Macroeconomic (In)stability of Interest Rate Rules in a Model with Banking System and Reserve Markets

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Motivation

- Macroeconomic (In)stability
  - The number of pre-determined variables vs. the number of stable roots.
  - Endogenous business fluctuations.
- The nominal interest rate rules (Taylor, 1993)

$$\begin{aligned} &Federal\ funds\ rate\ target \\ &\quad = inflation\ rate \\ &\quad + equilibrium\ real\ federal\ funds\ rate \\ &\quad + 0.5 * inflation\ gap + 0.5 * output\ gap \end{aligned}$$

  - The Great Moderation.

- The existing literature:
  - Active rules and passive rules perform differently.
  - The relative desirability of active rules and passive rules crucially depends on the model features.

- The existing literature:
  - Active rules and passive rules perform differently.
  - The relative desirability of active rules and passive rules crucially depends on the model features.
- Implication:
  - The choice of an unsuitable interest rate feedback rule would cause the economy endogenous business fluctuations.

- The banking system and the reserves market
  - Open market operations
    - Adjust the supply of reserves.
    - To achieve the targets for the overnight loan rate.
- Common feature of the existing papers:
  - No federal funds market/rate.
  - The government bonds rate as the proxy for the federal funds rate.

This Paper

- Once the banking system and the reserves market are established, active rules and passive rules perform equally in regard to their macroeconomic stabilizing properties.

The credit channel of monetary transmission

Open market operations

$\Rightarrow$ The supply of reserves

$\Rightarrow$ The federal funds rate

$\Rightarrow$ Commercial banks' demand for excess reserves

$\Rightarrow$ The supply and the price of loans

$\Rightarrow$ Aggregate demand in the economy

- Bernanke and Blinder (1988, *AER*): "Money, the bank liability, is given a special role in the determination of aggregate demand. In contrast, bank loans are lumped together with other debt instruments in a bond market, which is then conveniently suppressed by Walras' Law."

- Empirical evidence that monetary transmission works through bank loans as well as bank deposits
  - Bernanke and Blinder (1992, *AER*), Kashyap et al. (1993, *AER*), Kashyap and Stein (1995, *Carnegies-Rochester CSPP*).
- The enhancement mechanism of the credit channel
  - Enhances the length and the depth of business fluctuations.
  - Monetary policy still matters even in a liquidity trap.
    - Bernanke and Blinder (1988, *AER*) and Bernanke and Gertler (1995, *JEP*)

Main Findings: labor-only economy

- Unique steady state.
- Equal performance of active rules and passive rules in regard to their macroeconomic stabilizing properties.
- The interplay between fiscal and monetary policies:
  - Non-indexed bonds: equilibrium indeterminacy.
  - Inflation-indexed bonds: determinacy.

Main Findings: endogenous-capital economy

- Unique steady state.
- Equal performance of active rules and passive rules in regard to their macroeconomic stabilizing properties.
- The interplay between fiscal and monetary policies:
  - Non-indexed bonds: saddle.
  - Inflation-indexed bonds: source.

Main Findings: the timing issue

- Background:
  - Carlstrom and Fuerst (2000a, *WP*) vs. Meng and Yip (2004, *ET*).
  - Dupor (2001, *JET*) versus Carlstrom and Fuerst (2005, *JET*), Li (2005, *WP*), and Huang and Meng (2007, *JEDC*).

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This paper:

- Forward-looking rules: our result survives the robustness check under the discrete-time modeling.
- Current-looking rules eliminate all the determinate equilibria.

The Economy

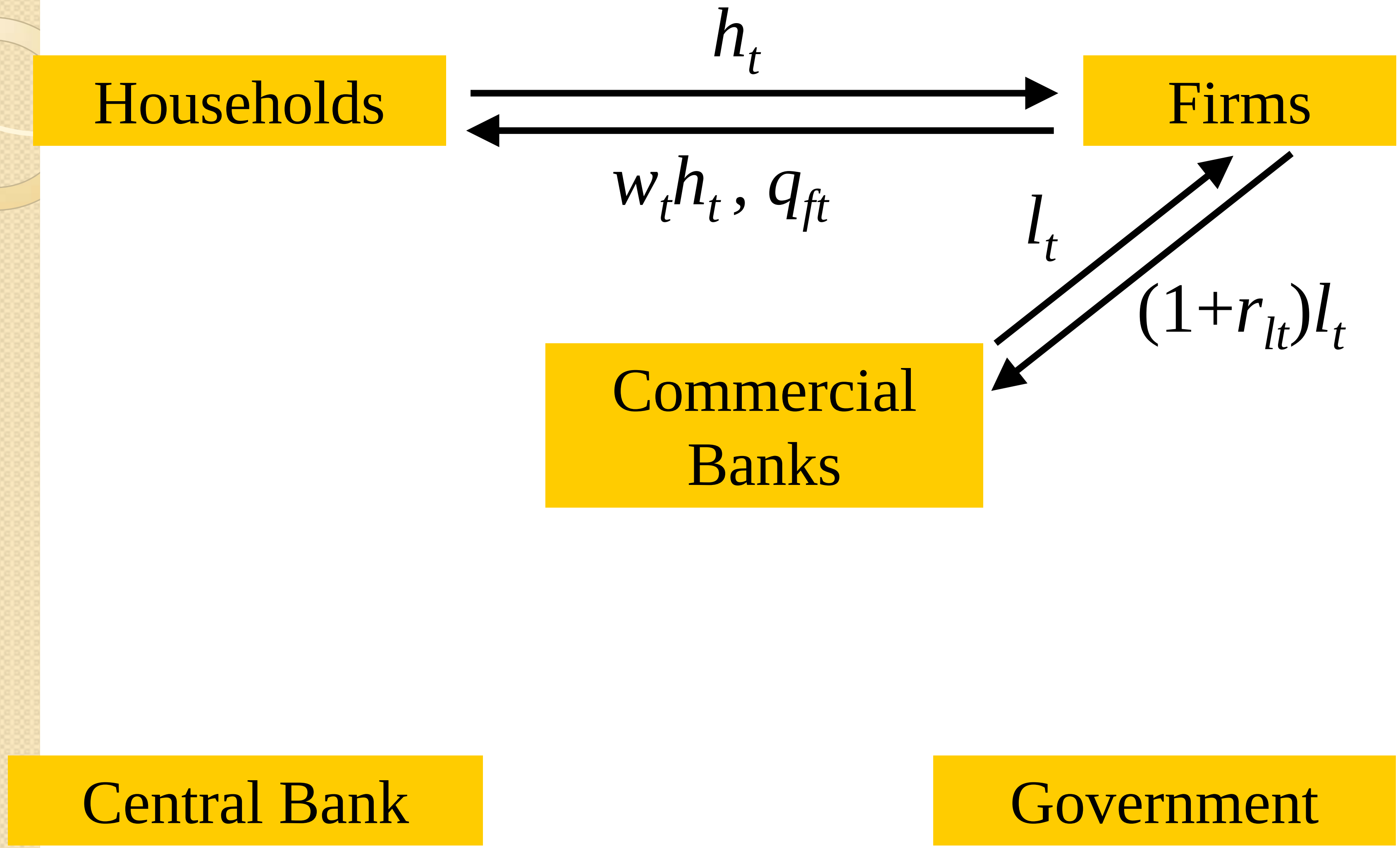
Households

Firms

Commercial Banks

Central Bank

Government

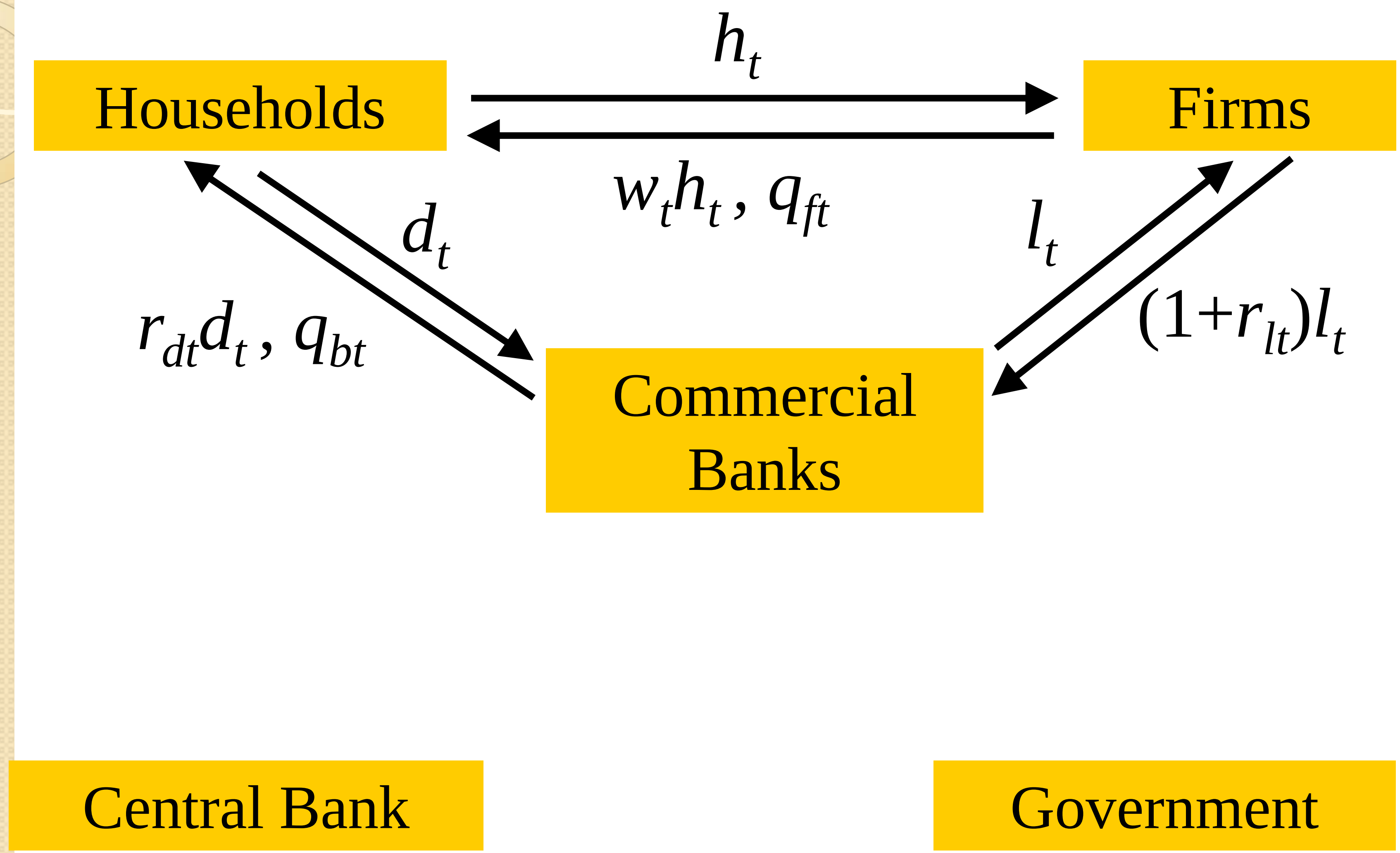

Households
h_t
Firms
$w_t h_t$, q_{ft}
l_t
$(1+r_{lt})l_t$
Commercial Banks
Central Bank
Government

Firms

- Production function: $y_t = h_t^{\alpha}, \alpha \in (0,1)$.
- Financial constraint: $w_t h_t \leq l_t^d$.
- Profits: $\Pi_{ft} = h_t^{\alpha} - w_t h_t - r_{lt} l_t^d$.
- Net transfers to households:

$$q_{ft} = \Pi_{ft} - l_t^d - \pi_t m_{ft}.$$

- FOC: $l_t^d = \frac{\alpha y_t}{1+r_{lt}}$.



h_t
Households
Firms
$w_t h_t$, q_{ft}
d_t
l_t
$r_{dt} d_t$, q_{bt}
$(1+r_{lt})l_t$
Commercial Banks
Central Bank
Government

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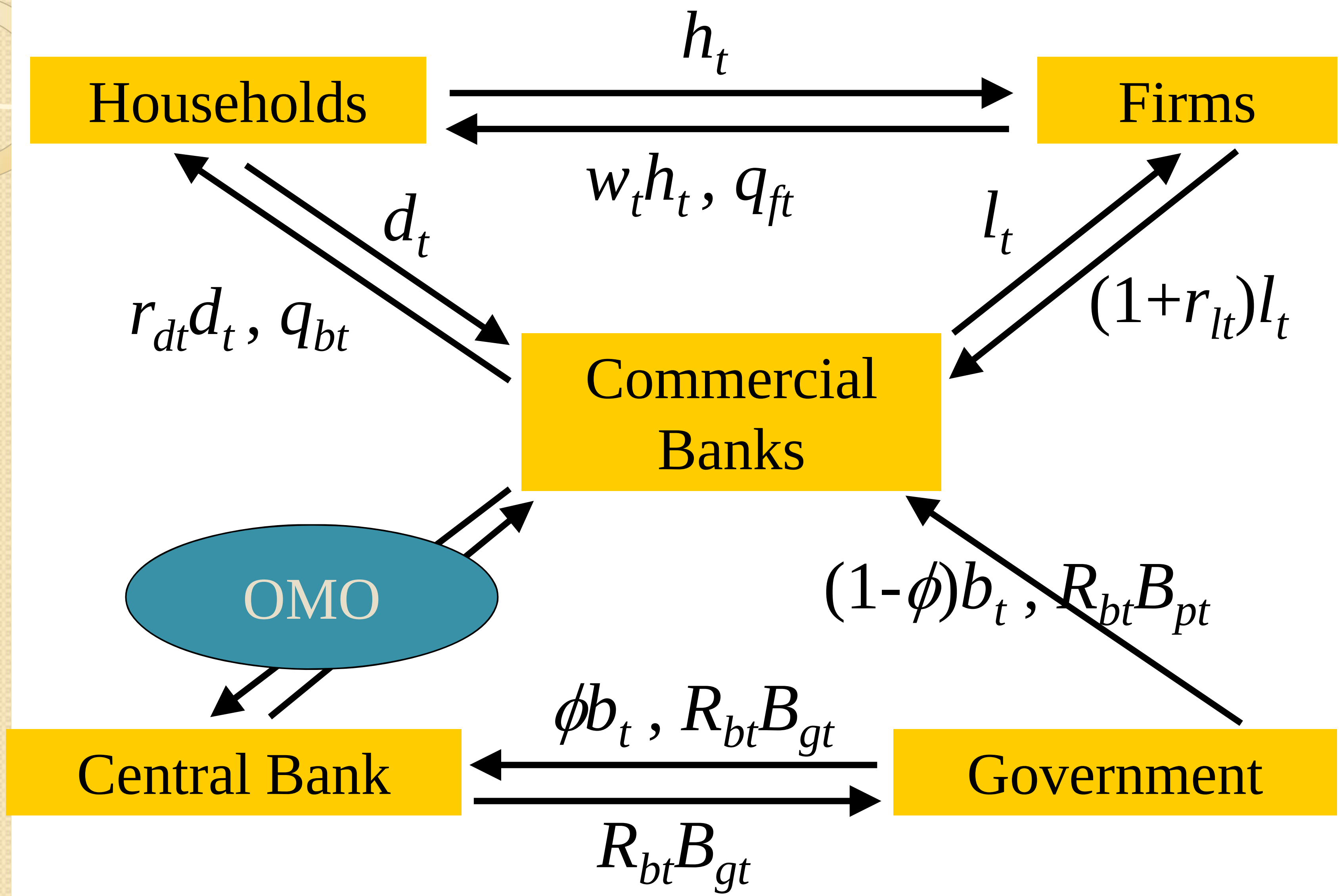
Households

- Life-time utility: $U = \int_0^\infty lnc_t e^{-\rho t} dt$.
- Liquidity constraint: $c_t \leq m_{ht} + \theta d_t$.
- Budget constraint:

$$\dot{m}_{ht} + \dot{d}_t = w_t - c_t + r_{dt} d_t - \pi_t m_{ht} + q_{ft} + q_{bt}$$

- The transactions cost of withdrawing deposits drives a wedge between the rates of deposits of government bonds:

$$R_{dt} = (1 - \theta)\left(\frac{1}{c_t \lambda_t} - 1\right).$$



Households
Firms
Commercial Banks
Central Bank
Government
OMO
h_t
$w_t h_t$, q_{ft}
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$r_{dt} d_t$, q_{bt}
l_t
$(1+r_{lt}) l_t$
$(1-\phi) b_t$, $R_{bt} B_{pt}$
ϕb_t , $R_{bt} B_{gt}$
$R_{bt} B_{gt}$

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Commercial Banks

- Balance sheet:

$$RR_t + ER_t + l_t^s + b_{pt} = d_t,$$

where $RR_t = vd_t$, $v \in (0,1)$,

$$e_t \equiv \frac{ER_t}{d_t} = e(R_{fft}),\ e' < 0.$$

  - Taylor (2001, *WP*), Carpenter and Demiralp (2006, *JMCB*) and Mishkin (2007).

- Profits: $\Pi_{bt} = r_{lt} l_t^s + r_t b_{pt} - r_{dt} d_t$.
- FOC: $r_{lt} = \frac{r_{dt}}{1-v-e_t}$.
- Net transfers to households:

$$q_{bt} = \Pi_{bt} + l_t^s - \pi_t(RR_t + ER_t).$$

Government and Central Bank

- Monetary rule: $R_{fft} = \psi(\pi_t), \psi' > 0.$
- Balance sheet of the central bank:

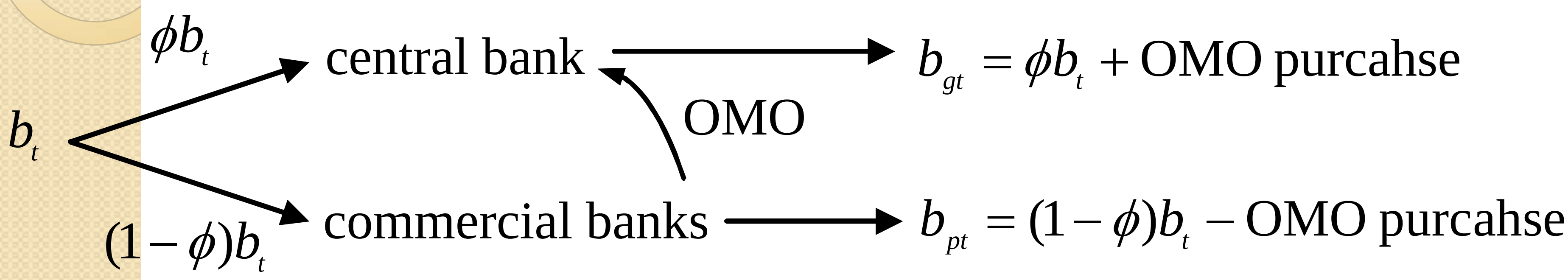
$$b_{gt} = m_t + RR_t + ER_t.$$

- Government's budget constraint:

$$\dot{b}_t = r_t b_{pt} - \pi_t b_{gt},$$

where $\pi_t b_{gt}$ measures the inflation taxes on high-powered money.

Open Market Operation



- The amount of open market purchases and hence the amount of reserves injected into the reserves market is $b_{gt} - \phi b_t$.

- Reserves market equilibrium:

$$RR_t + ER_t = b_{gt} - \phi b_t.$$

- Credit Market Equilibrium:

$$l_t = \frac{\alpha y_t}{1+r_{lt}} = (1 - v - e_t)d_t - b_{pt}.$$

- Resource constraint: $c_t = y_t$.

Dynamical System

$$\dot{b}_t = F(b_t, \lambda_t),$$
$$\dot{\lambda}_t = G(b_t, \lambda_t).$$

Steady state: $\dot{b}_t = \dot{\lambda}_t = 0$

$$b_t = b^*(R_{ff}^*), \lambda_t = \lambda^*(R_{ff}^*),$$

where R_{ff}^* is the solution to the function:

$$\mathrm{f}\left(R_{ff}^*\right) = 0.$$

Local Dynamics

- The system (b_t, λ_t) has 1 (0) initial condition if government bonds are inflation-indexed (non-indexed).

- The interest rate feedback function:

$$R_{fft} = \psi_0 + \psi_1 \pi_t.$$

  - McCallum and Nelson (1999, *JME*) and Kurozumi (2006, *JME*), among others.

- Linear excess reserve ratio function:

$$e_t = e_0 - e_1 R_{fft}.$$

  - Taylor (2001, *WP*).

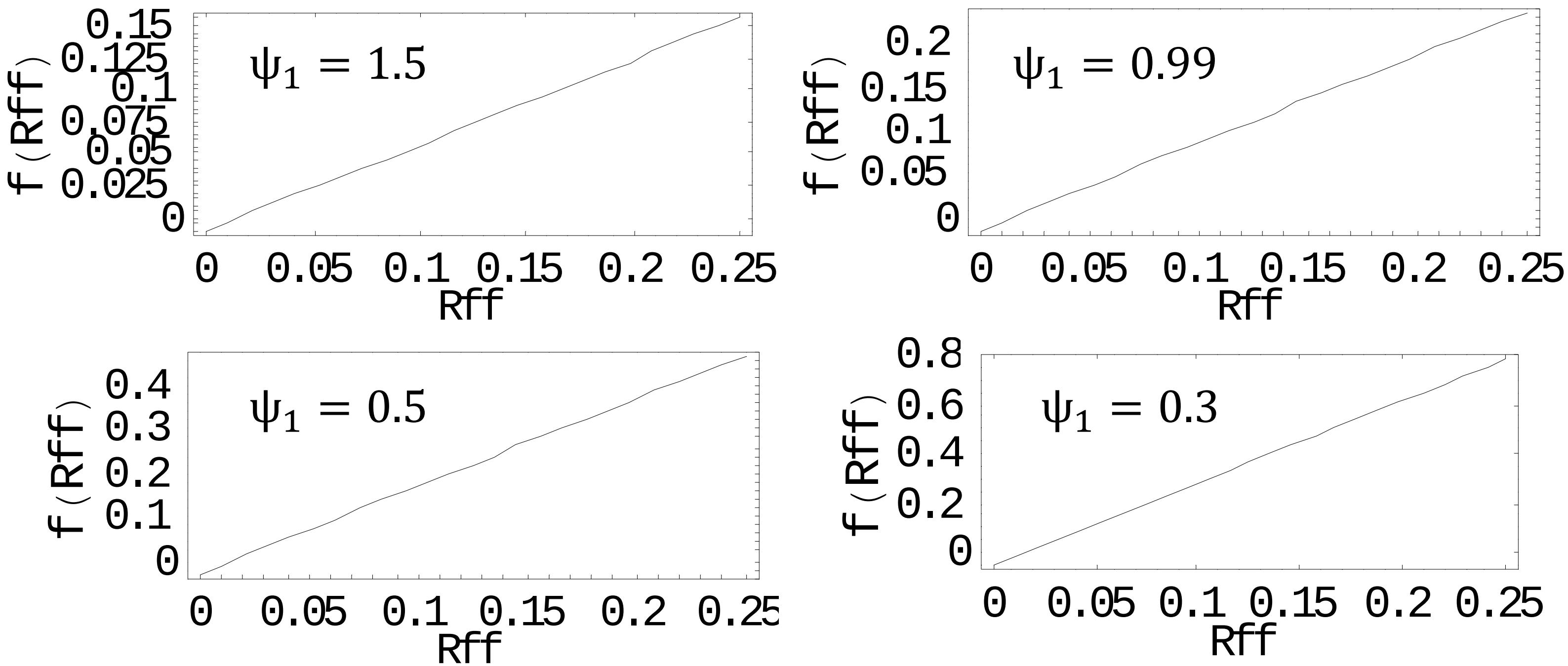
Benchmark parameterization

- Labor share $\alpha = 0.66$.
- Rate of time preference $\rho = 0.0045$.
  - Implying an annual 1.8% discount rate.
- $e_0 = 0.05482$, $e_1 = 0.00178$, $v = 0.01482$.
  - Monthly data of the effective federal funds rate and aggregate reserves and deposits of depository institutions provided by the Board of Governors of the Federal Reserve System, over the period 1980:1-2009:12.

- $\phi = \frac{m_t}{b_t} = 0.084.$
  - Data Download Program of the Board of Governors of the Federal Reserve System.
  - Federal Reserve Economic Data (FRED) provided by the Federal Reserve Bank of St. Louis.
- $\theta = 1 - \frac{R_{dt}}{R_t} = 0.958.$
- $\psi_1 = 1.5$ (0.99) for active (passive) rules, $\psi_0 = 0.015$.

$\Rightarrow$ 6% annual federal funds rate (1980:1-2009:12).

Benchmark Case



- All the steady states are characterized by 1 positive root and 1 negative root.

$\Rightarrow$ Sink for non-indexed bonds and saddle for indexed bonds. (Robust)

Mechanism of Equilibrium (In)determinacy

- Model without the banking system and the reserves market:

$$\frac{\dot{\lambda}_t}{\lambda_t} = \rho - \underbrace{\left(\frac{1}{c_t\lambda_t} - 1\right)}_{R_t} + \pi_t,\ R_t = \psi(\pi_t).$$

- This paper:

$$\frac{\dot{\lambda}_t}{\lambda_t} = \rho - \underbrace{\left(\frac{1}{c_t\lambda_t} - 1\right)}_{R_t} + \pi_t,\ R_{fft} = \psi(\pi_t).$$

Model without the banking system and the reserves market

- $\frac{\dot{\lambda}_t}{\lambda_t} = \rho - \underbrace{(R_t - \pi_t)}_{r_t},\ R_t = \psi(\pi_t).$

Higher expected inflation

$\Rightarrow R_t \uparrow$

$\Rightarrow$ Active rules: $r_t \uparrow \Rightarrow \lambda_t \downarrow \Rightarrow c_t \downarrow \Rightarrow \pi_t \downarrow$

Passive rules: $r_t \downarrow \Rightarrow \lambda_t \uparrow \Rightarrow c_t \uparrow \Rightarrow \pi_t \uparrow$

This paper

- $\frac{\dot{\lambda}_t}{\lambda_t} = \rho - \frac{r_{dt}+\theta\pi_t}{1-\theta}.$

$$r_{dt}\uparrow \Rightarrow \lambda_t\downarrow \Rightarrow c_t\downarrow$$
$$\pi_t\uparrow \Rightarrow \lambda_t\downarrow \Rightarrow c_t\downarrow$$

- How does a higher expected inflation affects r_{dt}?

1. $R_{fft}\uparrow$ by $\psi'\Delta\pi_t\% \Rightarrow R_{lt}\uparrow$ by $\Delta\pi_t\%$

   $\Rightarrow R_{dt}\uparrow$ by $(1-\theta)\Delta\pi_t\%$

   $\Rightarrow r_{dt}\downarrow$ by $\theta\Delta\pi_t\%$

2. Non-indexed bonds:

   $r_t(=R_t-\pi_t)\downarrow \Rightarrow r_{lt}\downarrow \Rightarrow r_{dt}\downarrow$

   [$r_{dt}\downarrow$ by more than $\theta\Delta\pi_t\%$]

   Indexed bonds:

   $\bar{r}_t(=R_t-\pi_t) \Rightarrow \bar{r}_{lt} \Rightarrow \bar{r}_{dt}$

   [$r_{dt}\downarrow$ by $\theta\Delta\pi_t\%$]

- $\frac{\dot{\lambda}_t}{\lambda_t} = \rho - \frac{r_{dt}+\theta\pi_t}{1-\theta}$

Higher expected inflation $\Rightarrow$

1. Non-indexed bonds:

   $r_{dt}\downarrow$ by more than $\theta\Delta\pi_t\%$

   $\therefore\ \lambda_t\uparrow \Rightarrow c_t\uparrow \Rightarrow \pi_t\uparrow$

2. Indexed bonds:

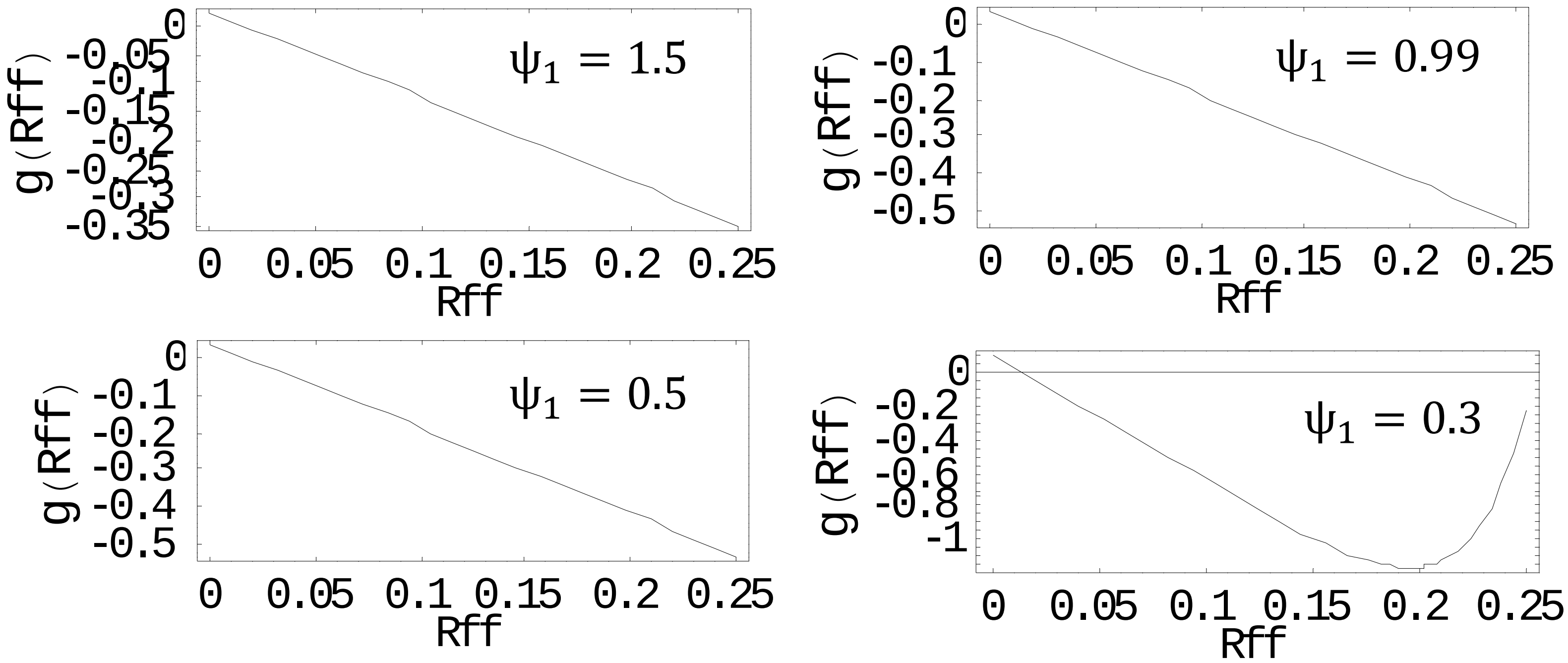
   $r_{dt}\downarrow$ by $\theta\Delta\pi_t\%$

   $\therefore\ \bar{\lambda}_t \Rightarrow \bar{c}_t \Rightarrow \bar{\pi}_t$

Model with Investment

- Households invest in new capital, and rent the capital stock in a competitive market to firms for production purposes.
- Production function: $y_t = h_t^{\alpha} k_t^{\beta}, \alpha, \beta \in (0,1)$.
- Law of motion of capital: $\dot{k}_t = i_t - \delta k_t$.
- Resource constraint: $y_t = c_t + i_t$.
- Dynamical system: (b_t, λ_t, k_t)
  - 2 (1) initial condition if government bonds are inflation-indexed (non-indexed).
  - $\beta = 0.3, \delta = 0.025$.

Benchmark Case



- 2 positive roots and 1 negative root.

$\Rightarrow$ Saddle for non-indexed bonds and source for indexed bonds. (Robust)

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- Consistent with Meng and Yip (2004, *ET*):
  - The role of endogenous physical capital is that it adds into the model an additional initial condition.
- In contrast with M-Y:
  - The interplay between fiscal and monetary policies is crucial for the macroeconomic stabilizing properties of monetary rules.

Robustness Check under a Discrete-Time Modeling

- Carlstrom and Fuerst (2000a, *WP*) vs. Meng and Yip (2004, *ET*)
  - M-Y with inelastic or elastic but separable leisure: determinacy.
  - C-F with separable leisure:
    1. Forward-looking rules: determinacy for passive rules;
    2. Current-looking rules: determinacy is impossible

- Dupor (2001, *JET*) versus Carlstrom and Fuerst (2005, *JET*), Li (2005, *WP*) and Huang and Meng (2007, *JEDC*)
  - D: determinacy for passive rules.
  - C-F:
    1. Forward-looking rules: determinate equilibria are eliminated;
    2. Current-looking rules: passive rules lead to indeterminacy.

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- Dupor (2001, *JET*) versus Carlstrom and Fuerst (2005, *JET*), Li (2005, *WP*) and Huang and Meng (2007, *JEDC*)
  - D: determinacy for passive rules.

    $$r_{kt} - \delta = R_t - \pi_t.$$

  - C-F:

    1. Forward-looking rules: determinate equilibria are eliminated;
    2. Current-looking rules: passive rules lead to indeterminacy.

    $$r_{kt+1} + 1 - \delta = \frac{1+R_t}{p_t},$$

    where $p_t \equiv \frac{P_{t+1}}{P_t} =$ expected gross inflation.

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- Different no-arbitrage conditions for continuous- and discrete-time models.
- The discrete-time model with a forward-looking rule has a zero-eigenvalue, therefore the indeterminacy region is enlarged.
- The inflation rate enters the no-arbitrage condition twice, therefore the inflation coefficient has a decisive role in the stabilizing properties of monetary rules.

This paper (forward-looking rules: $R_{fft} = \psi(p_t)$)

- Continuous-time model:

$$r_{kt} - \delta = r_{dt} + \theta\left(\frac{1}{c_t\lambda_t} - 1\right) = \left(\frac{1}{c_t\lambda_t} - 1\right) - \pi_t \, .$$

- Discrete-time model:

$$r_{kt+1} + 1 - \delta = \frac{1+R_{dt+1}/(1-\theta)}{p_t} = \frac{1}{p_t c_{t+1}\lambda_{t+1}}.$$

  - Same no-arbitrage conditions.
  - No zero-eigenvalue.
  - The inflation rate enters the no-arbitrage condition once.

This paper (current-looking rules: $R_{fft} = \psi(p_{t-1})$

- Discrete-time model:

$$r_{kt+1} + 1 - \delta = \frac{1+R_{dt+1}/(1-\theta)}{p_t} = \frac{1}{p_t c_{t+1} \lambda_{t+1}}.$$

  - A zero-eigenvalue.
  - An additional difference equation of p_t and an eigenvalue which lies within unit circle is introduced into the system through:

$$r_{lt} = \frac{r_{dt}}{1-v-e_t}.$$

  - All the determinate equilibria are eliminated.

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Conclusion

- The macroeconomic stabilizing properties of the nominal interest rate rules change quite substantially when we move from a model without a banking system to one with a banking system and a reserves market.
- The interplay between fiscal and monetary policies, in particular inflation-indexed versus non-indexed bonds, is crucial in determining the macroeconomic stabilizing properties of monetary rules.
- Active rules and passive rules perform equally in regard to their macroeconomic stabilizing properties.

- Continuous- and discrete-time specifications deliver the same/different (in)determinacy results for both the labor-only model and the endogenous-capital model under forward-looking/current-looking rules.
- The inclusion of physical investment narrows the indeterminacy region under forward-looking rules.
- Current-looking rules make equilibrium determinacy impossible for both the labor-only economy and the endogenous-capital economy.

Future Researches

- Allow firms or commercial banks to issue debt or equity instruments to raise external funds.
- New Keynesian features of imperfect markets and nominal rigidities.
- “The financial accelerator” proposed by Ben Bernanke.