Lecture 9: An Equilibrium Business Cycle Model

See Barro Ch. 8

Trevor Gallen

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Introduction-I

- We built a model of GDP growth (trend)
- Production function, TFP growth
- We also built in consumption, labor, capital markets
- Can talk about how the system responds to shocks in the short and long run

Preview

- Now let's try to use it to understand business cycles
- A medium-term negative shock to TFP, "A", causes:
  - Wages to go down (lower productivity)
  - Interest rates to go down (lower productivity)
  - Investment to go down a lot (lower interest rates and too high capital stock)
  - Consumption to go down a little (people like to smooth and eat out of savings (capital stock))
- If all these move together in the business cycle, we have a candidate for the cause of the business cycle

Trend and Deviation

- First we have to separate the "trend" from the "business cycle" or "deviation."
- The basic idea:

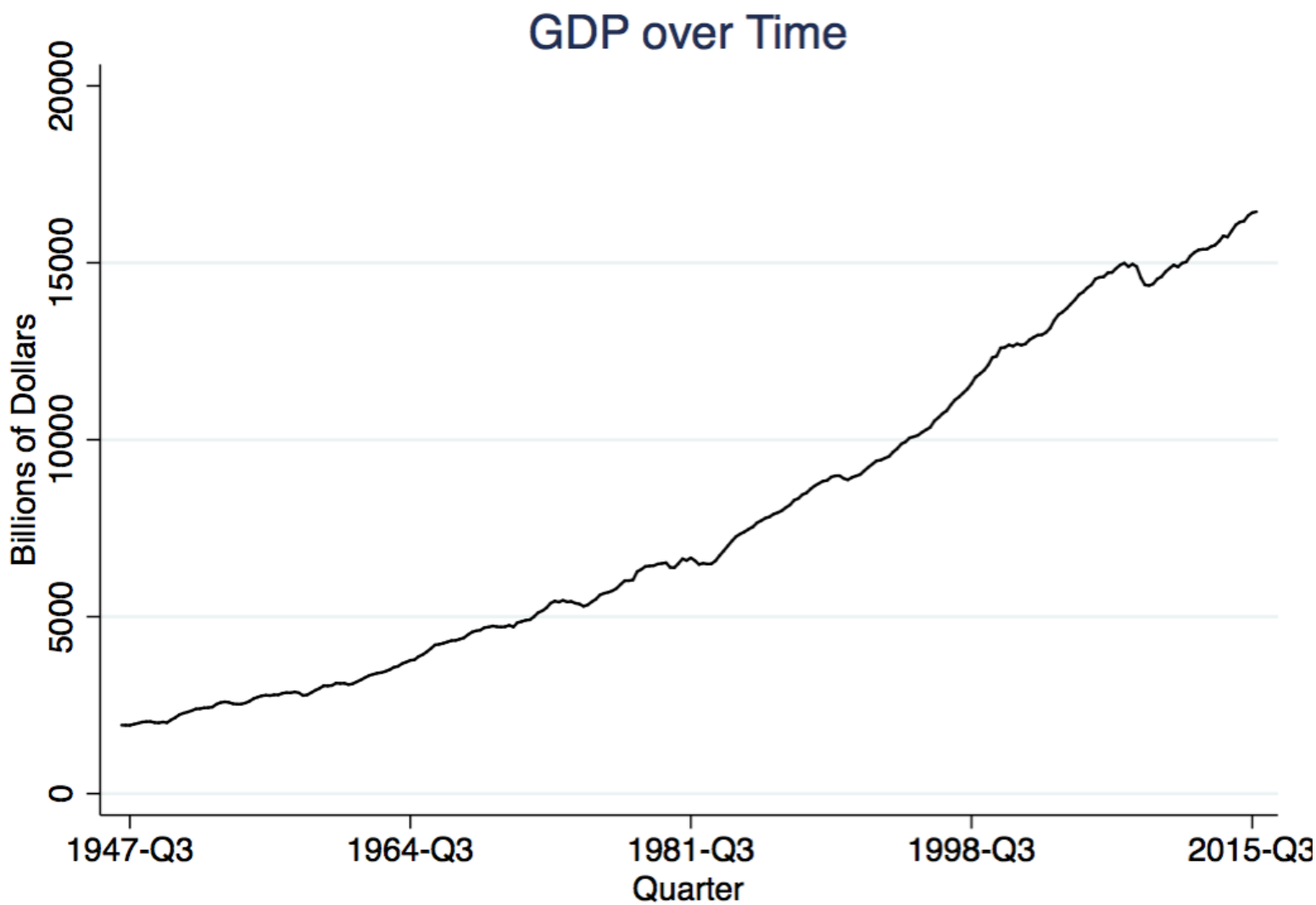
$$\text{Real GDP} = \text{Real GDP Trend} + \text{Real GDP Deviations}$$

- How do we split them?
- Define a trend and subtract the difference to find deviations:

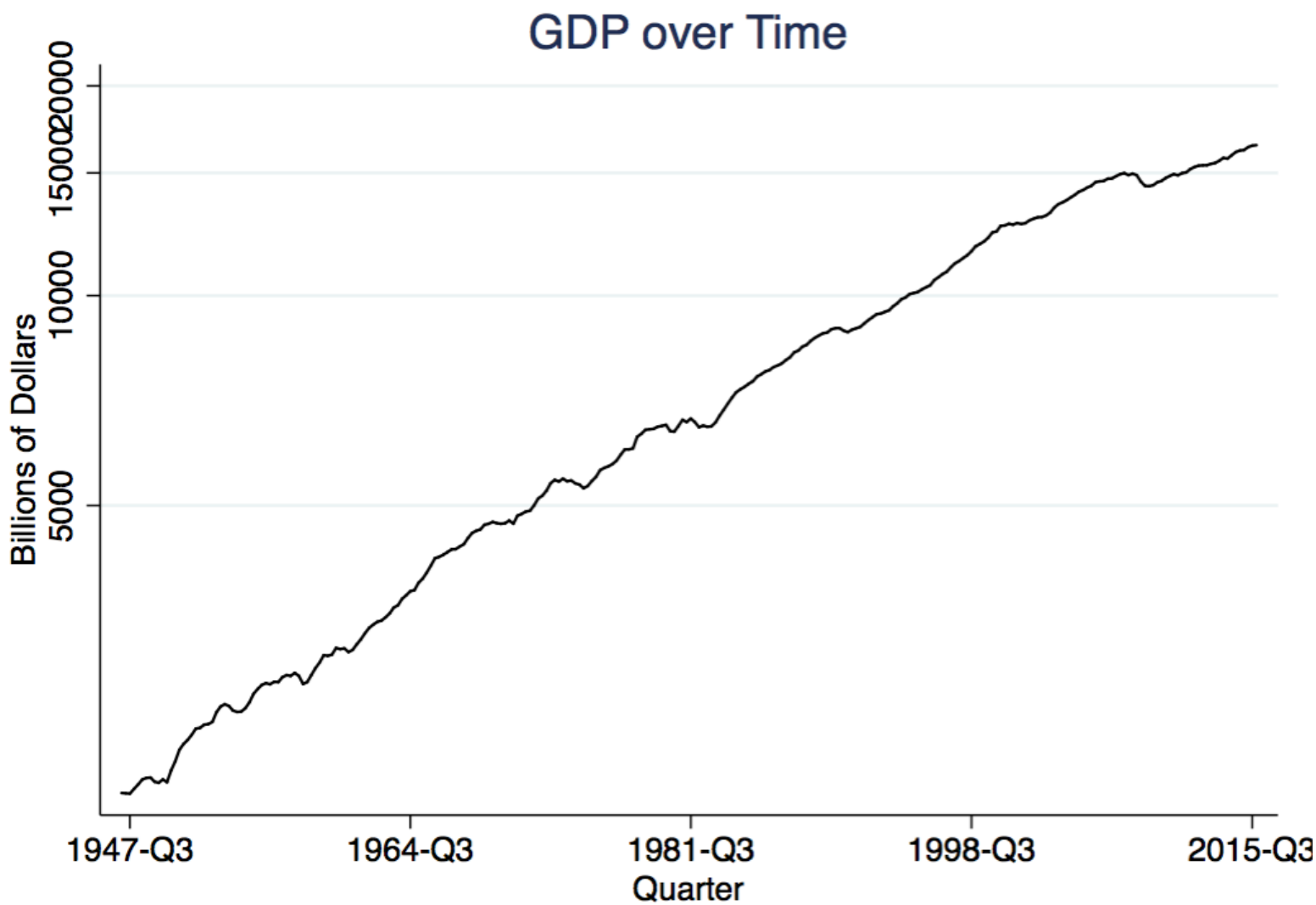
$$\text{Real GDP Deviations} = \text{Real GDP} - \text{Real GDP Trend}$$

- Note: I'll do everything in per-capita terms, but everything looks like Barro
- Note: Barro uses an "HP"-filter, which allows itself to change slope slowly, while I'll use both the HP and an unchanging linear trend

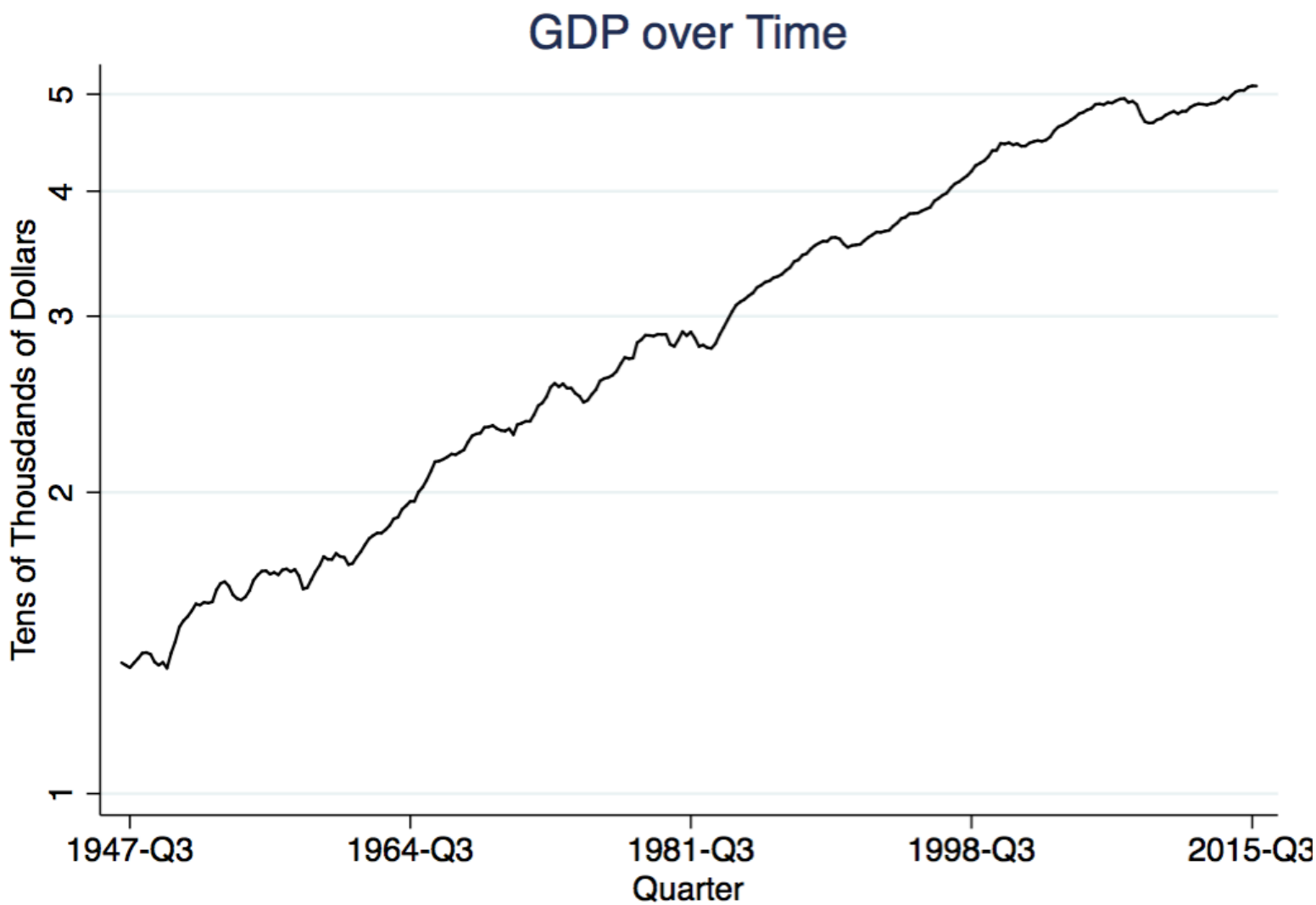
GDP-Trend and Deviations-I



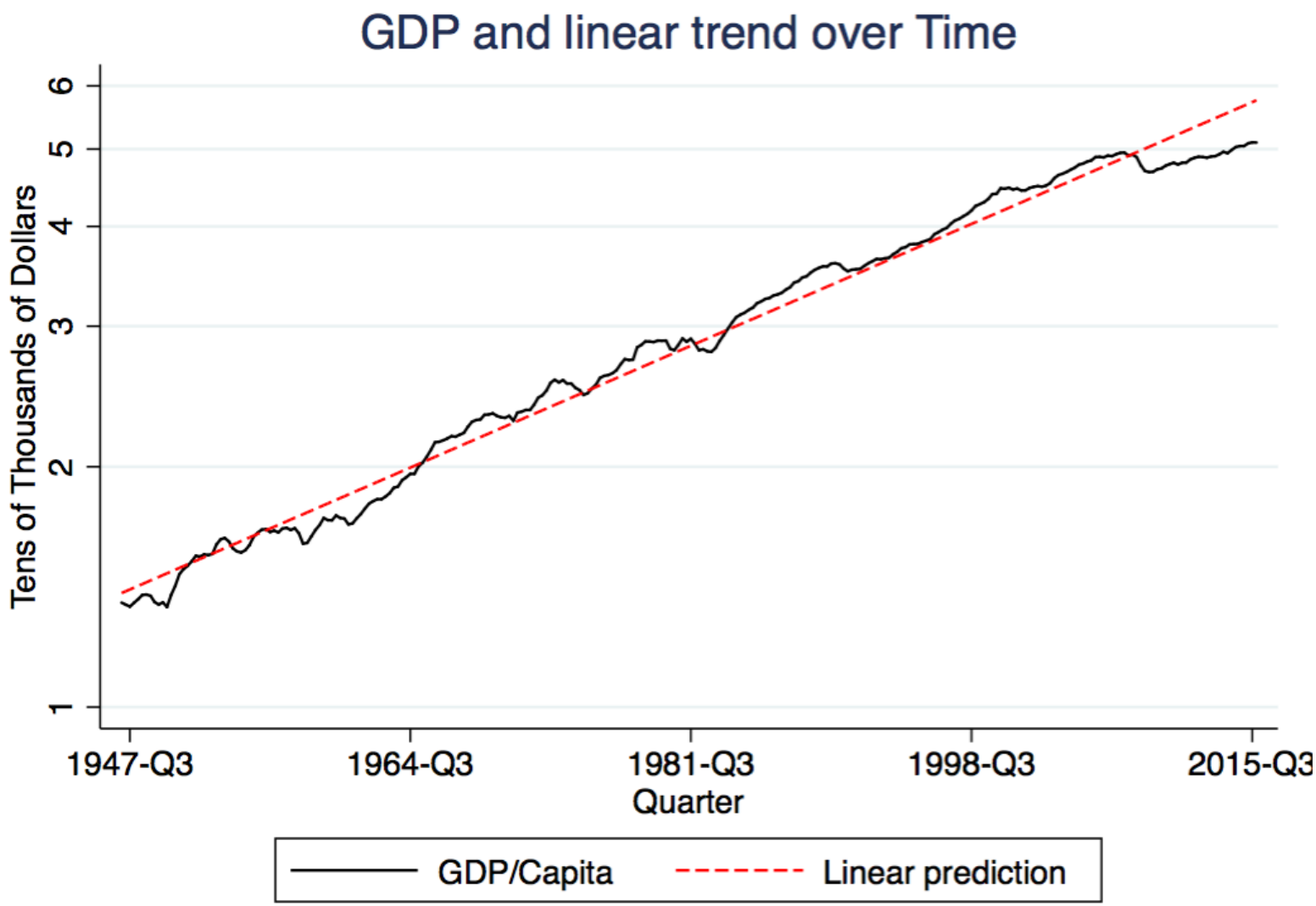
GDP-Trend and Deviations-II



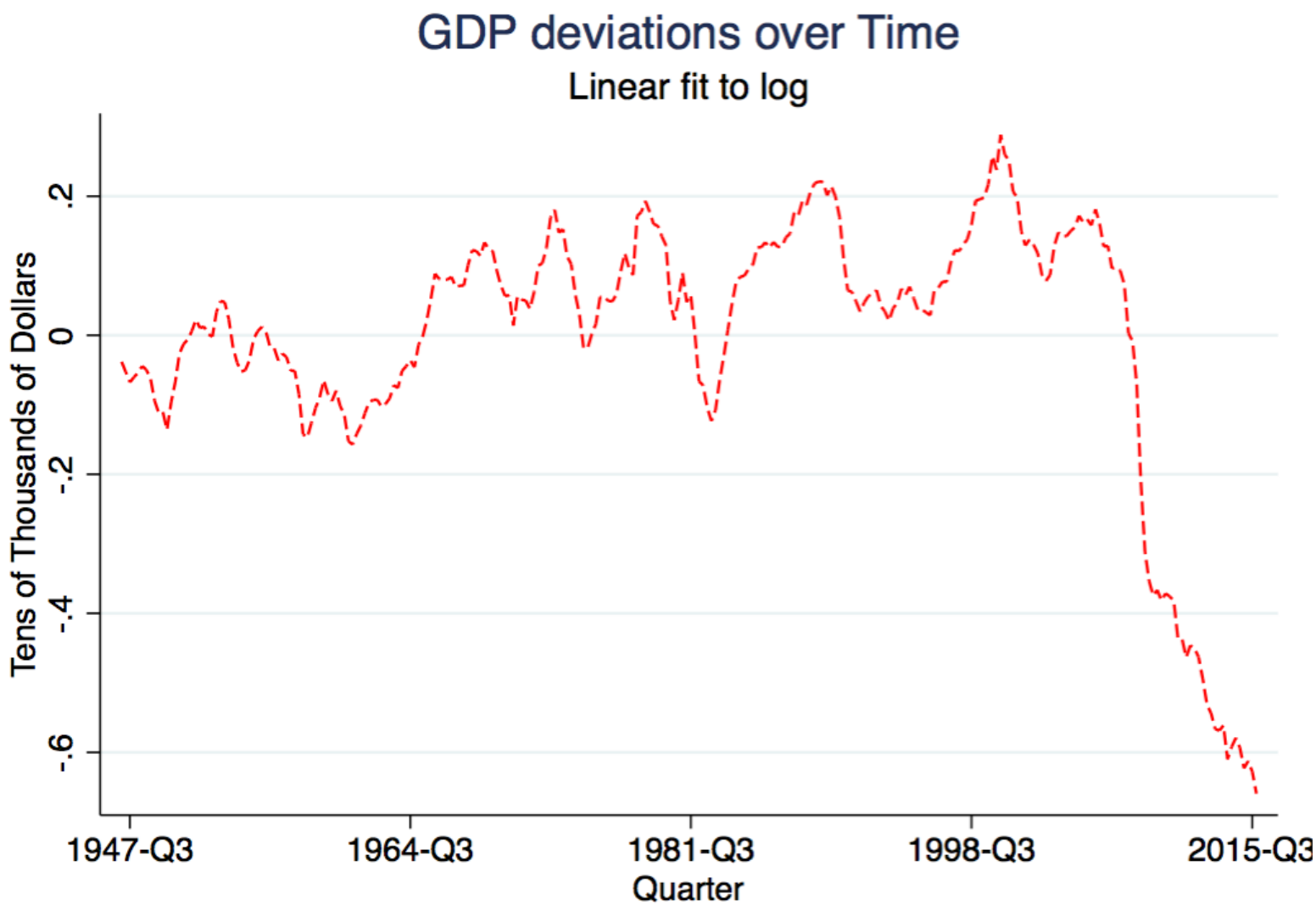
GDP-Trend and Deviations-III



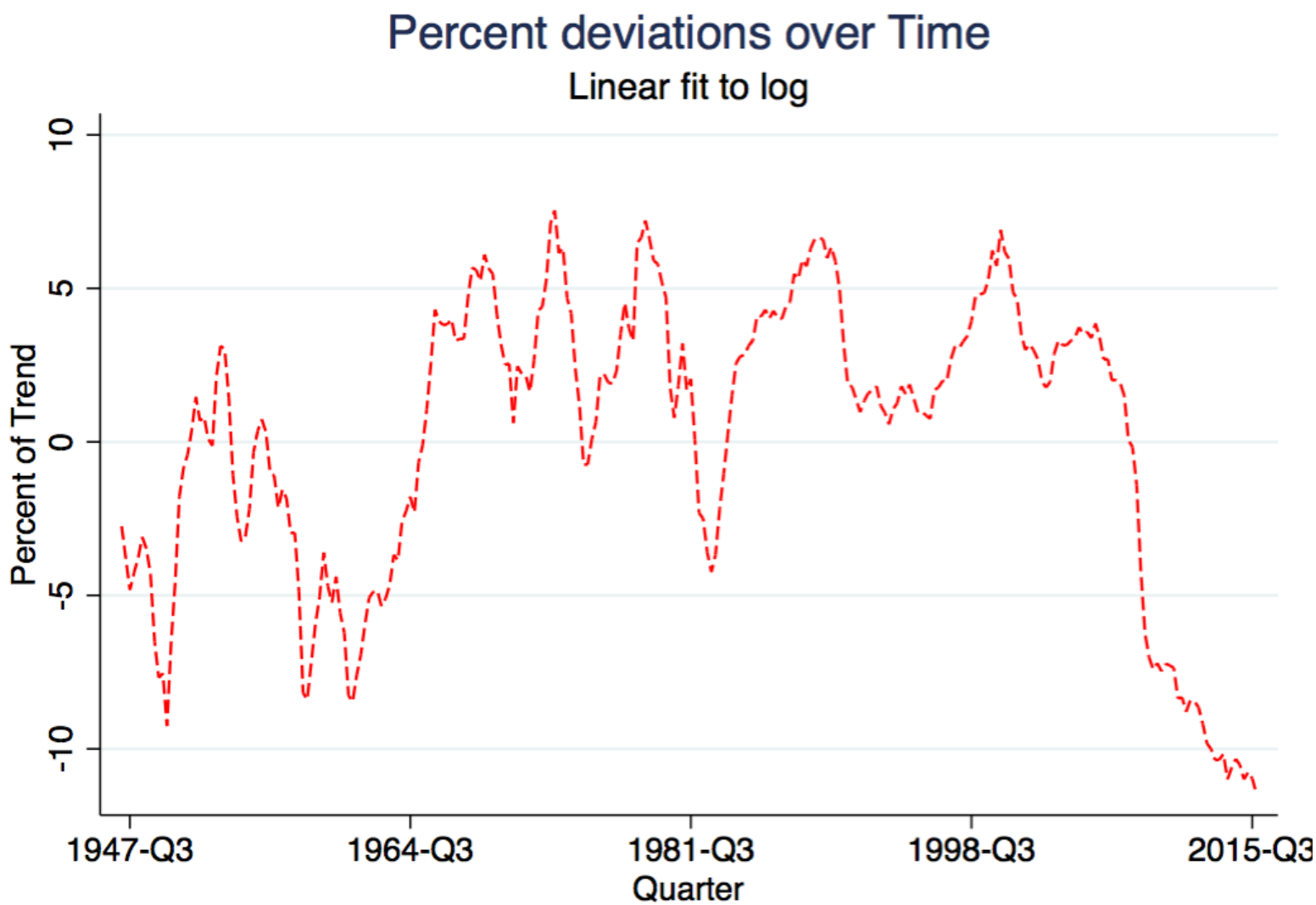
GDP-Trend and Deviations-IV



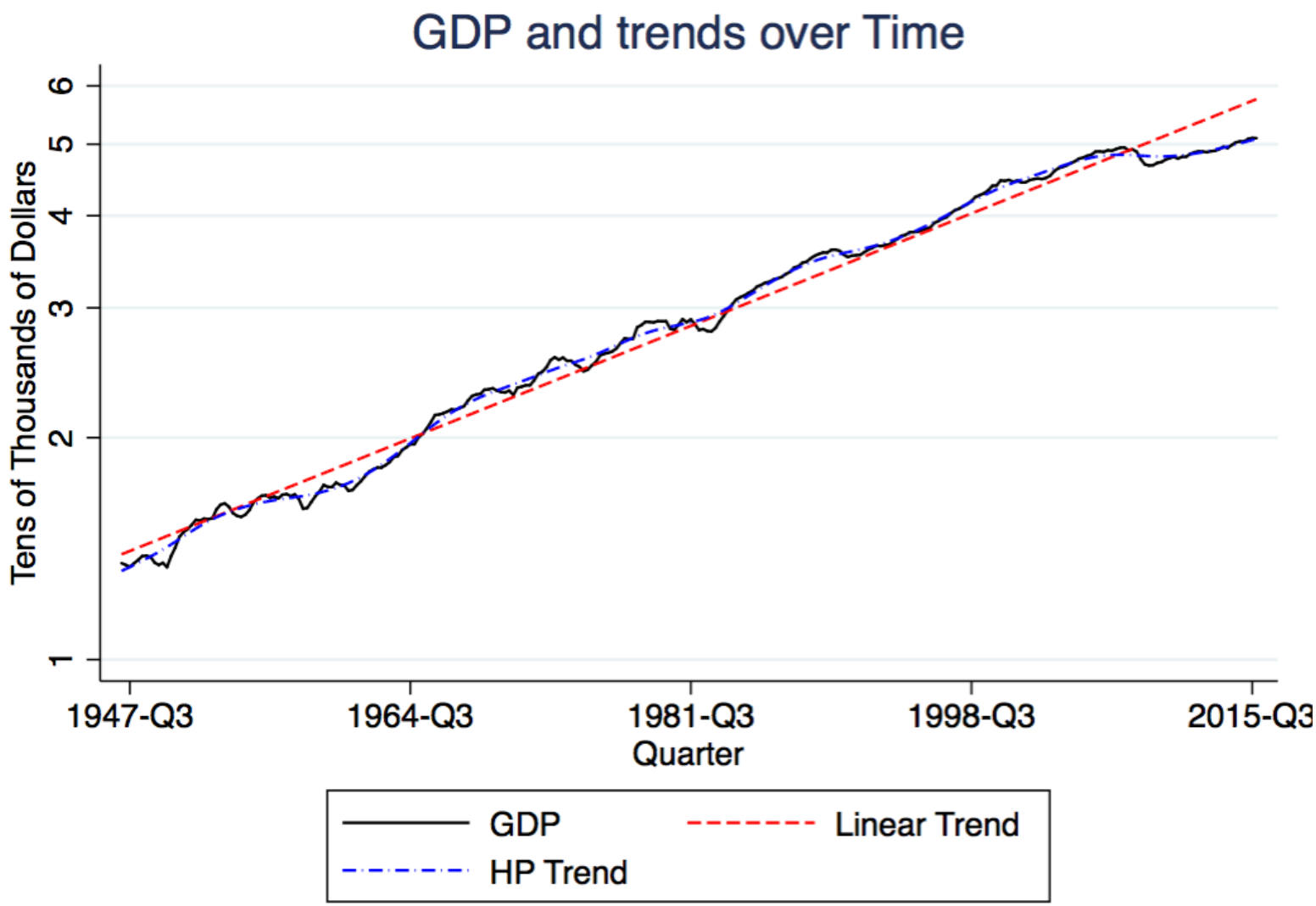
GDP-Trend and Deviations-V



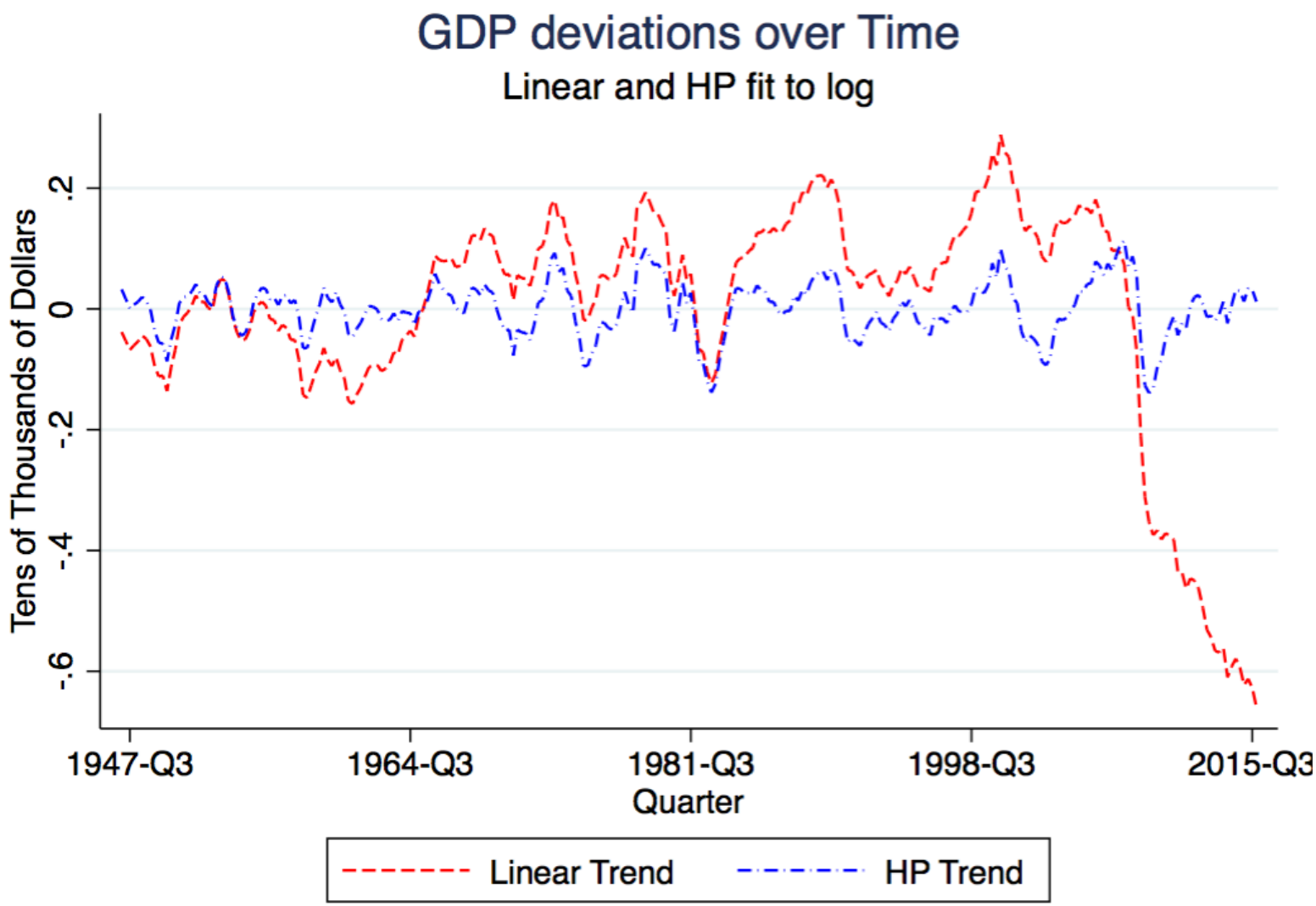
GDP-Trend and Deviations-VI



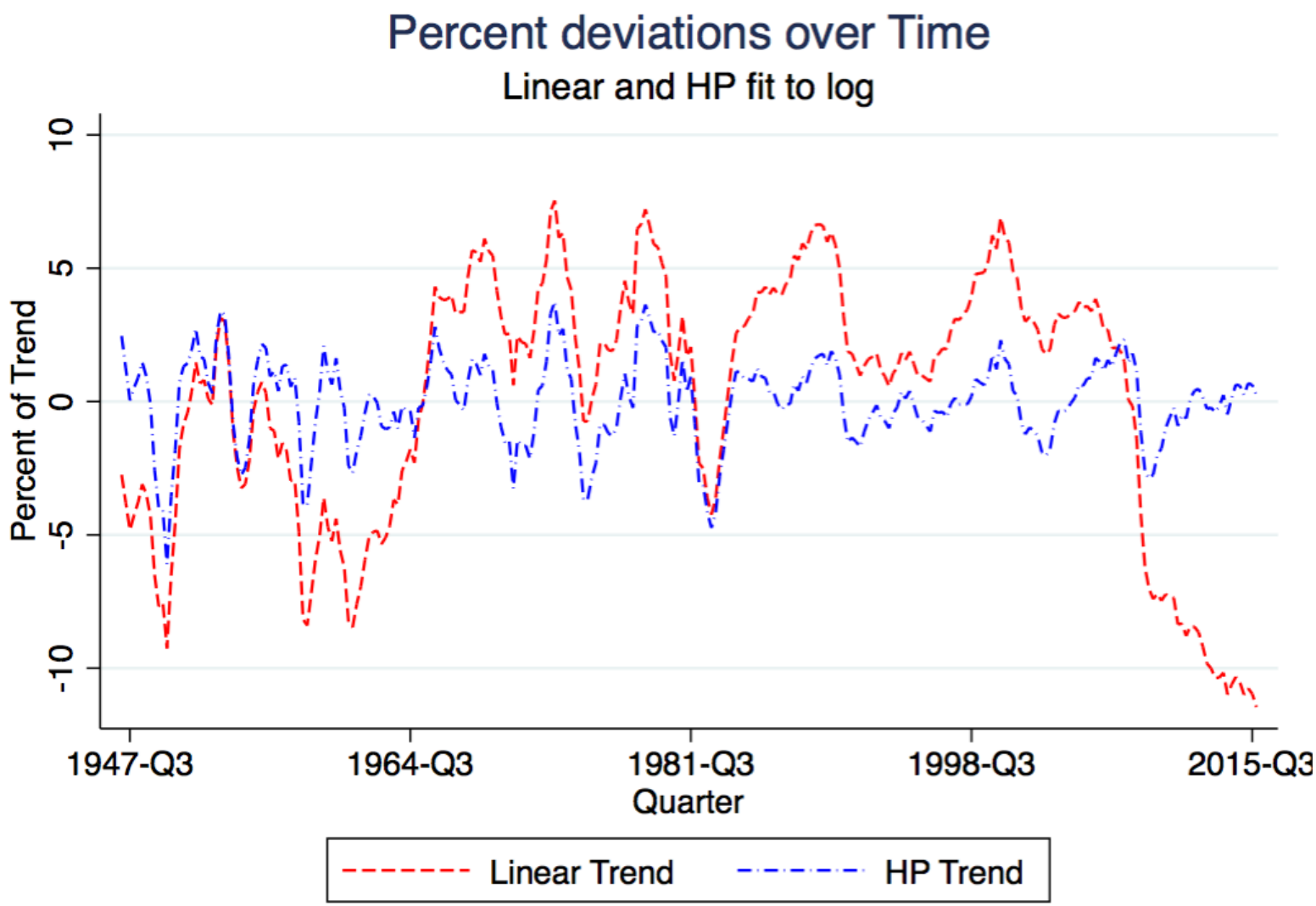
GDP-Trend and Deviations-VII



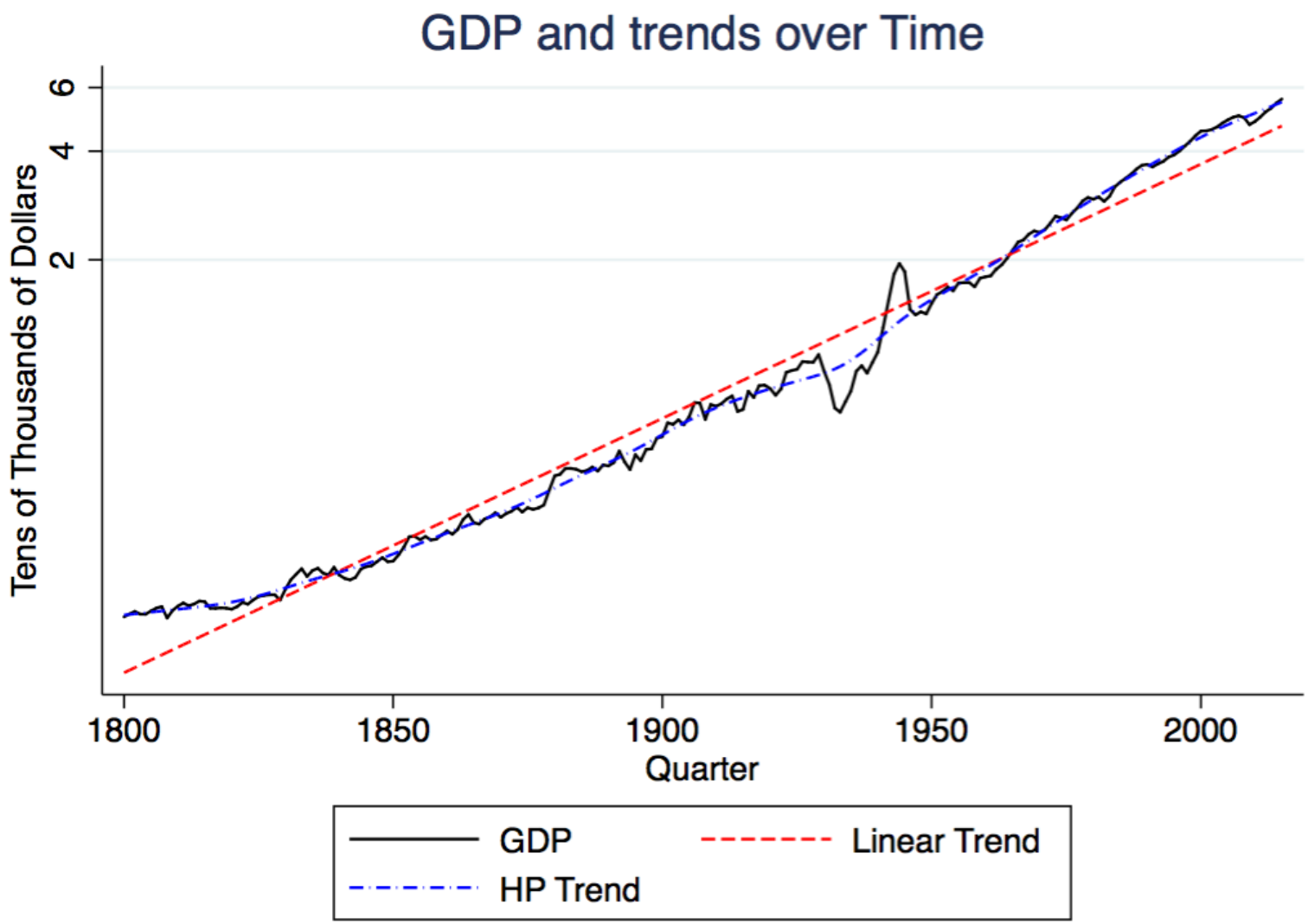
GDP-Trend and Deviations-VIII



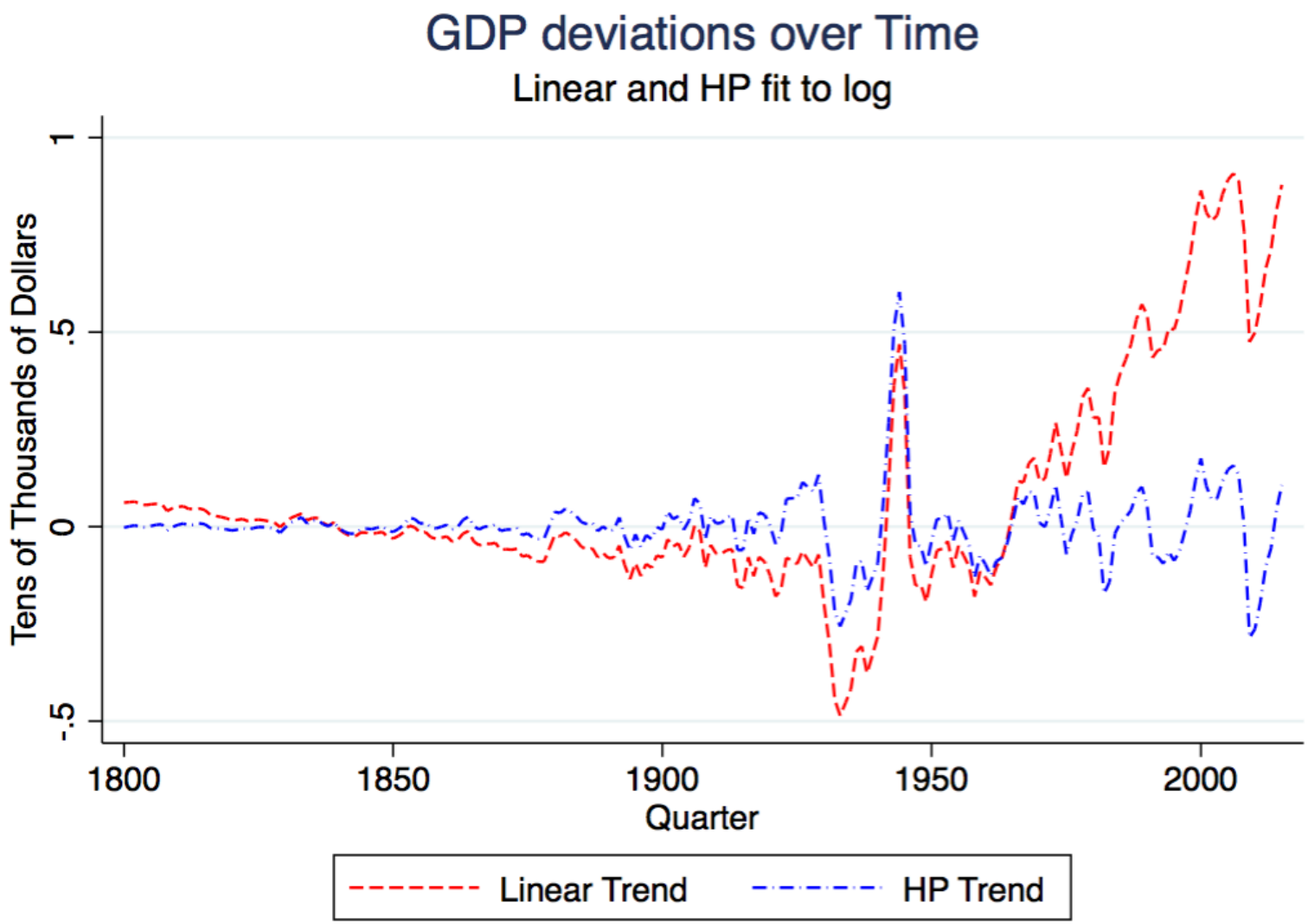
GDP-Trend and Deviations-IX



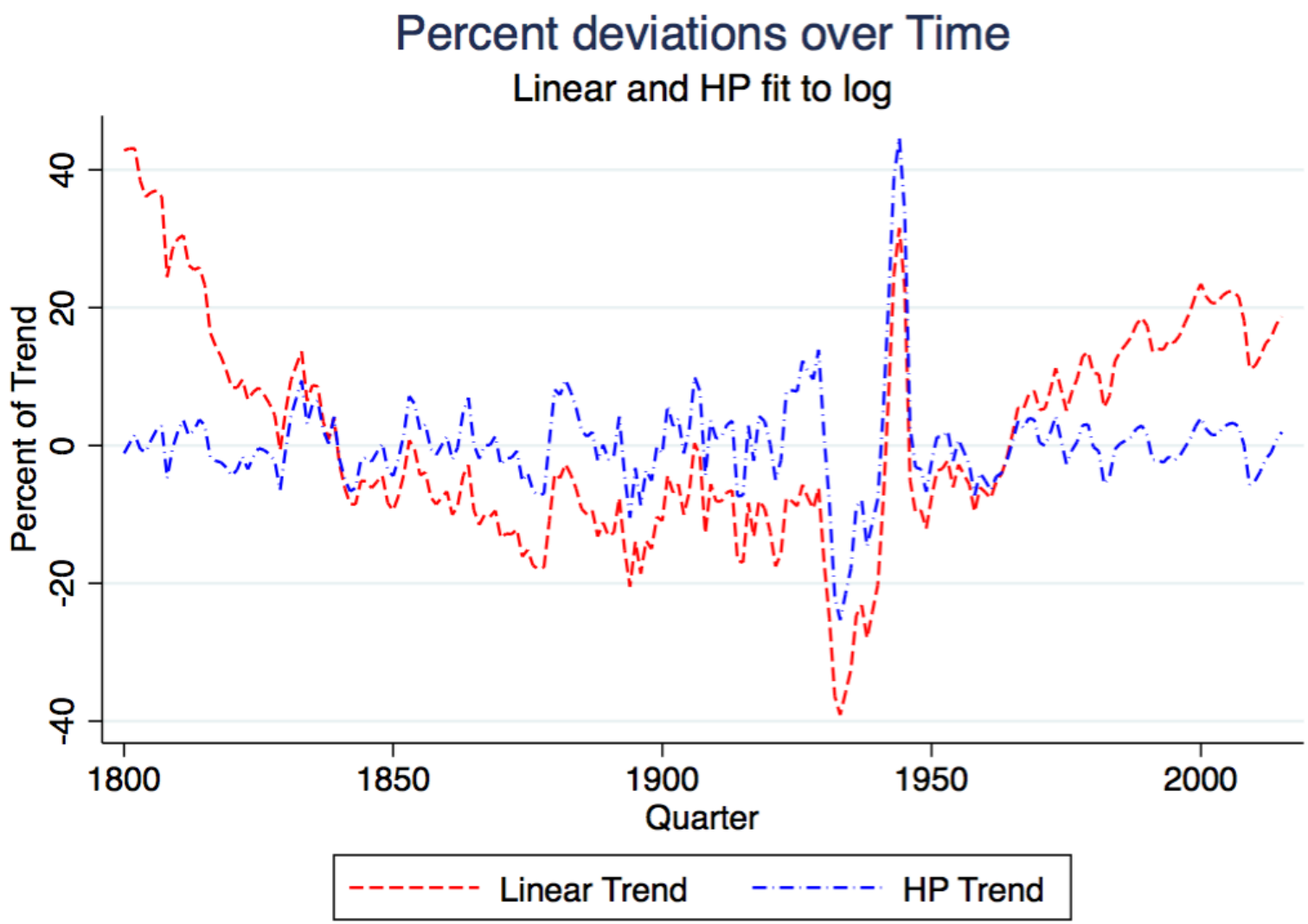
GDP-Trend and Deviations-X



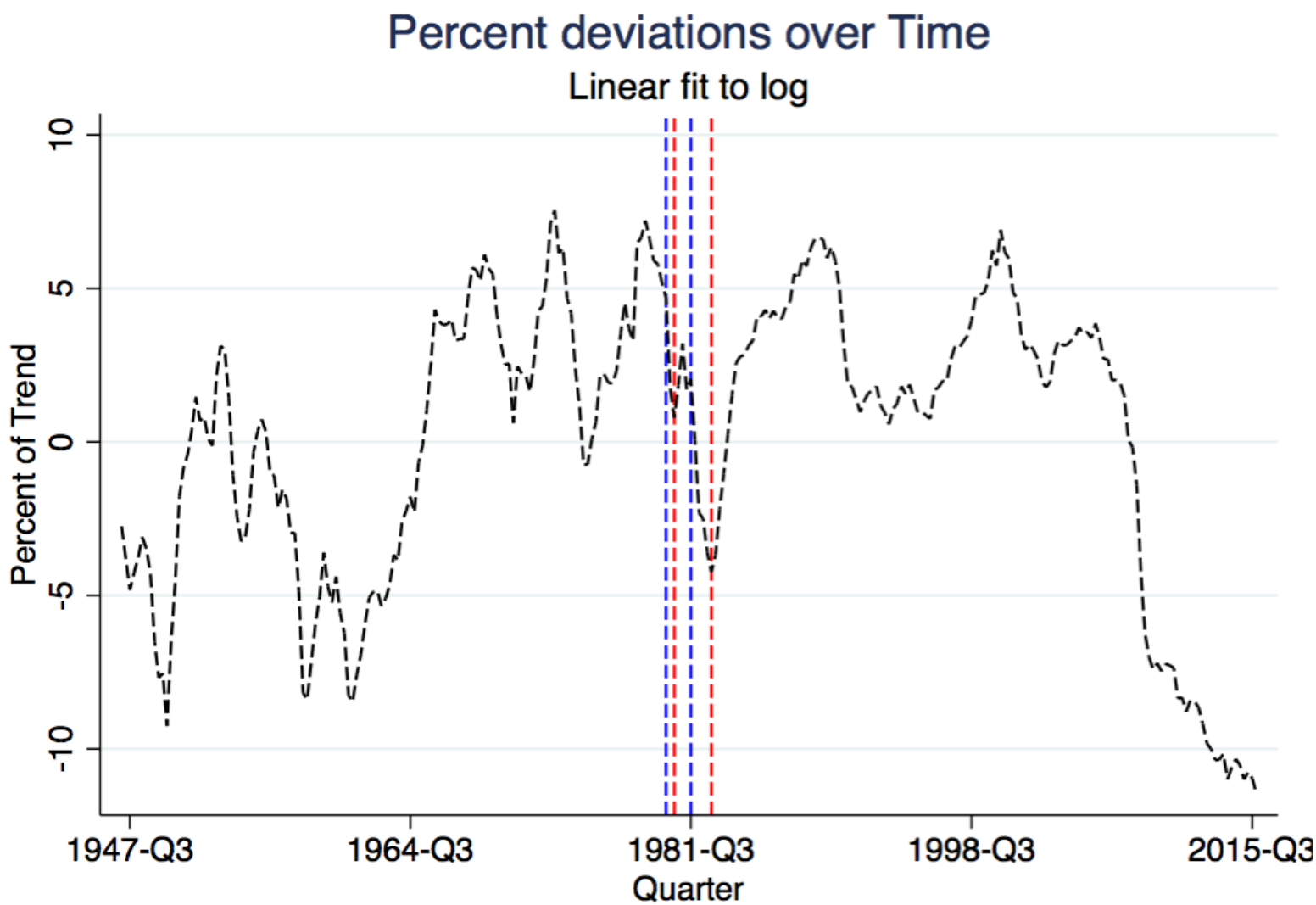
GDP-Trend and Deviations-XI



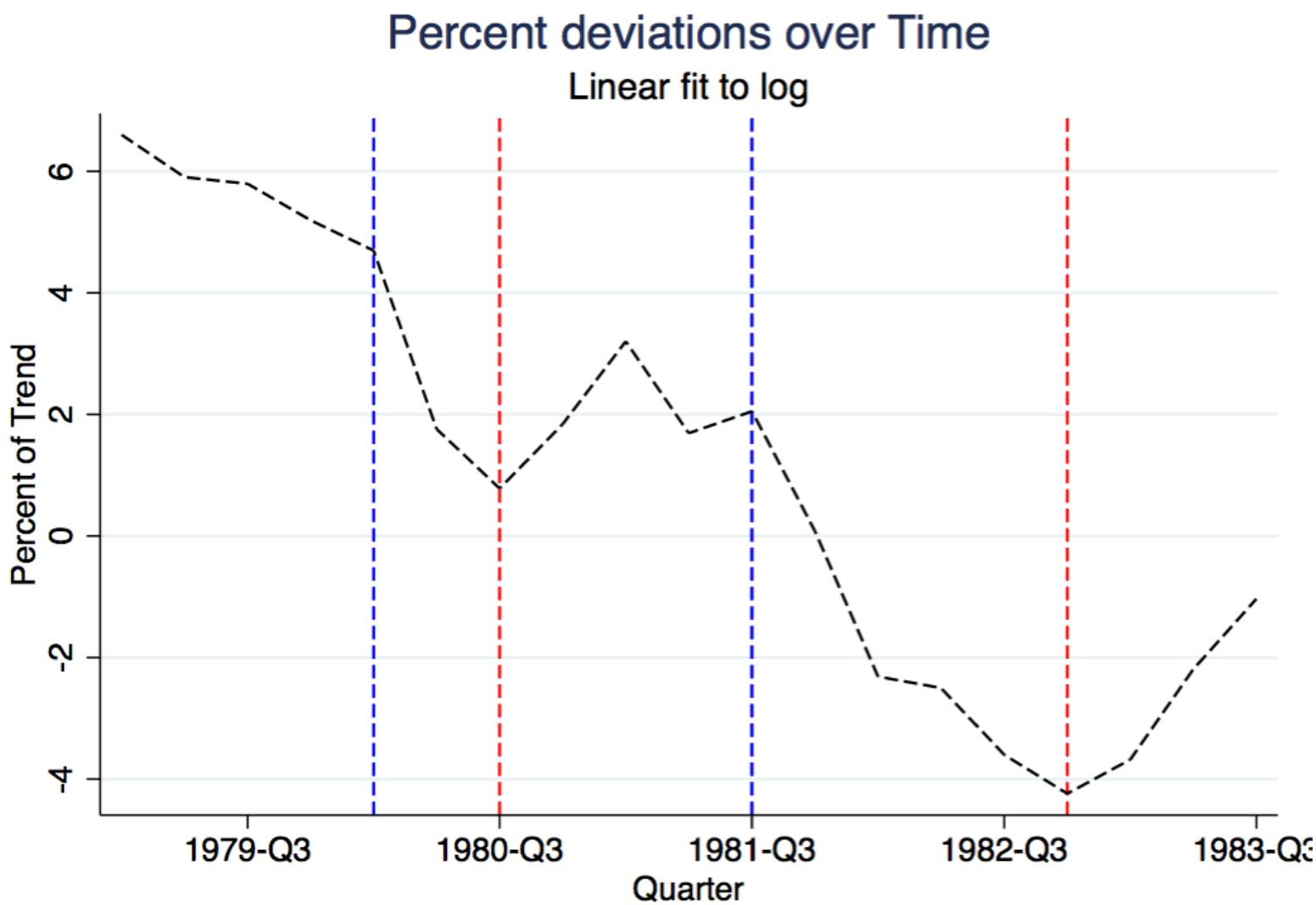
GDP-Trend and Deviations-XII



GDP-Trend and Deviations-XIII



GDP-Trend and Deviations-XIII



Postwar Recessions

Beginning	End	HP % Deviation (trough)
November 1948	October 1949	-6.1%
July 1953	May 1954	-2.76%
August 1957	April 1958	-3.90%
April 1960	February 1961	-2.68
December 1969	November 1970	-3.26%
November 1973	March 1975	-3.71%
January 1980	July 1980	-1.30%
July 1981	November 1982	-4.73%
July 1990	March 1991	-1.70%
March 2001	November 2001	-2.03%
December 2007	June 2009	-2.88%

Note: Differ from Barro a little. Standard deviation 1.63% of GDP.

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Takeaways

- We define a recession as when GDP is going down (peak to trough) *not* peak to peak!
- Deviations are very small compared to trend: typically between -1.7% and +1.7% of trend
- The difference between the linear and HP tells us that this last recession is a pretty big deal because we're "off trend."
- We can talk about business cycles now

The RBC Model: Shocks to the Economy

- Barro calls this an "equilibrium business cycle model."
- Recall our production function:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

- A recession bops A (productivity, technology, knowledge) on the nose
- We've seen that growth is A_t going up
- We'll think about business cycles are A_t shifting around
- From measurements of Y_t, K_t, and L_t, we can back out what A_t is
- Then, in our model, we can see what *would* happen to Y_t, K_t, and L_t if agents were hit by a A_t shocks we measured
- This isn't as tautological as it appears: only if agents make the same K, L choices as in the data will our model get the right predictions

Shocks to A-I

- It makes sense that technology/knowledge can go up
- It's a bit less sensible to think knowledge is destroyed
- But recall Barro Chapter 5 or Lucas 1990: many things are in "A"
  - If the true production function had oil O_t in it,

$$Y_t = A_t K_t^{\alpha} L^{1-\alpha} O_t^{\beta}$$

  - Then our measured A would be shifting around by O_t as well!

$$Y_t = (A_t O_t^{\beta}) K_t^{\alpha} L^{1-\alpha}$$

  - Oil price shocks in 1956-1957, 1973-1974, 1978-1979, 1980, 1990-1991, and 2007-2008 correspond to recessions
  - This is just an example: it's hard to write a model where they're a big enough deal to cause a recession (β is too small)

Shocks to A-II

- Many things could cause A to go down
  - Oil shocks
  - Trade shocks
  - Legal and political changes that change
    - Competitiveness
    - Trade
  - Weather & Natural Disaster shocks
  - War

Shocks to A and the labor market

- Remember the production function and profit function:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

and

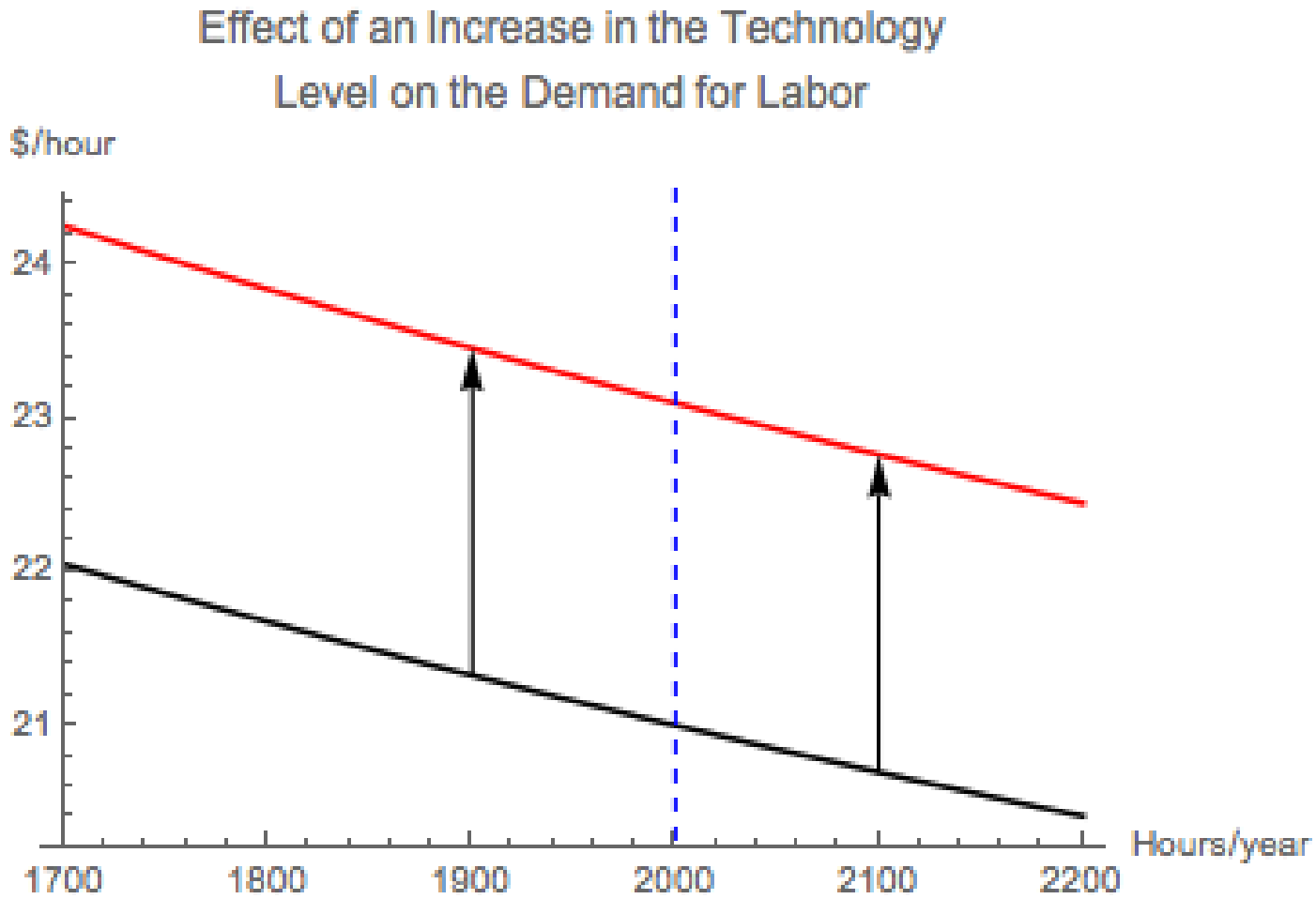
$$\pi_t = A_t K_t^{\alpha} L_t^{1-\alpha} - w_t L_t - r_t K_t$$

- So, taking FOC's:

$$w_t = (1-\alpha) A_t K_t^{1-\alpha} L_t^{-\alpha}$$

- If A_t increases by 1%, w_t goes up by
- We can graph this as a function of L_t, holding K_t and A_t fixed.

Shocks to A and the labor market



Thinking about shocks to A and the labor market

- Wage is the marginal product of labor
- When productivity goes up, demand for labor goes up, ceteris paribus
- But (in our model) labor is fixed
- If wages didn't change, there would be a shortage of labor
- In order to get firms to demand the right amount of labor again, wages rise

Shocks to A and the capital market

- The production function and profit function:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

and

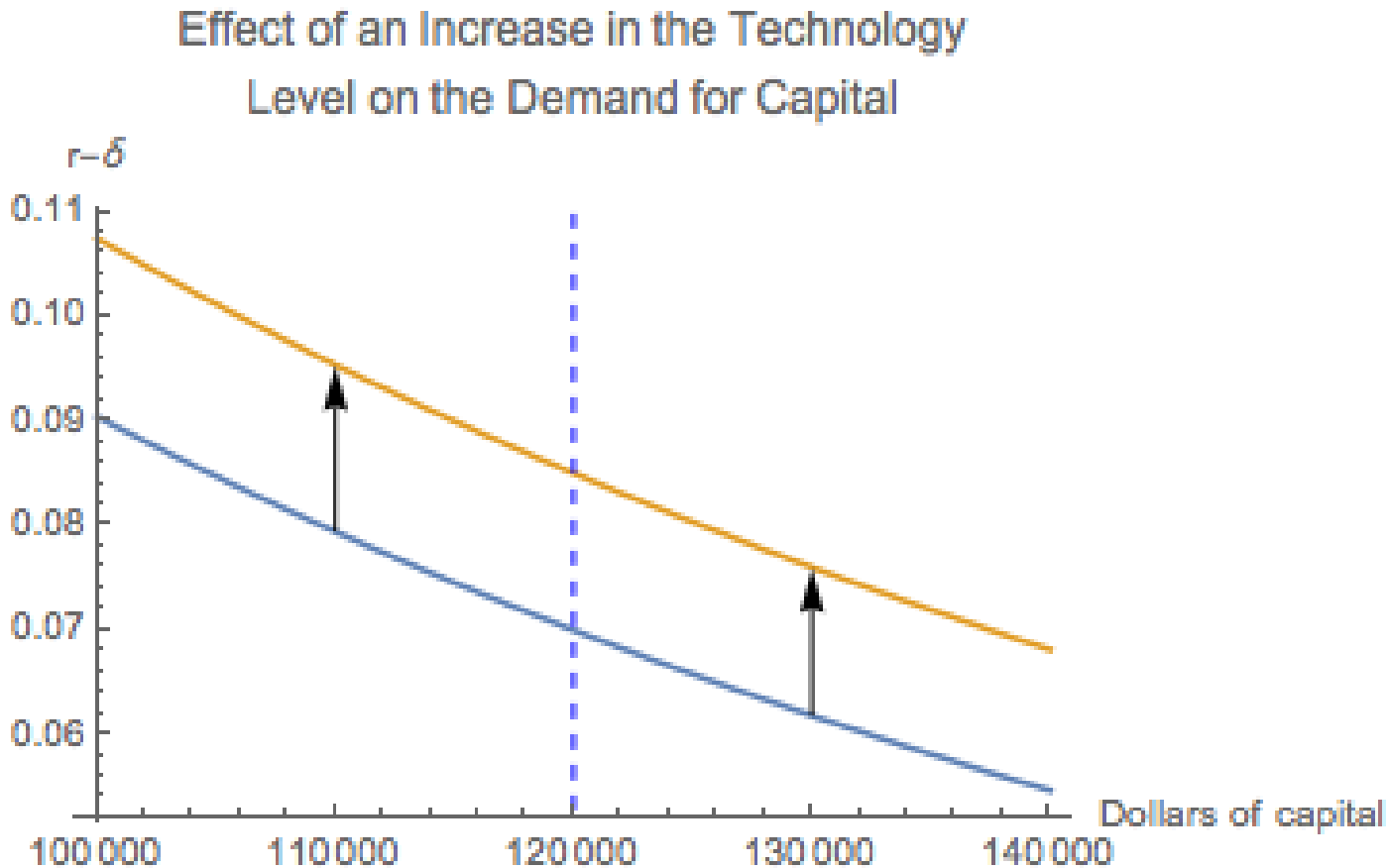
$$\pi_t = A_t K_t^{\alpha} L_t^{1-\alpha} - w_t L_t - r_t K_t$$

- So, taking FOC's:

$$r_t = \alpha A_t K_t^{-\alpha} L_t^{1-\alpha}$$

- We can graph this as a function of K_t, holding L_t and A_t fixed.

Shocks to A and the labor market



Thinking about shocks to A and the capital market

- The interest rate is the marginal product of capital
- When productivity goes up, demand for capital goes up, ceteris paribus
- But (in our model) capital is fixed
- If interest rate didn't change, there would be a shortage of capital
- In order to get firms to demand the right amount of capital again, the interest rate rises

Putting things together

- Economic booms happen when $A \uparrow$
- Our model says that $A \uparrow \Rightarrow \{w \uparrow, r \uparrow\}$
- Recall the interest rate on bonds, $i = \frac{R}{P} - \delta$
- So our model says that $A \uparrow \Rightarrow \{i \uparrow\}, too$
- If interest rate didn't change, there would be a shortage of capital
- In order to get firms to demand the right amount of capital again, the interest rate rises

Thinking about behavior: two different ways

- Recall the household's real budget constraint (Barro Chapter 7):

$$\underbrace{C}_{\text{Real Consumption}} + \underbrace{\frac{1}{P}\Delta B + \Delta K}_{\text{Real Savings}} = \underbrace{\frac{w}{P}L}_{\text{Real labor income}} + \underbrace{i\left(\frac{B}{P} + K\right)}_{\text{Real property income}}$$

- What happens when A increases?

Thinking about behavior: two different ways

- Recall the household's real budget constraint (Barro Chapter 7):

$$\underbrace{C}_{\text{Real Consumption}} + \underbrace{\frac{1}{P}\Delta B + \Delta K}_{\text{Real Savings}} = \underbrace{\frac{w}{P}L}_{\text{Real labor income}} + \underbrace{i\left(\frac{B}{P} + K\right)}_{\text{Real property income}}$$

- What happens when A increases?
  - A increases $\frac{w}{P}$, as just seen, and L doesn't change, so labor income increases.
  - A increases R (and therefore i), as just seen, and K doesn't change in SR, so nonlabor income increases
  - The household is richer, so either consumption or real savings go up (or both)

Thinking about behavior: two different ways

- Alternatively, you can think of things using the aggregate budget constraint (Barro Chapter 7):

$$\underbrace{C}_{\text{Real Consumption}} + \underbrace{\Delta K}_{\text{Real Net Investment}} = \underbrace{Y}_{\text{Real GDP}} - \underbrace{\delta K}_{\text{Depreciation}}$$

  or, writing Y explicitly:

$$\underbrace{C}_{\text{Real Consumption}} + \underbrace{\Delta K}_{\text{Real Net Investment}} = \underbrace{AK^{\alpha}L^{1-\alpha}}_{\text{Real GDP}} - \underbrace{\delta K}_{\text{Depreciation}}$$

- What happens when A increases?
  - A increases Y
  - δK is fixed in the short run
  - The household is richer, so either consumption or real investment go up.

An increase in A: income and substitution effects

- When A goes up, i goes up, and household is richer. What happens to consumption now and tomorrow?
  - Income effect: the household is richer, consumption in all periods goes up
  - Substitution effect: the interest rate is higher, so consumption today is more expensive than tomorrow: consumption today goes down, consumption tomorrow goes up
- Our prediction is ambiguous for the present (income up means $c_{now} \uparrow$, interest rate up means $c_{now} \downarrow$), and unambiguous in the long run.

Permanent vs. temporary shocks to A

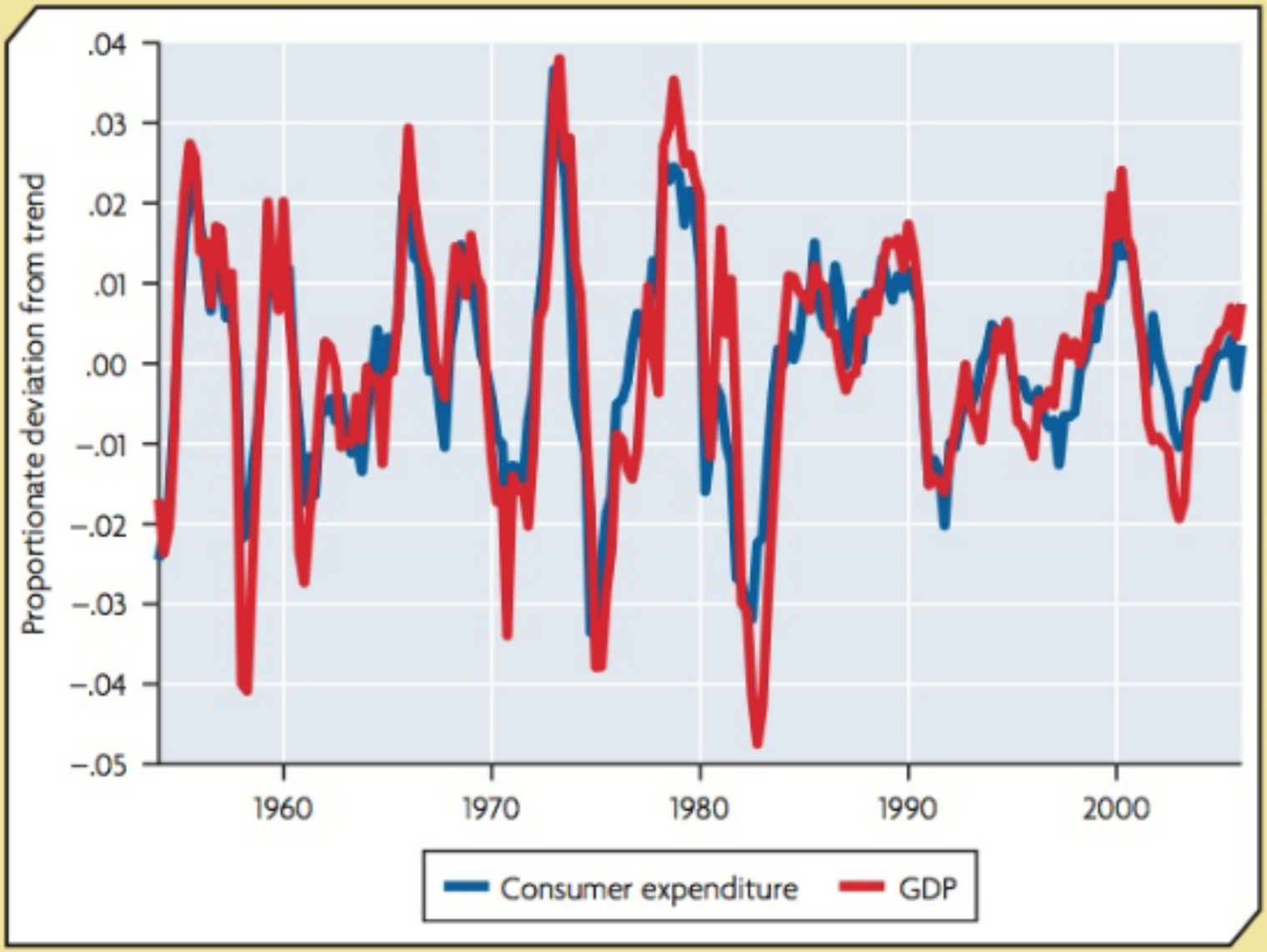
- Recall Chapter 7's discussion of increases in income
  - If all current and future incomes rise by the same amount, then consumption in all periods rise by that amount
    - In other words, you'll eat all of your benefit today, because you'll have it again tomorrow
  - So if $A \uparrow$ permanently, then it's likely $c_{now} \uparrow$
  - If $A \uparrow$ only today, then c_{now} may go up or down.
- For the duration of Chapter 8, we consider permanent shocks to A

Matching Theory with Facts-I

- We're going to think that A_t is moving Y_t around (permanently)
- If that's the case,
  - C_t should be "procyclical" (move with GDP)
  - C_t should be less volatile than Y_t (why?)
    - People like to smooth consumption
  - I_t should be "procyclical" (move with GDP)
  - I_t should be more volatile than Y_t (why?)
    - When $A_t \uparrow$, $r_t \uparrow$, so C_t doesn't go up by the amount A_t does. Consequently, $I_t \uparrow$ by more to balance it out.
    - Note: empirical evidence suggests this intertemporal effect should be small, but in reality it seems to be big...we'll think about why

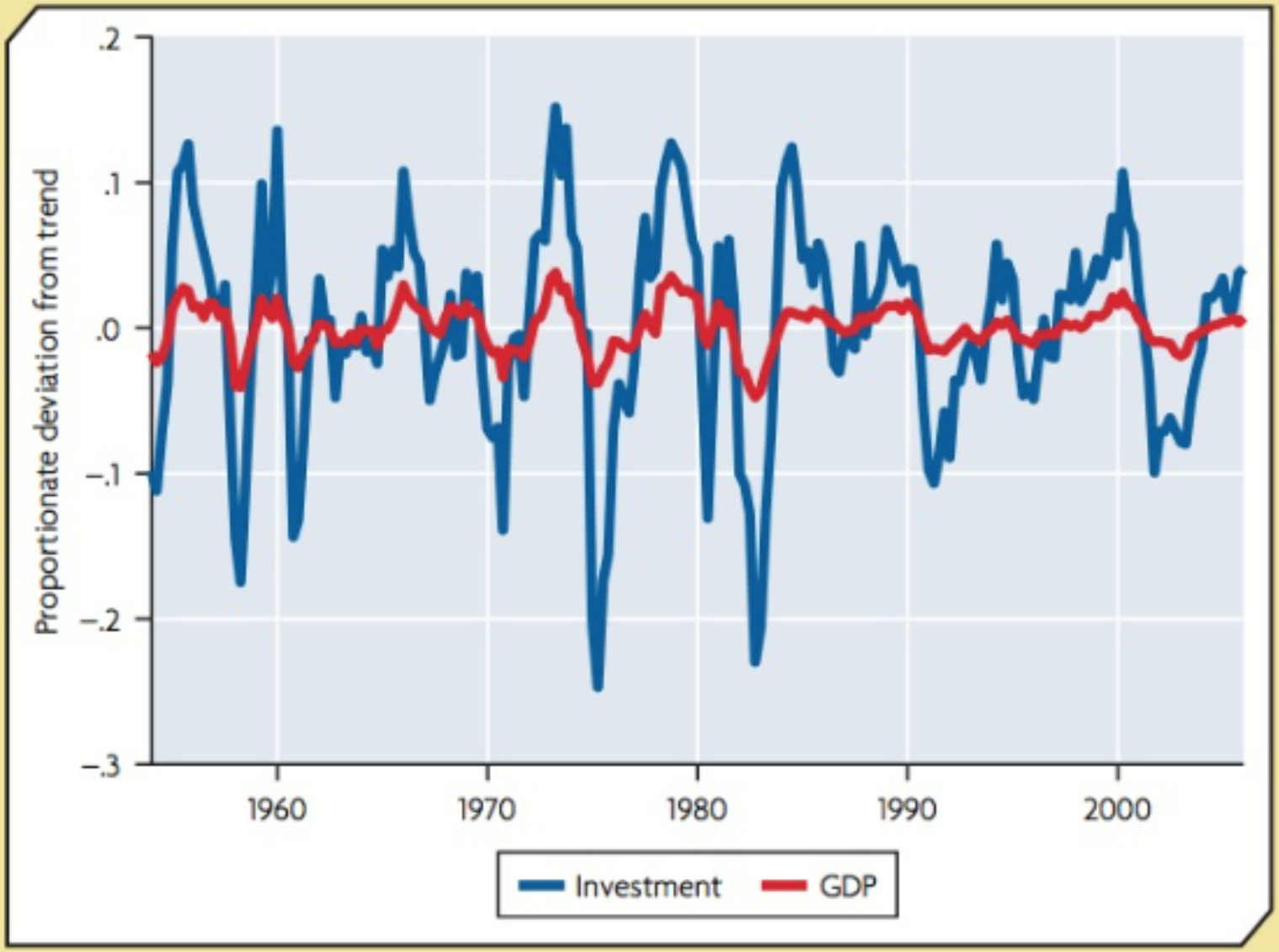
Consumption procyclical, less volatile

Figure 8.9 *Cyclical Behavior of U.S. Real GDP and Consumer Expenditure*



Investment procyclical, more volatile

Figure 8.10 *Cyclical Behavior of U.S. Real GDP and Investment*

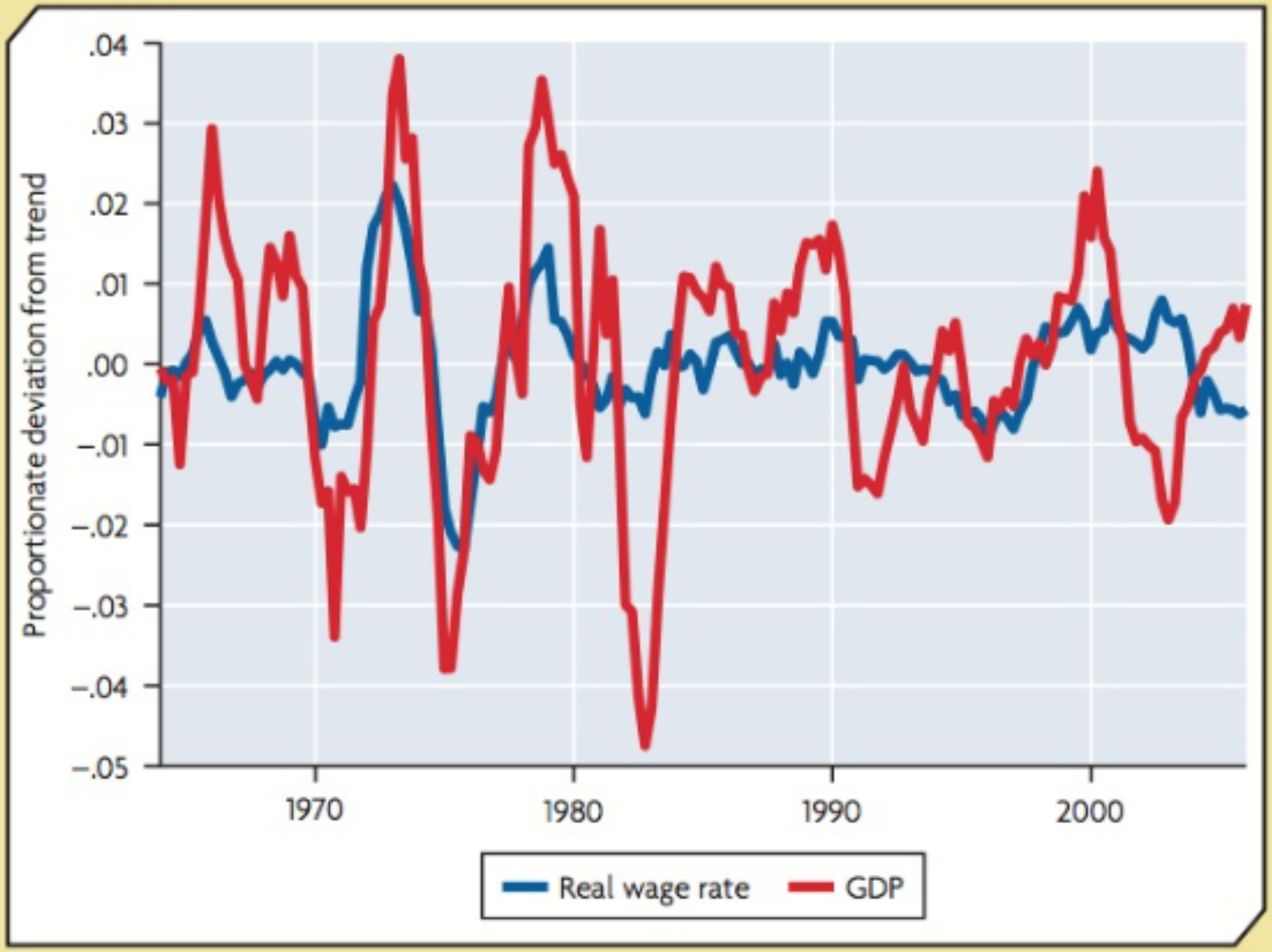


Other predictions?

- If A_t is moving around then w_t should be procyclical too because marginal product of labor increases with A_t
- If A_t is moving around then r_t should be procyclical too because marginal product of capital increases with A_t

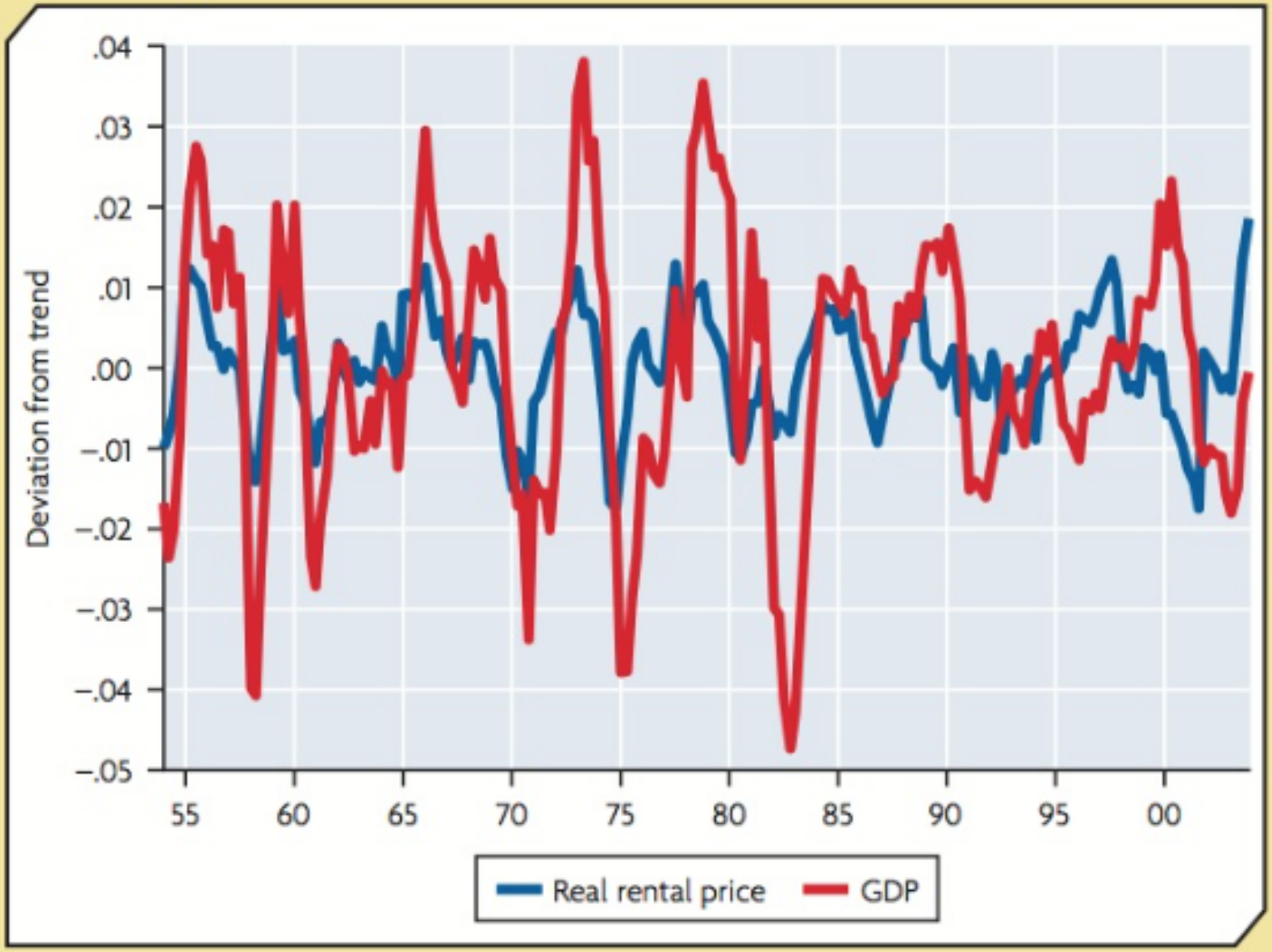
Wages are procyclical

Figure 8.11 *Cyclical Behavior of U.S. Real GDP and the Real Wage Rate*



Interest rate is procyclical

Figure 8.12 *Cyclical Behavior of U.S. Real GDP and the Real Rental Price of Capital*



Taking stock

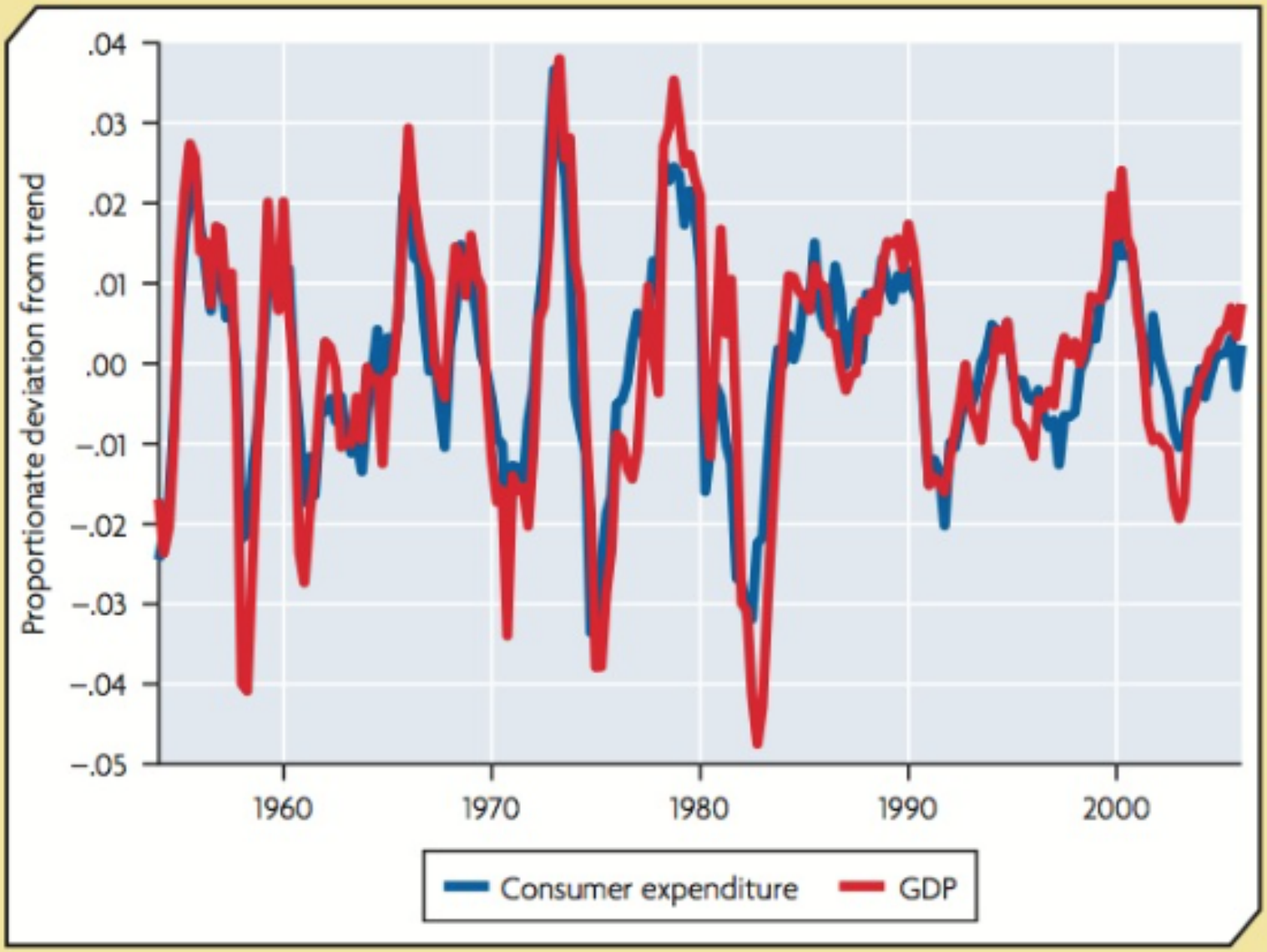
- We want to analyze the business cycle
- We will do so by assuming that A_t, productivity/knowledge, is getting bopped around
- If that's the case, then we would predict that:
  - C_t, I_t, w_t, and r_t would all be procyclical
    - They are!
  - C_t would be less volatile than GDP and I_t would be more
    - They are!
- Things are looking pretty good, but it's hard to justify just how little consumption moves compared to GDP: intertemporal substitution effect would have to be very large

Thinking about temporary shocks

- So far we've been thinking about permanent shocks
- When a shock is permanent, it hits all periods equally, so all consumptions rise by roughly the same amount
- What about when a shock is temporary?
  - Then still big effects on the interest rate
  - But now small effects on consumption, because income effect spread over many periods
- If shocks are temporary, then consumption would barely covary with GDP

Consumption procyclical, less volatile

Figure 8.9 *Cyclical Behavior of U.S. Real GDP and Consumer Expenditure*



Temporary and Permanent Shocks

- We're faced with a conundrum
  - If shocks are permanent, then consumption and GDP move together because all periods wealthier
    - But to explain investment being so volatile, we would need an unrealistic intertemporal effect
    - Another way of putting this is that Y and C move together too much with permanent shocks
  - If shocks are temporary, then consumption and GDP don't move together income spread over many periods
    - But it explains investment volatility well!
  - When you come to a fork in the road, take it: we split the difference and conclude that shocks to A are long-lasting but less than permanent (are persistent)

Variation in labor input-I

- We've given labor a pretty short shrift...it never varies?
- Don't we care about what happens to labor hours during recessions and booms? Isn't that a pretty big deal?
- Yes: let's add labor.
- Basic effects on labor in a one-period model:
  - When income goes up, leisure and consumption both go up, labor goes down (income effect)
  - When wages go up, consumption goes up, but we don't know what happens to labor/leisure (income and substitution effects)

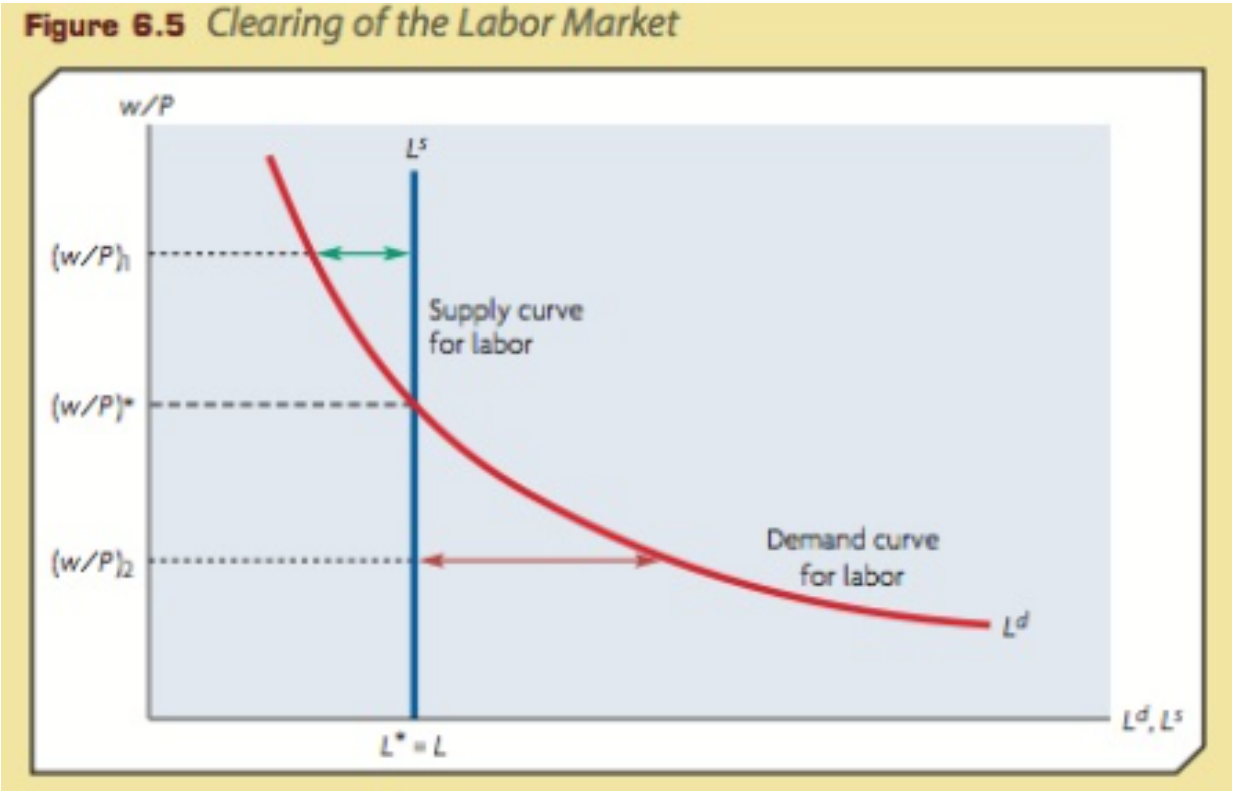
Variation in labor input-II

- We can amp up the substitution effect relative to the income effect on labor supply by increasing wages only for one period
- If wages are only high today, then consumption today only goes up by a little, because the benefit is divided over many periods, so the income effect is small
- But the substitution effect remains in full force
- Consequently, we know that labor will go up

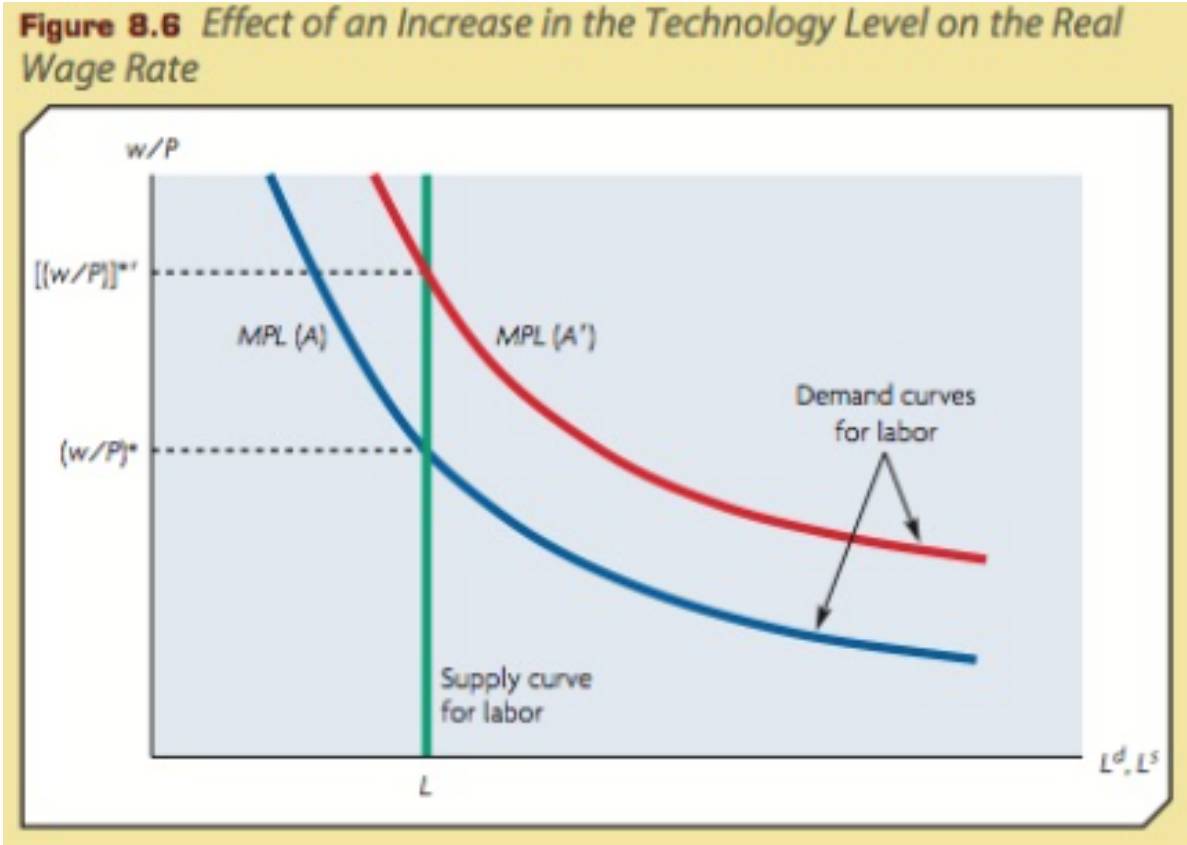
Variation in labor input-II

- We can amp up the substitution effect relative to the income effect on labor supply by increasing wages only for one period
- If wages are only high today, then consumption today only goes up by a little, because the benefit is divided over many periods, so the income effect is small
- But the substitution effect remains in full force
- Consequently, we know that labor will go up
- The point: if *long run* (permanent wage shift) labor supply is inelastic, *short run* (temporary wage shift) is elastic.

Before: Demand (and supply(?))

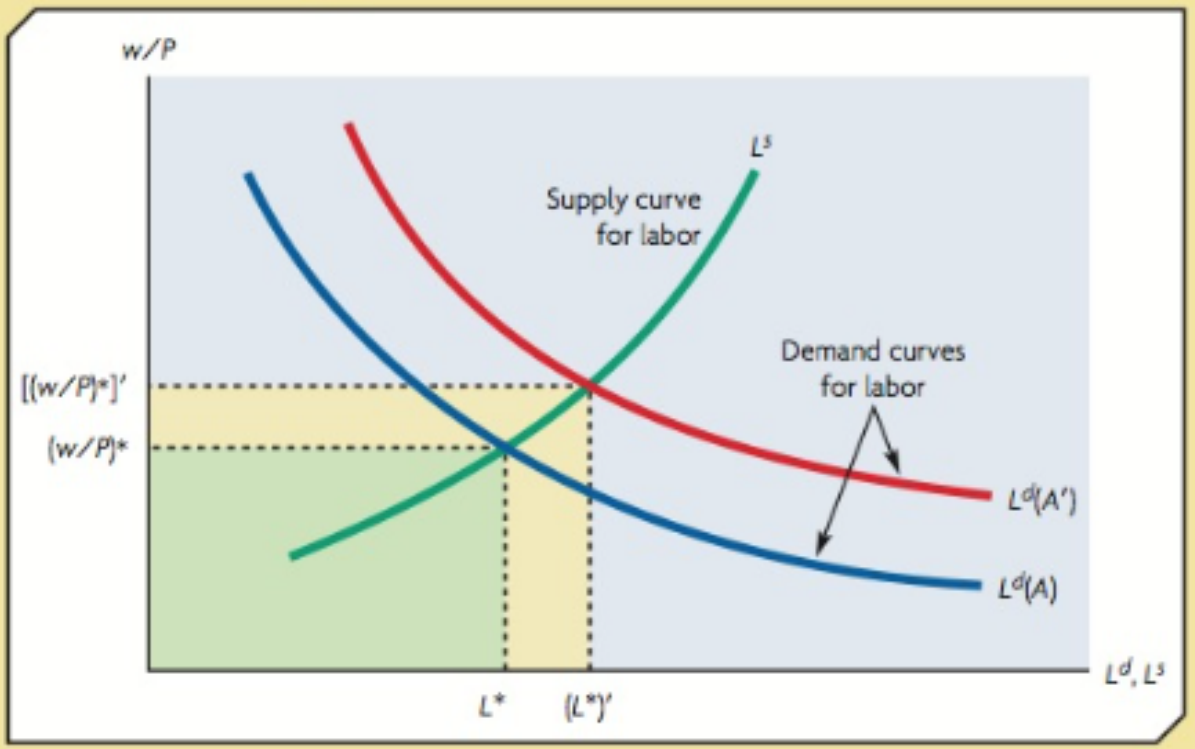


Before: Demand (and supply(?))



Now: Supply and Demand

Figure 8.15 *Clearing of the Labor Market*



The Good News: Model v. Reality

- We're trying to explain business cycles with persistent but not permanent productivity (A_t) shocks
- Does it stack up with reality?

Concept	Symbol	Reality	Model
Total Factor Productivity	A_t	$\downarrow/?$	$\downarrow$
Labor	L_t	$\downarrow$	$\downarrow$
Wages	w_t	$\downarrow$	$\downarrow$
Interest rates	r_t	$\downarrow$	$\downarrow$
Consumption	c_t	$\downarrow$	$\downarrow$
Investment	i_t	$\Big\downarrow$	$\Big\downarrow$
Labor productivity	$\frac{L_t}{Y_t}$	$\downarrow$	$\downarrow$

- So far so good, with a few peculiarities & tweaks

Differences between model and reality

- We depend on big intertemporal effects
  - But empirical studies find smaller-than-necessary effects
  - Response: shocks are persistent but not permanent
- We depend on big wage/substitution/price effects to get big cyclicality of labor
  - But some empirical studies find little response of labor to temporary wage changes
- We think labor productivity should be procyclical
  - But in reality it's less procyclical than we'd expect.
- Takeaway: there are some quantitative puzzles, but this is going pretty well so far, everything is going in the right direction.
- Let's add more realistic capital and unemployment/matching (Chapter 9).