
# Lecture 12: Transmission Mechanisms of Monetary Policy and OLG Model with Money

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# Outline

- The transmission mechanisms of monetary policy
  - traditional interest-rate channels
  - other asset prices channels
  - credit channels
- An OLG model with money
  - Environment
  - monetary equilibrium
  - golden rule consumption plan

Required reading For monetary transmission mechanisms, see Mishkin (1996); For the OLG model with money, see Chap.1 of Champ, Freeman and Haslag (2011).

# The Transmission Mechanism of Monetary Policy (1 of 6)

- We have seen from last lecture how central banks conduct monetary policy. Now the question is how monetary policy is transmitted to affect real economic activities to achieve certain macroeconomic goals. In other words, what are the transmission mechanisms of monetary policy?
- Identifying the transmission mechanisms of monetary policy has been an important research issue. Economists have identified several channels through which monetary policy affects aggregate demand and hence real output.
  - Traditional interest-rate channels
  - Other asset prices channels
  - Credit channels
  - These channels complement to each other, all contributing to the transmission of monetary policy.

# The Transmission Mechanism of Monetary Policy (2 of 6)

- Traditional interest-rate channels
  - This is the monetary transmission mechanism in the Keynesian IS-LM and AD-AS models.
  - The Mechanism can be characterized by the following schematic

$$M \uparrow \Longrightarrow i \downarrow \Longrightarrow r \downarrow \Longrightarrow I \uparrow \Longrightarrow Y \uparrow,$$

    where $M \uparrow$ indicates an expansionary monetary policy. It leads to a fall in nominal interest rate ($i \downarrow$) and real interest rate ($r \downarrow$), which in turn lowers the cost of capital, causing a rise in investment spending ($I \uparrow$), thereby leading to an increase in aggregate demand and a rise in real output ($Y \uparrow$).
  - How changes in the short-term nominal interest rate induced by the central bank result in a corresponding change in the real interest rate on short- and long-term bonds ($i \downarrow \Longrightarrow r \downarrow$)?

# The Transmission Mechanism of Monetary Policy (3 of 6)

- The real interest rate equals the nominal interest rate minus the rate of inflation $r = i - \pi$
- When the central bank lowers short term nominal interest rate ($i$), due to the phenomenon known as sticky prices, aggregate price level ($\pi$) adjusts slowly over time, such that short-term real interest rate ($r$) is lower.
- The expectation hypothesis of the term structure, which states that the long-term interest rate is an average of expected future short-term interest rates, suggests that the lower real short-term interest rate leads to a fall in the real long-term interest rate.
- The lower real interest rates lead to rises in business fixed investment, residential housing investment, inventory investment, and consumer durable expenditure. All of which produce the rise in aggregate output.

## Other asset prices channel

- Exchange rate effects on net exports:

$$M \uparrow \Longrightarrow r \downarrow \Longrightarrow E \downarrow \Longrightarrow NX \uparrow Y \uparrow,$$

  where $E \downarrow$ means the currency depreciates. Why $r \downarrow \Longrightarrow E \downarrow$? When domestic real interest rates fall, domestic assets become less attractive to foreign assets such that demand for domestic currency falls.

- Tobin's $q$ theory:

$$M \uparrow \Longrightarrow P_e \uparrow \Longrightarrow q \uparrow \Longrightarrow I \uparrow Y \uparrow,$$

  where $P_e$ denotes the price of equity, $q$ is defined as the market value of firms divided by the replacement cost of capital.

- Wealth effects: $M \uparrow \Longrightarrow P_e \uparrow \Longrightarrow$ wealth $\uparrow \Longrightarrow C \uparrow \Longrightarrow Y \uparrow$, where $C$ denotes spending by consumer on nondurable goods and services.

# The Transmission Mechanism of Monetary Policy (5 of 6)

- Credit channels
  - Bank lending channels:
    $M \uparrow \Longrightarrow$ bank deposits $\uparrow \Longrightarrow$ bank loans $\uparrow \Longrightarrow$ $I \uparrow \Longrightarrow$ $Y \uparrow$
    - An important implication: monetary policy will have a greater effect on expenditure by smaller firms, which are more dependent on bank loans.
  - Balance sheet channels: $M \uparrow \Longrightarrow$ $P_e \uparrow \Longrightarrow$ net worth $\uparrow \Longrightarrow$ lending $\uparrow \Longrightarrow$ $I \uparrow \Longrightarrow$ $Y \uparrow$
    - Why net worth $\uparrow \Longrightarrow$ lending $\uparrow$ ? The net worth businesses is used for collateral for their loans.
  - Household liquidity effects:
    $M \uparrow \Longrightarrow$ $P_e \uparrow \Longrightarrow$ financial assets $\uparrow \Longrightarrow$ financial distress $\downarrow$ $\Longrightarrow$ consumer durable and housing expenditure $\uparrow \Longrightarrow$ $Y \uparrow$

# The Transmission Mechanism of Monetary Policy (6 of 6)

- Remarks:
  - All these channels work together to transmit monetary policy. Depends on the state of the economy when the policy is introduced, certain channels may dominate others.
  - In past two decades there has been a resurgence of interest in developing quantitative, monetary general equilibrium models of the business cycle, in response to the importance of monetary policy in stabilizing the economy and the ongoing debates on monetary policy issues.
  - A theme of this research agenda is to explicitly model and quantitatively evaluate the transmission mechanism of monetary policy shock under certain economic conditions so as to provide guidance for the conduct of monetary policy.
  - An influential work is "The financial accelerator in a quantitative business cycle framework" by Bernanke and Gertler (1999).

# An OLG Model with Money

Introduction:

- A prominent feature of the business cycle in the U.S. and many other countries is the striking coherence between movements in monetary aggregates and output.
- Historically, this has led many economists to conclude that money causes output, while others argue that the correlation of output with money reflects reverse causation.
- Question: What are the real effects of money? Further, since inflation is closely correlated with money growth, we ask what are the real effects of a growing money supply or inflation.
- In the next few lectures we will examine these questions in a simple OLG model with money, which is taken from Champ, Freeman and Haslag (2011) Chap. 1 and 3.
- At the end, we will give a discussion of the optimal inflation rate to give some justifications for the inflation targeting practice among central banks.

# The Environment (1 of 2)

- Time is discrete, and the time horizon is infinite, $t = 1, 2, \ldots$
- Population: The economy is populated with 2-period lived overlapping generations. In period $t$, $L_t$ individuals are born. Population grows at rate $n$, i.e. $\frac{L_{t+1}}{L_t} = 1 + n$ . The individuals born in periods 1, 2, 3,. . . are called the future generations. In addition, in period 1, there are $L_0$ members of the initial old.
- There is only one good in this economy. **Assume that the good cannot be stored from one period to the next**.

Individuals:

- Endowment: Each individual receives an endowment of $y$ units of good when young, and receives no endowment when old.

# The Environment (2 of 2)

- Preference:
  - The **initial old** live and consume only in the initial period and thus simply wish to maximize their consumption in that period $c_{2,1}$.
  - Members of the **future generations** consume both when young and when old. An individual member's lifetime utility is given by

$$U(c_{1t}, c_{2t+1}) = u(c_{1t}) + \beta u(c_{2t+1})$$

    where $u$ satisfies the ordinary conditions.
- How can people get consumption in the second period of life?
  Introduce a fixed stock $M$ of perfectly divisible units of fiat money.
  Each of the initial old begins with an equal amount, $M/L_0$.
  - Fiat money can be costlessly stored (held) from one period to the next and is costless to exchange.
  - Individuals derive no credit utility from holding or consuming money, fiat money will prove valuable only if it enables individuals to trade for something they wish for consume.

# The Equilibrium (1 of 7)

- We first consider the case without money.
  - Are there trades among individuals that could get them to consume in the second period of life?
  - The resulting equilibrium is called autarky; individuals have no economic interaction with others. Each individual consumes his entire endowment when young and nothing when old.
- Now we focus on the equilibrium with money, or what we call a monetary equilibrium.
  - The presence of fiat money opens up a trading possibility:
  - A young person can sell some of his endowment of goods (to old persons) for fiat money, hold the money until next period, and then trade the fiat money for goods (with the young of that period).
  - Young individuals save through holding money.

# The Equilibrium (2 of 7)

- Define:
  - $m_t$: units of fiat money acquired by a young person;
  - $v_t$: value of one unit of fiat money in terms of goods;
  - $p_t$: price of one unit of goods in terms of fiat money. Notice that

$$p_t = 1/v_t.$$

- An individual's budge constraint:
  - when young:

$$c_{1t} + v_t m_t = y \tag{1}$$

  - When old

$$c_{2t+1} = v_{t+1} m_t. \tag{2}$$

  - or lifetime budget constraint:

$$c_{1t} + \frac{1}{v_{t+1}/v_t} . c_{2t+1} = y. \tag{3}$$

$\frac{v_{t+1}}{v_t}$ is the real rate of return of fiat money because it expresses how many goods can be obtained in period $t+1$ if one unit of money is acquired and saved in period $t$ .

# The Equilibrium (3 of 7)

- The individual's problem:

$$\max_{m_t} \quad U(c_{1t}, c_{2t+1}) \quad s.t.\,(1),(2);$$

$$or \quad \max_{c_{1t}, c_{2t+1}} \quad U(c_{1t}, c_{2t+1}) \quad s.t.\,(3).$$

- The Euler equation: From the Langrangian:

$$L = U(c_{1t}, c_{2t+1}) + \lambda \left( y - c_{1t} - \frac{1}{v_{t+1}/v_t}.c_{2t+1} \right)$$

FOCs with respect to $c_{1t}$ and $c_{2t+1}$, respectively:

$$\frac{\partial L}{\partial c_{1t}} = U_1(c_{1t}, c_{2t+1}) - \lambda = 0 \implies U_1(c_{1t}, c_{2t+1}) = \lambda,$$

$$\frac{\partial L}{\partial c_{2t+1}} = U_2(c_{1t}, c_{2t+1}) - \frac{\lambda}{v_{t+1}/v_t} = 0 \implies U_2(c_{1t}, c_{2t+1}) = \frac{\lambda}{v_{t+1}/v_t}$$

# The Equilibrium (4 of 7)

- Combining the two FOCs, we obtain the Euler equation

$$\frac{U_1(c_{1t}, c_{2t+1})}{U_2(c_{1t}, c_{2t+1})} = \frac{v_{t+1}}{v_t}. \tag{4}$$

  - Eq. (4) states that the marginal rate of substitution between consumption in two periods equals the rate of return on money $\frac{v_{t+1}}{v_t}$.
  - Given $\frac{v_{t+1}}{v_t}$ (individuals take this as given), (3) and (4) determine the consumption plan $(c_{1t}^*, c_{2t+1}^*)$ that maximizes the utility of individuals of future generations.
- How can we determine the rate of return of fiat money? Using the market clearing condition for the money market.

$$L_t m_t = M, \forall t. \tag{5}$$

In real terms: $L_t v_t m_t = v_t M$. From (1), $v_t m_t = y - c_{1t}$, then

$$L_t(y - c_{1t}) = v_t M.$$

# The Equilibrium (5 of 7)

- This in turn implies that

$$v_t = \frac{L_t(y - c_{1t})}{M}, v_{t+1} = \frac{L_{t+1}(y - c_{1t+1})}{M}.$$

So the rate of return of fiat money is given by

$$\frac{v_{t+1}}{v_t} = \frac{\frac{L_{t+1}(y-c_{1t+1})}{M}}{\frac{L_t(y-c_{1t})}{M}} = \frac{L_{t+1}}{L_t} \cdot \frac{y - c_{1t+1}}{y - c_{1t}} = (1+n)\frac{y - c_{1t+1}}{y - c_{1t}}. \quad (6)$$

- We look for a steady state or a stationary monetary equilibrium, where $c_{1t} = c_1$ and $c_{2t} = c_2$ for all $t$, i.e., all future generations choose the same consumption plan.
- In a stationary monetary equilibrium, the real rate of return on money is given by:

$$\frac{v_{t+1}}{v_t} = 1 + n. \quad (7)$$

# The Equilibrium (6 of 7)

- Eq. (7) implies that with a constant money supply, the value of money grows at the same rate as population or endowment (we can think of $n$ as the growth rate of the economy). We also have

$$\frac{p_{t+1}}{p_t} = \frac{1}{1+n},$$

  i.e., the price level decreases at rate $n$. In other word, we have deflation in this economy.
- Substituting (7) into the Euler equation (4) and the lifetime budget constraint (3), and let $c_{1t} = c_1^*, c_{2t+1} = c_2^*$ for all $t$ , we get the 2 **conditions that characterize the consumption plan in the stationary monetary equilibrium**.

$$\frac{U_1(c_1^*, c_2^*)}{U_2(c_1^*, c_2^*)} = 1 + n \tag{8}$$

$$c_1^* + \frac{1}{1+n} c_2^* = y. \tag{9}$$

# The Equilibrium (7 of 7)

- what is the initial old's consumption? Note that

$$c_{2,1} = v_1 \cdot \frac{M}{L_0} = \frac{L_1(y - c_1^*)}{M} \cdot \frac{M}{L_0} = (1+n)(y - c_1^*) = c_2^*,$$

  where the second equality follows from $v_1 = \frac{L_1(y-c_1^*)}{M}$ (see slide 16- Eqs. (6-7)), and the last equality follows from Eq. (9).
- In other words, the initial old consume the same as old individuals of all future generations. Therefore, in the stationary monetary equilibrium, all young individuals consume the same, and all old individuals consume the same.
- Note that the real rate of return on money and thus real decisions are not affected by the size of the constant stock of fiat money, $M$. This property of the monetary equilibrium is known as the neutrality of money: The neutrality of money is said to exist if a once-for-all change in money supply does not affect the real values of the variables in the economy.

# The Golden-rule Consumption Plan (1 of 3)

- Is the equilibrium consumption plan the golden-rule consumption plan? Is the monetary equilibrium Pareto-efficient?
- The golden-rule problem maximizes the steady state lifetime utility of future generations ($U(c_1, c_2)$), subject to the stationary resource constraint of the economy (refer to Lecture 4).
- The resource constraint of the economy is given by:

$$L_t c_{1t} + L_{t-1} c_{2t} = L_t y \tag{10}$$

dividing both sides by $L_t$ yields

$$c_{1t} + \frac{1}{1+n} c_{2t} = y.$$

# The Golden-rule Consumption Plan (2 of 3)

- So the stationary resource constraint of the economy is given by:

$$c_1 + \frac{1}{1+n} c_2 = y. \tag{11}$$

- So the golden-rule problem is:

$$\max_{c_1, c_2} \; U(c_1, c_2), \quad s.t.(11).$$

It is easy to derive the conditions that determine the golden rule consumption plan $(\bar{c}_1, \bar{c}_2)$ (do this as an exercise):

$$\frac{U_1(\bar{c}_1, \bar{c}_2)}{U_2(\bar{c}_1, \bar{c}_2)} = 1 + n \tag{12}$$

$$\bar{c}_1 + \frac{1}{1+n} \bar{c}_2 = y. \tag{13}$$

# The Golden-rule Consumption Plan (3 of 3)

- Notice that conditions that determine the golden-rule consumption plan (Eq. (12) and (13)) are **exactly the same** as conditions that determine the equilibrium consumption plan (Eq. (8) and (9)), so

$$c_1^* = \bar{c}_1, \quad c_2^* = \bar{c}_2.$$

- Conclusion: With constant stock of money supply, the stationary monetary equilibrium coincides with the golden-rule allocation, and thus it is Pareto-efficient.
- Next lecture: Consider growing money supply in the basic model to examine the effects of inflation. Discuss the considerations in setting the optimal rate of inflation.