

---

# Monetary Policy

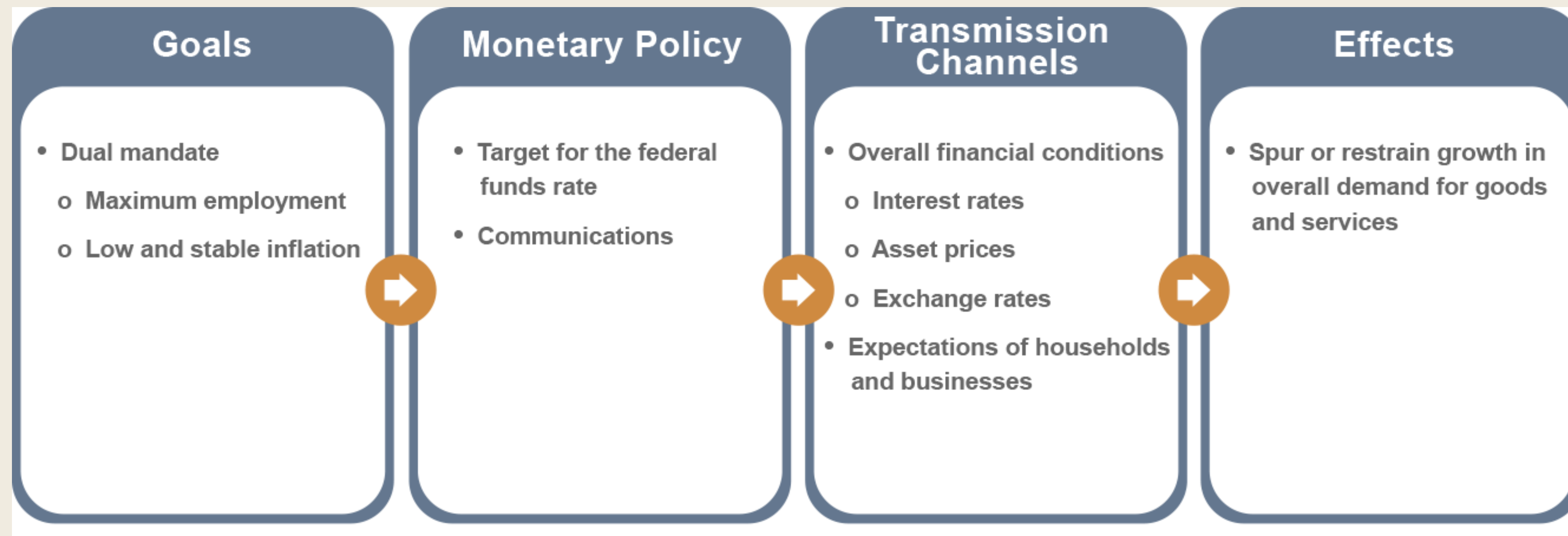
EC502 Macroeconomics  
Topic 10

Masao Fukui

2026 Spring

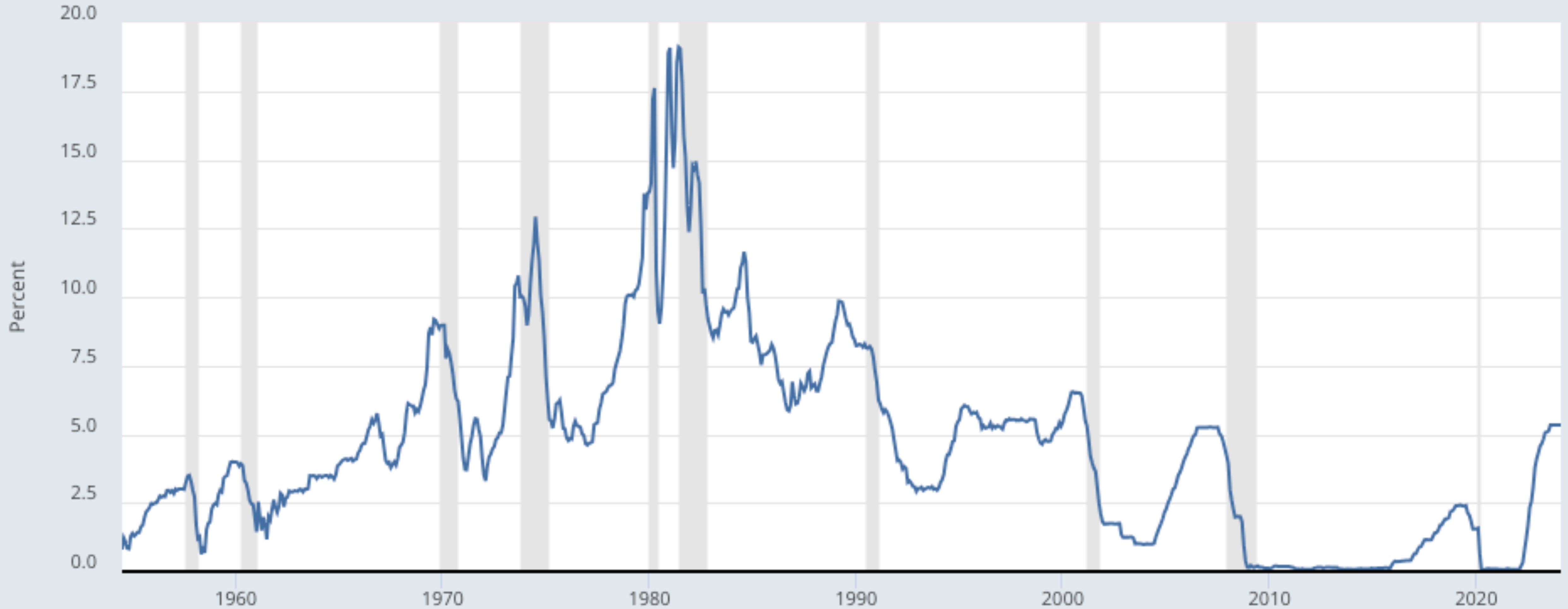
# Monetary Policy

- Monetary policy is a central macroeconomic policy tool
- What are the goals of monetary policy? The Federal Reserve Act states:
  1. maximum employment
  2. stable prices
- How does monetary policy work? FRB website writes:



# Federal Funds Rate

**FRED**  — Federal Funds Effective Rate



---

# Does Monetary Policy Work in Our Model?

- FRB and many people believe monetary policy affects employment and prices
- We have already built a macroeconomic model (RBC model)
- What does our model say?
- But our model was already expressed everything in “real” term
  - in the units of consumption goods
- Let us rewrite RBC model in “nominal” term
  - in the units of dollar

---

# Monetary Neutrality

---

# RBC without Investment

- For the most part, we will abstract from capital and investment
- We simply assume production function is

$$Y_t = A_t L_t$$

- We will add back them at the end

---

# Households

- Households have the following preferences

$$u(C_0) - v(l_0) + \beta u(C_1)$$

- Now the budget constraints are

$$P_0 C_0 + A_0 = W_0 l_0 + D_0$$

$$P_1 C_1 = (1 + i)A_0 + W_1 l_1 + D_1$$

- $P_0, P_1$ : nominal price level (CPI) at  $t = 0, 1$
  - $W_0, W_1$ : nominal wage at  $t = 0, 1$
  - $1 + i$ : nominal interest rate
- Define the inflation in this economy as

$$1 + \pi_1 = \frac{P_1}{P_0}$$

---

# Firms

- The firms solve

$$\max_{L_0, L_1} D_0 + \frac{1}{1+i} D_1$$

subject to

$$D_0 = P_0 A_0 L_0 - W_0 L_0$$

$$D_1 = P_1 A_1 L_1 - W_1 L_1$$

---

# Market Clearing Conditions

- Market clearing conditions:

$$C_0 = A_0 L_0$$

$$C_1 = A_1 L_1$$

$$l_0 = L_0$$

$$l_1 = L_1$$

- Monetary policy sets  $i$
- Suppose now monetary policy changes  $i$ 
  1. Can it affect prices?
  2. Can it affect employment?

# Converting into Real Model

- We can rewrite the household's budget constraint as

$$C_0 + a_0 = w_0 l_0 + d_0$$

$$C_1 = (1 + r)a_0 + w_1 l_1 + d_1$$

- $a_0 \equiv A_0/P_0$ : real saving,  $w_t \equiv W_t/P_t$ : real wage,  $d_t \equiv D_t/P_t$ : real profit
- $1 + r \equiv (1 + i) \frac{P_0}{P_1}$ : real interest rate

- Similarly, firms' profits are ( $d_t = D_t/P_t$ )

$$\max_{L_0, I_1, K_1, L_1} d_0 + \frac{1}{1 + r} d_1$$

$$d_0 = A_0 L_0 - w_0 L_0$$

$$d_1 = A_1 L_1 - w_1 L_1$$

---

# Solutions

- $\{C_0, C_1, L_0, r\}$  solve

$$v'(L_0) = A_0 u'(C_0)$$

$$u'(C_0) = \beta(1 + r)u'(C_1)$$

$$C_0 = A_0 L_0$$

$$C_1 = A_1 L_1$$

---

# Monetary Policy and Employment

- So, do changes  $i$  affect employment,  $L_0$ ?
- No, because  $i$  never showed up in the previous conditions.

---

# Monetary Policy and Prices

- Do changes  $i$  affect price levels,  $P_0$ ?
- With  $\{C_0, C_1\}$  pinned down,  $r$  is also pinned down via Euler

$$C_0^{-\sigma} = \beta(1 + r)C_1^{-\sigma}$$

- Recall

$$1 + r \equiv (1 + i)\frac{P_0}{P_1}$$

Given  $r$  and  $i$ ,  $P_0/P_1$  is pinned down from this equation

- From now on, we will fix  $P_1 = \bar{P}_1$  ( $P_1$  is generally indeterminate). Then

$$P_0 = \frac{1 + r}{1 + i}\bar{P}_1$$

A higher  $i$  lowers price level today,  $P_0$

---

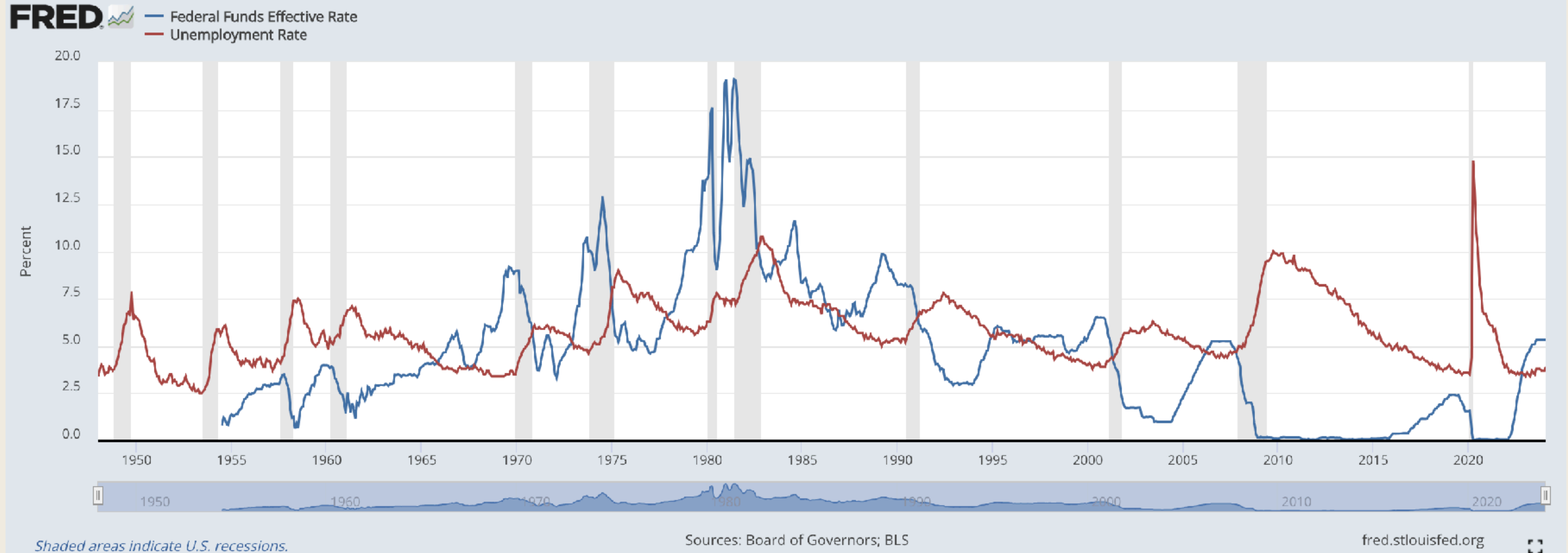
# Monetary Neutrality

- If monetary policy raises the **nominal** interest rate  $i$ ,
  1. No effect on employment or any quantities
  2. Price level today goes down (inflation from  $t = 0$  to  $t = 1$ ,  $P_1/P_0$ , goes up)
- Monetary policy is neutral with respect to macro quantities
- Why? – Price level  $P_0$  immediately drops to keep the **real** interest rate  $r$  unchanged
- Real interest rate is what matters for the households and firms decisions
  - No one cares about nominal interest rate per se (in theory)
- Nominal wage also drops so that real wage  $w_0 = W_0/P_0$  is unchanged as well

---

# **Empirical Evidence on Monetary Non-Neutrality**

# Naive Argument



- “Tighter monetary policy (higher  $i$ ) lowers unemployment!”
- What’s wrong with such an argument?

---

# Monetary Policy is Endogenous

“Unfortunately for us as empirical scientists, the Federal Reserve does not randomize when setting interest rates.

Quite to the contrary, the Federal Reserve employs hundreds of PhD economists to pore over every bit of data about the economy so as to make monetary policy as endogenous as it possibly can be.”

— Nakmaura and Steinsson (2018)

---

# Monetary Policy is Endogenous

- Fed changes interest rate for a reason
- When a recession happens, Fed lowers the interest rate
- We cannot conclude from this that a lower interest rate *caused* the recession
- If Fed didn't lower the rate, maybe the recession could have been worse
- Is it possible to figure out the **causal** effect of monetary policy?

---

# In Search of Exogenous Monetary Policy

- Suppose Fed ever changes interest rate for a reason unrelated to the economy
  - Not because the economy is in recession
  - Not because the economy is having unusually high inflation
- Looking at the response of the economy following such change gives us the answer
- We will cover three approaches
  1. Narrative approach (Romer-Romer, 1989)
  2. Quantitative version of narrative approach (Romer-Romer, 2004)
  3. High-frequency identification

---

# 1. Narrative Approach

- Romer and Romer (1989, 2023):
  - Read transcripts and records of FOMC meetings
    - 50-100 pages of detailed summaries of discussions for each meeting
  - Judge whether monetary policymakers changed interest rates for reasons unrelated to current or prospective real economic activity
  - These are their monetary policy “shocks”
    - Monetary policy changes that are not responses to economic activity

---

# Monetary Policy “Shocks” Dates

---

---

## New dates

---

October	1947	(−)
August	1955	(−)
September	1958	(−)
December	1968	(−)
January	1972	(+)
April	1974	(−)
August	1978	(−)
October	1979	(−)
May	1981	(−)
December	1988	(−)

---

---

# December 1988

- 1987-1988:
  - Continuous actions toward **stabilizing** inflation
  - Not “shock”
- December 1988:
  - A desire to **reduce** inflation and a willingness to accept output consequences became widespread
  - “I think the job before us is to contain the inflation and to slow this economy down”
  - “if it is the aim of the Committee... to restore a downward trend by 1990, then it may be necessary to run the risk of some financial stress and economic weakness”
  - This counts as a shock because the shift is due to changes in policymakers’ views
  - Not because something happened in the economy in December 1988

# Impact on Unemployment

$$y_{t+h} = \beta_h S_t + \mathbf{X}'_t \boldsymbol{\gamma}_h + \epsilon_{t+h}$$

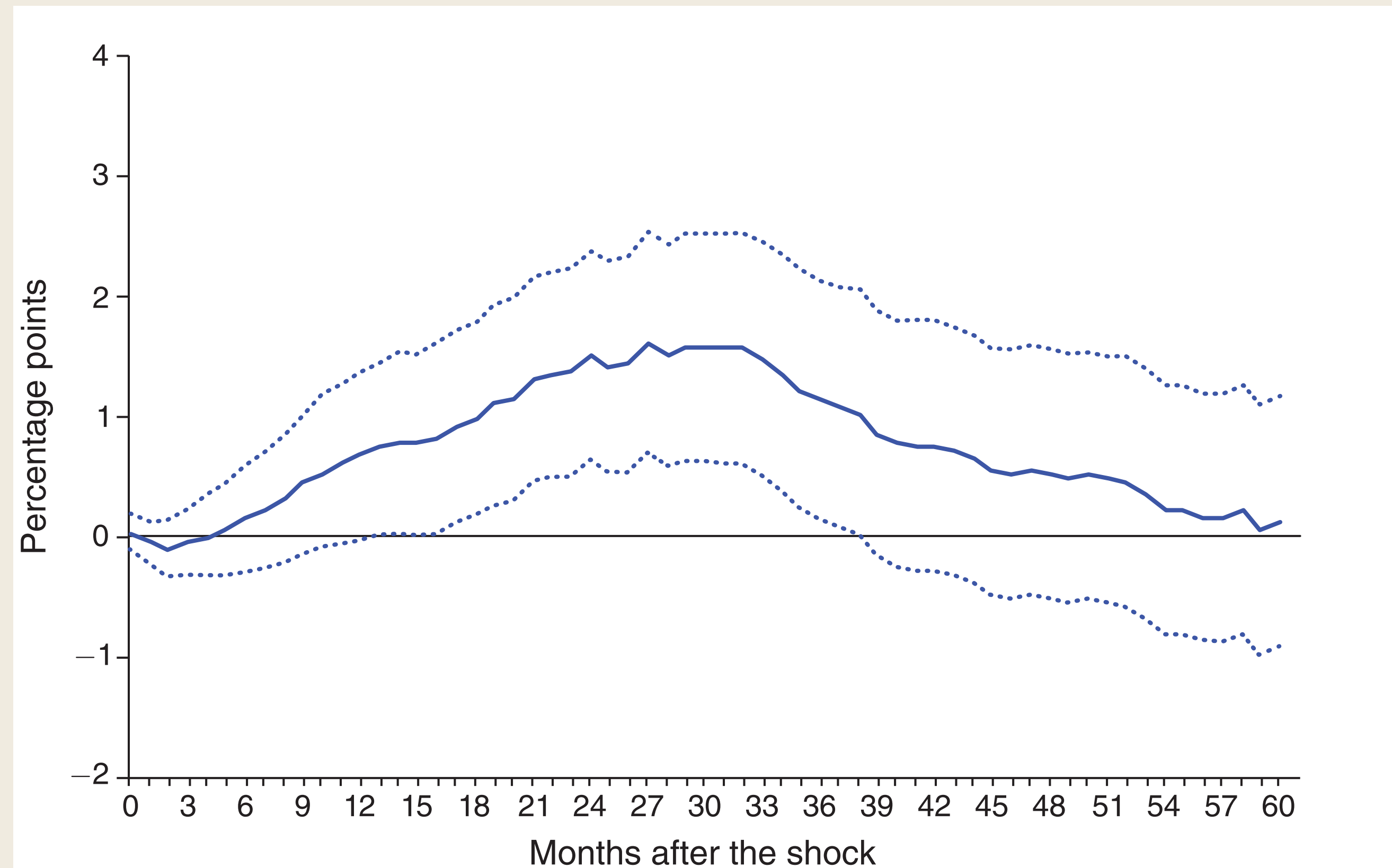
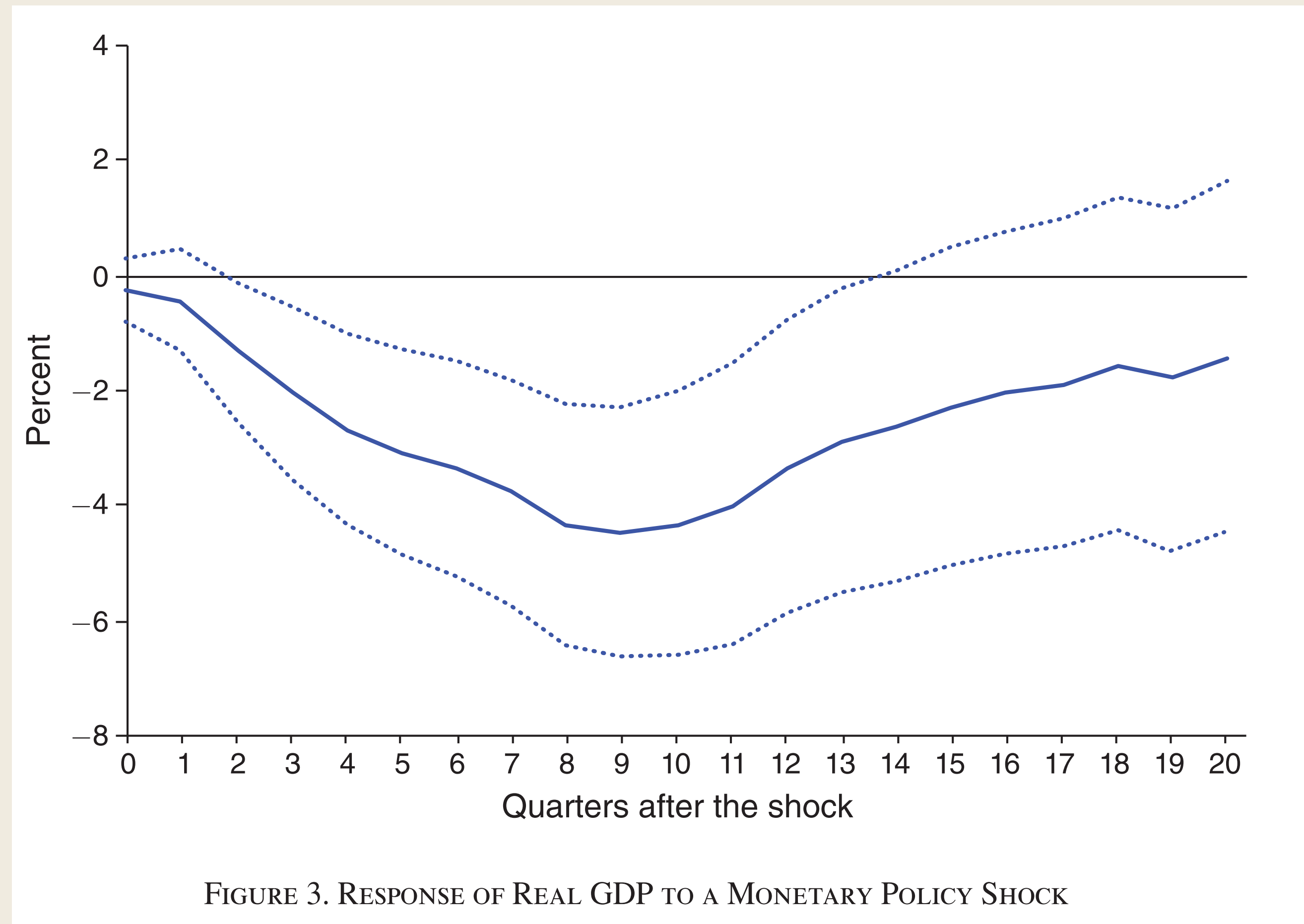
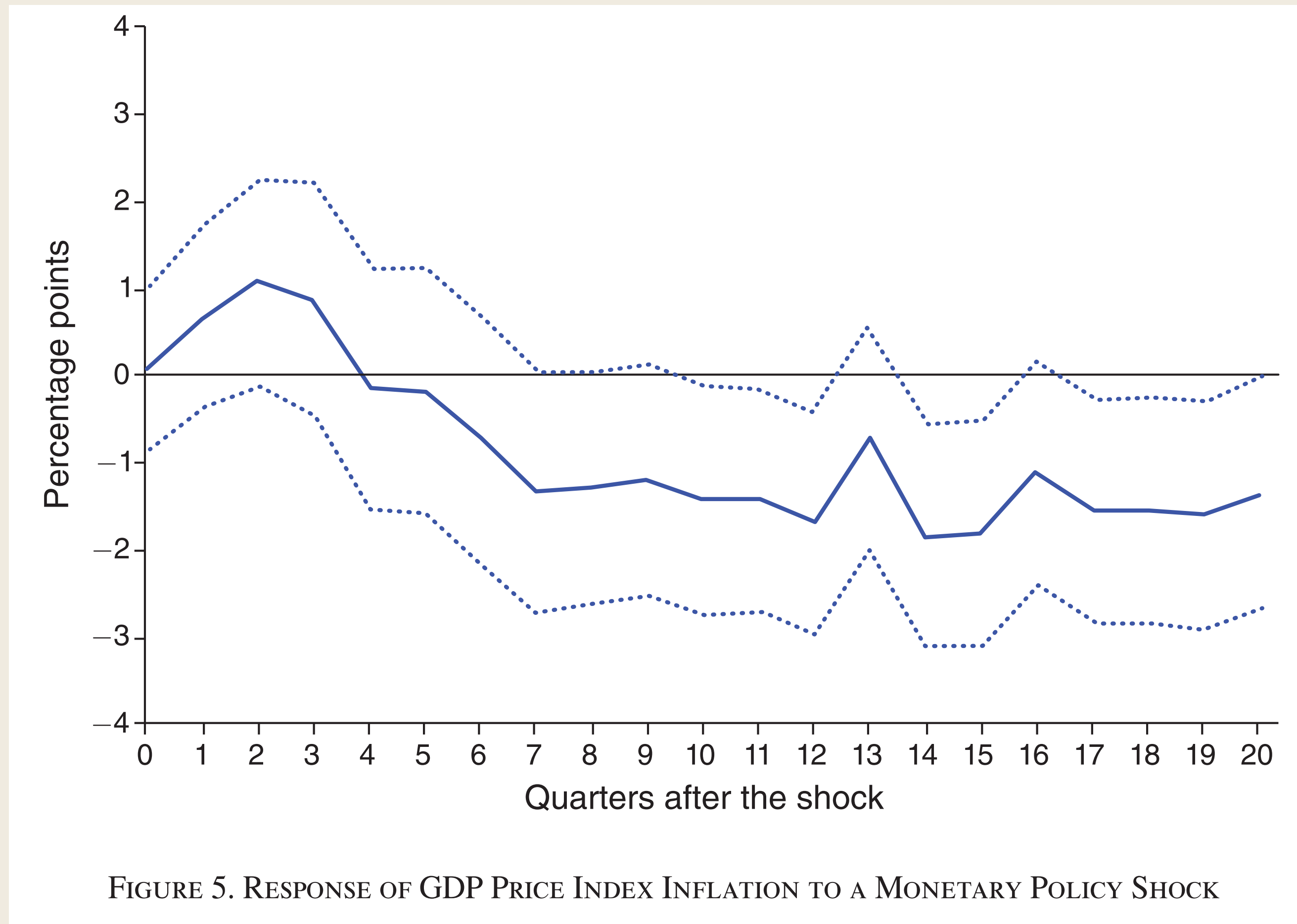


FIGURE 1. RESPONSE OF THE UNEMPLOYMENT RATE TO A MONETARY POLICY SHOCK

# Real GDP Response



# Response of Prices



---

## 2. Quantitative Version of Narrative Approach

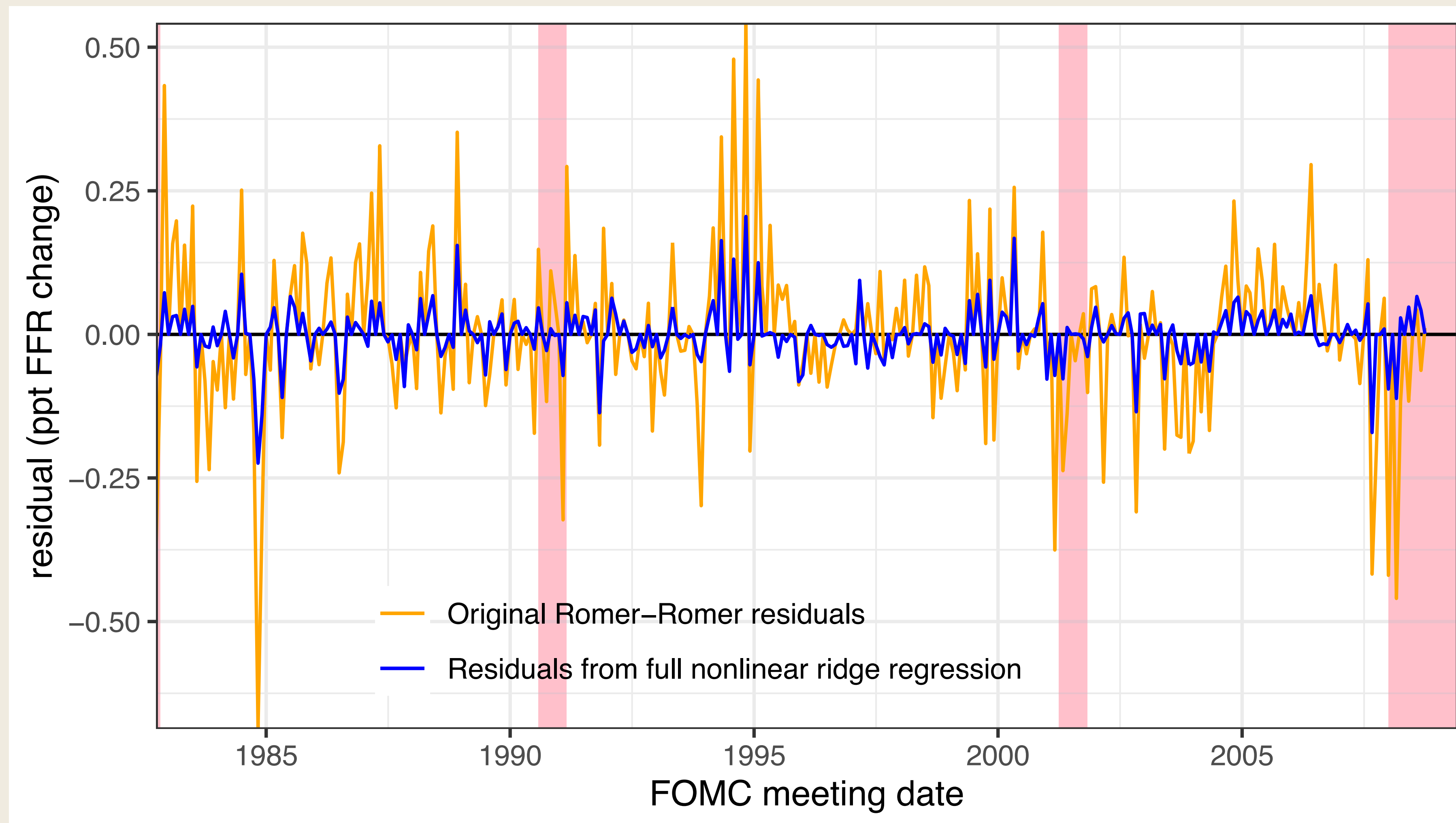
- Goal:  
Isolate policy changes for reasons unrelated to current/prospective economic activity
- Consider the following regression:

$$\Delta i_t = \mathbf{X}_t' \boldsymbol{\gamma} + \epsilon_t$$

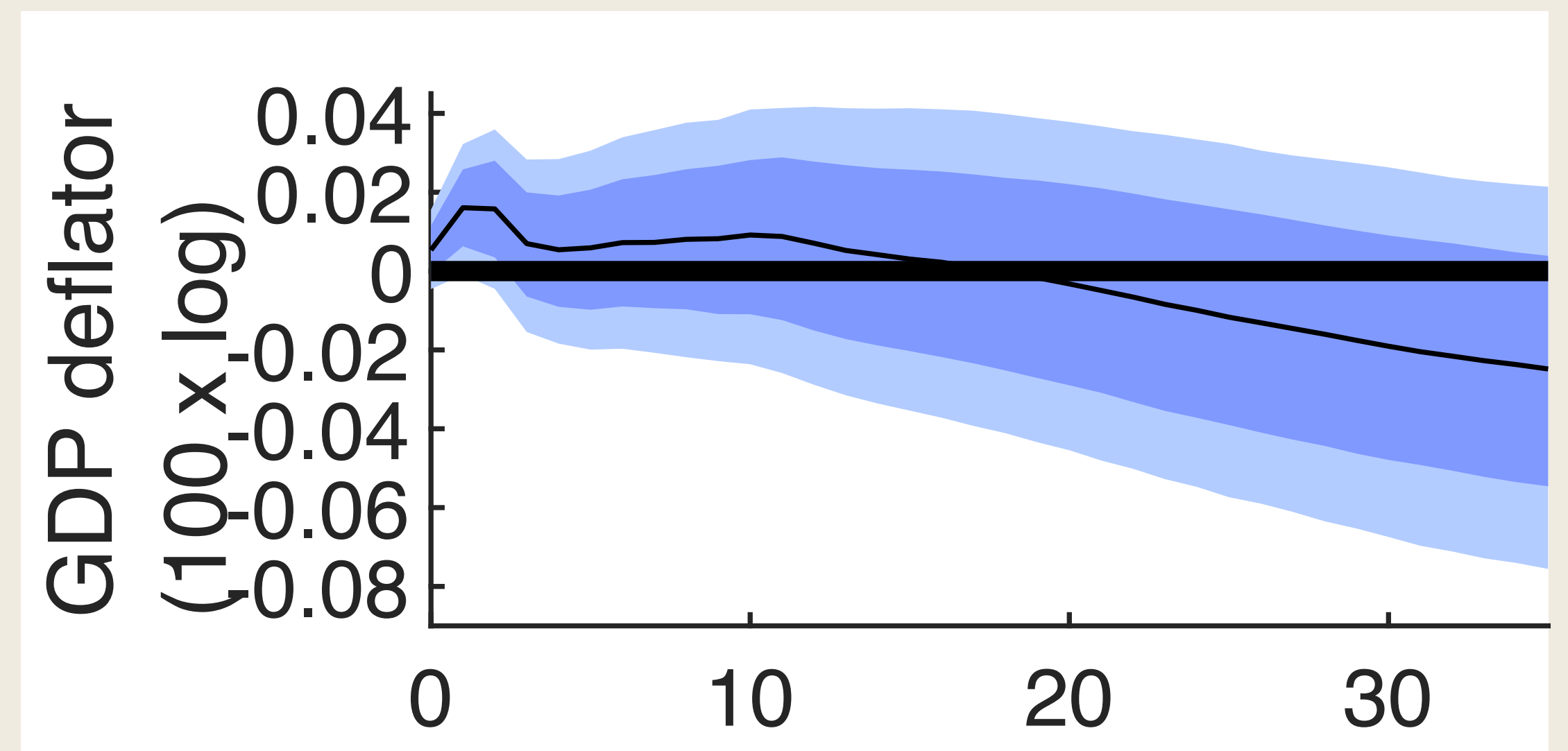
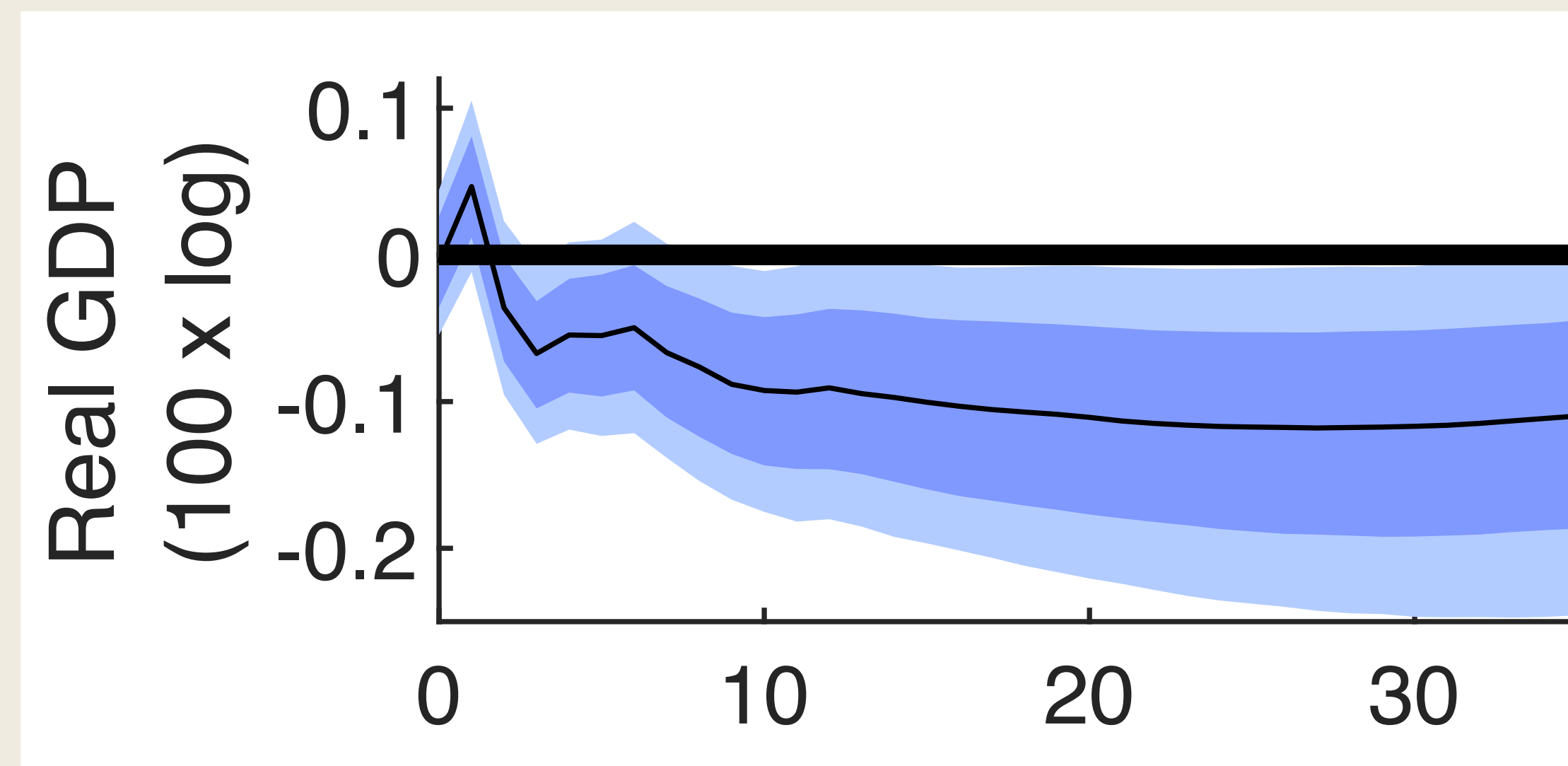
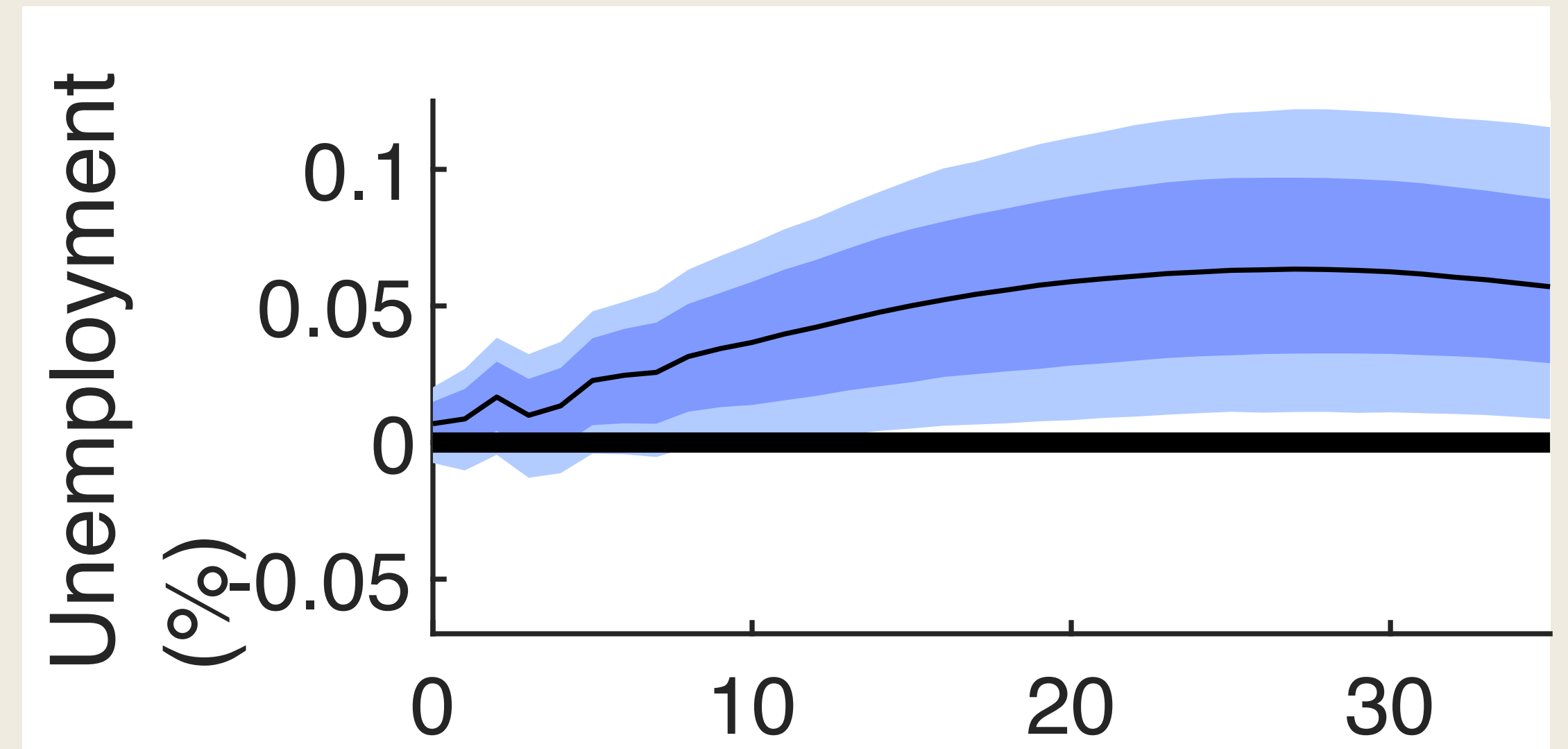
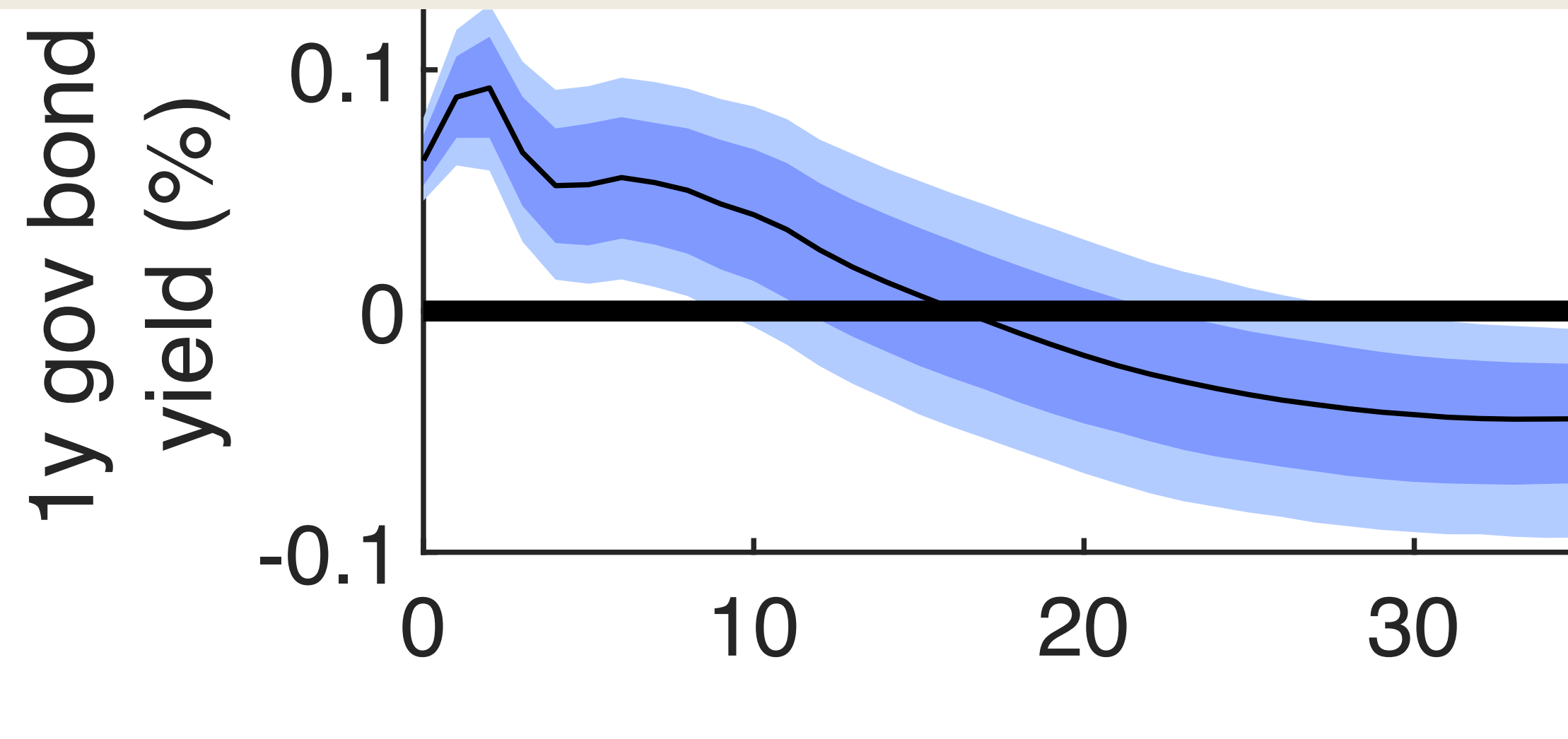
- $\Delta i_t$ : changes in Federal Funds rate (FFR)
  - $\mathbf{X}_t$ : FOMC members' forecasts or sentiments about economic activity (from FOMC meeting documents)
  - $\epsilon_t$ : changes in FFR for reasons unrelated to FOMC members' forecasts/sentiments
- We now treat the OLS residual  $\epsilon_t$  as monetary policy "shocks"
    - What are they?
      - Changes in FOMC members' tastes/goals/beliefs/moods/politics/objectives

# Monetary Policy Shock

Figure 4: ESTIMATED MONETARY POLICY SHOCKS

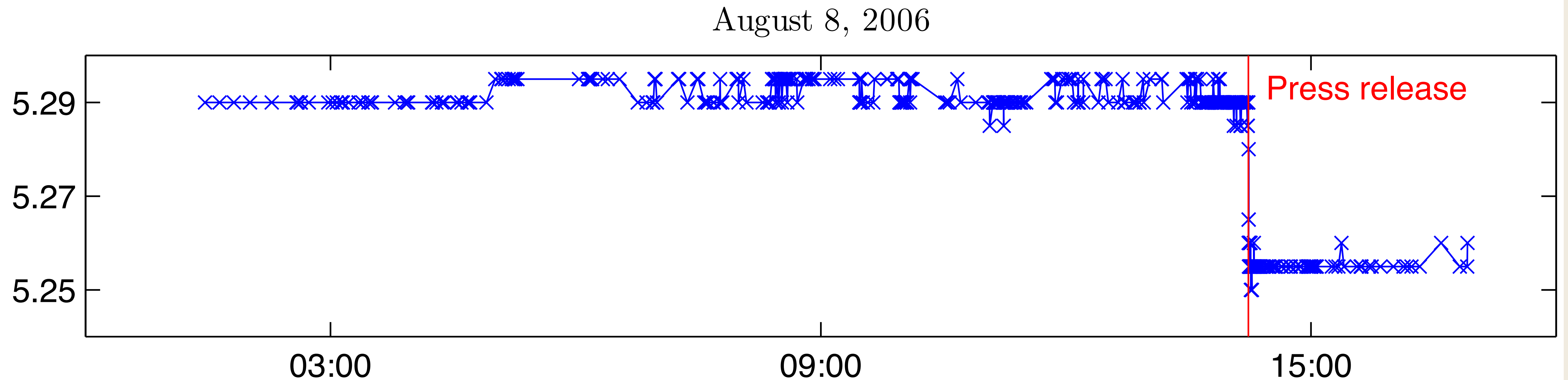


# Response of Macro Variables



# 3. High-Frequency Identification

Figure 2: Intraday Trading in Globex Federal Funds Futures



Source: Gorodnichenko and Weber (2015)

---

# 3. High-Frequency Identification

- Focus on 30-minutes window surrounding the FOMC announcements
- Extract changes in FFR during the 30-minutes time interval,  $\Delta i_t$ 
  - Changes in FFR unexpected by market participants
- Why is this monetary policy “shock”?
  - Nothing else other than FOMC announcements happen during the time interval
  - Not a response to changes in the economic activity
- Nakmaura-Steinsson (2018) ask: Does  $\Delta i_t$  impact the real interest rate,  $r_t$ ?
  - In RBC, the answer is profound no

# Impact on Real Rate

$$\Delta y_t = \beta \Delta i_t + \epsilon_t$$

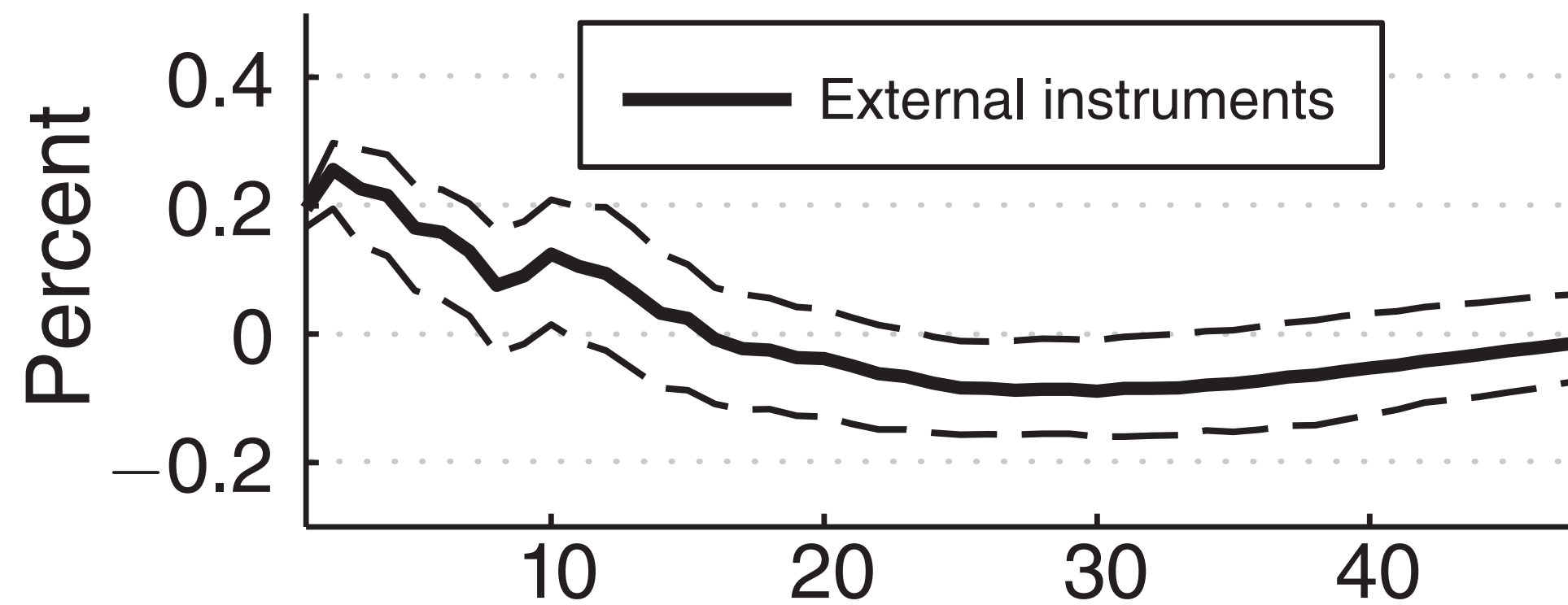
TABLE I  
RESPONSE OF INTEREST RATES AND INFLATION TO THE POLICY NEWS SHOCK

	Nominal	Real	Inflation
3M Treasury yield	0.67 (0.14)		
6M Treasury yield	0.85 (0.11)		
1Y Treasury yield	1.00 (0.14)		
2Y Treasury yield	1.10 (0.33)	1.06 (0.24)	0.04 (0.18)
3Y Treasury yield	1.06 (0.36)	1.02 (0.25)	0.04 (0.17)
5Y Treasury yield	0.73 (0.20)	0.64 (0.15)	0.09 (0.11)
10Y Treasury yield	0.38 (0.17)	0.44 (0.13)	-0.06 (0.08)
2Y Treasury inst. forward rate	1.14 (0.46)	0.99 (0.29)	0.15 (0.23)
3Y Treasury inst. forward rate	0.82 (0.43)	0.88 (0.32)	-0.06 (0.15)
5Y Treasury inst. forward rate	0.26 (0.19)	0.47 (0.17)	-0.21 (0.08)
10Y Treasury inst. forward rate	-0.08 (0.18)	0.12 (0.12)	-0.20 (0.09)

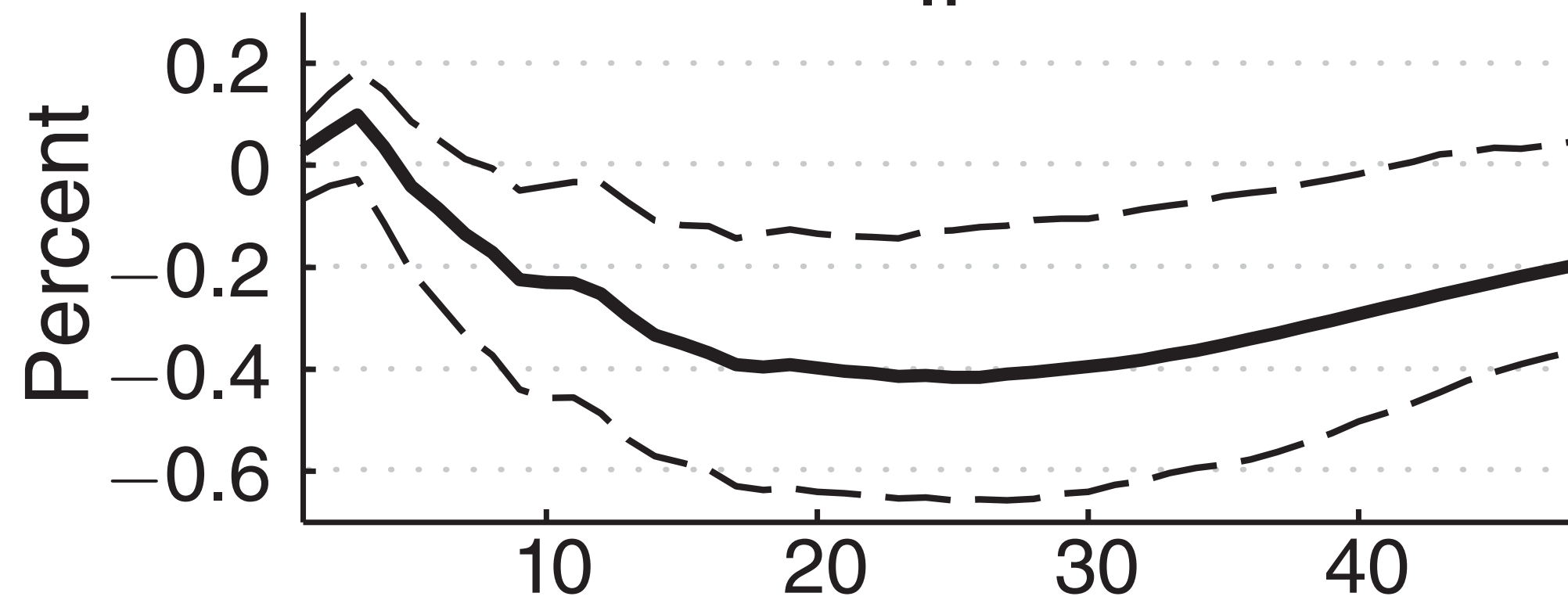
# Impact of High-Frequency Shocks on Macro

- Geterler-Karadi (2015) use similar shock to investigate the impact on macro

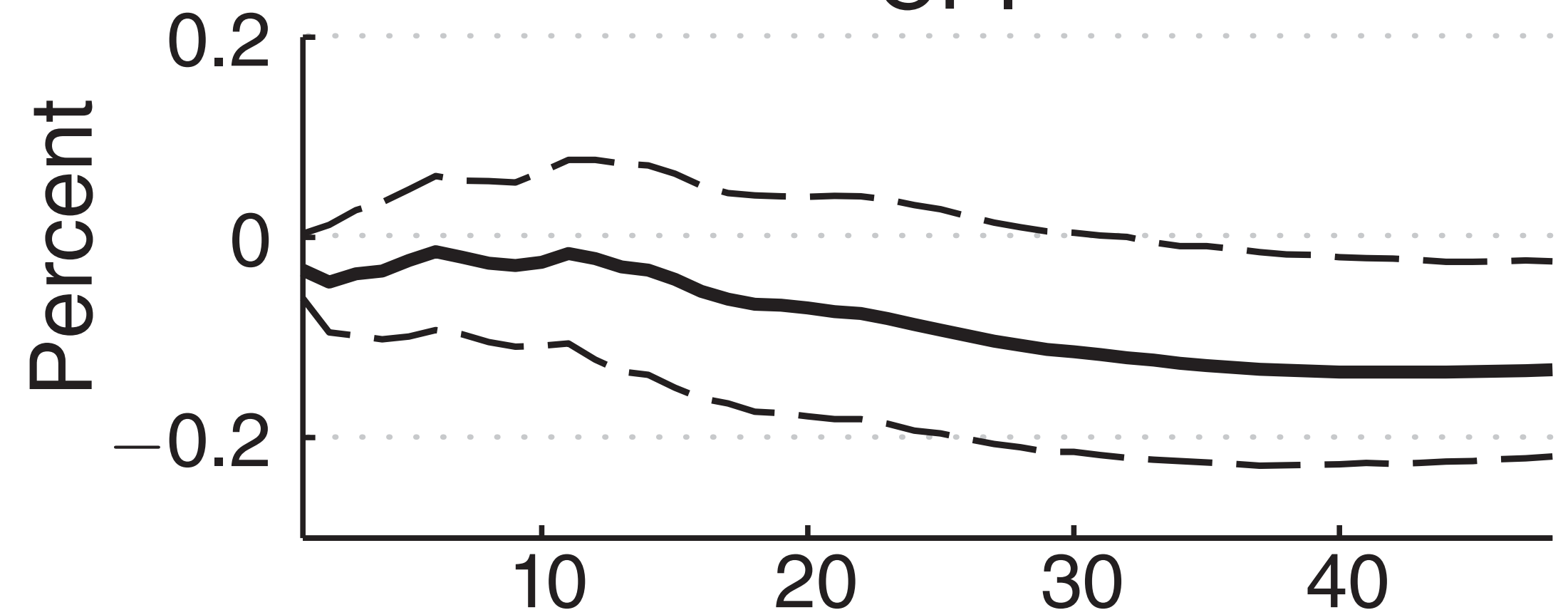
One-year rate



IP



CPI



---

# Takeaway

- Monetary policy is highly endogenous to economic activity
  - If it weren't, our society would be in deep trouble
- Various attempts to isolate monetary policy "shocks"
- Although none of them is a true "shock", we reach robust conclusions
- If monetary policy tightens:
  - unemployment rises
  - output falls
  - price level tends to fall
  - real interest rate rises
- Monetary policy is not neutral – a rejection of RBC model

---

# Source of Monetary Non-Neutrality

---

# Sticky Prices

- We have seen, empirically, that monetary policy is not neutral
- Why?
- Many believe the core underlying reason is price/wage stickiness
- Unlike RBC model, prices do not immediately adjust to keep the real rate constant

# Prices Do Not Adjust Everyday



## Maruchan - Seimen Japanese Instant Ramen Noodles Soy Sauce Taste 18.5oz (For 5 Bowls)

by Maruchan

4.5 ★★★★★ 255 ratings

"fresh noodles -- the soy-sauce-flavor soup suitable for vegetables whose flavor of the sweet herb was effective against inside thick noodle of the smooth texture by a process while it had been nice."

[Report an issue with this product or seller](#)



**100% Real Mushrooms for Natural Immune Support**  
Lions Mane Mushroom...

**10% off** Ends in 03:08

**\$26.99** ~~\$29.99~~



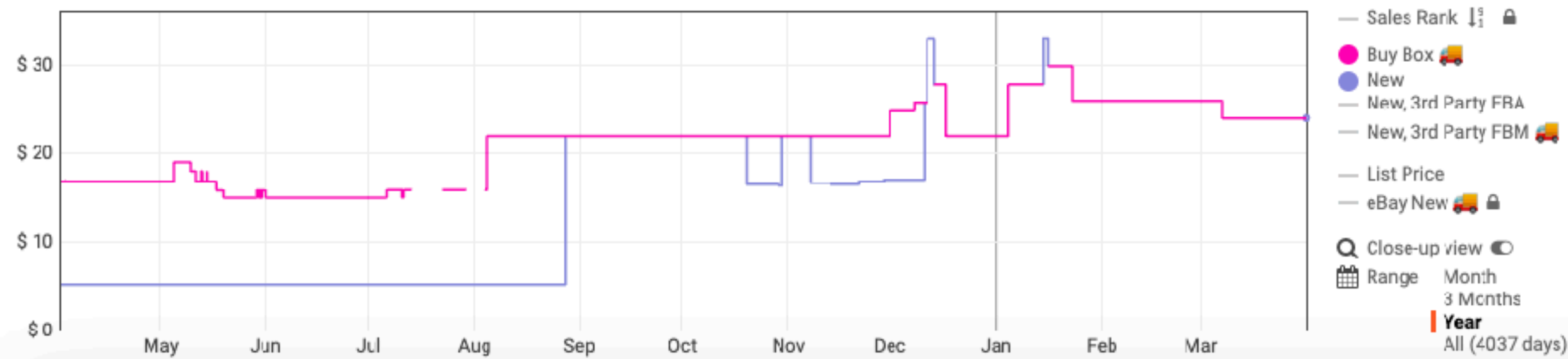
Sponsored

Click image to open expanded view



Price history Track product Data Earn Money Settings → [ebay](#)

[Keapa Box](#) [News](#) [Support](#) [Manage Price Watches](#) [Product Finder](#) [Find related Deals](#) [Related Best Sellers](#) [Log In / Register](#)



Select area to zoom in. Double-click to reset. = shipping included

Buy new: **\$24.00**  
Typical price: ~~\$26.00~~  
Save: \$2.00 (8%)

Two-Day

FREE delivery **Tuesday**. Order within **24 mins**

Deliver to Masao - Brookline 02446

**Only 12 left in stock - order soon.**

Quantity: 1

Add to Cart

Buy Now

Ships from Amazon  
Sold by Mayuko shop  
Returns Non-returnable due to food safety reasons  
Payment Secure transaction  
[See more](#)

Add a gift receipt for easy returns

Add to List

New (4) from **\$24.00**

**Other Sellers on Amazon**  
**\$27.54** (\$1.49 / ounce) [Add to Cart](#)  
Sold by: BRUT Company

# Price Stickiness

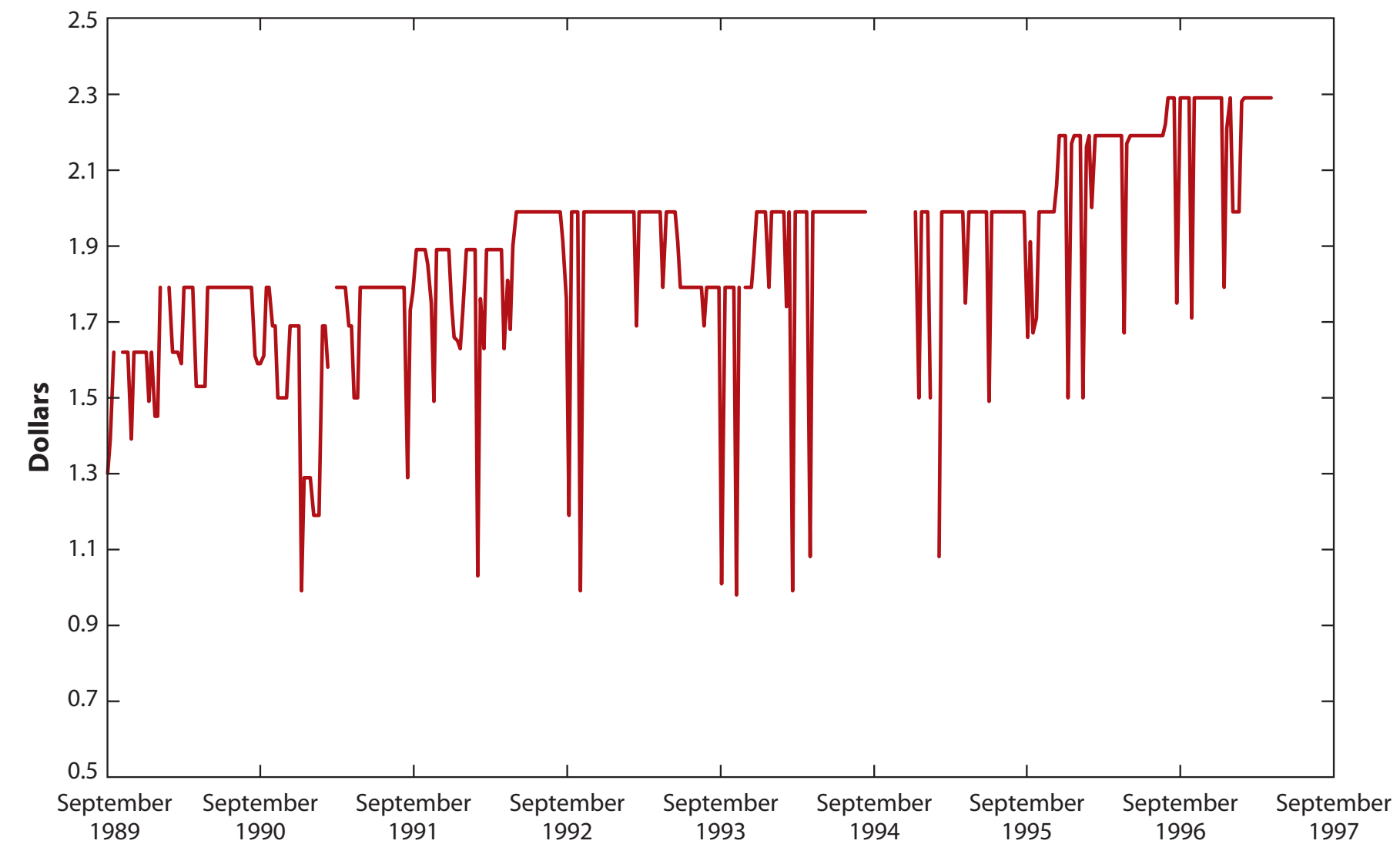


Figure 2

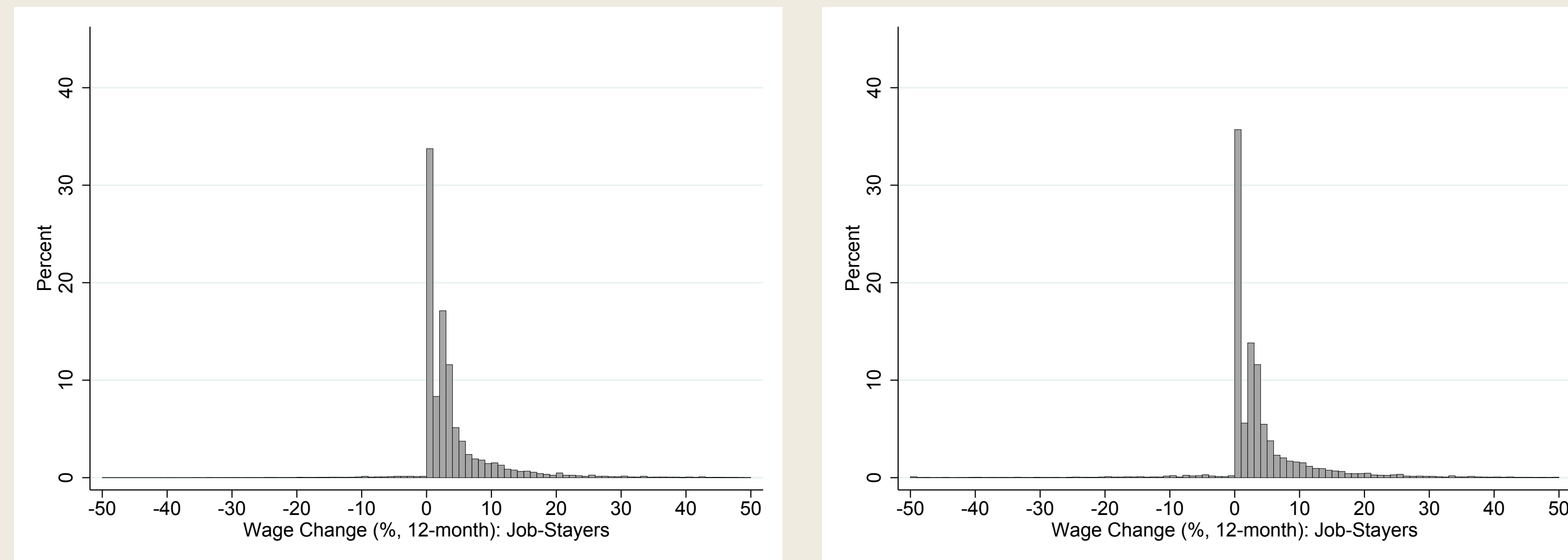
Price series of Nabisco Premium Saltines (16 oz) at a Dominick's Finer Foods store in Chicago.

- Nakamura & Steinsson (2008) analyze microdata underlying CPI
- The median frequency of price changes is
  - 9-12% per month excluding sales
  - 19-20% per month including sales

# Wage Stickiness

- Grigsby, Hurst, Yildirmaz (2021):  
Analyze payroll data of the largest U.S. payroll processing company
- Base nominal wages are sticky:
  - 35% of workers do not experience base wage changes year over year
  - Almost no worker receives nominal wage cut

Figure 2: 12-Month Nominal Base Wage Change Distribution, Job-Stayers



PANEL A: HOURLY WORKERS

PANEL B: SALARIED WORKERS

---

# Monopolistic Retailer

---

# Goal

- Want a model that is jointly consistent with
  1. Monetary non-neutrality
  2. Sticky prices
- We will extend the RBC model by incorporating 2 and show that it implies 1

---

# Moving Away from Perfect Competition

- Just introducing price stickiness into the RBC model will not behave well
  1. If two firms charge different prices, no one will buy a more expensive product
  2. No firm can set prices. Not able to think about the price-setting of firms
- We therefore need to depart from a perfectly competitive product market

---

# Monopoly Power

- Consider a continuum of symmetric retailers,  $j \in [0,1]$
- Assume each retailer  $j$  faces the following demand curve

$$y_t(j) = \left( \frac{P_t(j)}{P_t} \right)^{-\eta} Y_t$$

- $P_t(j)$ : the price of retailer  $j$ 's product
  - $P_t$ : average of all retailers' prices
  - $\eta$ : how much demand goes down if I over-price relative to the average (demand elasticity)
  - $Y_t$ : aggregate demand
- The perfectly competitive environment can be thought of as  $\eta \rightarrow \infty$

---

# Monopolist Retailer's Problem

- Retailers buy wholesale products at price  $p_t$  and sell them to customers
- Taking  $P_t$  and  $p_t$  as given, each retailer solves

$$\max_{p_t(j), y_t(j)} P_t(j)y_t(j) - p_t y_t(j) \quad \text{subject to} \quad y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\eta} Y_t$$

- The first-order condition is

$$P_t(j) = p_t + P_t(j) \frac{1}{\eta}$$

- LHS: benefit of producing one more unit
- RHS: cost of producing one more unit
  - The marginal cost is  $p_t$
  - Producing more lowers the price by  $1/\eta$  percent

---

# Optimal Pricing

## ■ Rearranging

$$P_t(j) = \underbrace{\frac{\eta}{\eta - 1}}_{\text{Markup}} \times \underbrace{p_t}_{\text{Marginal Cost}}$$

- If  $\eta = \infty$ , prices are equal to the marginal cost (as in competitive models)
- Lower  $\eta$  implies firms charge higher markup and earn higher profits

---

# RBC + Monopolist Retailers

---

# Putting into General

- We embed the above mechanism into the RBC model
- The economy now consists of three types of agents
  1. Households (nearly identical to RBC)
  2. Wholesale firms
  3. Retailers: buy wholesale goods and sell them to households and firms
- We still have flexible price

---

# Households

- Households purchase consumption goods from all retailers
- The price they pay per unit consumption is  $P_t$  (the average price retailers charge)
- Households solve

$$\max_{C_0, C_1, A_0, l_0} u(C_0) - v(l_0) + \beta u(C_1)$$

subject to

$$P_0 C_0 + A_0 = W_0 l_0 + D_0$$

$$P_1 C_1 = (1 + i)A_0 + W_1 l_1 + D_1$$

---

# Firms

- Firms sell their own product at the wholesale price  $p_t$

$$\max_{L_0, L_1} D_0 + \frac{1}{1+i} D_1$$

subject to

$$D_0 = p_0 A_0 L_0 - W_0 L_0$$

$$D_1 = p_1 A_1 L_1 - W_1 L_1$$

---

# Retailers

- Continuum of retailers  $j \in [0,1]$
- They buy wholesale goods from firms and sell it to households

$$\max_{p_t(j), y_t(j)} P_t(j)y_t(j) - p_t y_t(j) \quad \text{subject to} \quad y_t(j) = \left( \frac{P_t(j)}{P_t} \right)^{-\eta} Y_t$$

- The market clearings are

$$C_0 = A_0 L_0$$

$$C_1 = A_1 L_1$$

$$l_0 = L_0$$

$$l_1 = L_1$$

---

# Optimal Pricing

- As before, the price of retailer  $j$  is

$$P_t(j) = \underbrace{\frac{\eta}{\eta - 1}}_{\text{Markup}} \times \underbrace{p_t}_{\text{Marginal Cost}}$$

- Since all retailers are symmetric and prices are flexible,

$$P_t = \frac{\eta}{\eta - 1} p_t$$

---

# Optimality Conditions

- Household labor supply is

$$u'(C_0) \frac{W_0}{P_0} = v'(L_0)$$

- Euler equation is

$$u'(C_0) = \beta(1 + i) \frac{P_0}{P_1} u'(C_1)$$

- Firm's labor demand curve:

$$A_t = \frac{W_t}{P_t}$$

- Retailer's price setting

$$P_t = \frac{\eta}{\eta - 1} p_t$$

---

# Optimality Conditions

- Using  $1 + r = (1 + i)\frac{P_0}{P_1}$ , we can rewrite the previous conditions as follows

$$u'(C_0)A_0 \left( 1 - \frac{1}{\eta} \right) = v'(L_0)$$

$$u'(C_t) = \beta(1 + r)u'(C_{t+1})$$

- The only modification from RBC model is the red parts (inverse of markup)
  - Monopoly power implies that extra production is costly. It lowers the price by  $-1/\eta$
  - This lowers both MPL

---

# Equilibrium Conditions

- $\{C_0, C_1, r, L_0\}$  solve

$$u'(C_0)A_0 \left( 1 - \frac{1}{\eta} \right) = v'(L_0)$$

$$u'(C_0) = \beta(1 + r)u'(C_1)$$

$$C_0 = A_0L_0$$

$$C_1 = A_1L_1$$

---

# Same as RBC

- At this point, nothing is really different from RBC
- It's just MPL is multiplied by a constant (inverse markup)
- As before,  $i$  never shows up in the eqm conditions, so monetary neutrality holds
- If  $i$  increases,  $P_0$  falls and  $1 + r = (1 + i) \frac{P_0}{\bar{P}_1}$  remains unchanged

---

# **RBC + Monopolist Retailers + Rigid Prices**

---

# Rigid Prices

- Suppose that retailers' prices at  $t = 0$  are completely rigid

$$P_0 = \bar{P}_0$$

- Prices at  $t = 1$ :

$$P_1 = \frac{\eta}{\eta - 1} p_1 = \bar{P}_1$$

- This implies that changes in  $i$  do affect  $r$ :

$$1 + r = (1 + i) \frac{\bar{P}_0}{\bar{P}_1}$$

# Optimality Conditions

- Household labor supply is

$$u'(C_0) \frac{W_0}{P_0} = v'(L_0)$$

- Euler equation is

$$u'(C_0) = \beta(1+i) \frac{P_0}{P_1} u'(C_1)$$

- Firm's labor demand

$$A_t = \frac{W_t}{P_t}$$

- Retailer's price setting

$$\cancel{P_t = \frac{\eta}{\eta-1} p_t} \quad P_0 = \bar{P}_0, \quad P_1 = \frac{\eta}{\eta-1} p_1 = \bar{P}_1$$

---

# Consumption

- After substituting  $C_1 = A_1 L_1$  and  $u(C) = \frac{C^{1-\sigma}}{1-\sigma}$ 
$$C_0^{-\sigma} = \beta(1+i) \frac{\bar{P}_0}{\bar{P}_1} (A_1 L_1)^{-\sigma}$$
- This equation alone pins down  $C_0$
- If  $i$  goes up,  $C_0$  goes down
- Write this relationship as  $C_0(i)$

---

# Rest of the Equilibrium Conditions

- The goods market clearing condition is

$$C_0(i) = A_0 L_0$$

- This equation alone pins down  $L_0$
- Since  $C_0(i)$  is decreasing,  $L_0$  also decreasing in  $i$
- The economy has less aggregate demand, so we need less labor

- Combining labor supply and labor demand,

$$C_0^{-\sigma} A_0 = \frac{\bar{P}_0}{p_0} \bar{v} L_0^\nu$$

- Given  $C_0$  and  $L_0$  pinned down, the above eq. residually pins down  $p_0$
- Higher  $i$  lowers  $C_0$  and  $L_0$ , and the wholesale price  $p_0$  goes down
- Fluctuations in  $\bar{P}_0/p_0$  resembles fluctuations in  $\bar{v}$  (labor disutility shock)

---

# Summary

- When prices are rigid, monetary policy is no longer neutral
- Higher interest rate  $i$  lowers  $C_0, L_0, Y_0$ , consistent with the evidence
- But we couldn't talk about the response of prices since we assume they are rigid

---

# **RBC + Monopolist Retailers + Sticky Prices**

**– New Keynesian Model**

---

# Sticky Prices

- Suppose that some firms cannot adjust prices in response to monetary policy
- A fraction  $\lambda \in [0,1]$  of retailers' prices at  $t = 0$  are

$$P_0 = \bar{P}_0 = \frac{\eta}{\eta - 1} \bar{p}_0$$

- $\bar{p}_0$ : Wholesale price at  $t = 0$  in the absence of monetary policy changes
- The remaining fraction  $1 - \lambda$  of retailers set prices freely
- Prices at  $t = 1$  are fully flexible

# Sticky Prices

- The firms that adjust prices solve

$$\max_{p_t(j), y_t(j)} P_t(j)y_t(j) - p_t y_t(j) \quad \text{subject to} \quad y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\eta} Y_t$$

resulting in

$$P_t(j) = \frac{\eta}{\eta - 1} p_t$$

- The average price in the economy is

$$\begin{aligned} P_0 &= (1 - \lambda)P_0(j) + \lambda\bar{P}_0 \\ &= (1 - \lambda)\frac{\eta - 1}{\eta} p_0 + \lambda\bar{P}_0 \end{aligned}$$

- Nests both flexible price ( $\lambda = 0$ ) and rigid price ( $\lambda = 1$ )

# Equilibrium Conditions

- Household labor supply is

$$C_0^{-\sigma} \frac{W_0}{P_0} = \bar{v} L_0^\nu$$

- Euler equation is

$$C_0^{-\sigma} = \beta(1+i) \frac{P_0}{P_1} C_1^{-\sigma}$$

- Firm's labor demand

$$A_t = \frac{W_t}{P_t}$$

- Retailer's price setting

$$P_0 = (1-\lambda) \frac{\eta-1}{\eta} p_0 + \lambda \bar{P}_0, \quad P_1 = \frac{\eta}{\eta-1} p_1 = \bar{P}_1$$

- Goods market clearing

$$C_t = A_t L_t$$

---

# Prices

- Combining labor supply, demand, and market clearing

$$\frac{p_0}{P_0} = \frac{1}{(A_0)^{1-\sigma}} \bar{v} L_0^{\nu+\sigma}$$

- Solving for  $p_0$  and substituting into the retailers' pricing equation

$$P_0 = (1 - \lambda) \frac{\eta - 1}{\eta} \frac{1}{(A_0)^{1-\sigma}} \frac{\bar{v}}{1 - \alpha} L_0^{\nu+\sigma} P_0 + \lambda \bar{P}_0$$

- Solving for  $P_0$ ,

$$P_0 = \frac{1}{1 - (1 - \lambda) \frac{\eta - 1}{\eta} \frac{1}{(A_0)^{1-\sigma}} \frac{\bar{v}}{1 - \alpha} L_0^{\nu+\sigma}} \lambda \bar{P}_0 \tag{1}$$

---

# Phillips Curve

$$P_0 = \frac{1}{1 - (1 - \lambda) \frac{\eta - 1}{\eta} \frac{1}{(A_0)^{1-\sigma}} \bar{v} L_0^{\nu+\sigma}} \lambda \bar{P}_0$$

- Assume the denominator is always positive (always true if shocks are not too big)
- Prices are higher if  $L_0$  is higher:  
households are working more  
⇒ wages and the wholesale price goes up  
⇒ retailer's marginal cost goes up
- Such a relationship is called (New Keynesian) Phillips Curve

---

# Aggregate Demand

- The consumption Euler equation is

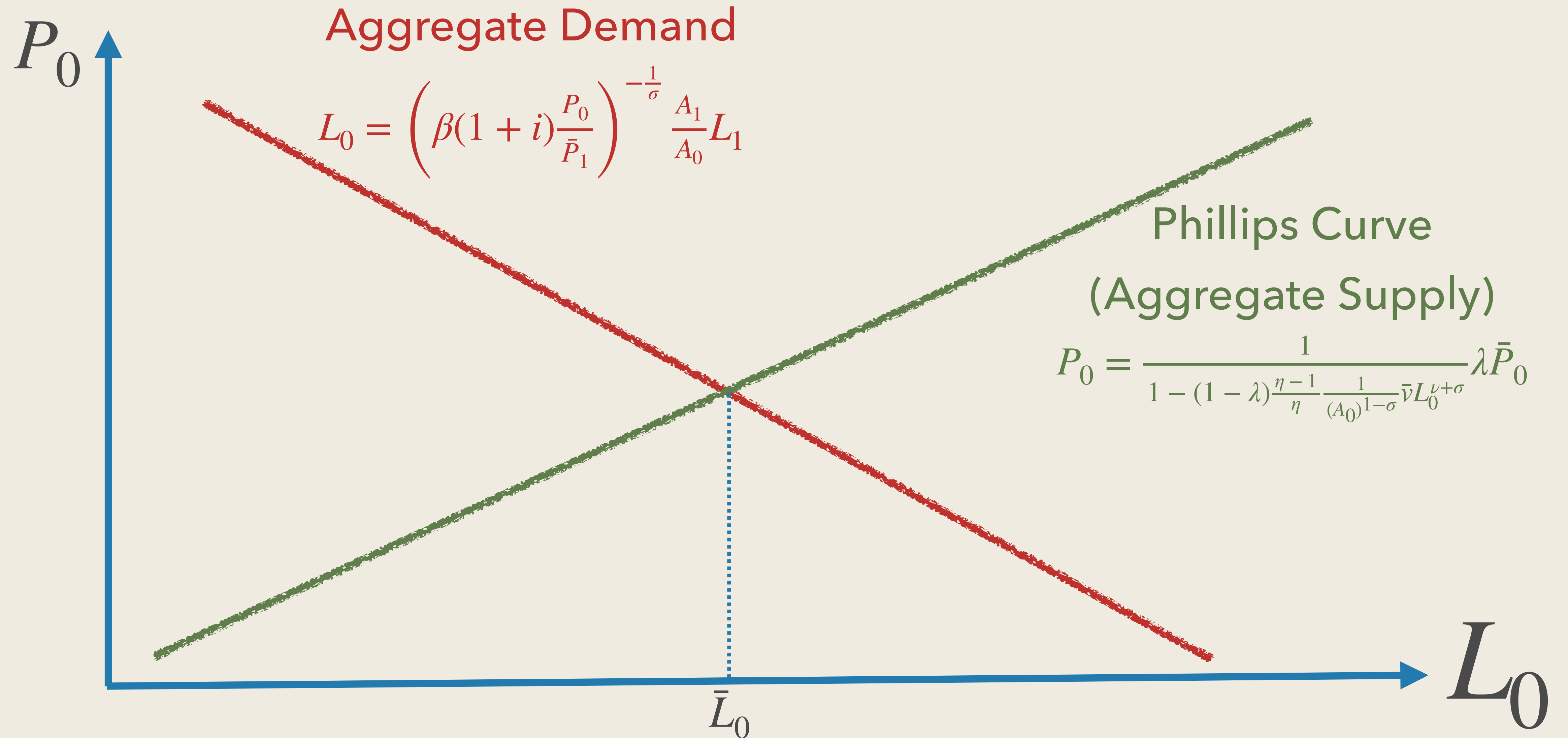
$$C_0^{-\sigma} = \beta(1+i)\frac{P_0}{\bar{P}_1} (A_1 L_1)^{-\sigma}$$

- Given  $P_0$  and  $i$ , the above equation determines  $C_0$
- $C_0$  is decreasing in both  $P_0$  and  $i$
- Solving for  $C_0$  and plug into the goods market clearing ( $C_0 = A_0 L_0$ ) to solve for  $L_0$ :

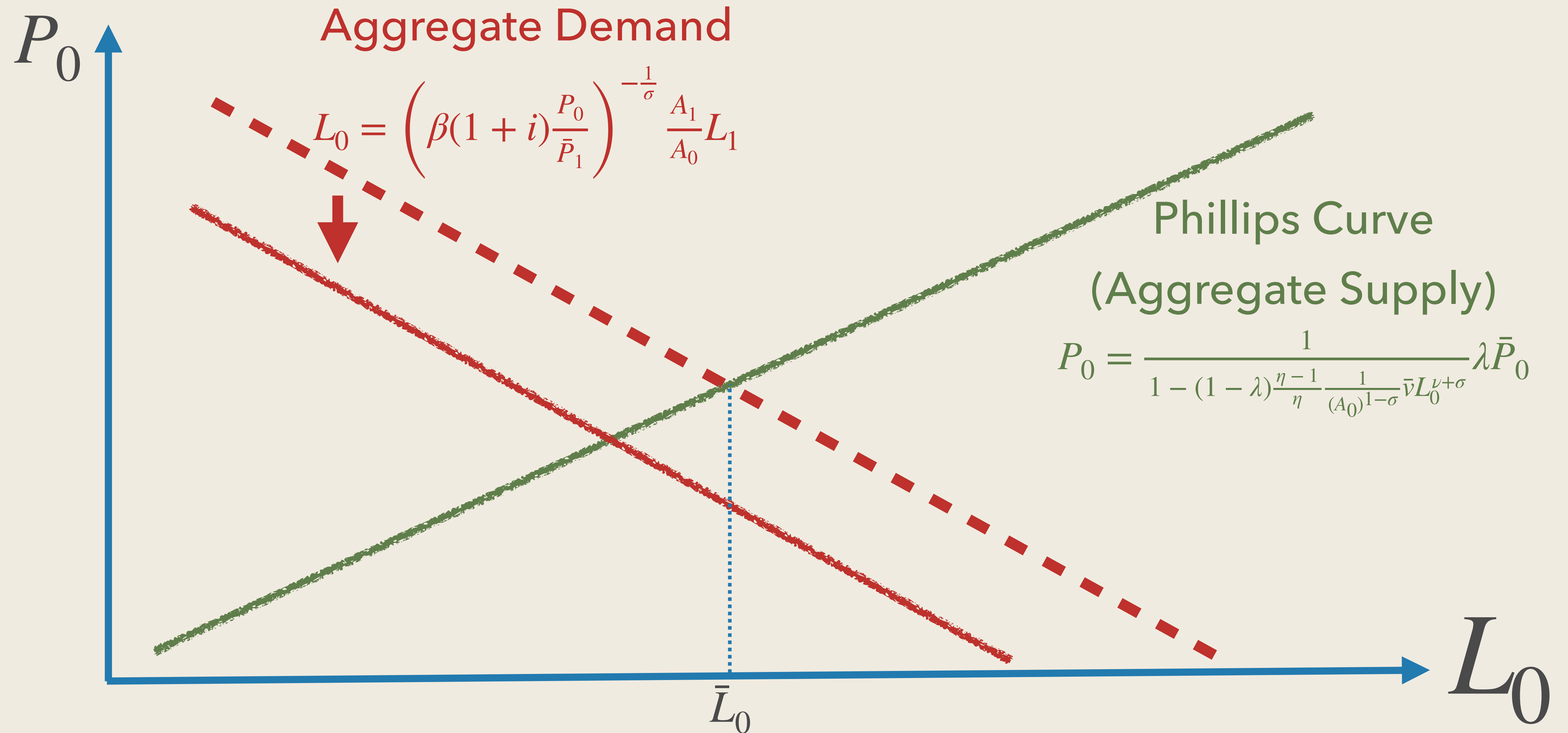
$$L_0 = \left( \beta(1+i)\frac{P_0}{\bar{P}_1} \right)^{-\frac{1}{\sigma}} \frac{A_1}{A_0} L_1$$

- $L_0$  is decreasing in both  $P_0$  and  $i$

# AS-AD Diagram



# Monetary Policy Tightening



---

# Monetary Policy Transmission

- When monetary policy tightens, both  $L_0$  and  $P_0$  go down
- Higher interest rates discourage people from consuming today
- Aggregate demand drops
- Labor demand drops
- Wages and, therefore wholesale price goes down
- This lowers the marginal cost of retailers, and prices tend to go down
- How does this mechanism depend on price stickiness  $\lambda$ ?

---

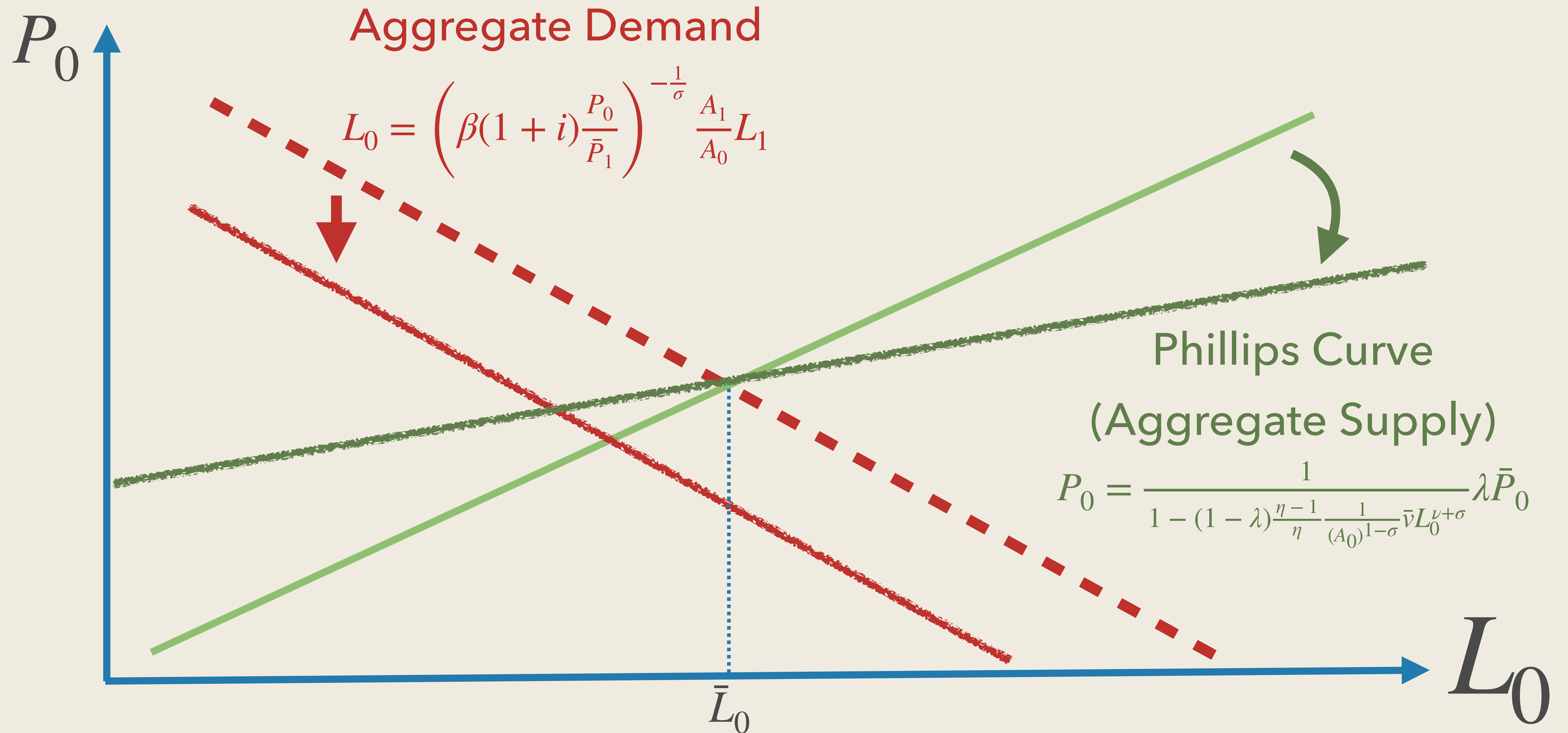
# The Slope of Phillips Curve

- The slope of Phillips curve in the neighborhood of  $L_0 = \bar{L}_0$  is

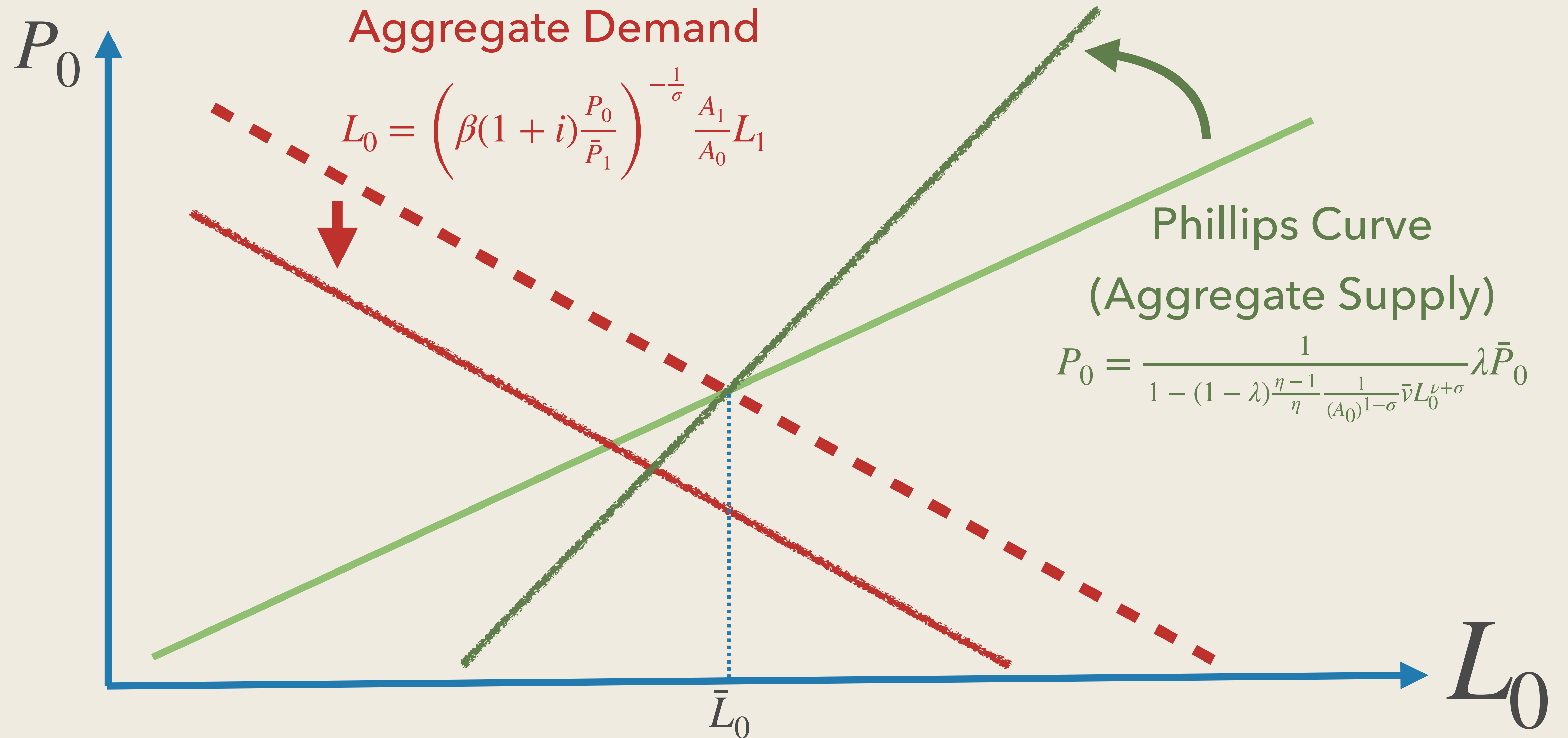
$$\left. \frac{dP_0}{dL_0} \right|_{L_0=\bar{L}_0} = \frac{(1-\lambda)(\nu+\sigma)}{\lambda \bar{L}_0} \bar{P}_0$$

- The slope of Phillips curve is flatter when price stickiness  $\lambda$  is higher
- Conversely, the Phillips curve is steeper when  $\lambda$  is lower

# Higher Price Stickiness $\lambda$



# Lower Price Stickiness $\lambda$



---

# Takeaway

- Introducing price stickiness into the RBC model leads to monetary non-neutrality
- This is called “New Keynesian Model”
- In response to monetary policy tightening,
  1. Consumption, labor, and output all fall
  2. Prices fall
- When prices are stickier, we have more of **1** and less of **2**
- When prices are more flexible, we have more of **2** and less of **1**

---

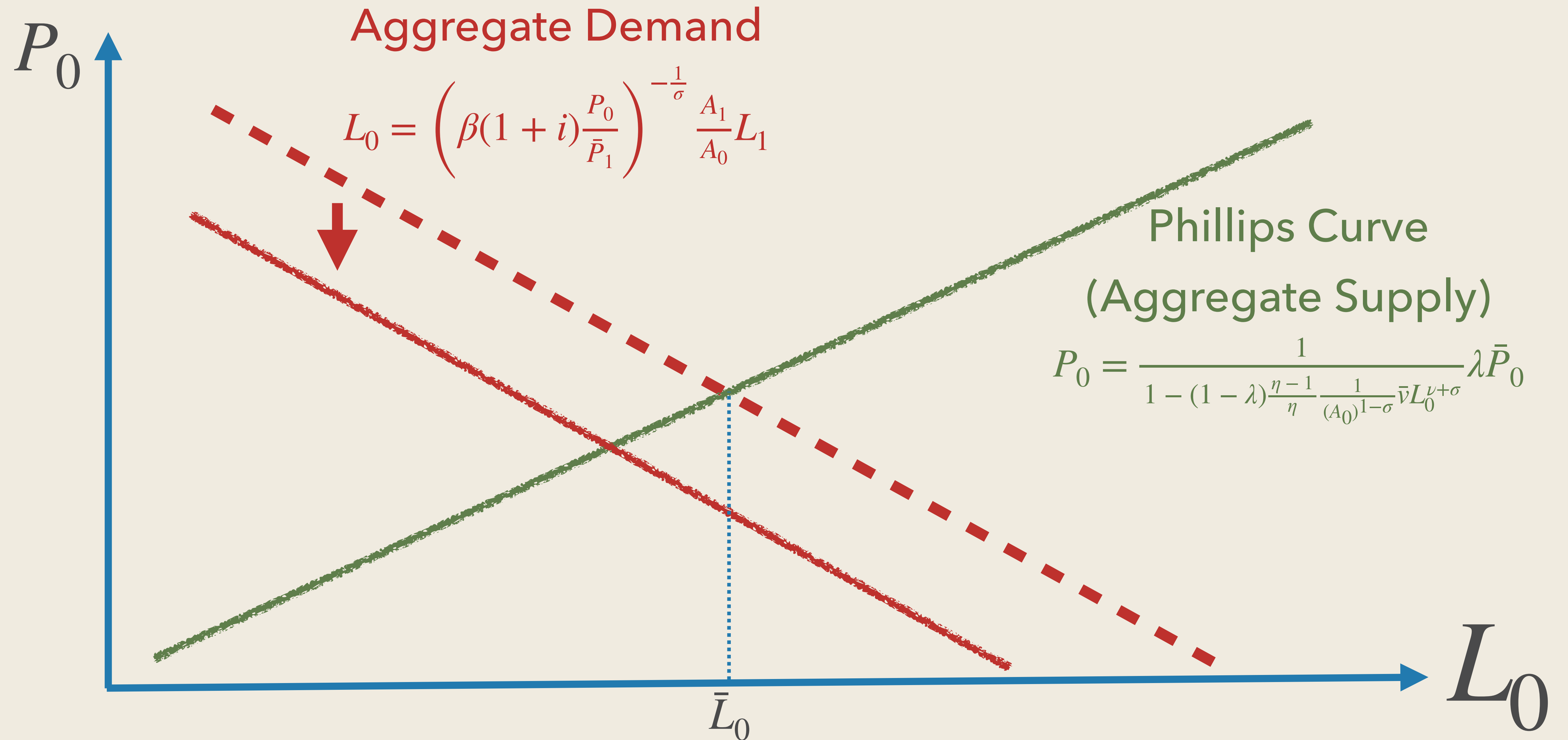
# Sources of Business Cycle Revisited

---

# Business Cycles Revisited

- In the RBC model, we have seen that shocks to  $A_0$  generate business cycles
- In the RBC model, we have seen that shocks to  $\beta$  or  $A_1$  cannot generate comovement
  - $C_0$  and  $L_0$  were moving in the opposite direction
- Let us revisit it with the New Keynesian model

# Increase in $A_0$ when $\sigma = 1$

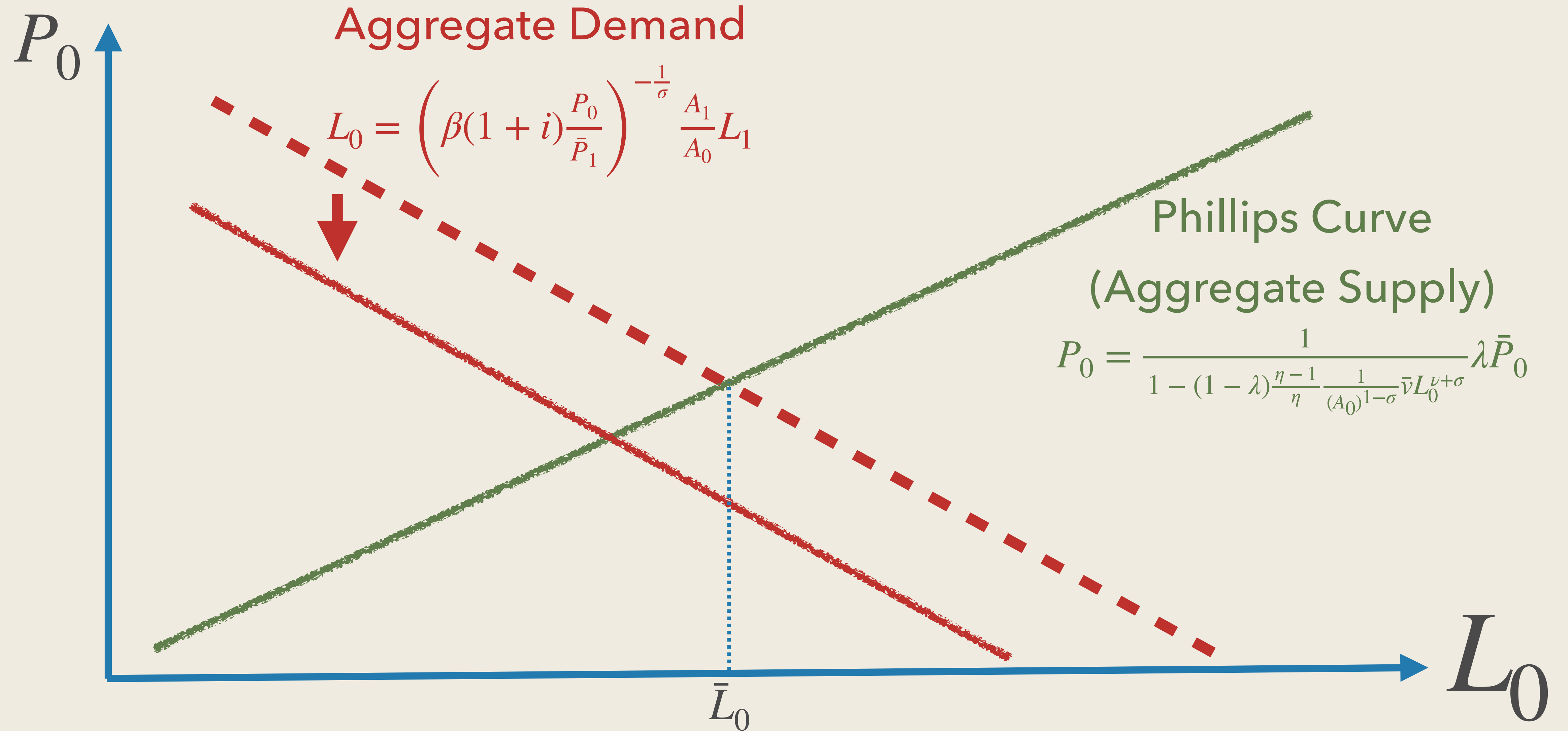


---

# Higher Productivity, Less Employment

- In the RBC model, an increase in  $A_0$  generates a rise in employment
- Now we see a fall in employment
- Why?
- In the NK model without monetary policy response, output is demand-determined
- When  $A_0$  goes up, we need less labor to meet the demand
- Employment falls

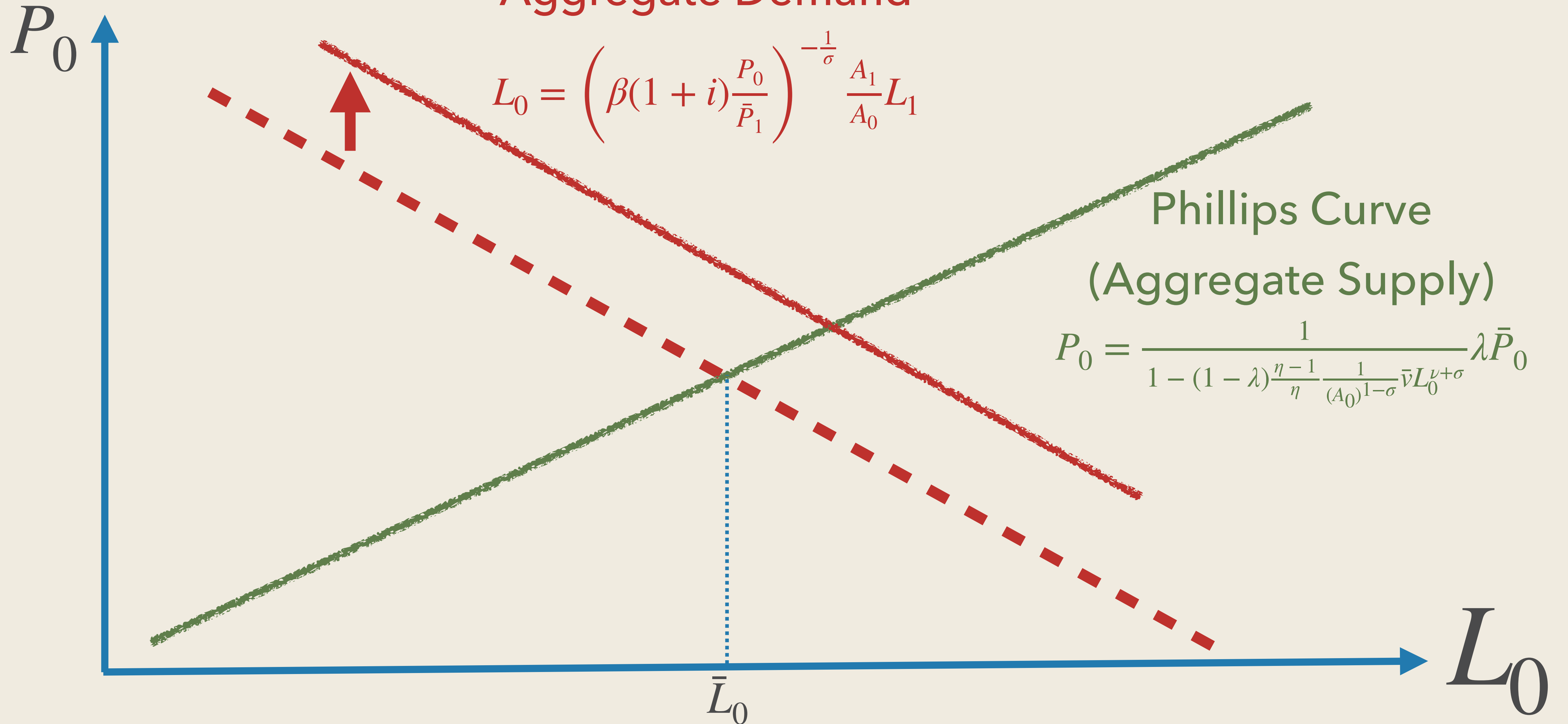
# Increase in $\beta$



# Increase in $A_1$

Aggregate Demand

$$L_0 = \left( \beta(1+i) \frac{P_0}{\bar{P}_1} \right)^{-\frac{1}{\sigma}} \frac{A_1}{A_0} L_1$$

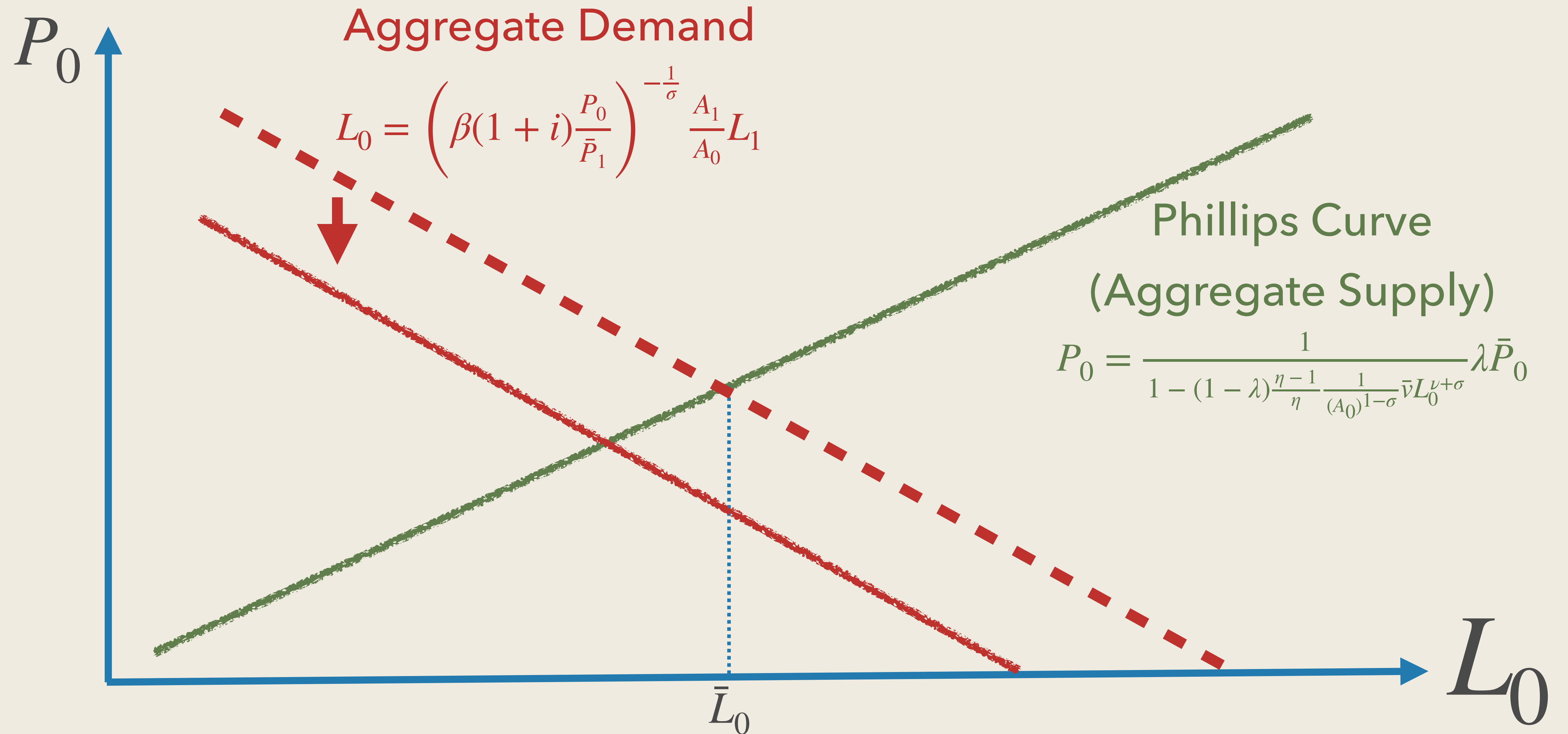


---

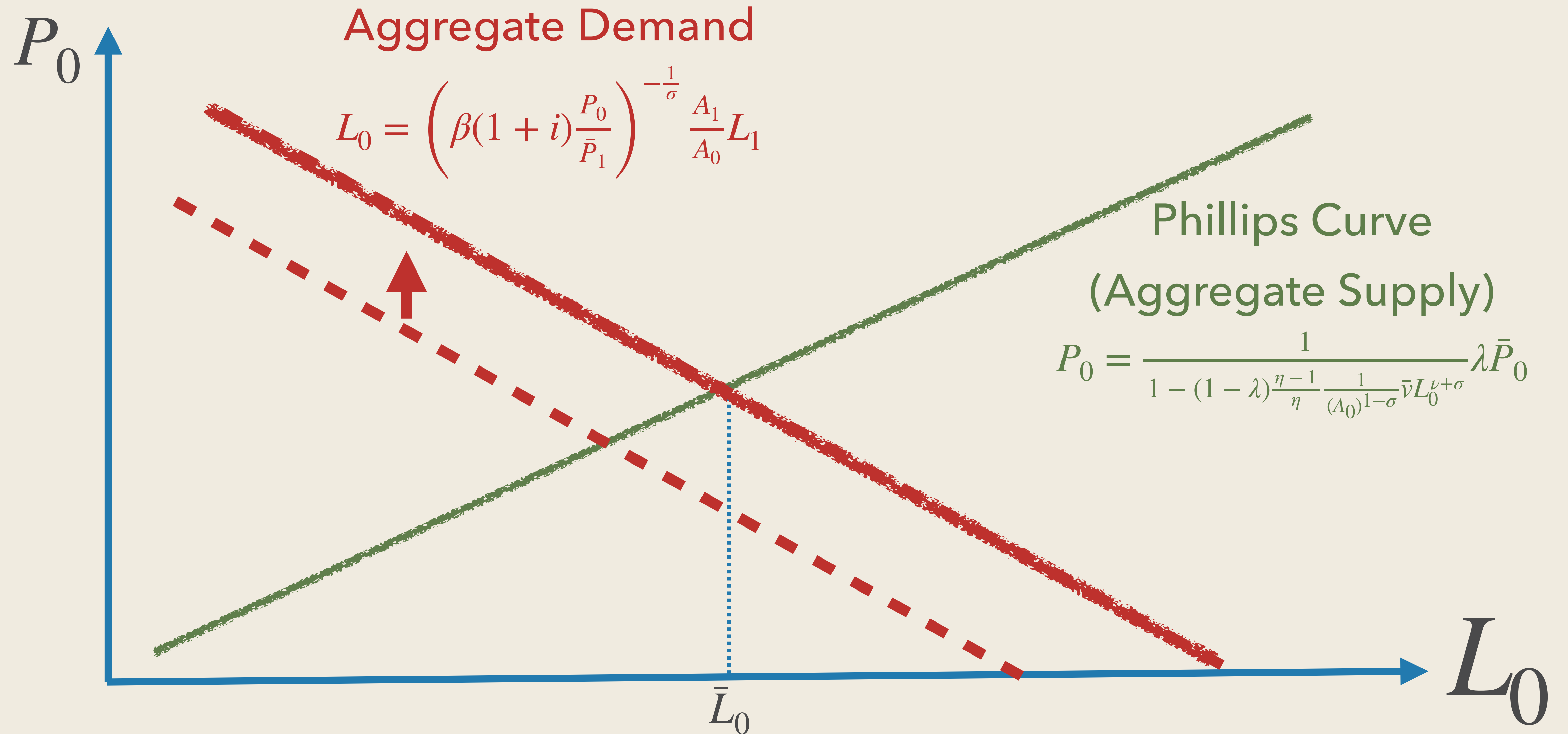
# Right Comovement

- Unlike the RBC model, patience and optimism can generate business cycles
- Why?
- When patience ( $\beta$ ) goes up, households cut spending today
- This lowers aggregate demand
- Under flexible prices, prices drop today so as to sustain aggregate demand
- When prices are sticky, prices cannot drop much, and we have lower employment
- The same mechanism operates for optimism ( $A_1$ )
- Can the Fed fight against such fluctuations?

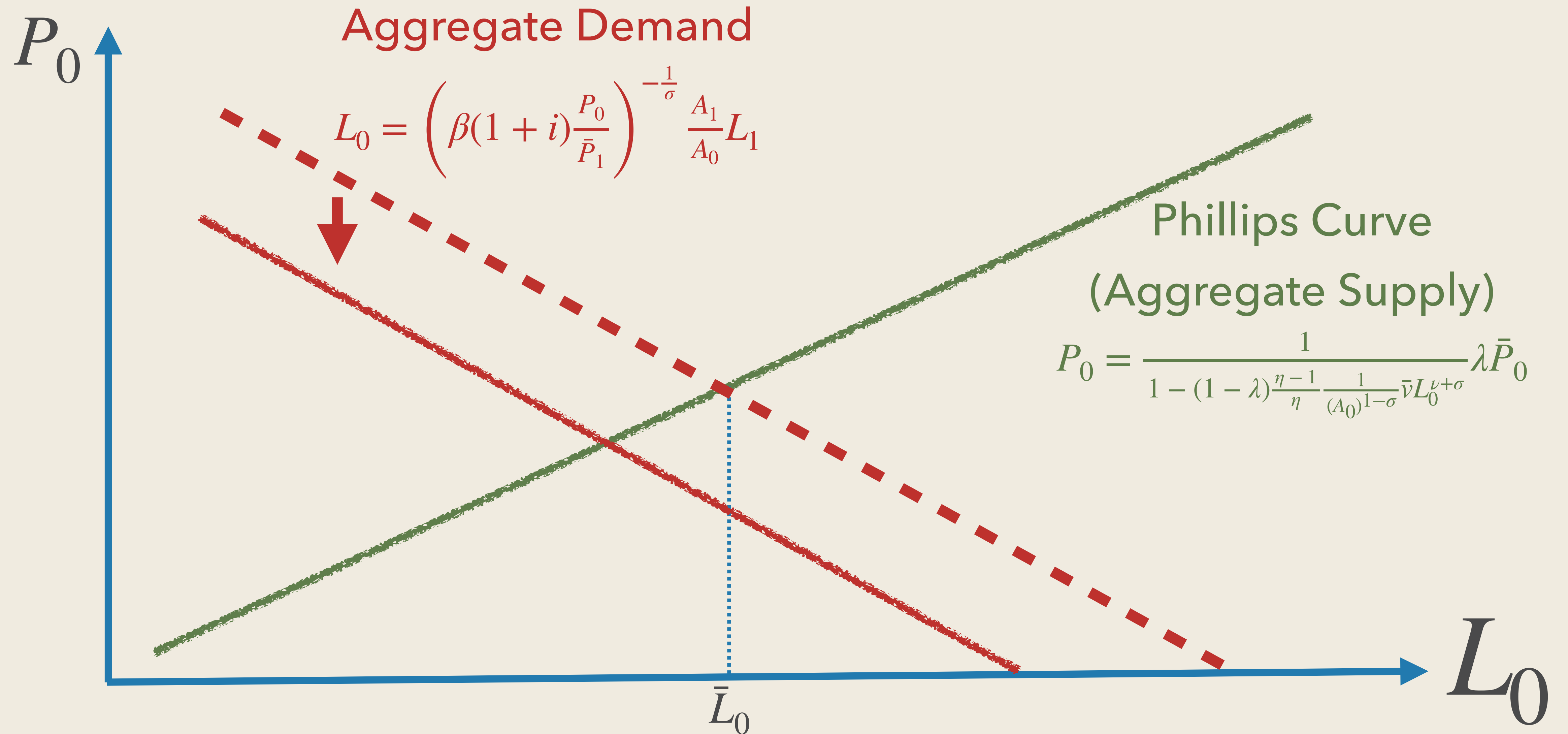
# Monetary Policy Response to Increase in $A_0$



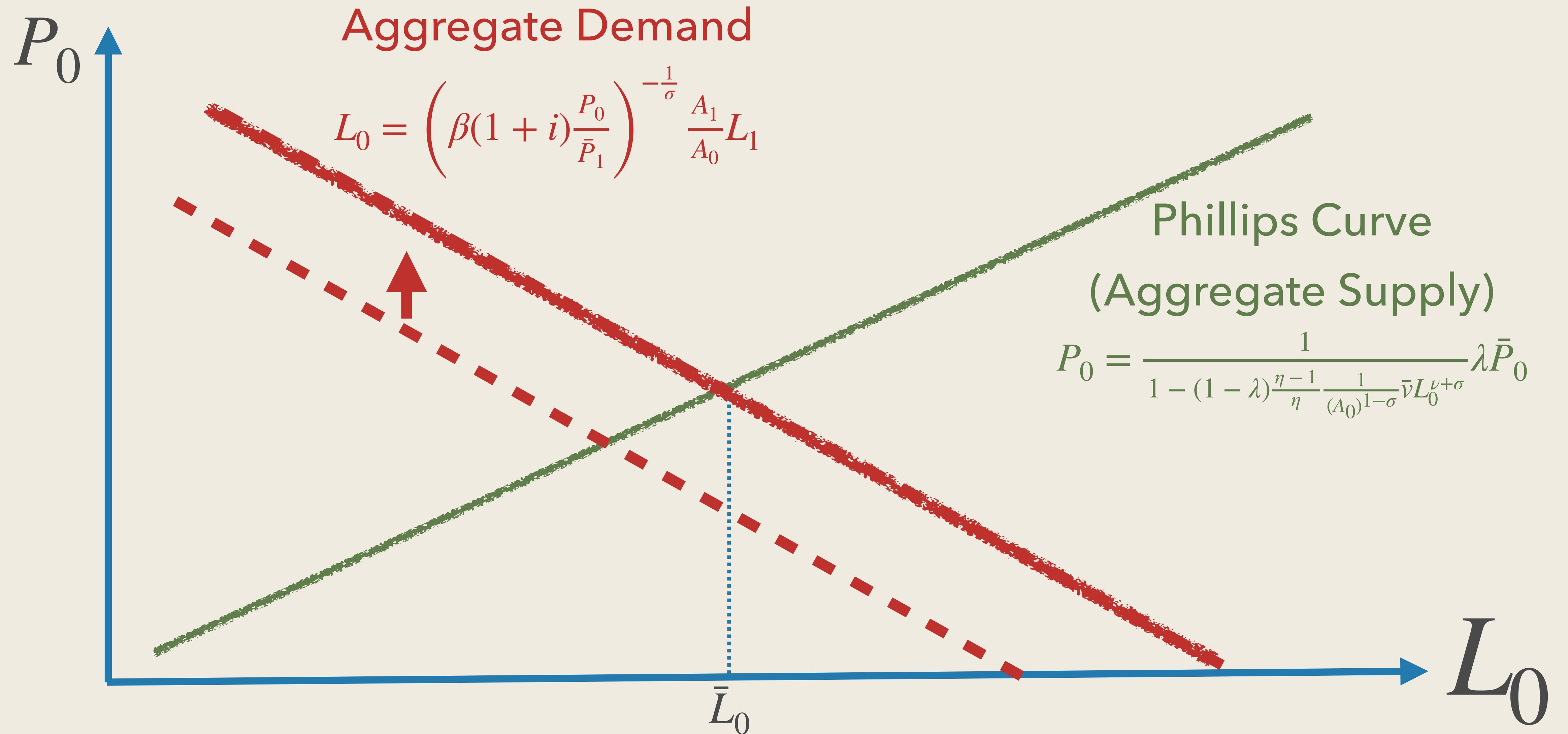
# Monetary Policy Response to Increase in $A_0$



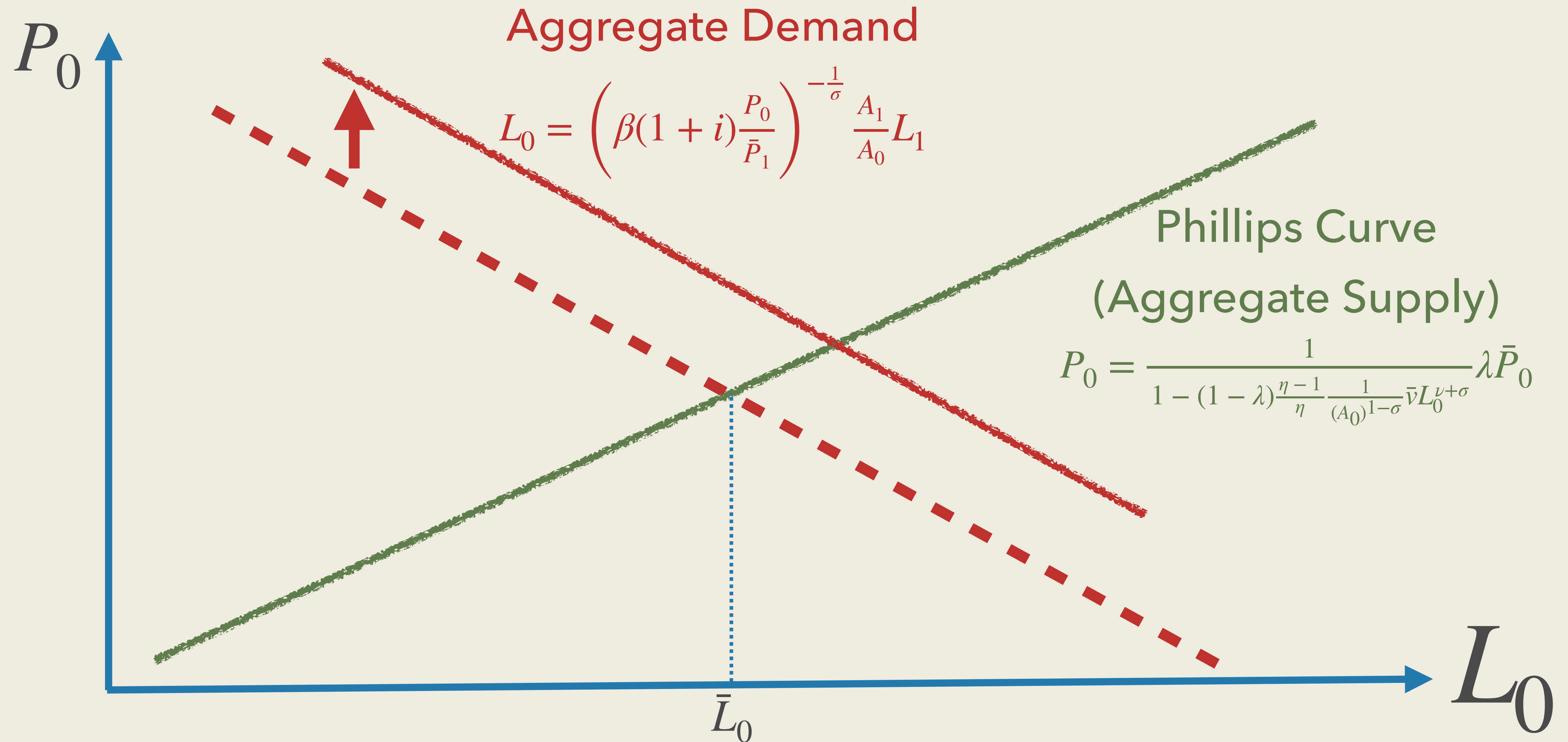
# Monetary Policy Response to Increase in $\beta$



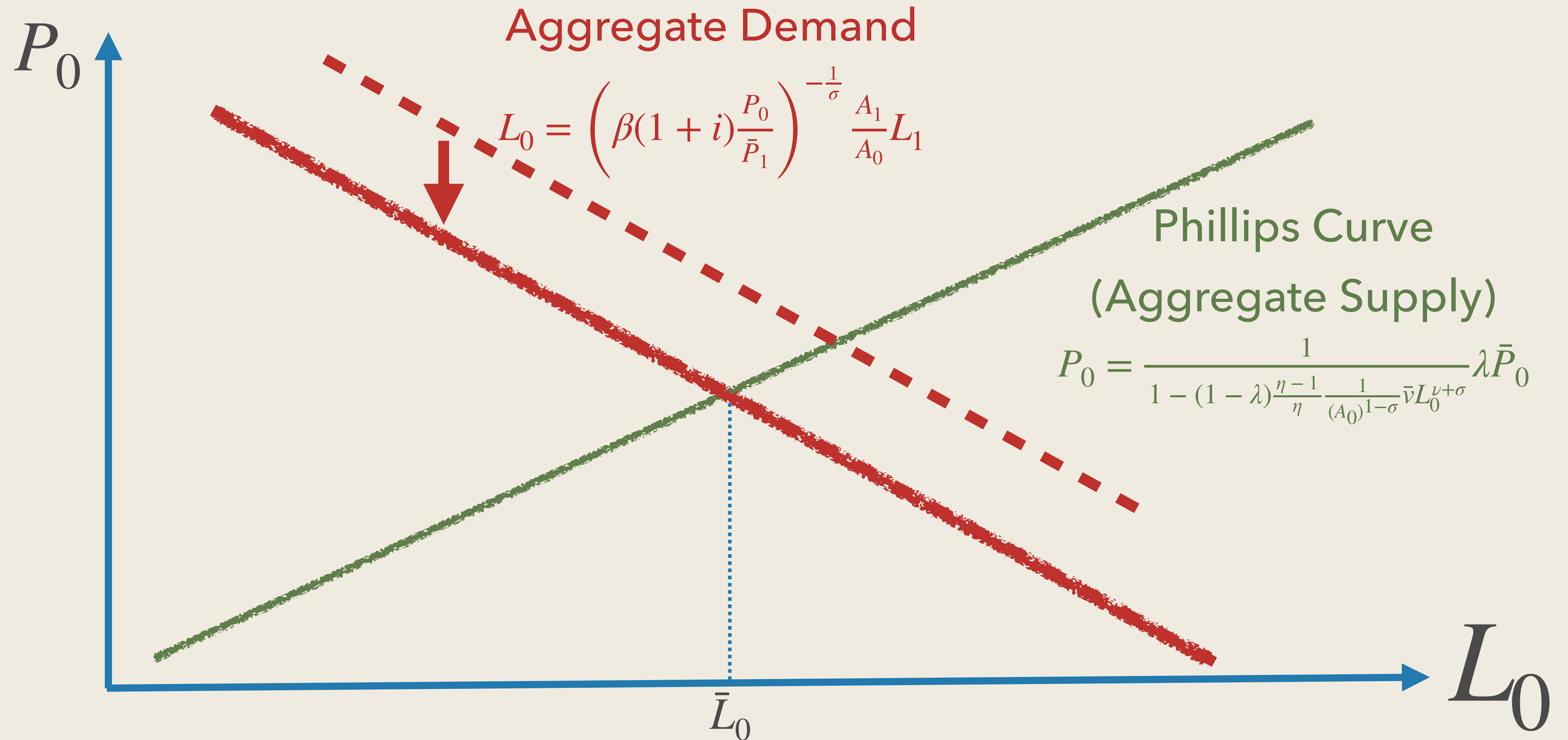
# Monetary Policy Response to Increase in $\beta$



# Monetary Policy Response to Increase in $A_1$



# Monetary Policy Response to Increase in $A_1$



---

# Monetary Policy Responses

- If the Fed lowers the rate appropriately, we avoid recession in response to  $A_0 \uparrow, \beta \uparrow$
- If the Fed raises the rate appropriately, we avoid boom in response to  $A_1 \uparrow$
- In both cases, monetary policy can stabilize **both** prices and employment
  - With a single instrument. This is an astonishing result.
- If the Fed cannot lower the rate, then the recession is worse
  - For example, due to the zero lower bound, as in the Great Recession

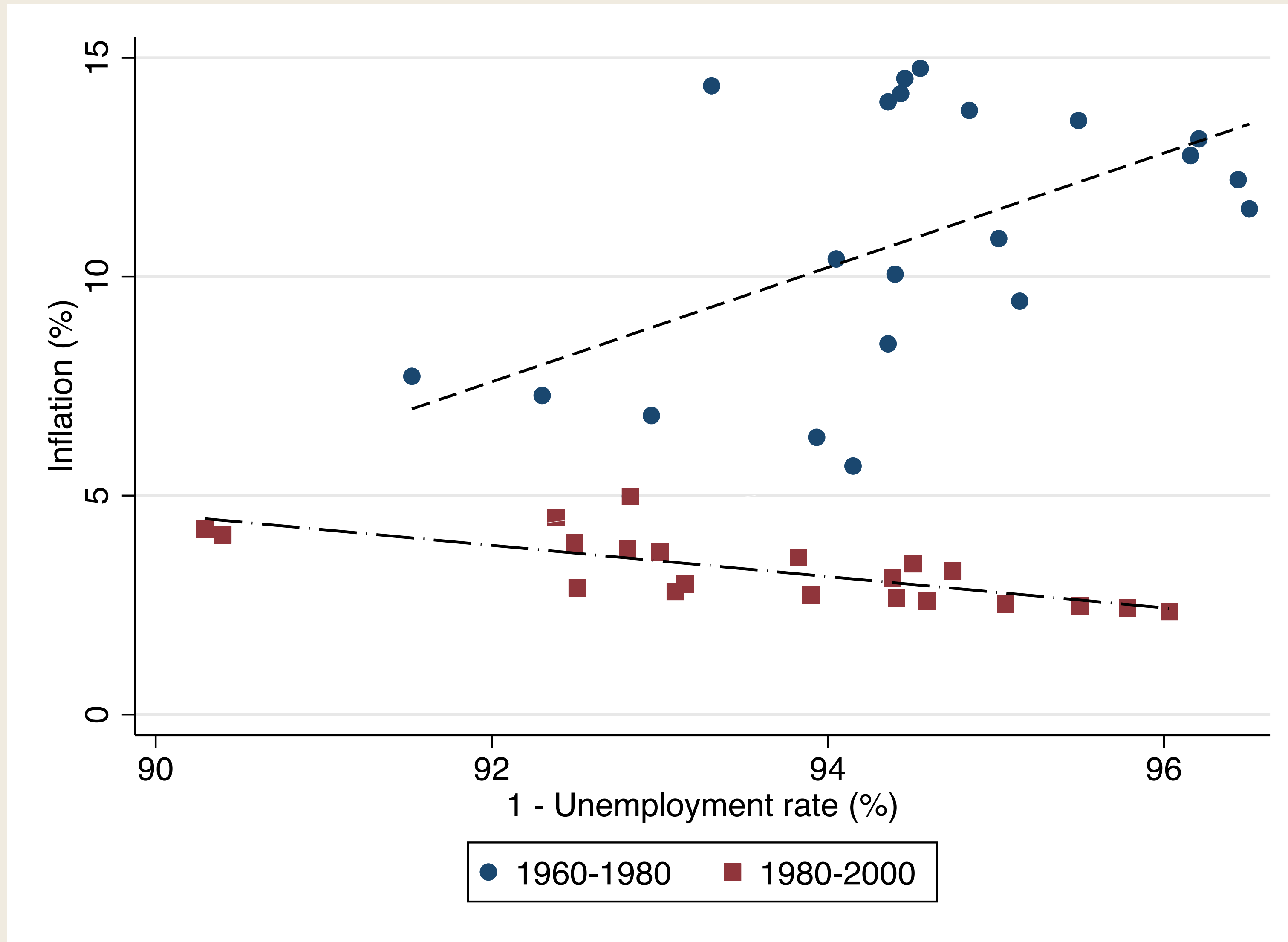
---

# Phillips Curve in the Data

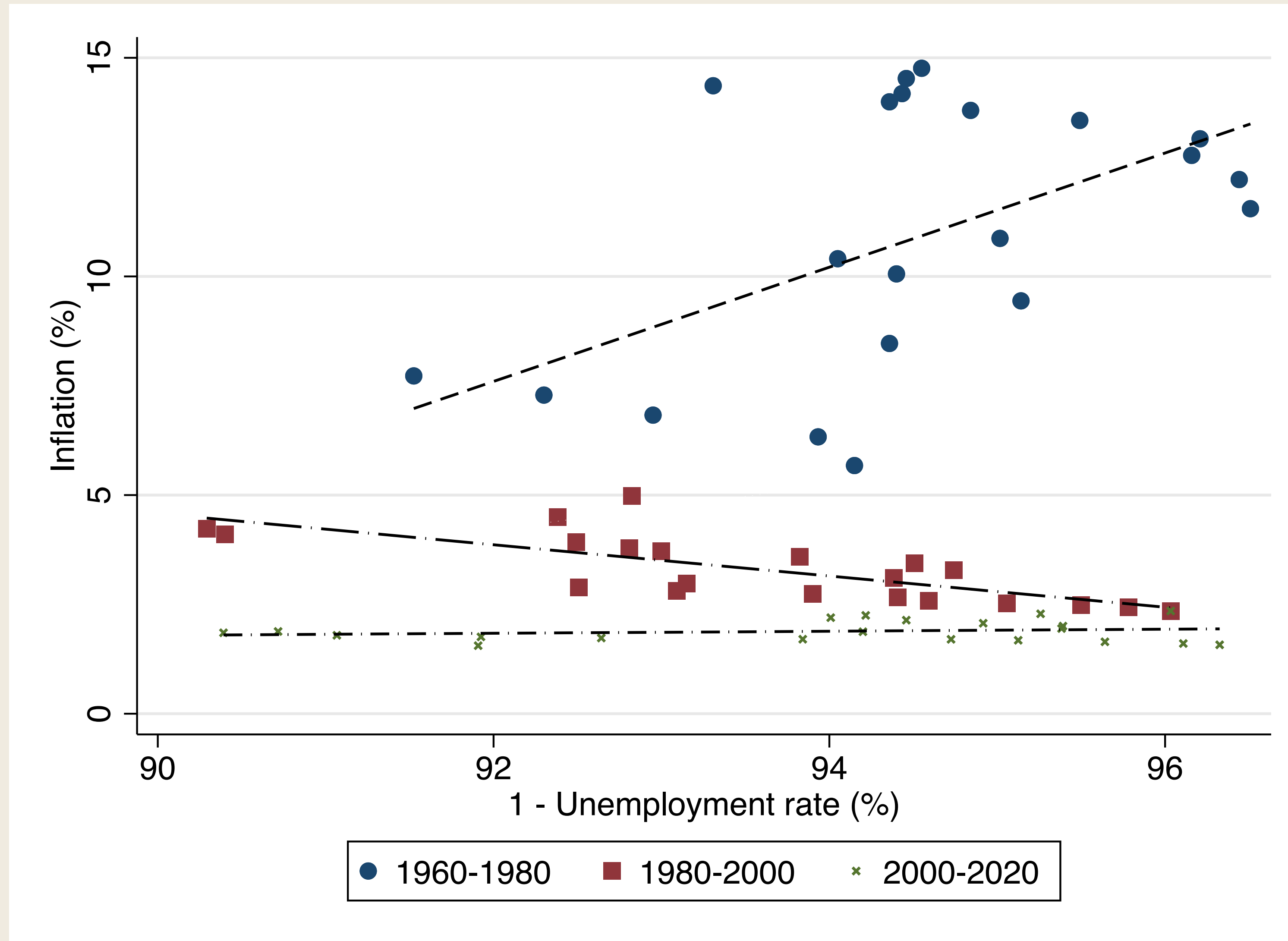
# Phillips Curve?



# Phillips Curve??



# Phillips Curve???

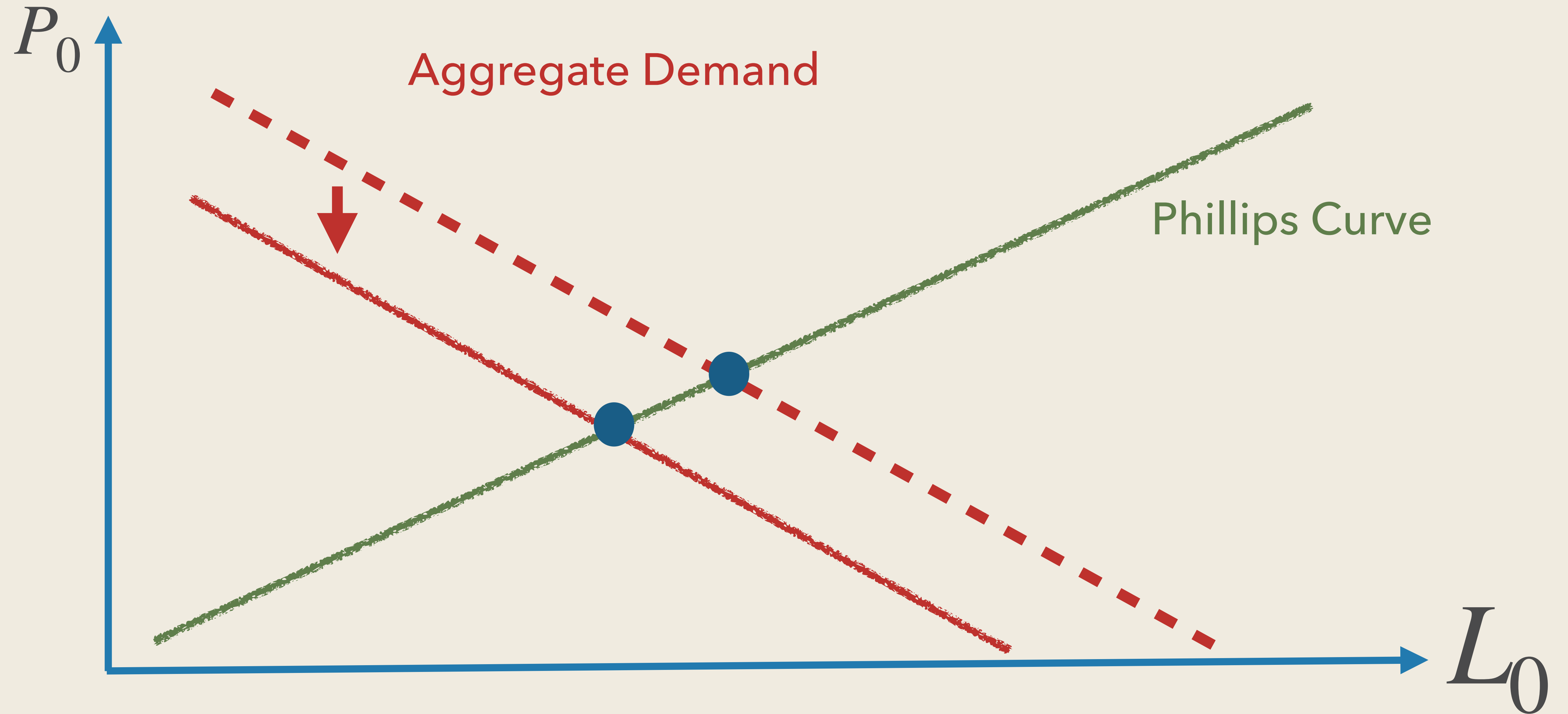


---

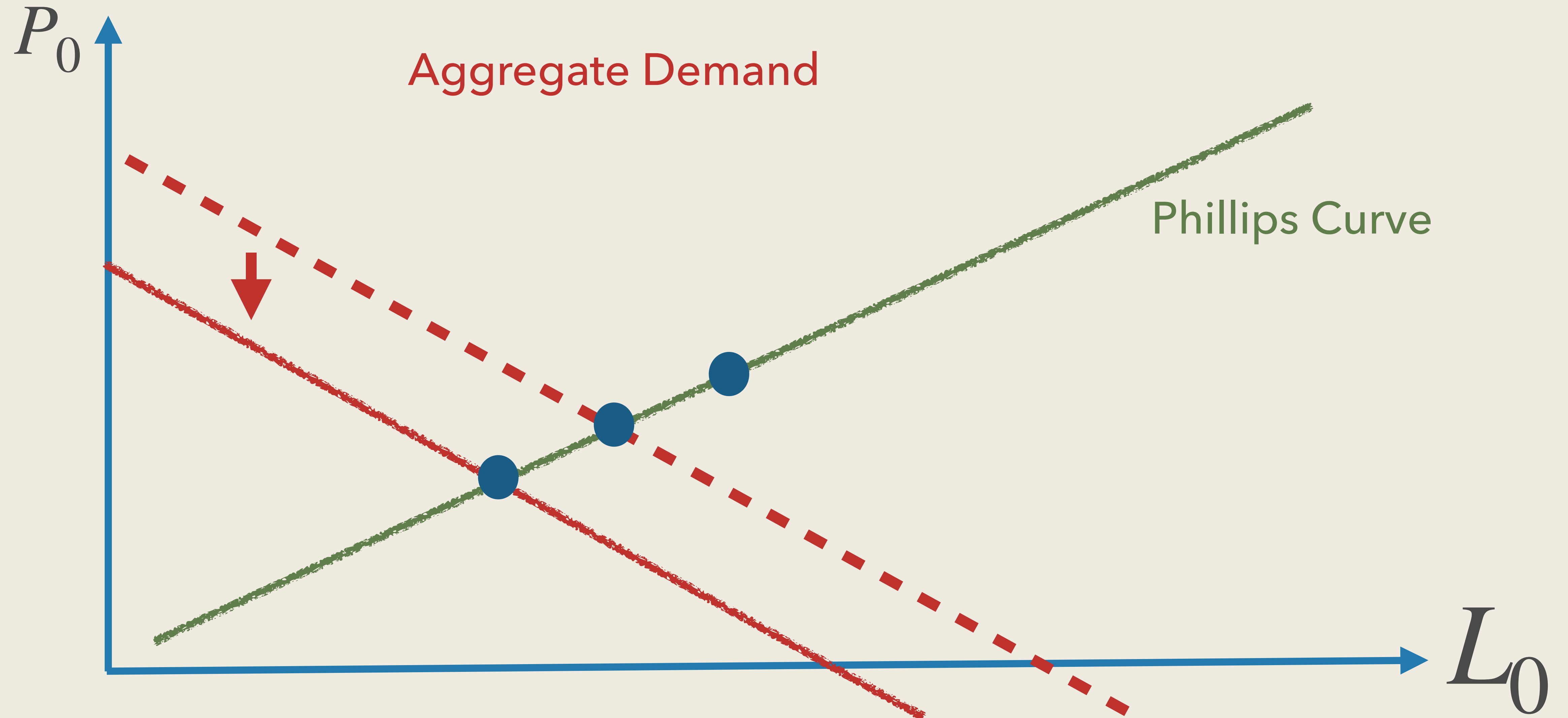
# Common Criticism to NK Model

- There is no clear relationship between unemployment and inflation after 1980
  - Even the "opposite" sign
- "Hence, NK model is rejected in the data"
- Is this a valid criticism?

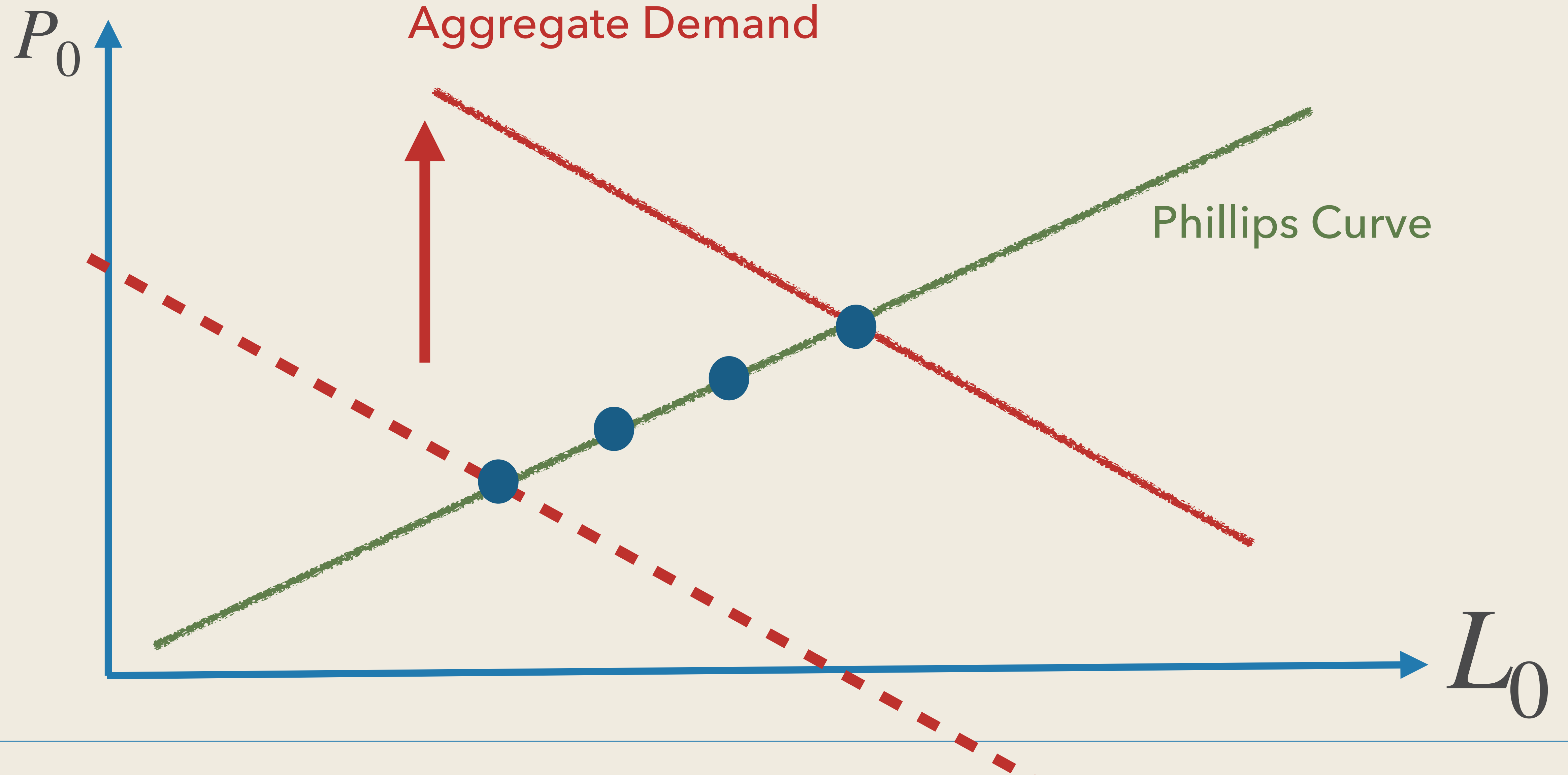
# AS-AD Diagram Again



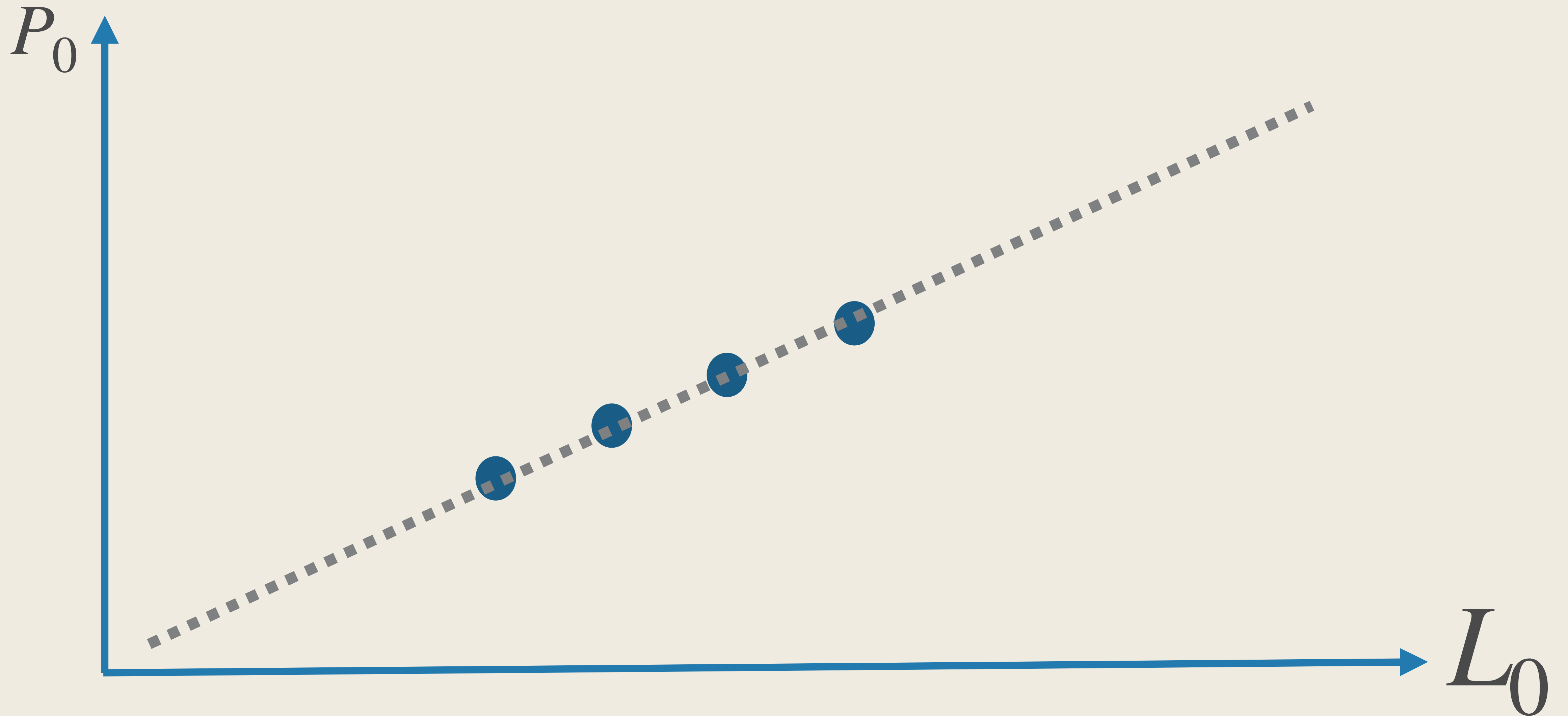
# AS-AD Diagram Again



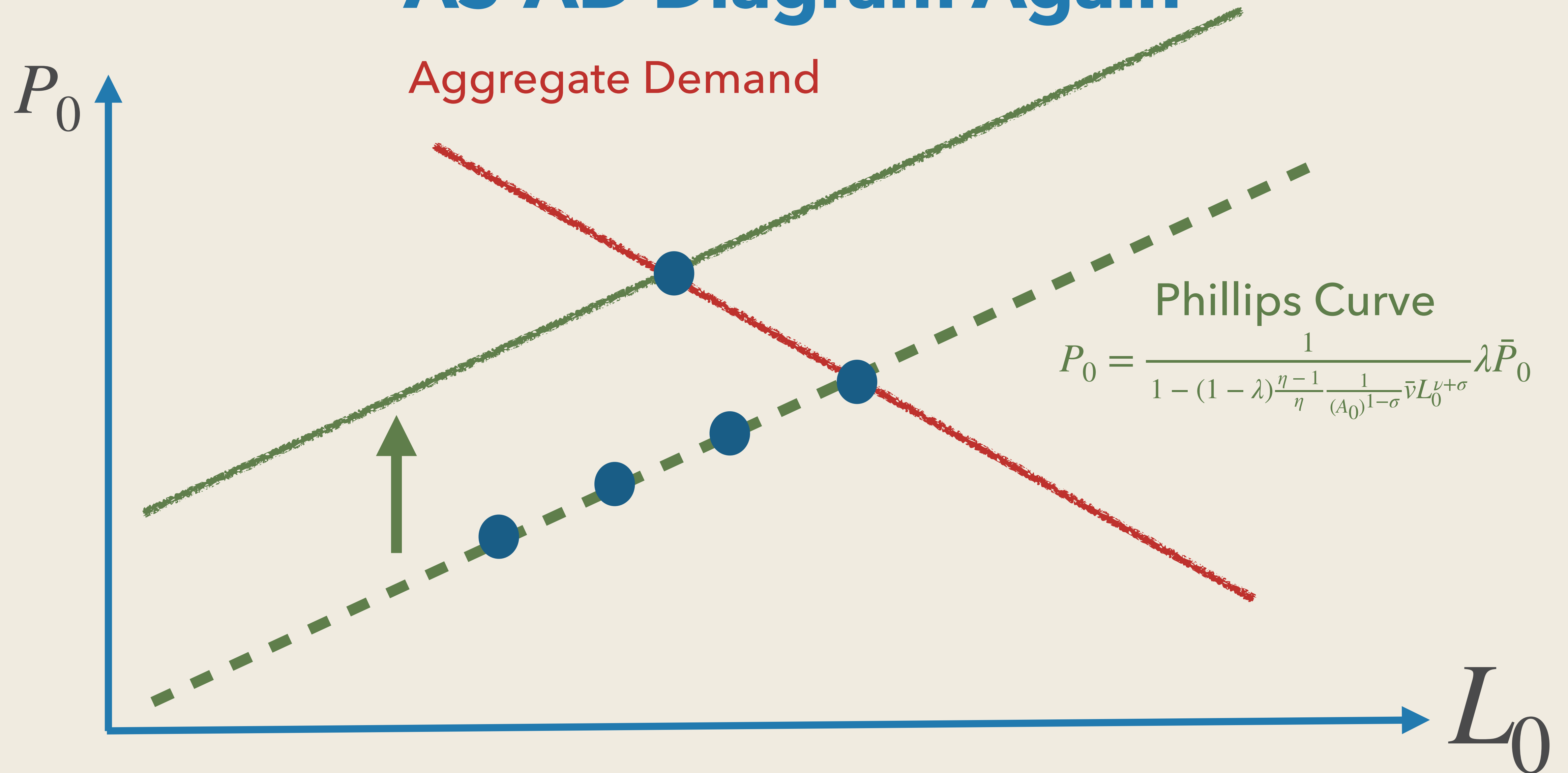
# AS-AD Diagram Again



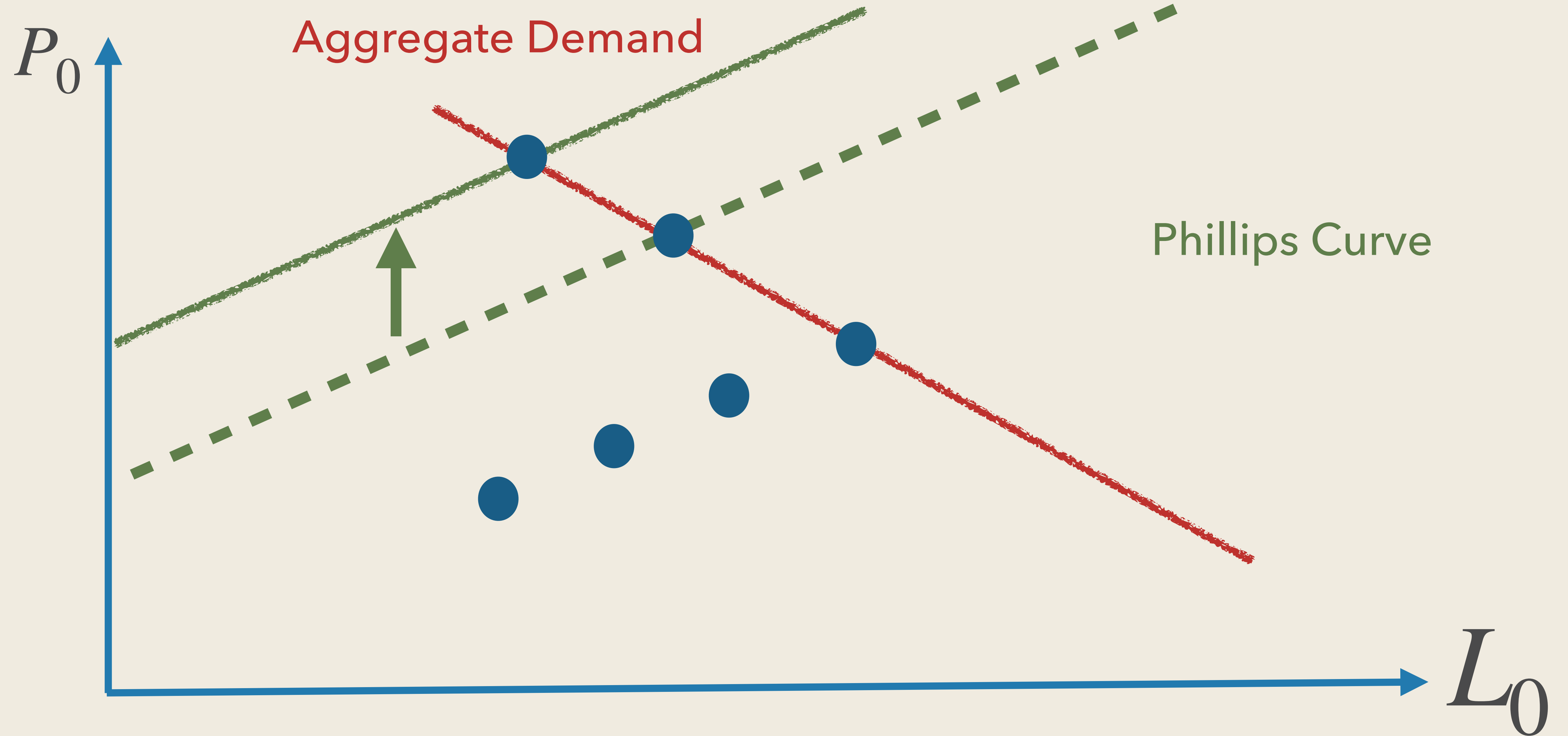
# Data Points We Observe



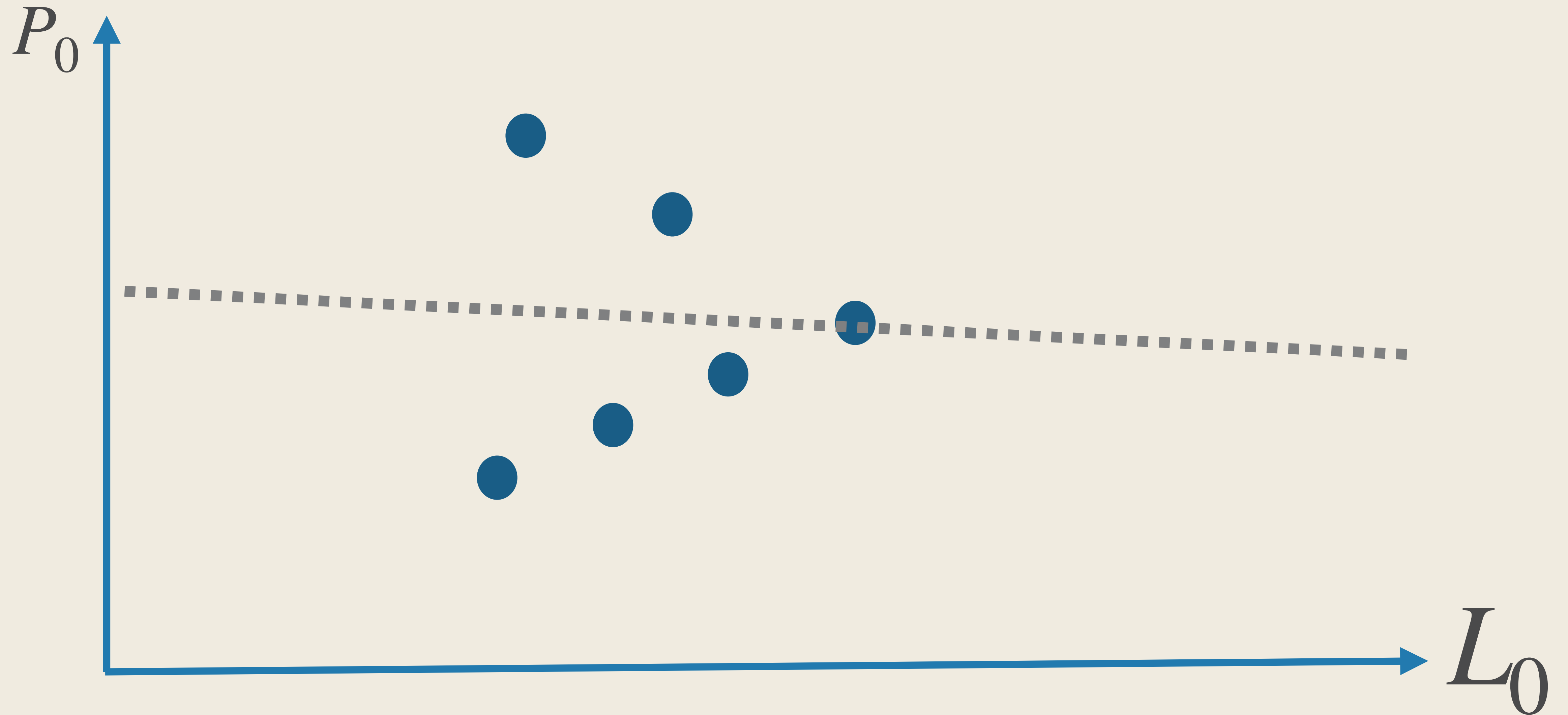
# AS-AD Diagram Again



# AS-AD Diagram Again



# Data Points We Observe



---

# Lack of Identification

- Phillips curve itself shifts around due to changes in  $\nu, \lambda, \eta, \alpha$  or  $A_0$  (when  $\sigma \neq 1$ )
- In that case, correlation between  $(P_0, L_0)$  does not reveal Phillips curve
  - nor aggregate demand curve
- Just as in correlation between  $P$  and  $Q$  does not tell us about supply nor demand
- The weak relationship between  $P_0$  and  $L_0$  is not a rejection of NK model

---

# Infinite Horizon New Keynesian Model

---

# Environment

- The economy consists of
  1. Households
  2. Firms
  3. Retailers
  4. Central bank
- Retailers purchase wholesale goods from firms
- Retailers sell the final goods to households (for  $C$ ) and firms (for  $I$ )
  - We now add back investment

# Households and Firms

- Households solve

$$\max_{\{C_t, l_t, a_t\}} \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_t^{1-\sigma}}{1-\sigma} - \bar{v} \frac{l_t^{1+\nu}}{1+\nu} \right]$$

subject to

$$P_t C_t + A_t = (1 + i_{t-1})a_{t-1} + W_t l_t + D_t$$

- Firms solve

$$\max_{\{I_t, K_{t+1}, D_t, L_t\}} \sum_{t=0}^{\infty} \frac{1}{\prod_{s=0}^{t-1} (1 + i_s)} D_t$$

subject to

$$D_t = p_t A K_t^\alpha L_t^{1-\alpha} - W_t L_t - P_t I_t - P_t \frac{\phi}{2} \left( \frac{I_t}{K_t} \right)^2 K_t$$

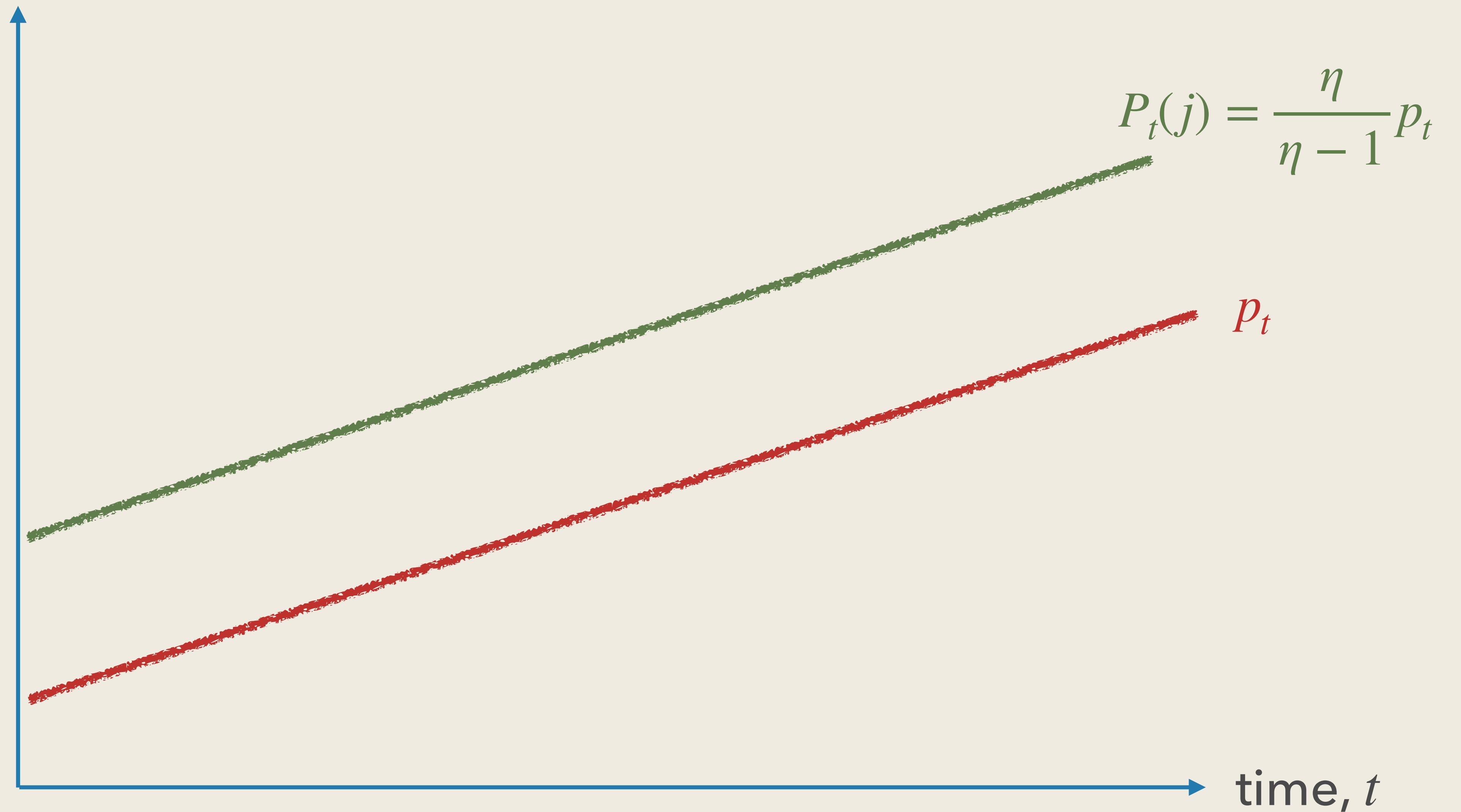
$$K_{t+1} = (1 - \delta)K_t + I_t$$

---

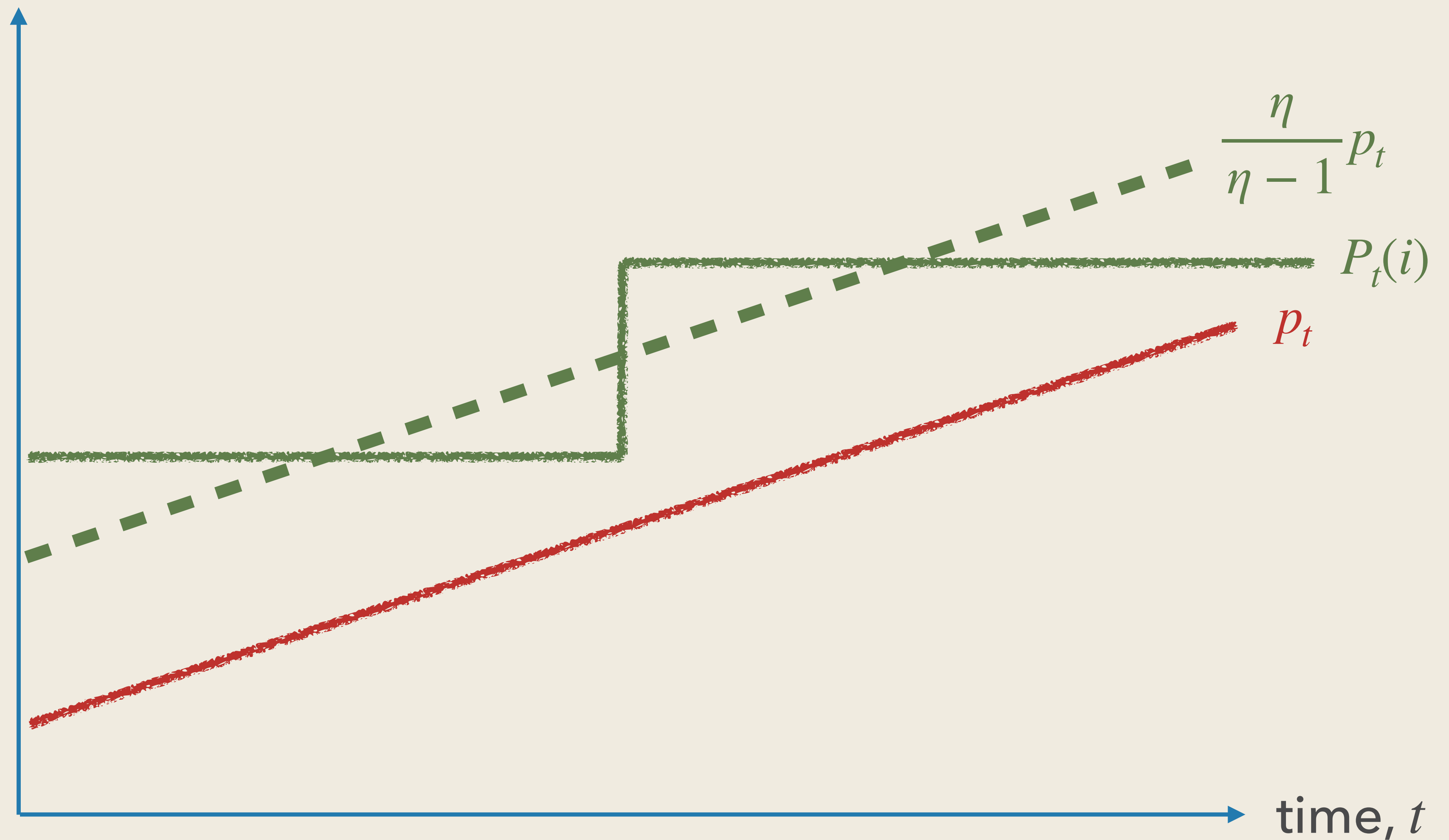
# Sticky Prices

- Retailers purchase wholesale goods at price  $p_t$  and sell it to households and firms
- Retailers can adjust their prices only with probability  $1 - \lambda$
- How should retailers set prices?

# When prices are flexible, $\lambda = 0$



# When prices are Sticky, $\lambda > 0$



# New Keynesian Phillips Curve

$$\pi_t = \kappa \left[ \frac{\eta - 1}{\eta} \frac{p_t}{P_t} - 1 \right] + \beta \pi_{t+1}$$

with  $\kappa = \frac{(1 - \beta\lambda)(1 - \lambda)}{\lambda}$  and  $\pi_t = \frac{P_t}{P_{t-1}} - 1$

- Suppose prices are flexible,  $\lambda = 0$ , then

$$P_t = \frac{\eta}{\eta - 1} p_t$$

- Suppose prices are completely rigid,  $\lambda = 1$

$$\pi_t = 0$$

---

# Intuition

$$\pi_t = \kappa \left[ \frac{\eta - 1}{\eta} \frac{p_t}{P_t} - 1 \right] + \beta \pi_{t+1}$$

- Inflation today depends on today's wholesale cost  $p_t$ 
  - If wholesale cost goes up, firms who can adjust prices want to raise prices
  - Inflationary.
  - The strength of the inflationary pressure is governed by  $\kappa = \frac{(1 - \beta\lambda)(1 - \lambda)}{\lambda}$
- Inflation today depends on future inflation  $\pi_{t+1}$ 
  - Suppose firms expect inflation to be high in the future
  - If firms have opportunity to adjust, they start raising today
  - Because firms may not have opportunity to raise prices when inflation happens

---

# Central Bank

- The central bank sets the nominal interest rate in the economy
- We assume

$$i_t = \bar{i} + \phi_\pi \pi_t + \epsilon_t$$

- $\phi_\pi$ : how much the central bank is willing to fight against inflation
  - $\epsilon_t$ : monetary policy "shock" (e.g., changes in moods of FOMC members)
- Taylor (1993) argued this is a good description of the US monetary policy

---

# Fisher Equation

- The relationship between nominal and real rate is

$$r_t = i_t - \pi_{t+1}$$

- This called Fisher equation

# Equilibrium Conditions: $\{C_t, L_t, I_t, K_{t+1}, q_t, p_t/P_t, r_t, i_t, \pi_t\}$

1. Euler equation:

$$u'(C_t) = \beta(1 + r_t)u'(C_{t+1})$$

2. Labor demand/supply:

$$\frac{p_t}{P_t} \frac{\partial F_t(K_t, L_t)}{\partial L_t} u'(C_t) = v'(L_t)$$

3. Investment:

$$\frac{I_t}{K_t} = \frac{1}{\phi} [q_t - 1], \quad q_t = \frac{1}{1 + r_t} \left[ \frac{p_t}{P_t} \frac{\partial F_{t+1}(L_{t+1}, K_{t+1})}{\partial K_{t+1}} - \frac{I_{t+1}}{K_{t+1}} - \frac{\phi}{2} \left( \frac{I_{t+1}}{K_{t+1}} \right)^2 + \left( \frac{I_{t+1}}{K_{t+1}} + (1 - \delta) \right) q_{t+1} \right]$$

4. Capital stock evolution:

$$K_{t+1} = (1 - \delta)K_t + I_t$$

5. Goods market clearing:

$$C_t + I_t + \Phi(I_t, K_t) = F_t(K_t, L_t)$$

6. New Keynesian Phillips curve:

$$\pi_t = \kappa \left[ \frac{\eta - 1}{\eta} \frac{p_t}{P_t} - 1 \right] + \beta \pi_{t+1}$$

7. Monetary policy:

$$i_t = \bar{i} + \phi_\pi \pi_t + \epsilon_t$$

8. Fisher equation:

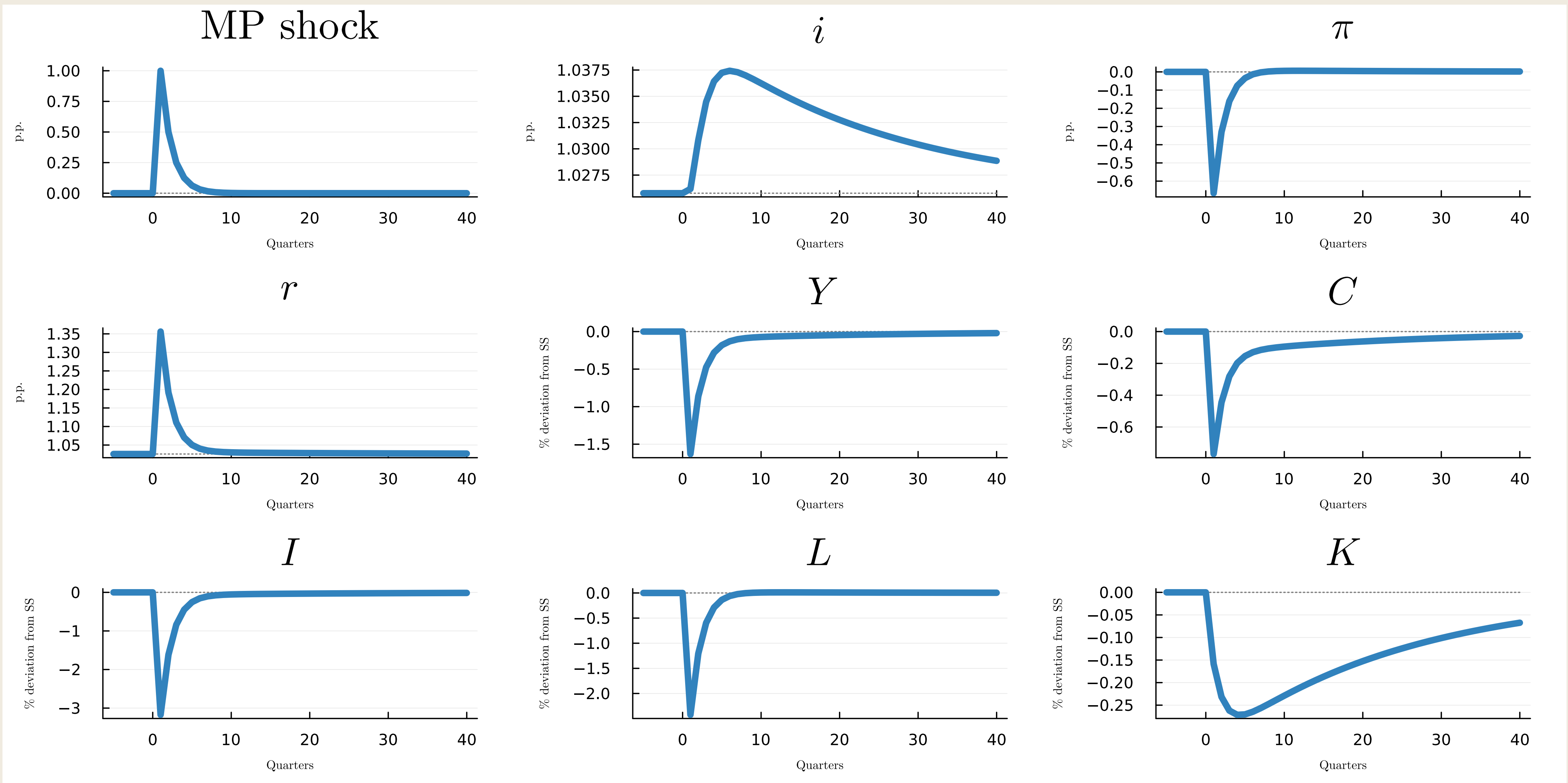
$$r_t = i_t - \pi_{t+1}$$

---

# Parametrization (Calibration)

- The same parameters as in the RBC model for those in common
- We set the price stickiness to  $\lambda = 0.75$
- We set  $\phi_\pi = 1.5$ , as suggested by Taylor (1993)
- We simulate the response of the economy to monetary policy shock  $\epsilon_t$ 
  - Set the autocorrelation of the shock to 0.5

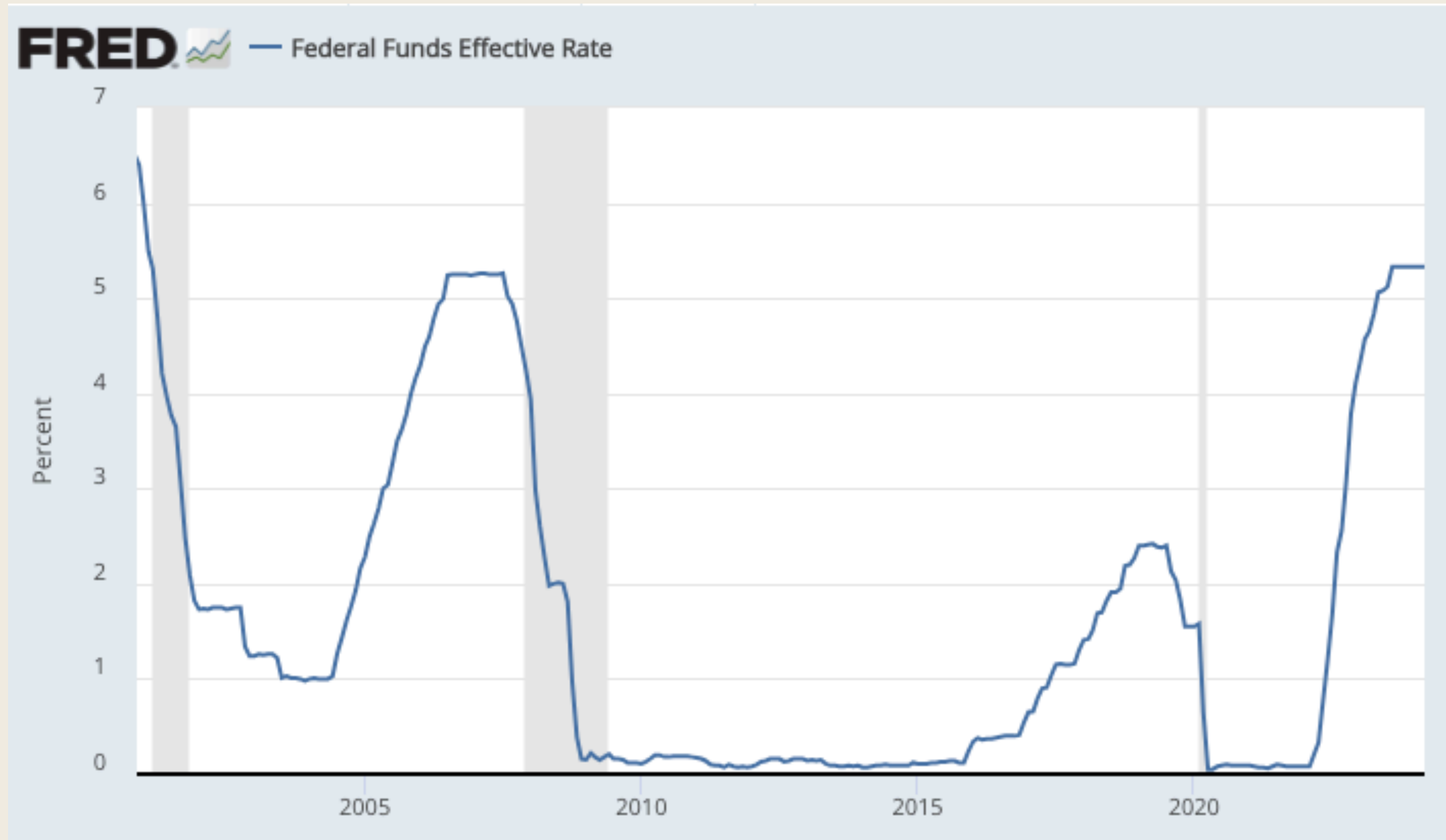
# Monetary Policy Shock



---

# Zero Lower Bound

# Federal Funds Rate

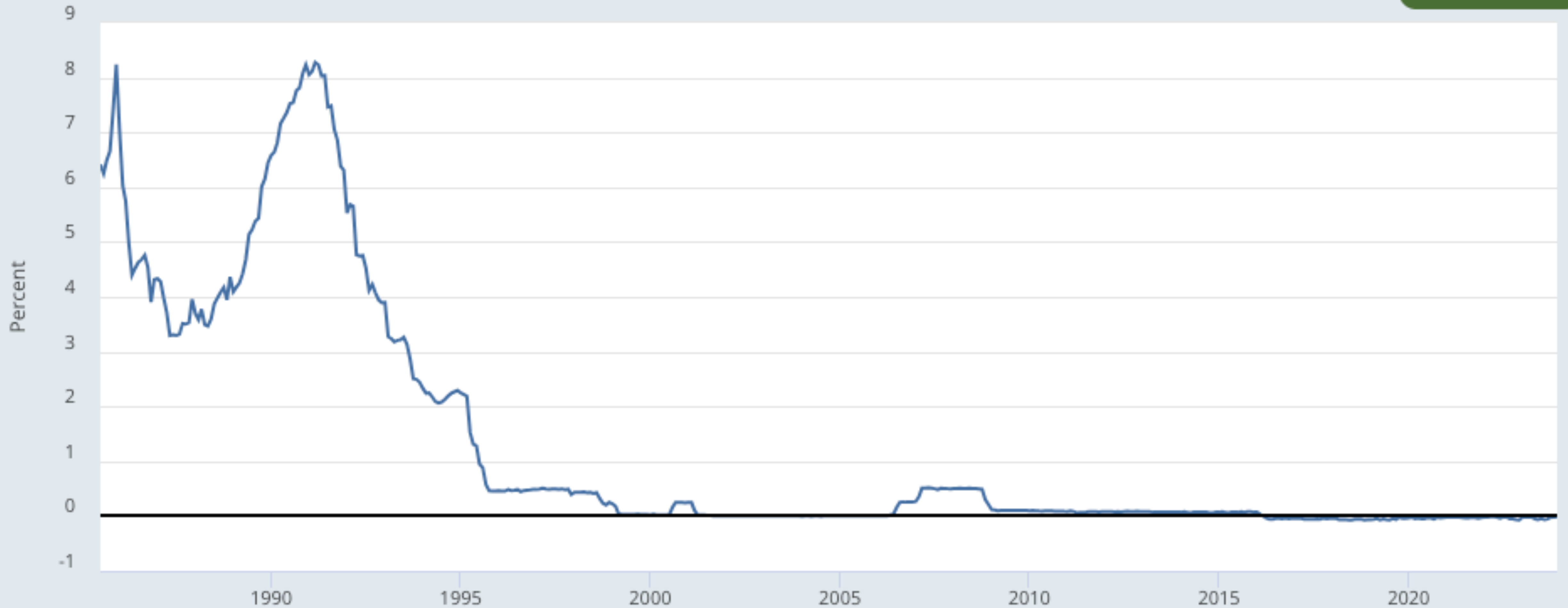


# Interest Rate in Japan

FRED 

— Interest Rates: Immediate Rates (< 24 Hours): Call Money/Interbank Rate: Total for Japan

[VIEW MAP](#) 



---

# Zero Lower Bound

$$i_t \geq 0$$

- Why?
- Holding physical money always gives the return of  $i_t^M = 0$
- If  $i_t < 0$ , no one holds bank deposits or bonds
- Everyone can earn infinite by borrowing at rate  $i_t < 0$  and invest in money with  $i_t^M = 0$
- What are the macro implications?

---

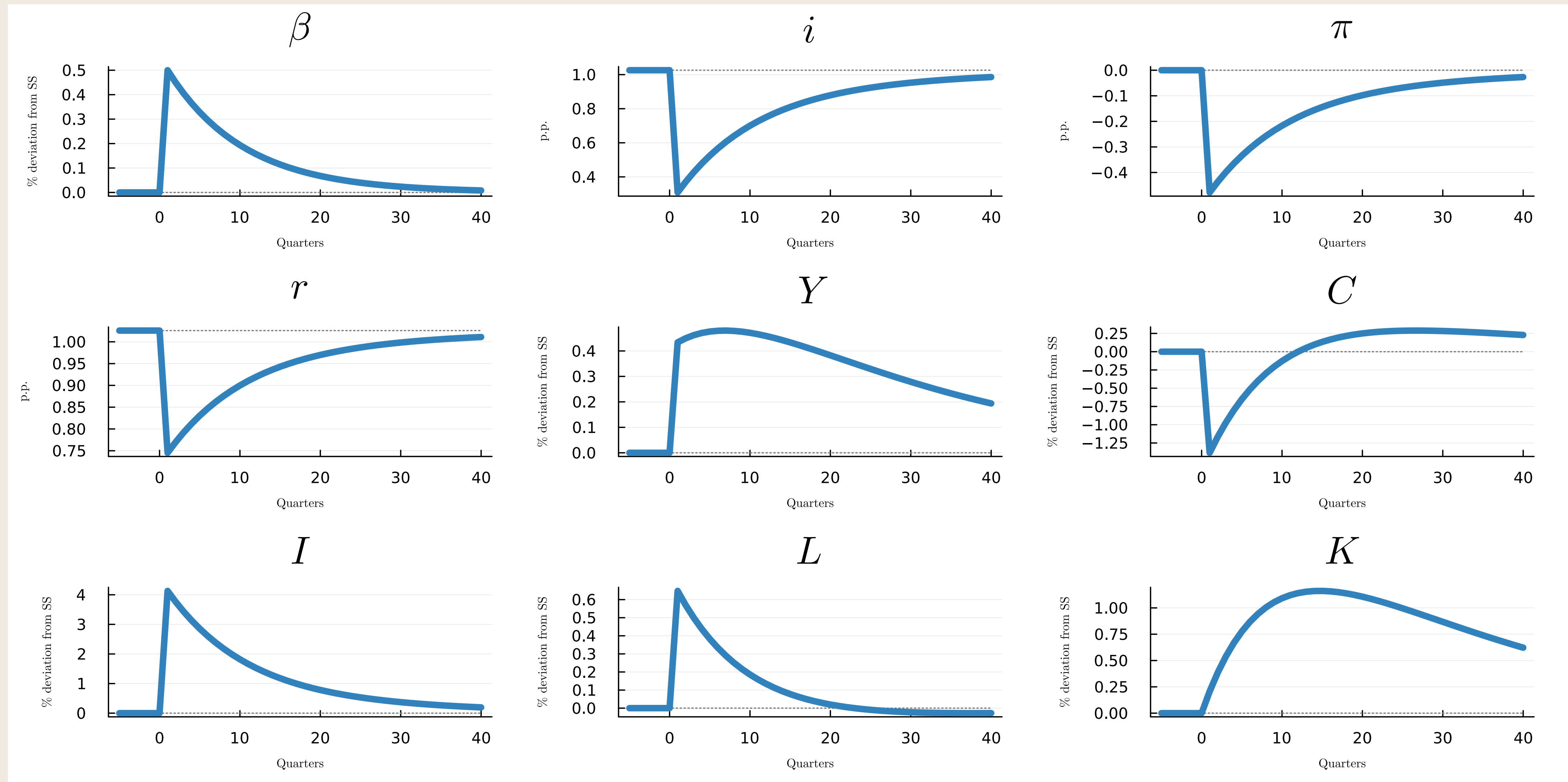
# Monetary Policy Rule with ZLB

- We modify the monetary policy rule as

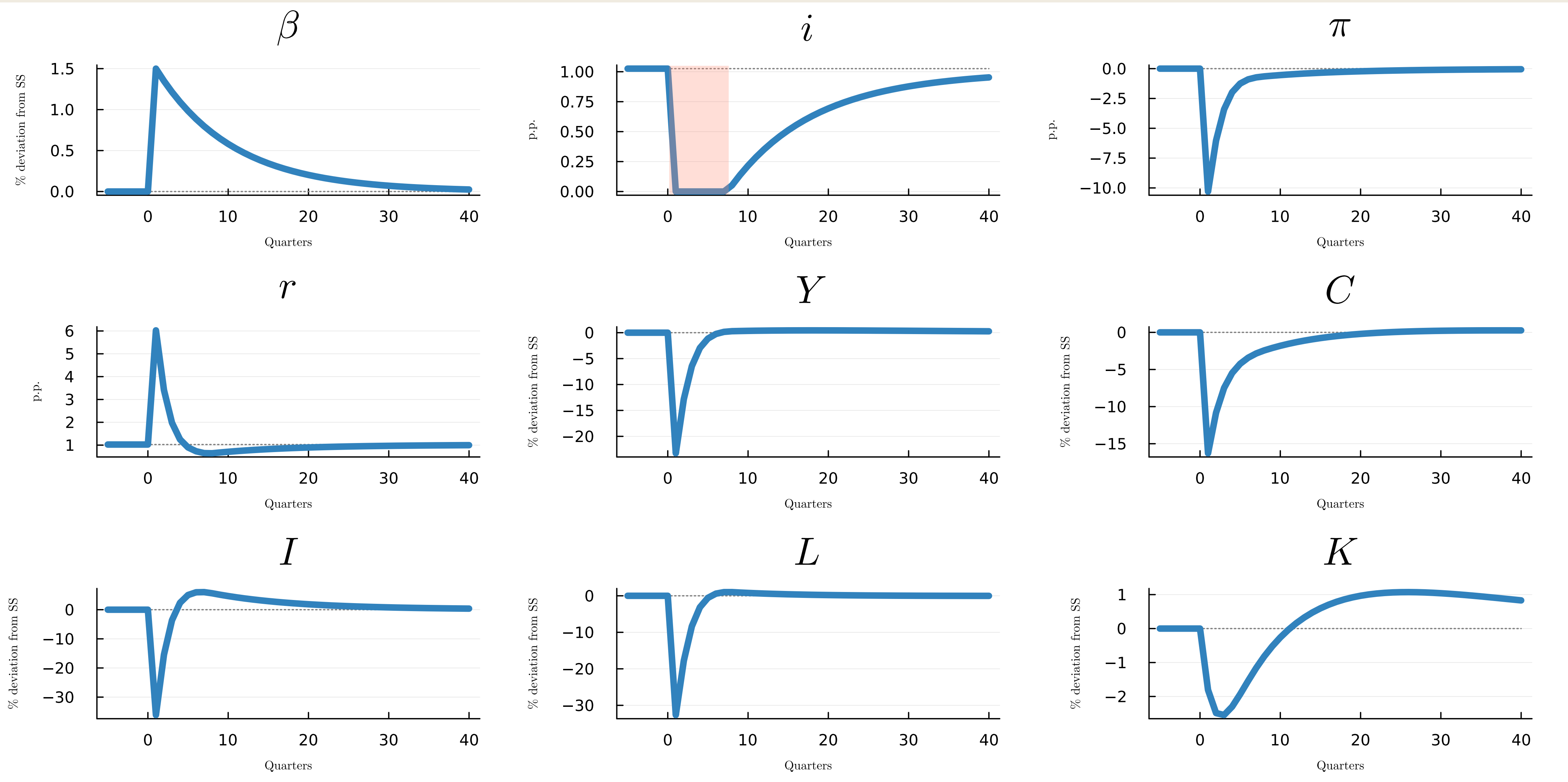
$$i_t = \max\{0, \bar{i} + \phi_\pi \pi_t + \epsilon_t\}$$

- We will focus on negative consumption demand shock (an increase in  $\beta$ )
- Many argue this resembles what happened during 2007-2009 recession
  - Households were in trouble repaying mortgages
  - They are forced to cut spendings
  - We will talk more on this later

# Small Increase in $\beta$



# Larger Increase in $\beta$



---

# ZLB $\Rightarrow$ The Great Recession

- As in the two-period model, in response to  $\beta \uparrow$ , if monetary policy can respond,
  - Consumption falls
  - Labor supply, investment, and output all boom
  - Just as in RBC model
- However, the inability of monetary policy to respond leads to
  - a fall in consumption
  - a fall in labor supply, investment, and output
- Why?
  - $C \downarrow$  implies less aggregate demand
  - If  $r$  is fixed, need less labor and capital  $\Rightarrow$  fall in  $L$  and  $I$
  - A fall in  $L$  implies  $\pi_t \downarrow$ , and this implies  $r$  goes up because  $r = i_t + \pi_t$
  - A higher  $r$  discourages consumption and investment further...

---

# What Can be Done?

- When the central bank hits the ZLB, is there nothing left that can be done?
- What did Fed do during the 2007-2009 recession?

# Forward Guidance

the Committee will maintain the target range for the federal funds rate at 0 to ¼ percent and anticipates that economic conditions are likely to warrant exceptionally low levels of the federal funds rate for an extended period.

March 18, 2009



economic conditions . . . are likely to warrant exceptionally low levels of the federal funds rate at least through mid-2013.

August 9, 2011

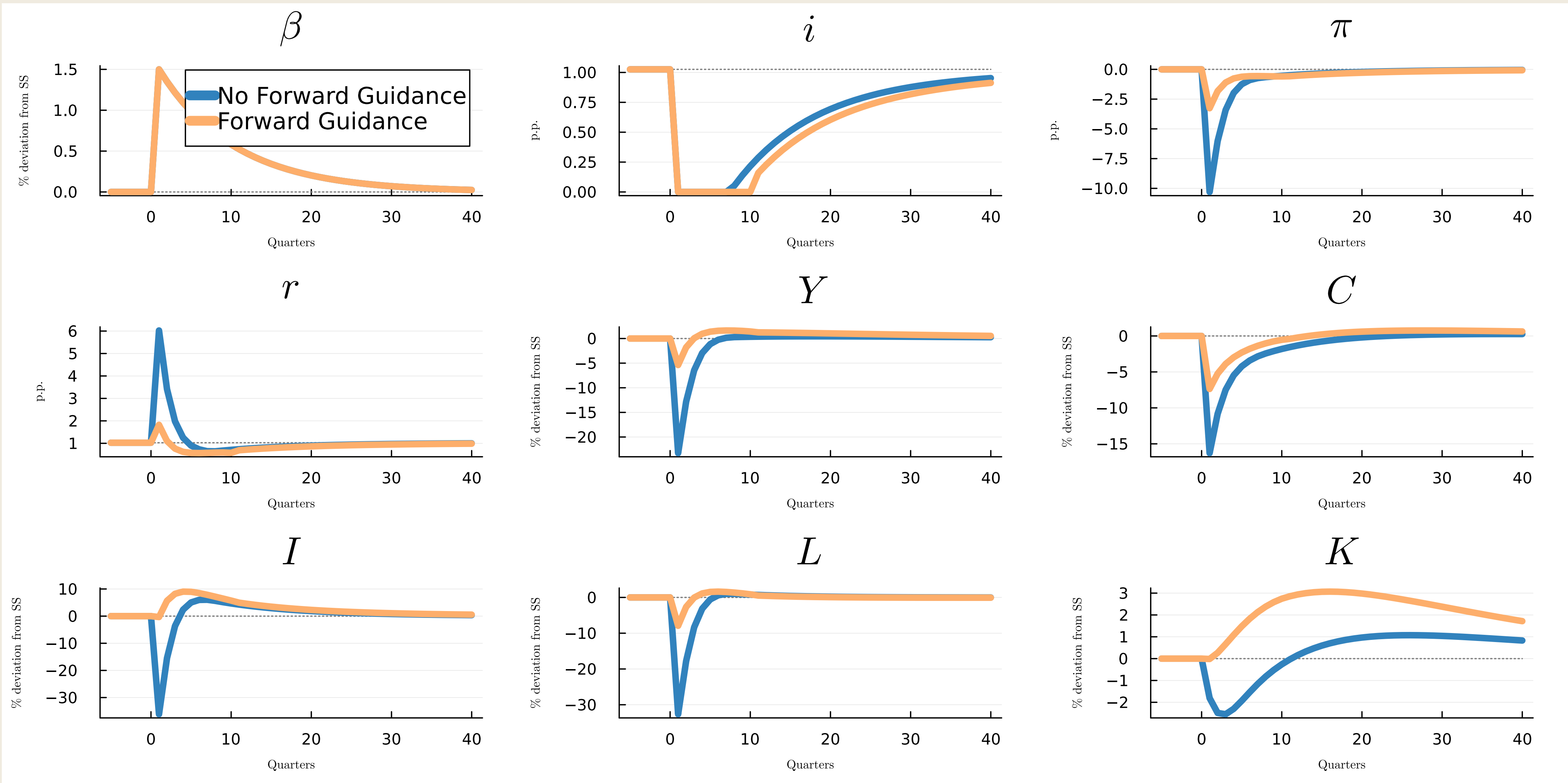


---

# The Power of Forward Guidance?

- Suppose now the central bank commits to maintaining  $i_t = 0$  for extended periods
  - More than what is prescribed by  $i_t = \max\{0, \bar{i} + \phi_\pi \pi_t + \epsilon_t\}$
- Can the central bank fight against recession?

# The Power of Forward Guidance



---

# Mechanism

- Forward guidance significantly alleviates the recession, but why?

- Consider the household's Euler equation

$$C_t^{-\sigma} = \beta(1 + r_t)C_{t+1}^{-\sigma}$$

- Taking log and iterating forward,

$$\log C_t = -\frac{1}{\sigma} \log \beta - \frac{1}{\sigma} \log(1 + r_t) + \log C_{t+1} = -\frac{1}{\sigma} \log \beta - \frac{1}{\sigma} \sum_{s=t}^{\infty} \log(1 + r_s) + \log C_{\infty}$$

- Suppose prices are rigid,  $\pi_t = 0$ , so that  $r_s = i_s$
- Then promising lower  $i_s$  in the far future can stimulate consumption today
- Even if Fed cannot lower  $i_t$  today, a promise to lower  $i_t$  in the future works

---

# Summary

- Monetary policy is widely considered a central stabilization tool
- If prices are flexible, monetary policy is neutral in our model
- Empirically,
  1. mounting evidence that monetary policy is not neutral
  2. prices at the micro level are sticky
- We show that: RBC + price stickiness  $\Rightarrow$  monetary non-neutrality
- Such a model is called New Keynesian model