MONEY IN THE INFINITE-PERIOD ECONOMY

FEBRUARY 15, 2010

BASICS

- Extend our infinite-period model
  - Introduce money and bonds into the Chapter 8 model
  - So now three types of assets (stocks, bonds, money) for representative consumer to use for savings purposes
- Will allow us to think further about what the "pricing kernel" is
- Will allow us to think about connection between bond prices and stock prices
- Will allow us to think about issue of monetary neutrality (the main issue in the RBC vs. New Keynesian debate)
  - i.e., does money (and thus monetary policy) have important consequences for ***real*** (i.e., consumption and real GDP) variables?

IS MONETARY POLICY NEUTRAL?

- An enduring question in macroeconomics: does monetary policy have any important effects on the ***real*** (i.e, ***real*** GDP, consumption, etc) economy?
- Definition: Money (and hence monetary policy) is neutral if changes in the money supply (i.e., changes in monetary policy) have no effect on the real economy
  - Monetary policy is non-neutral if it does have effects on the real economy
- New Keynesian view: money is non-neutral (because prices are rigid / sticky, often for long periods of time)
- RBC view: money is neutral (because prices are not rigid / sticky in any important way)
- To seriously consider the issue, need to finally explicitly think about money and monetary policy
  - It's only been in the background of our analyses thus far…

THE ROLES OF MONEY

- The roles played by money
  - Medium of exchange
    - Eases double-coincidence of wants problem
  - Unit of account
    - A common "language" for all prices to be quoted in
  - Store of value
    - Bananas will perish in short amount of time, dollar bills won't
- How to conceptually "model" money a surprisingly hard problem
  - Much more difficult than, i.e., "consumption-leisure model" or "consumption-savings model"
  - How to formally (mathematically) represent these roles of money?
- A shortcut: suppose money directly yields utility
  - Period-*t* utility function

$$u\left(c_t, \frac{M_t}{P_t}\right)$$

  - Money-in-the-utility-function (MIU) formulation
  - IMPORTANT: It's not M_t in the utility function, but rather M_t / P_t

Real Money Balances

- **M_t / P_t a key variable for macroeconomic analysis**
- **Unit Analysis (i.e., analyze algebraic units of variables)**
  - **Units(M_t) = $**
  - **Units(P_t) = $ / unit of consumption**
  - **Units(M_t / P_t) =** $\frac{\$}{\frac{\$}{\text{unit of consumption}}} = \$ \cdot \frac{\text{unit of consumption}}{\$}$

    $= \text{unit of consumption}$
- **Utility (composite of medium of exchange, unit of account, store of value) depends on *real* money (*M / P*), not nominal money (*M*)**
  - **Measures the purchasing power of (nominal) money holdings…**
  - **…which is presumably what people most care about**
- **M_t and P_t can potentially grow at different rates in the short run**
  - **In which case real money balances change**

Basics

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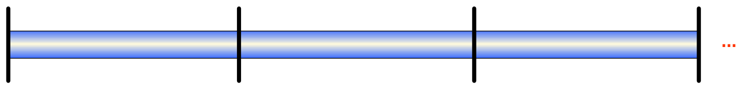
- **Will allow us to think about connection between bond prices and stock prices**
- **Will allow us to think about issue of monetary neutrality (the main issue in the RBC vs. New Keynesian debate)**
  - **i.e., does money (and thus monetary policy) have important consequences for *real* (i.e., consumption and real GDP) variables?**
- **Index time periods by arbitrary indexes t, t+1, t+2, etc.**
  - **Important: all of our analysis will be conducted from the perspective of the very beginning of period t…**
- **Sequential Lagrangian analysis (with money in the utility function)**

Basics

- **Timeline of events**



- **Notation**
  - c_t: consumption in period t
  - P_t: nominal price of consumption in period t
  - Y_t: nominal income in period t ("falls from the sky")
  - a_{t-1}: real stock holdings at beginning of period t / end of period t-1

Basics

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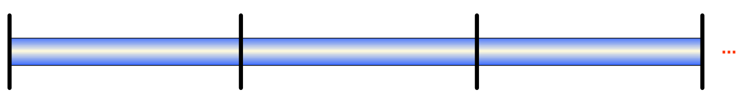

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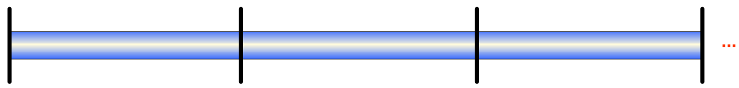
  - M_{t-1}: nominal money holdings at beginning of period t / end of period t-1
  - B_{t-1}: nominal bond holdings at beginning of period t / end of period t-1
  - S_t: nominal price of a unit of stock in period t
  - D_t: nominal dividend paid in period t by each unit of stock held at the start of t
  - P^b_t: nominal price of a bond in period t
  - i_t: nominal interest rate on a bond purchased in t and which pays off in t+1
  - π_{t+1}: net inflation rate between period t and period t+1
  - y_t: real income in period t (= Y_t / P_t)

Now *three* types of assets consumers can use for savings purposes (a_{t-1}, M_{t-1}, B_{t-1})

Basics

- Timeline of events



- Notation
  - c_{t+1}: consumption in period $t+1$
  - P_{t+1}: nominal price of consumption in period $t+1$
  - Y_{t+1}: nominal income in period $t+1$ ("falls from the sky")
  - a_t: real stock holdings at beginning of period $t+1$ / end of period t
  - M_t: nominal money holdings at beginning of period $t+1$ / end of period t
  - B_t: nominal bond holdings at beginning of period $t+1$ / end of period t
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  - i_{t+1}: nominal interest rate on a bond purchased in $t+1$ and which pays off in $t+2$
  - π_{t+2}: net inflation rate between period $t+1$ and period $t+2$
  - y_{t+1}: real income in period t (= Y_{t+1} / P_{t+1})

Now *three* types of assets consumers can use for savings purposes

a_{t-1}
B_{t-1}
M_{t-1}

Economic events during period t: income, consumption, savings

a_t
B_t
M_t

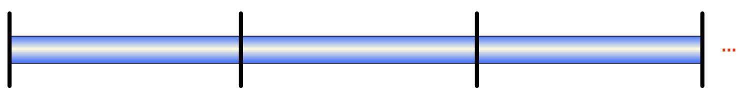
Economic
period
consump

Period t

Peri

Basics

- Timeline of events



- Notation
  - And so on for period $t+2$, $t+3$, etc…

BUDGET CONSTRAINT(S)

- **Extend budget constraints from Chapter 8 stock-pricing model to now include the three distinct types of assets: stocks, money, and bonds**
- **Need infinite budget constraints to describe economic opportunities and possibilities**
  - **One for each period**
  - **In period *t***

$$\underbrace{P_t c_t + P_t^b B_t + M_t + S_t a_t}_{} = \underbrace{Y_t + M_{t-1} + B_{t-1} + S_t a_{t-1} + D_t a_{t-1}}_{}$$

Total outlays in period *t*: period-*t* consumption + stocks to *carry into period t*+1 + money to *carry into period t*+1 + bond purchases

Total income in period *t*: period-*t* Y + income from stock-holdings *carried into period t* (has value S_t and pays dividend D_t) + money-holdings *carried into period t* + bond-holdings *carried into period t* (each unit repays *FV* = 1)

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  - **In period *t*+1**

$$\underbrace{P_{t+1} c_{t+1} + P_{t+1}^b B_{t+1} + M_{t+1} + S_{t+1} a_{t+1}}_{} = \underbrace{Y_{t+1} + M_t + B_t + S_{t+1} a_t + D_{t+1} a_t}_{}$$

Total outlays in period *t*+1: period-*t*+1 consumption + stocks to *carry into period t*+2 + money to *carry into period t*+2 + bond purchases

Total income in period *t*+1: period-*t*+1 Y + income from stock-holdings *carried into period t*+1 (has value S_{t+1} and pays dividend D_{t+1}) + money-holdings *carried into period t*+1 + bond-holdings *carried into period t*+1 (each unit repays *FV* = 1)

  - **And identical-looking budget constraints in period *t*+2, *t*+3, *t*+4, etc.**

LAGRANGE ANALYSIS: SEQUENTIAL APPROACH

- **Step 1: Construct Lagrange function (starting from *t*)**

$$u(c_t, M_t/P_t) + \beta u(c_{t+1}, M_{t+1}/P_{t+1}) + \beta^2 u(c_{t+2}, M_{t+2}/P_{t+2}) + \ldots$$

First the lifetime utility function….(no different than Chapter 8)

$$+\lambda_t\left[Y_t + (S_t + D_t)a_{t-1} + M_{t-1} + B_{t-1} - P_t c_t - S_t a_t - M_t - P_t^b B_t\right]$$

…then the period *t* constraint…

$$+\beta\lambda_{t+1}\left[Y_{t+1} + (S_{t+1} + D_{t+1})a_t + M_t + B_t - P_{t+1}c_{t+1} - S_{t+1}a_{t+1} - M_{t+1} - P_{t+1}^b B_{t+1}\right]$$

…then the period *t*+1 constraint…

$$+\beta^2\lambda_{t+2}\left[Y_{t+2} + (S_{t+2} + D_{t+2})a_{t+1} + M_{t+1} + B_{t+1} - P_{t+2}c_{t+2} - S_{t+2}a_{t+2} - M_{t+2} - P_{t+2}^b B_{t+2}\right]$$

…then the period *t*+2 constraint…

$$+\beta^3\lambda_{t+3}\left[Y_{t+3} + (S_{t+3} + D_{t+3})a_{t+2} + M_{t+2} + B_{t+2} - P_{t+3}c_{t+3} - S_{t+3}a_{t+3} - M_{t+3} - P_{t+3}^b B_{t+3}\right]$$

…then the period *t*+3 constraint…

$$+\ldots$$

Infinite number of terms

Infinite-Period Model: Sequential Formulation

LAGRANGE ANALYSIS: SEQUENTIAL APPROACH

- **Step 1: Construct Lagrange function (starting from *t*)**

$$u(c_t, M_t/P_t) + \beta u(c_{t+1}, M_{t+1}/P_{t+1}) + \beta^2 u(c_{t+2}, M_{t+2}/P_{t+2}) + \ldots$$

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$$+\lambda_t\left[Y_t + (S_t + D_t)a_{t-1} + M_{t-1} + B_{t-1} - P_t c_t - S_t a_t - M_t - P_t^b B_t\right]$$

…then the period *t* constraint…

$$+\beta\lambda_{t+1}\left[Y_{t+1} + (S_{t+1} + D_{t+1})a_t + M_t + B_t - P_{t+1}c_{t+1} - S_{t+1}a_{t+1} - M_{t+1} - P_{t+1}^b B_{t+1}\right]$$

…then the period *t*+1 constraint…

$$+\beta^2\lambda_{t+2}\left[Y_{t+2} + (S_{t+2} + D_{t+2})a_{t+1} + M_{t+1} + B_{t+1} - P_{t+2}c_{t+2} - S_{t+2}a_{t+2} - M_{t+2} - P_{t+2}^b B_{t+2}\right]$$

…then the period *t*+2 constraint…

$$+\beta^3\lambda_{t+3}\left[Y_{t+3} + (S_{t+3} + D_{t+3})a_{t+2} + M_{t+2} + B_{t+2} - P_{t+3}c_{t+3} - S_{t+3}a_{t+3} - M_{t+3} - P_{t+3}^b B_{t+3}\right]$$

…then the period *t*+3 constraint…

$$+\ldots$$

Infinite number of terms

- **Step 2: Compute FOCs with respect to c_t, a_t, B_t, M_t, …**

with respect to c_t: $u_1(c_t, M_t/P_t) - \lambda_t P_t = 0$ — Equation 1

with respect to a_t: $-\lambda_t S_t + \beta\lambda_{t+1}(S_{t+1} + D_{t+1}) = 0$ — Equation 2

with respect to B_t: $-\lambda_t P_t^b + \beta\lambda_{t+1} = 0$ — Equation 3

with respect to M_t: $\dfrac{u_2(c_t, M_t/P_t)}{P_t} - \lambda_t + \beta\lambda_{t+1} = 0$ — Equation 4 (need chain rule of calculus to derive this)

ASSET PRICING REVISITED

$$u_1(c_t, M_t / P_t) - \lambda_t P_t = 0$$ Equation 1

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$$\frac{u_2(c_t, M_t / P_t)}{P_t} - \lambda_t + \beta\lambda_{t+1} = 0$$ Equation 4

- **Equation 2 →** $S_t = \left(\frac{\beta\lambda_{t+1}}{\lambda_t}\right)(S_{t+1} + D_{t+1})$ STOCK-PRICING EQUATION

  Period-*t* stock price = Pricing kernel x Future return

- **Much of finance theory concerned with pricing kernel**
  - **Theoretical properties**
  - **Empirical models of kernels**
- **Pricing kernel where macro theory and finance theory intersect**

ASSET PRICING REVISITED

$$u_1(c_t, M_t / P_t) - \lambda_t P_t = 0$$ Equation 1

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  Period-*t* stock price = Pricing kernel x Future return

- **Equation 3 →** $P_t^b = \frac{\beta\lambda_{t+1}}{\lambda_t}$ BOND-PRICING EQUATION
- **Price of a bond *<u>is</u>* the pricing kernel**
  - **Stock prices and bond prices are connected**
  - **Most (all?) asset prices fundamentally connected to bond prices**
  - **(Advanced finance course: pricing kernel reflects the price / return of the least risky asset in the economy – U.S. Treasury bonds)**

Asset Pricing Revisited

$$u_1(c_t, M_t/P_t) - \lambda_t P_t = 0 \quad \text{Equation 1}$$
$$-\lambda_t S_t + \beta\lambda_{t+1}(S_{t+1} + D_{t+1}) = 0 \quad \text{Equation 2}$$
$$-\lambda_t P_t^b + \beta\lambda_{t+1} = 0 \quad \text{Equation 3}$$
$$\frac{u_2(c_t, M_t/P_t)}{P_t} - \lambda_t + \beta\lambda_{t+1} = 0 \quad \text{Equation 4}$$

- **Equation 2 →** $S_t = \left(\frac{\beta\lambda_{t+1}}{\lambda_t}\right)(S_{t+1} + D_{t+1})$ STOCK-PRICING EQUATION

  Period-*t* stock price = Pricing kernel x Future return

- **Equation 3 →** $P_t^b = \frac{\beta\lambda_{t+1}}{\lambda_t}$ BOND-PRICING EQUATION
- **Recall** $P_t^b = \frac{1}{1+i_t}$
- **→ can express pricing kernel as** $\frac{\beta\lambda_{t+1}}{\lambda_t} = \frac{1}{1+i_t}$

Fisher Equation

$$u_1(c_t, M_t/P_t) - \lambda_t P_t = 0 \quad \text{Equation 1}$$
$$-\lambda_t S_t + \beta\lambda_{t+1}(S_{t+1} + D_{t+1}) = 0 \quad \text{Equation 2}$$
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$$\frac{u_2(c_t, M_t/P_t)}{P_t} - \lambda_t + \beta\lambda_{t+1} = 0 \quad \text{Equation 4}$$

- **Combining stock-pricing equation with bond-pricing equation →**

  $$1 + r_t = \frac{1+i_t}{1+\pi_{t+1}} \quad \text{FISHER EQUATION}$$

  - **Fisher equation a relationship between returns on nominal bonds and returns on stock (finance theory: "no-arbitrage" condition)**
  - **(See derivation in Chapter 14)**
- **Was a building block of two-period model**
- **Recall approximate form: *r ≈ i - π***

Consumption-Money Optimality Condition

Begin with equation 4:

$$\frac{u_2(c_t, M_t/P_t)}{P_t} - \lambda_t = -\beta\lambda_{t+1}$$

Use $\beta\lambda_{t+1} = \lambda_t P^b_t$ from equation 2

$$\frac{u_2(c_t, M_t/P_t)}{P_t} - \lambda_t = -\lambda_t P^b_t$$

Divide through by λ_t

$$\frac{u_2(c_t, M_t/P_t)}{\lambda_t P_t} - 1 = -P^b_t$$

Use $\lambda_t P_t = u_{1t}$ from equation 1

$$\frac{u_2(c_t, M_t/P_t)}{u_1(c_t, M_t/P_t)} = 1 - P^b_t$$

Use $P^b_t = 1/(1+i_t)$

CONSUMPTION-MONEY OPTIMALITY CONDITION

$$\underbrace{\frac{u_2(c_t, M_t/P_t)}{u_1(c_t, M_t/P_t)}}_{\text{MRS}} = \underbrace{\frac{i_t}{1+i_t}}_{\text{price ratio}}$$

MRS (between consumption and *real* money holdings)

price ratio (between consumption and money)

Money Demand

- Consumption-money optimality condition the foundation of money demand function
- Example: suppose $u\left(c_t, \frac{M_t}{P_t}\right) = \ln c_t + \ln\left(\frac{M_t}{P_t}\right)$
- Thus, $u_1\left(c_t, \frac{M_t}{P_t}\right) = \frac{1}{c_t}$ and $u_2\left(c_t, \frac{M_t}{P_t}\right) = \frac{1}{M_t/P_t}$ (no chain rule this time…)
- Consumption-money optimality condition (for this utility function…) is

$$\frac{P_t c_t}{M_t} = \frac{i_t}{1-i_t}$$

Isolate the M_t/P_t term

$$\frac{M_t}{P_t} = c_t \cdot \left(\frac{1+i_t}{i_t}\right)$$

REAL MONEY DEMAND FUNCTION: depends positively on c_t and negatively on i_t (i_t is the opportunity cost of money)

- **Will use this money demand function to analyze**
  - **The monetary neutrality debate**
  - **The long-run (aka steady-state) connection between monetary policy and inflation**

MONEY IN THE INFINITE-PERIOD ECONOMY: THE NEUTRALITY DEBATE AND THE STEADY STATE

FEBRUARY 15, 2010

IS MONETARY POLICY NEUTRAL?

- An enduring question in macroeconomics: does monetary policy have any important effects on the ***real*** (i.e, ***real*** GDP, consumption, etc) economy?
- Definition: Money (and hence monetary policy) is neutral if changes in the money supply (i.e., changes in monetary policy) have no effect on the real economy
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- New Keynesian view: money is non-neutral (because prices are rigid/sticky, often for long periods of time)
- RBC view: money is neutral (because prices are not rigid/sticky in any important way)
- MIU model allows us to consider how/why money is or is not neutral

Money Demand

CONSUMPTION-MONEY OPTIMALITY CONDITION

$$\underbrace{\frac{u_2(c_t, M_t/P_t)}{u_1(c_t, M_t/P_t)}}_{\text{MRS (between consumption and } \underline{\textit{real}} \text{ money holdings)}} = \underbrace{\frac{i_t}{1-i_t}}_{\text{price ratio (between consumption and money)}}$$

NOTE: consumption-money optimality condition and money demand function are the ***same thing***, just viewed from different points of view

Using utility function $u\left(c_t, \frac{M_t}{P_t}\right) = \ln c_t + \ln\left(\frac{M_t}{P_t}\right)$,

generate money demand function

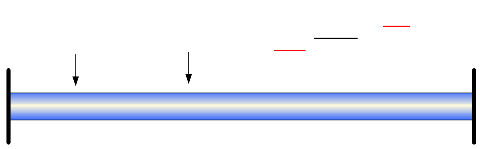
REAL MONEY DEMAND FUNCTION: depends positively on c_t and negatively on i_t (i_t is the opportunity cost of money)

$$\frac{M_t}{P_t} = c_t \cdot \left(\frac{1+i_t}{i_t}\right)$$

- Use money demand function to illustrate effects of **money shocks**
- Gets at core of neutrality debate
- Let's be even more precise about the timing of events…

Monetary Neutrality Debate

- Precise timing of events **within period t**



- Fed sets **"actual M_t"** after consumers makes their choices of c_t and **"planned M_t"** (and other choices, too…)
  - If actual M_t differs from planned M_t, **money shock** has occurred
- **Question: which adjusts (P_t or c_t) to ensure consumption-money optimality condition holds?** (simplify by assuming i_t doesn't adjust)

$$\frac{M_t}{P_t} = c_t \cdot \left(\frac{1+i_t}{i_t}\right)$$

Monetary Neutrality Debate

- Question: which adjusts (P_t or c_t) to ensure consumption-money optimality condition holds? (simplify by assuming i_t doesn't adjust)

$$\frac{M_t}{P_t} = c_t \cdot \left(\frac{1+i_t}{i_t}\right)$$

- Keynesian / New Keynesian view
  - P_t cannot adjust because prices are sticky
    - (Prices will adjust ***later*** (i.e, in period t+1 or later), just not in period t)
  - A positive (negative) money shock leads to a rise (fall) in c_t
  - Money (and hence monetary policy) is not neutral
- RBC view
  - P_t can adjust because prices are not sticky
  - No reason for c_t to adjust (they do reflect optimal choices, after all…)
  - A positive (negative) money shock leads to no change (no change) in c_t
  - Money (and hence monetary policy) is neutral
- Empirical evidence for "how sticky" are prices is very mixed…

Monetary Neutrality Debate: Example

- Assume i_t = 0.1 is fixed
- Consumers' "planned" choices are c_t = 2 and M_t = 180
- This plan was made with P_t = 10 in mind
- Fed sets actual M_t = 270 (a positive money shock because actual M_t greater than planned M_t)
- Keynesian / New Keynesian view
  - P_t = 10 won't change (sticky prices)
  - c_t will rise (to c_t = 3) to make consumption-money optimality condition hold
  - Monetary policy is non-neutral

$$\frac{M_t}{P_t} = c_t \cdot \left(\frac{1+i_t}{i_t}\right)$$

- RBC view
  - Consumers' plan of c_t = 2 is what the economy really wants
  - P_t can fully and quickly adjust to accommodate this → P_t = 15
  - Monetary policy is neutral; only effect of monetary policy is on inflation

MONEY AND INFLATION IN THE LONG-RUN

- **Question: what determines inflation in the long run (i.e., in steady-state)?**
  - **Use both period-(t-1) and period-t money demand functions to analyze**

Money demand function in t-1

$$\frac{M_{t-1}}{P_{t-1}} = c_{t-1}\cdot\left(\frac{1+i_{t-1}}{i_{t-1}}\right)$$

Money demand function in t

$$\frac{M_t}{P_t} = c_t\cdot\left(\frac{1+i_t}{i_t}\right)$$

Divide period t money demand by period t-1 money demand

$$\frac{M_t/P_t}{M_{t-1}/P_{t-1}} = \frac{c_t}{c_{t-1}}\cdot\left(\frac{1+i_t}{i_t}\right)\left(\frac{i_{t-1}}{1+i_{t-1}}\right)$$

Monetary Policy Analysis: Long-Run Effects

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$$\frac{M_{t-1}}{P_{t-1}} = c_{t-1}\cdot\left(\frac{1+i_{t-1}}{i_{t-1}}\right)$$

Money demand function in t

$$\frac{M_t}{P_t} = c_t\cdot\left(\frac{1+i_t}{i_t}\right)$$

Divide period t money demand by period t-1 money demand

$$\frac{M_t/P_t}{M_{t-1}/P_{t-1}} = \frac{c_t}{c_{t-1}}\cdot\left(\frac{1+i_t}{i_t}\right)\left(\frac{i_{t-1}}{1+i_{t-1}}\right)$$

Recall definition of inflation $\pi_t = \frac{P_t}{P_{t-1}} - 1$

And now define the ***money growth rate*** in an analogous way: $\mu_t = \frac{M_t}{M_{t-1}} - 1$

$$\frac{1+\mu_t}{1+\pi_t} = \frac{c_t}{c_{t-1}}\cdot\left(\frac{1+i_t}{i_t}\right)\left(\frac{i_{t-1}}{1+i_{t-1}}\right)$$

Impose steady state — i.e., $c_{t-1} = c_t = c$, $i_{t-1} = i_t = i$, $\pi_t = \pi$, and $\mu_t = \mu$

$$\frac{1+\mu}{1+\pi} = \frac{c}{c}\cdot\left(\frac{1+i}{i}\right)\left(\frac{i}{1+i}\right)$$

$$\boxed{\mu = \pi}$$

IN LONG RUN, RATE OF MONEY GROWTH = RATE OF INFLATION

MONETARISM

$\mu = \pi$ IN LONG RUN, RATE OF MONEY GROWTH = RATE OF INFLATION

- In steady state, inflation determined solely by how quickly central bank (Fed) expands (or shrinks) the nominal money supply
- This relationship the basis for the monetarist school of thought
  - Milton Friedman's famous dictum: "Inflation is always and everywhere a monetary phenomenon"
    - Policy translation: "A central bank should not worry about/try to control anything other than how quickly the money supply in the economy is growing. Keeping money growth under control will keep inflation under control."
  - Rose to prominence in mid- and late 1970's (during macro crises)
  - Largest policy influence in U.K., short-lived policy influence in U.S.
  - Largely died out as basis for serious policy advice by mid-1980's
- Nevertheless still viewed as fundamental "law" of macroeconomics
  - A concern today: Fed's "easy monetary policy" (read: Fed has increased money supply very rapidly) will spawn a burst of inflation

MONETARY POLICY

- In short-run, do changes in monetary policy have effects on consumption and real GDP?
  - Keynesian/New Keynesian view: yes because prices are sticky
  - RBC view: no because prices are not sticky
- In long-run, changes in money growth rate
  - Only have effects on inflation
  - Have no effects on consumption and real GDP
- Competing principles/theories influence policy-makers' decisions
- Basic models are guideposts for policy debates
- Actual policy-making quite messy
  - Requires lot of judgment
  - Requires hope/belief that basic models are at least *somewhat* useful guides to thinking
- Whether or not prices are sticky matters for policy advice