Outline:

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And just to be even clearer: The appendices are **not** required knowledge for the exam

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Regime shifting in the NKM
Model set-up

The NKM equilibrium as we know it:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t \qquad (18)$$

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1}) + e_t$$

- The shocks are AR(1) and mutually uncorrelated
- Kappa is 0.17
- If shocks instead i.i.d: Regime shifts still matters for the determinacy properties of equilibrium, but not for the equilibrium dynamics

$Familiar\ stuff$ ☺

Monetary policy in the NKM with flexible inflation targeting and regime shifting:

$$i_t = \alpha(s_t)\pi_t + \gamma(s_t)x_t \qquad (20)$$

- As before, s_t evolves according to a Markov chain with a transition matrix of four probabilites (see slide 11) and s_t is still random and independent of the shock processes.

Regime shifting in the NKM

Equilibrium with regime shifting 2/4

- How to find the fixed regime equilibrium in the NKM?
  - Should know by now☺
- Shifting regime equilibrium:
  - Same propositions hold as for the Fisherian model with a "straightforward" (!!) extension.
  - Not required to calculate the solutions for inflation and output, but should be able to explain in words how to move forward to solve for determinate equilibrium and the final solutions in the NKM with regime-shifting
- Considering strict inflation targeting only (what does that mean?), let's study the determinacy regions in the NKM with regime shifting
  - For different probabilities
  - For different probabilities and different parameters (sigma and theta in "our" model)

Regime shifting in the NKM

Determinancy regions in the NKM with regime shifting 3/4

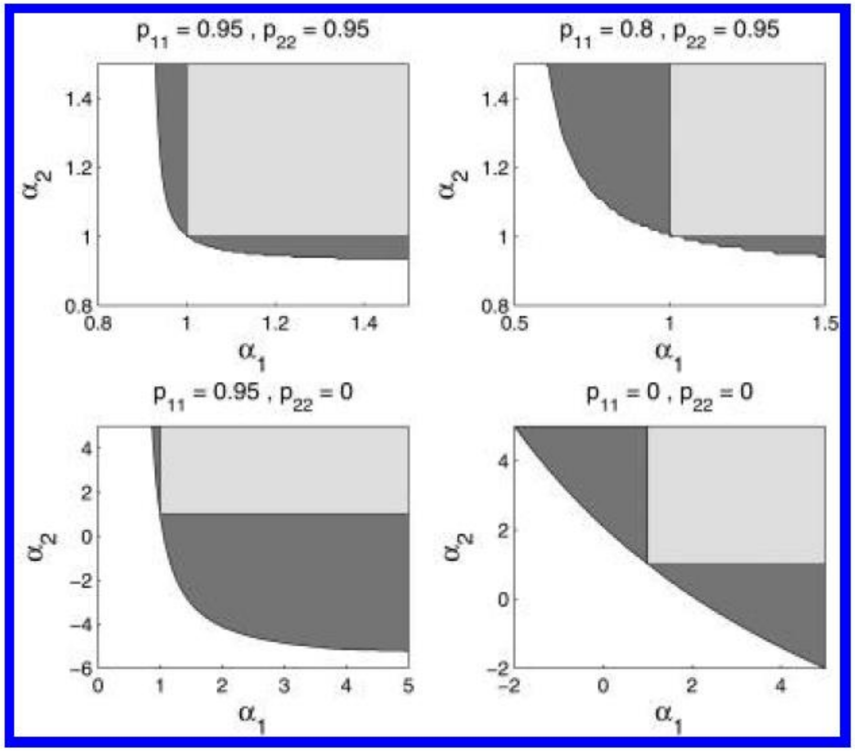

FIGURE 2. DETERMINACY REGIONS: NEW KEYNESIAN MODEL

Notes: Parameter combinations in the light-shaded regions imply a unique equilibrium in fixed-regime model; combinations in dark-shaded plus light-shaded regions imply a unique equilibrium in the regime-switching model.

- Recurring regime change can expand the regions of determinacy drastically
- Policy process matters a lot for the size of the regions
- As long as one regime is active:
  - The less persistent the other regime is, the smaller is the lower bound on the response of monetary policy to inflation
- When regimes are transitory, may have a large negative response to higher inflation!
  - Can we think of some real world example of such policies?

Regime shifting in the NKM
Determinacy regions in the NKM with regime shifting 4/4

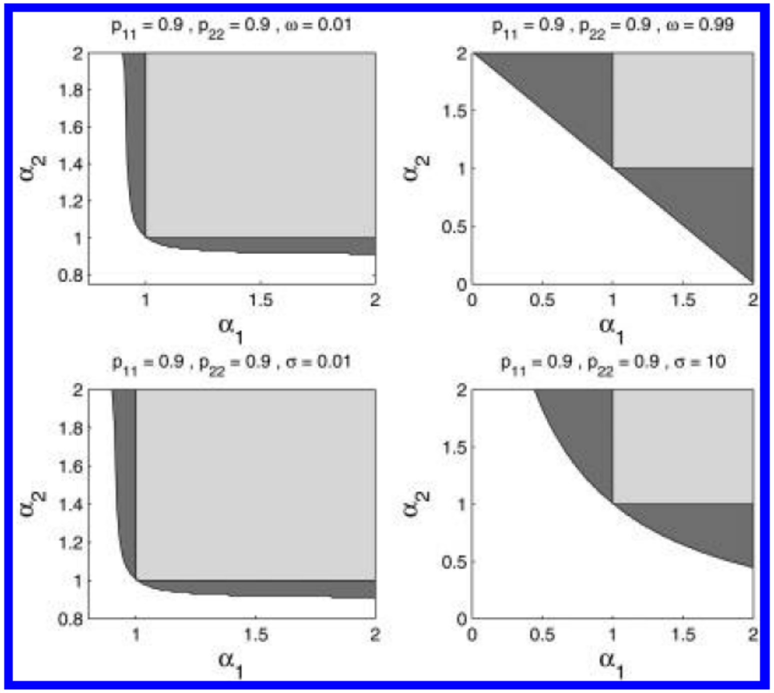

FIGURE 3. DETERMINACY REGIONS AND PRIVATE PARAMETERS: NEW KEYNESIAN MODEL

Notes: Parameter combinations in the light-shaded regions imply a unique equilibrium in fixed-regime model; combinations in dark-shaded plus light-shaded regions imply a unique equilibrium in regime-switching model for various settings of ω and σ.

- As opposed to with fixed regimes: Other parameter values matter for determinacy as well!
- Because the current regime is not expected to last:
  - Changes in parameters that affect the intertemporal margins (sigma, theta, beta) interact with expected policies and influence the determinacy regions
- If price rigidity drops: More focus on today's inflation relative to future inflation and expected regime changes matter less, shrinking the determinacy region

What about sigma?

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Practical and empirical implications of regime-switching

- Study yourself and try to draw lines to the current financial crisis

- Section **IV-A** can be dropped.

Next week

Monetary Policy in Norway

- The Monetary Policy Report 1/16
- The Norges Bank Watch Report 2016

Monetary Policy
(Advanced Monetary Economics)

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