

GRADING

- You probably know all classes will be graded SEM/UEM this semester.
- I expect you to complete all problem sets (with one grace exception).
- Final exam: 24 hour open note/open book (but no other resources).
- If personal hardship poses a hurdle, initiate thread with me and your residential dean and we will find an accommodation.

INFLATION AND MONETARY POLICY

Harvard Economics 1011B
Professor Gabriel Chodorow-Reich
Spring 2020

OUTLINE

1 MONEY

2 PRICES AND INFLATION

3 MONETARY POLICY

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1 MONEY

2 PRICES AND INFLATION

3 MONETARY POLICY

WHAT IS MONEY?

- Currency.
- M1: currency + checking deposits.
- M2: M1 + savings deposits and money market funds.
- “Money-like”: short-term TBills, repo, trade credit.

CHARACTERISTICS OF MONEY

① Unit of account.

- ▶ Apple costs \$1, orange costs \$2,... Then it takes two apples to trade for one orange. N goods characterized by N prices. Without unit of account, N goods requires $N(N+1)/2$ relative prices.
- ▶ Refer to as *numeraire*.

② Medium of exchange.

- ▶ Can exchange orange for dollars, dollars for apple. Solves problem of “double coincidence of wants” in barter economy.

③ Store of value.

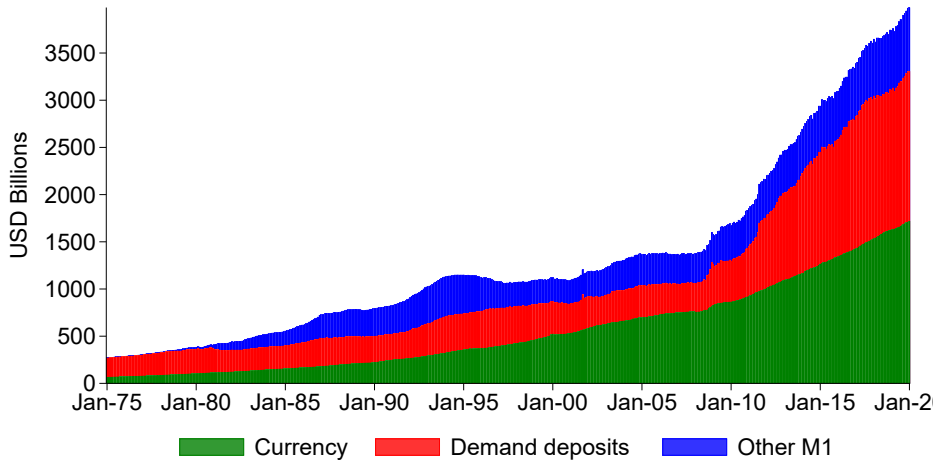
- ▶ Perfectly safe at short horizons.

TYPES OF MONEY

Instrument	Unit of account	Medium of exchange	Safe store of value
Currency	✓	✓	✓
Checking deposits ✓X	✓(checks/ debit cards)	✓	
Saving deposits ✓X	X	✓	
30 day Treasury bill	X	✓(repo)	✓
AAA rated security	X	✓(repo)	✓
Grocery store credit	X	✓	X
Bitcoin	✓	✓(limited)	X

- Currency issuance directly controlled by government (inside money).
- Currency has fiscal backing: taxes paid in dollars.
- AAA rated securities, grocery store credit created by private agents (outside money).
- What types of money matter most in practice?

COMPONENTS OF M1



CURRENCY

Value of currency in circulation, in billions of dollars as of December 31 of each year

	\$1	\$2	\$5	\$10	\$20	\$50	\$100	\$500 to \$10,000	TOTAL
2018	\$12.4	\$2.5	\$15.3	\$20.1	\$188.5	\$89.2	\$1,343.5	\$0.3	\$1,671.9
2017	\$12.1	\$2.4	\$14.8	\$19.6	\$183.8	\$86.4	\$1,251.7	\$0.3	\$1,571.1
2016	\$11.7	\$2.3	\$14.2	\$19.2	\$177.2	\$83.5	\$1,154.8	\$0.3	\$1,463.4
2015	\$11.4	\$2.3	\$13.7	\$19.0	\$171.3	\$79.8	\$1,082.2	\$0.3	\$1,380.0
2014	\$11.0	\$2.2	\$13.1	\$18.9	\$162.2	\$76.9	\$1,014.5	\$0.3	\$1,299.1
2013	\$10.6	\$2.1	\$12.7	\$18.5	\$155.0	\$74.5	\$924.7	\$0.3	\$1,198.3
2012	\$10.3	\$2.0	\$12.2	\$17.7	\$148.9	\$72.5	\$863.1	\$0.3	\$1,127.1
2011	\$10.0	\$1.9	\$11.8	\$17.2	\$141.1	\$69.6	\$782.6	\$0.3	\$1,034.5
2010	\$9.7	\$1.8	\$11.5	\$16.6	\$130.6	\$66.9	\$704.6	\$0.3	\$942.0
2009	\$9.6	\$1.7	\$11.2	\$16.2	\$127.5	\$65.3	\$656.4	\$0.3	\$888.3
2008	\$9.5	\$1.7	\$11.0	\$16.3	\$125.1	\$64.7	\$625.0	\$0.3	\$853.2
2007	\$9.3	\$1.6	\$10.8	\$16.2	\$121.8	\$63.0	\$569.3	\$0.3	\$792.2
2006	\$9.0	\$1.5	\$10.5	\$16.0	\$119.2	\$62.8	\$564.1	\$0.3	\$783.5
2005	\$8.8	\$1.5	\$10.3	\$15.5	\$115.4	\$62.1	\$545.0	\$0.3	\$758.8
2004	\$8.3	\$1.4	\$9.8	\$15.1	\$107.6	\$60.6	\$516.7	\$0.3	\$719.9
2003	\$8.2	\$1.3	\$9.7	\$15.1	\$107.8	\$59.9	\$487.8	\$0.3	\$690.2
2002	\$8.0	\$1.3	\$9.4	\$14.9	\$103.7	\$58.5	\$458.7	\$0.3	\$654.8
2001	\$7.8	\$1.3	\$9.2	\$14.7	\$100.9	\$57.0	\$421.1	\$0.3	\$612.3
2000	\$7.7	\$1.2	\$8.9	\$14.5	\$98.6	\$55.0	\$377.7	\$0.3	\$563.9
1999	\$7.5	\$1.2	\$9.0	\$16.2	\$116.1	\$64.7	\$386.2	\$0.3	\$601.2
1998	\$7.0	\$1.2	\$8.0	\$14.3	\$90.9	\$50.5	\$320.1	\$0.3	\$492.2

Includes Federal Reserve notes, U.S. notes, and currency no longer issued

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DEFINITIONS

- $1 + i_{t,t+1}$: gross nominal return on a one period bond. That is, invest \$1 in period t , receive $\$1 + i_{t,t+1}$ in period $t + 1$.
- P_t : dollar price of a unit of consumption (of what?) in period t .
- $1 + \pi_{t,t+1} = P_{t+1}/P_t$: gross inflation rate between t and $t + 1$.
- Consumption Euler equation:

$$\frac{1}{P_t} u'(C_t) = \beta \frac{(1 + i_{t,t+1})}{P_{t+1}} u'(C_{t+1}).$$

- Interpret: \$1 in period t buys $1/P_t$ units of consumption, which are valued at $u'(C_t)$. Or invest \$1, receive $\$1 + i_{t,t+1}$ in $t + 1$, purchase $(1 + i_{t,t+1})/P_{t+1}$ of consumption in $t + 1$, valued at $\beta u'(C_{t+1})$.

FISHER EQUATION

- Rewrite consumption Euler equation:

$$u'(C_t) = \beta \frac{(1 + i_{t,t+1})}{\left(\frac{P_{t+1}}{P_t}\right)} u'(C_{t+1}) = \beta \frac{(1 + i_{t,t+1})}{(1 + \pi_{t,t+1})} u'(C_{t+1}).$$

- Consumption Euler equation in terms of real interest rate $r_{t,t+1}$:

$$u'(C_t) = \beta(1 + r_{t,t+1})u'(C_{t+1}).$$

- Thus:

$$1 + r_{t,t+1} = \frac{(1 + i_{t,t+1})}{(1 + \pi_{t,t+1})}.$$

- Approximation using $(1 + r_{t,t+1})(1 + \pi_{t,t+1}) \approx 1 + r_{t,t+1} + \pi_{t,t+1}$:

$$r_{t,t+1} = i_{t,t+1} - \pi_{t,t+1} \text{ (Fisher equation).}$$

- Fisher equation with uncertainty over path of inflation:

$$r_{t,t+1} = i_{t,t+1} - E_t \pi_{t,t+1}.$$

FIRM PRICE SETTING PROBLEM

- Consider a firm choosing its relative price $P_{i,t}/P_t$.
- Firm faces downward sloping demand curve ($\varepsilon > 1$):

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon}. \quad (1)$$

- Firm has real cost function $C(Y_{i,t})$, $C'(\cdot) > 0$.
- Firm maximizes real profits $\Pi_{i,t} = \frac{P_{i,t}}{P_t} Y_{i,t} - C(Y_{i,t})$:

$$\max_{P_{i,t}, Y_{i,t}} \frac{P_{i,t}}{P_t} Y_{i,t} - C(Y_{i,t}) \text{ s.t. (1)} = \max_{Y_{i,t}} Y_{i,t}^{1-\frac{1}{\varepsilon}} - C(Y_{i,t}).$$

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- FOC:

$$\begin{aligned} \left(1 - \frac{1}{\varepsilon}\right) Y_{i,t}^{-\frac{1}{\varepsilon}} &= C'(Y_{i,t}) \implies \left(1 - \frac{1}{\varepsilon}\right) \frac{P_{i,t}}{P_t} = C'(Y_{i,t}) \\ \implies P_{i,t} &= \frac{\varepsilon}{\varepsilon - 1} P_t C'(Y_{i,t}). \end{aligned}$$

- Interpret: price is a markup over marginal cost.

FIRM PRICE SETTING PROBLEM, STICKY PRICES

- Now suppose firm chooses one price to last for $T + 1$ periods.
- Firm has forecast of average price P_{t+1}, P_{t+2}, \dots
- Firm maximizes discounted real profits with discount factor β :

$$\begin{aligned} \max_{P_{i,t}, \{Y_{i,t+h}\}_{h=0}^T} \sum_{h=0}^T \beta^h \left[\frac{P_{i,t}}{P_{t+h}} Y_{i,t+h} - C(Y_{i,t+h}) \right] \text{ s.t. (1)} \\ = \max_{P_{i,t}} \sum_{h=0}^T \beta^h \left[\left(\frac{P_{i,t}}{P_{t+h}} \right)^{1-\varepsilon} - C \left(\left(\frac{P_{i,t}}{P_{t+h}} \right)^{-\varepsilon} \right) \right]. \end{aligned}$$

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- FOC:

$$\sum_{h=0}^T \frac{\beta^h}{P_{t+h}} \left[(1-\varepsilon) \left(\frac{P_{i,t}}{P_{t+h}} \right)^{-\varepsilon} + \varepsilon \left(\frac{P_{i,t}}{P_{t+h}} \right)^{-\varepsilon-1} C'(Y_{i,t+h}) \right] = 0$$

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DETERMINANTS OF INFLATION

- Flexible price:

$$P_{i,t} = \frac{\varepsilon}{\varepsilon - 1} P_t C'(Y_{i,t}).$$

- Sticky price: if a firm expects its price to remain fixed for periods $t, t+1, t+2, \dots, t+T$, it sets a price to minimize a weighted average of deviations $P_{i,t+h} - \frac{\varepsilon}{\varepsilon-1} P_{t+h} C'(Y_{i,t+h})$.
- Inflation is the result of individual price setting decisions by millions of firms.
- To understand inflation, we should look to marginal cost and to firms' horizons when setting prices.

MARGINAL COST

- Real marginal cost typically increasing in output. Why?
 - ① Quasi-fixed factors and diminishing returns in production.
 - ② Higher wage or overtime premium required to increase hours per worker.
 - ③ Recruiting costs higher when economy is hotter because more firms compete to hire smaller pool of available workers.
- Equilibrating force: when all firms want to raise their relative price, the overall price level rises, total demand falls, and real marginal cost falls. Then firms no longer want to raise relative price.

MARGINAL COST EXAMPLE

- Production function:

$$Y_{i,t} = F(K_{i,t-1}, L_{i,t}) = K_{i,t-1}^{\alpha} L_{i,t}^{1-\alpha}.$$

- Because of time-to-build, firm cannot immediately increment capital ($K_{i,t-1}$ pre-determined).
- Variable costs: $w_{i,t}L_{i,t} + R(L_{i,t}, Y_t)$, where $w_{i,t}$ is wage per hour, $L_{i,t}$ is total hours hired, and $R(L_{i,t}, Y_t)$ is the cost of recruiting additional workers, $R_1 > 0, R_{1,2} > 0$.
 - ▶ w_t increasing in firm output because of overtime.
 - ▶ Recruiting cost increasing in individuals hired and in labor market tightness.

PRICE ADJUSTMENT HORIZON

- Median price in U.S. lasts about 4.5 months (including sales), or 8 months (excluding sales).
- Many prices adjusted exactly once per year.

EVIDENCE FROM INDIVIDUAL PRICE DATA

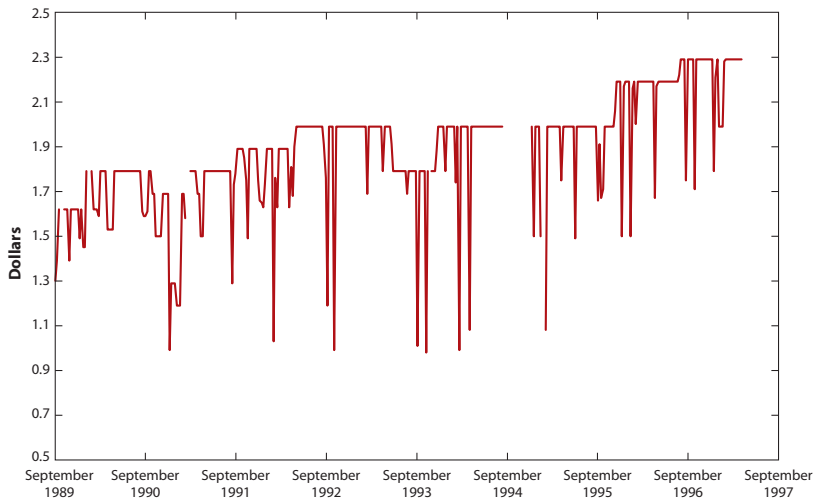


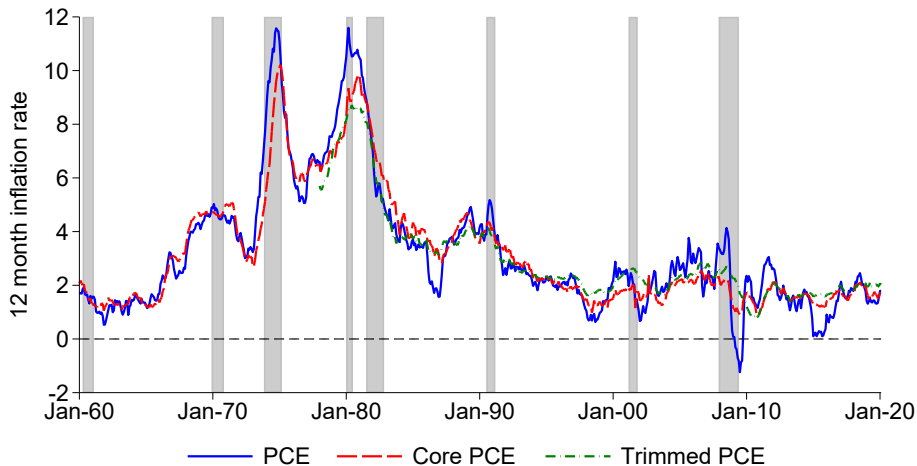
Figure 2

Price series of Nabisco Premium Saltines (16 oz) at a Dominick's Finer Foods store in Chicago.

SOURCES OF PRICE STICKINESS

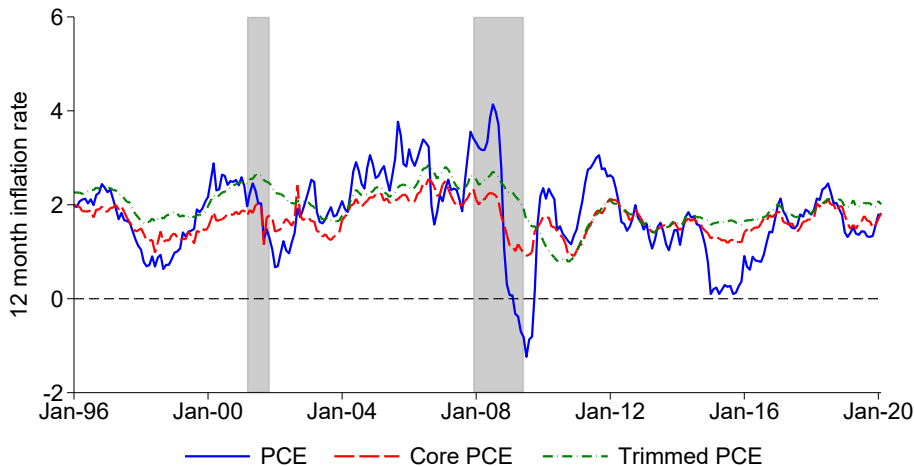
- Nominal rigidities: menu costs, attention costs.
- Real rigidity (strategic complementarity):
 - ▶ Suppose Felipe's adjusts its prices each January and Pinocchio's adjusts its prices each July.
 - ▶ Suppose the price of flour rises suddenly in December.
 - ▶ In January, Felipe's raises its prices since its marginal costs have risen.
 - ▶ But Felipe's tempers the price increases so as not to lose too much business to Pinocchio's between January and June.
 - ▶ In June, Pinocchio's raises its prices, but tempers the increase so as not to lose too much business to Felipe's between July and next January.
 - ▶ Next January Felipe's raises its prices again a bit more...
 - ▶ This generates sluggishness in inflation – prices respond only slowly to changes in underlying conditions.

INFLATION



- Why use different measures of inflation?

INFLATION IN YOUR LIFETIME



- Very sticky. “Expectations well anchored.”

INFLATION BY ITEM

Item	$\frac{P_{i,2019}}{P_{i,2000}}$	% per year
College tuition and fees	2.56	5.08
Gasoline, unleaded regular	1.78	3.09
All PCE	1.40	1.78
Fresh whole milk	1.29	1.35
New cars	1.01	0.07
Computers, peripherals, and smart home assistants	0.09	-11.74

- “I can’t eat an ipad.” (<http://www.reuters.com/article/us-usa-fed-dudley-ipad-idUSTRE72A4AC20110311>)
- “We run the risk of appearing out of touch, like one of those Presidents who doesn’t know the price of milk.” (<http://www.westwingtranscripts.com/wwscripts/5-04.txt>)

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FEDERAL RESERVE DUAL MANDATE

- Federal Reserve Act as amended in 1977: *“The Board of Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth of the monetary and credit aggregates commensurate with the economy’s long run potential to increase production, so as to promote effectively the goals of maximum employment, stable prices and moderate long-term interest rates.”*
- In practice, moderate long-term interest rates seen as bi-product of stable prices and maximum employment.

DUAL MANDATE IN PRACTICE: INFLATION TARGETING

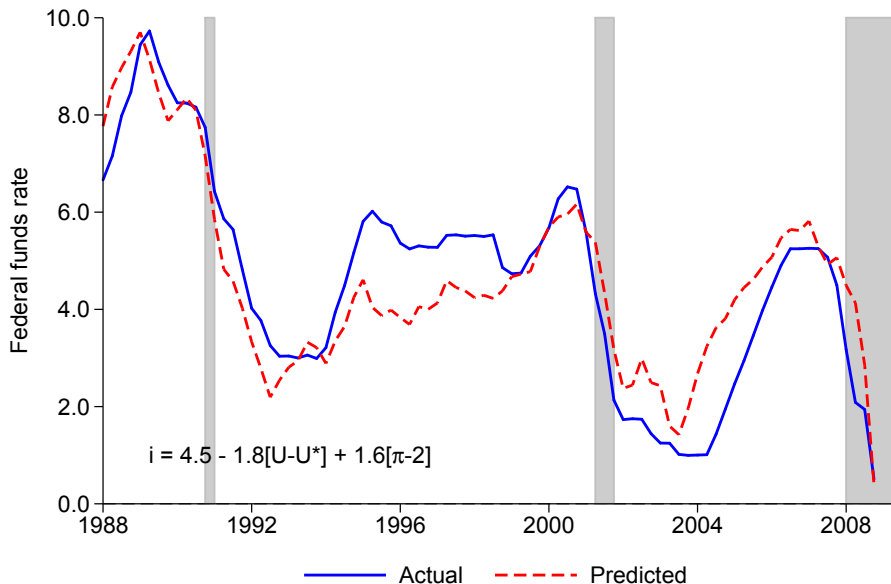
- Since 2012, Federal Reserve has practiced “inflation targeting.”
- Statement of longer run goals: *The inflation rate over the longer run is primarily determined by monetary policy, and hence the Committee has the ability to specify a longer-run goal for inflation. The Committee judges that inflation at the rate of 2 percent, as measured by the annual change in the price index for personal consumption expenditures, is most consistent over the longer run with the Federal Reserve’s statutory mandate... The maximum level of employment is largely determined by nonmonetary factors that affect the structure and dynamics of the labor market. These factors may change over time and may not be directly measurable... the Committee’s policy decisions must be informed by assessments of the maximum level of employment... In setting monetary policy, the Committee seeks to mitigate deviations of inflation from its longer-run goal and deviations of employment from the Committee’s assessments of its maximum level.*

MONETARY POLICY FEEDBACK RULE (TAYLOR RULE)

$$i_{t,t+1} = r_{t,t+1}^* + \pi_{t,t+1}^* + \phi_Y(Y_t - Y_t^*) + \phi_\pi(\pi_{t,t+1} - \pi_{t,t+1}^*).$$

- Y_t^* : Fed's target for output; $\pi_{t,t+1}^*$: Fed's target for inflation (2%);
 $r_{t,t+1}^*$: real interest rate when $Y_t = Y_t^*$ and $\pi_{t,t+1} = \pi_{t,t+1}^*$.
- $\phi_Y > 0$: when output is below target, Fed lowers interest rates.
- $\phi_\pi > 0$: when inflation is above target, Fed raises interest rates.
- Assumption: ϕ_Y, ϕ_π large enough, and inflation sluggish enough, that Fed raises real interest rate. This is usually true.

ESTIMATED TAYLOR RULE



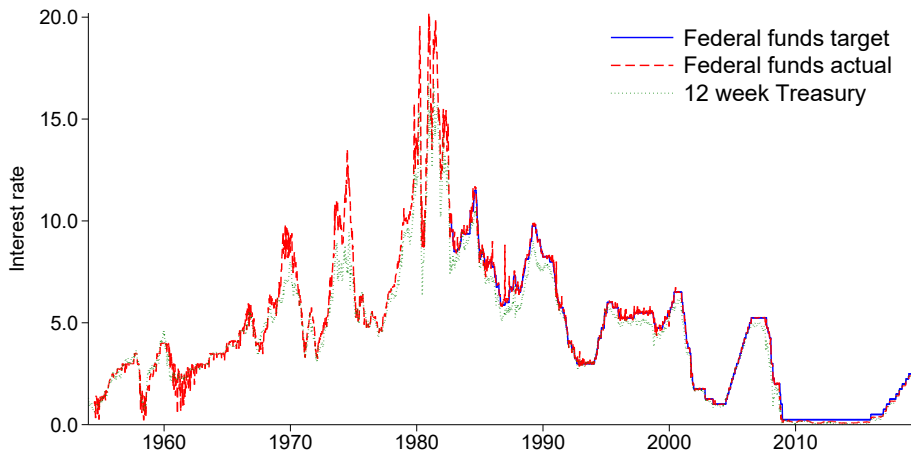
OTHER MONETARY REGIMES

- Price-level targeting.
- Nominal GDP targeting.
- Hybrid.
- Fixed exchange rate.
- Gold standard.
- Commodity standard.

MONETARY POLICY OPERATION

- The central bank (Federal Reserve, or “Fed”) sets i_t .
- How? Open market operations:
 - ① Expansionary open market operation: Fed buys Treasury security from bank.
 - ② Nominal interest rate is opportunity cost of holding money. If money stock changes, nominal interest rate will change (see e.g. Romer).
 - ③ Banks have required reserves to back their deposits. When Fed buys Treasury security, it pays for it by increasing bank's reserves at the Fed. Then bank can lend more, which reduces interest rates.
- How? Interest on reserves:
 - ① Fed pays interest on reserves of i_t^{ior} . Then no bank will lend at a rate below i_t^{ior} because Fed is safest counterparty.
- How? Reverse repo:
 - ① Fed announces it will borrow from non-banks at rate i_t^{rrp} . Then no non-bank will lend at a rate below i_t^{rrp} because Fed is safest counterparty.

MONETARY POLICY: HOW?



- For many purposes, we can just assume the Fed picks the 4 week or 13 week Treasury bill rate.

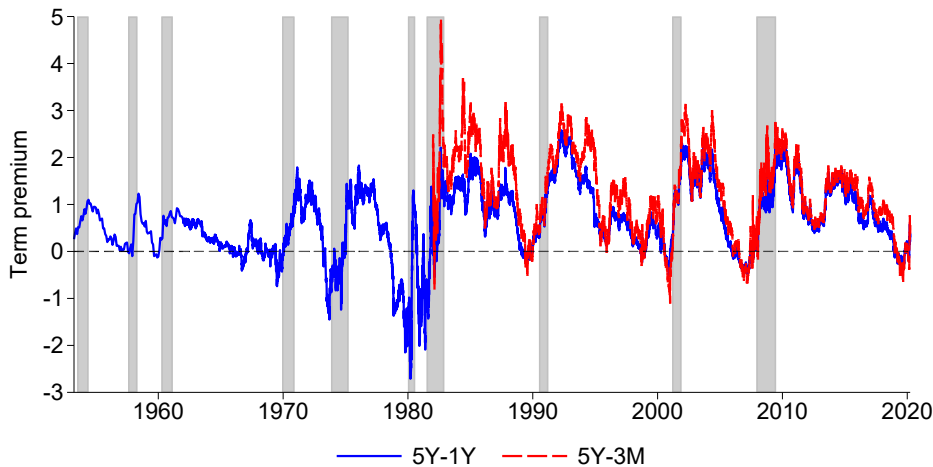
EXPECTATIONS HYPOTHESIS OF TERM STRUCTURE

- Useful fact: if x, y are small, then $(1+x)(1+y) \approx 1+x+y$.
- Using $R_{t,t+j} = 1 + i_{t,t+j}$ and the above fact:

$$i_{t,t+52} \approx E_t[i_{t,t+13} + i_{t+13,t+26} + i_{t+26,t+39} + i_{t+39,t+52}] + RP_{t,t+52}.$$

- Expectations hypothesis of the term structure: long-term interest rate equals the sum of expected short term interest rates over the contract horizon (ignores risk premium).
- Corollary: Fed affects long term interest rates through expectations of future short term interest rates.

YIELD CURVE



LENDER OF LAST RESORT: DISCOUNT WINDOW

Discount window lending under section 10B: *This part establishes rules under which a Federal Reserve Bank may extend credit to depository institutions and others. Except as otherwise provided, this part applies to United States branches and agencies of foreign banks that are subject to reserve requirements under Regulation D (12 CFR part 204) in the same manner and to the same extent as this part applies to depository institutions. The Federal Reserve System extends credit with due regard to the basic objectives of monetary policy and the maintenance of a sound and orderly financial system.*

LENDER OF LAST RESORT: EMERGENCY LENDING

Emergency lending under section 13(3): *In unusual and exigent circumstances, the Board of Governors of the Federal Reserve System, by the affirmative vote of not less than five members, may authorize any Federal reserve bank, during such periods as the said board may determine, at rates established in accordance with the provisions of section 14, subdivision (d), of this Act, to discount for any participant in any program or facility with broad-based eligibility, notes, drafts, and bills of exchange when such notes, drafts, and bills of exchange are indorsed or otherwise secured to the satisfaction of the Federal Reserve bank: Provided, That before discounting any such note, draft, or bill of exchange, the Federal reserve bank shall obtain evidence that such participant in any program or facility with broad-based eligibility is unable to secure adequate credit accommodations from other banking institutions. All such discounts for any participant in any program or facility with broad-based eligibility shall be subject to such limitations, restrictions, and regulations as the Board of Governors of the Federal Reserve System may prescribe.*

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