Macroeconomics

Week 7

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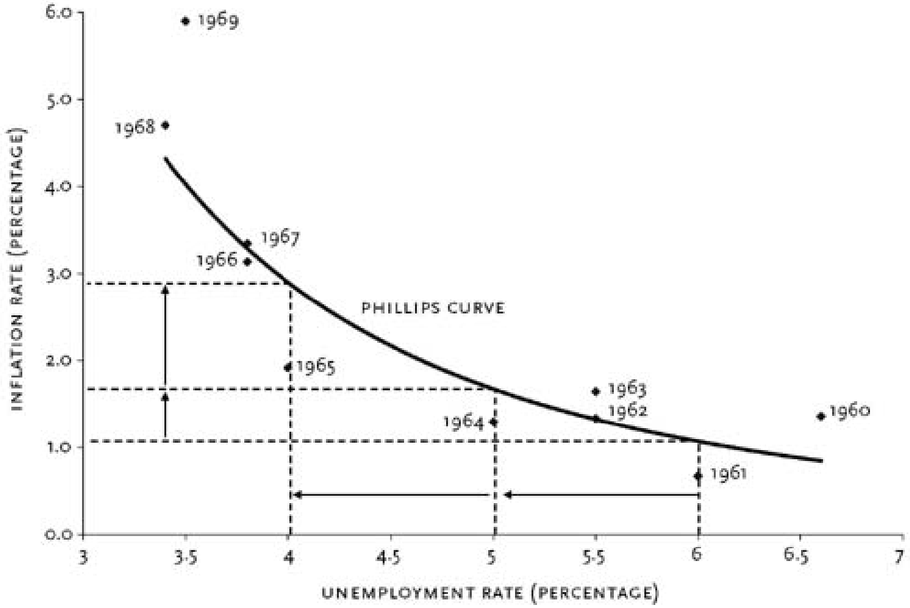
Aggregate Supply & the Phillips Curve

The Phillips Curve – Classic


Almarin Phillips

- **Almarin Phillips**: relationship between the inflation and the cyclical unemployment

- But… Not quite in the 70's and thereafter…



$$\pi = -\omega\left(U - U_n\right)$$

The Phillips Curve – Expectations Augmented

- **Milton Friedman** and **Edmund Phelps** introduced expectations

$$\pi = \pi^e - \omega\left(U - U_n\right)$$

- In this course we will assume **adaptive expectations**: $\pi_t^e = \pi_{t-1}$
- But… The relationship became weaker during the 70's (oil shocks)

The Phillips Curve – with Supply Shocks

- So **Supply Shocks** need to be considered

$$\pi = \pi^e - \omega\left(U - U_n\right) + \rho$$

- **Implication:**

$$\Delta\pi = \pi - \pi^e = -\omega\left(U - U_n\right) + \rho$$

The Okun's Law

- **Arthur Okun** found a relationship between the cyclical unemployment and the output gap

$$U - U_n = -\theta \left(Y - Y^P \right)$$

with $\theta \approx 0.5$

- Combining Okun's Law with the Phillips Curve we get a relationship between inflation and output — **a supply!**

The Aggregate Supply Function (AS) – Short-run

- The next equation combines the Phillips Curve with the Okun's Law (in red)

$$\pi = \pi^{e} - \omega\left(-\theta\left(Y - Y^{P}\right)\right) + \rho$$

The Aggregate Supply Function (AS) – Long-run

- In the long-run there are **no output gaps**: the economy is producing at full capacity
- And the **prices can adjust** immediately
- Aggregate Supply will be a vertical line

$$\boxed{Y = Y^P}, \quad \forall \pi$$

Appendix

Logs and growth rates

- By definition the growth rate g_x of a variable x between periods t and $t+1$ can be computed as:

$$g_x \equiv \frac{x_{t+1} - x_t}{x_t} = \frac{x_{t+1}}{x_t} - 1$$

- Then we can write:

$$1 + g_x = \frac{x_{t+1}}{x_t}$$

Logs and growth rates

- Taking logs in both sides:

$$\ln\left(1+g_x\right)=\ln\left(x_{t+1}\right)-\ln\left(x_t\right)$$

- But, by the **L'Hôpital rule**:

$$\lim_{g_x\to 0}\frac{\ln\left(1+g_x\right)}{g_x}=\lim_{g_x\to 0}\frac{\ln'\left(1+g_x\right)}{g_x'}=\lim_{g_x\to 0}\frac{\frac{1}{1+g_x}}{1}=1$$

Logs and growth rates

- Then, for $g_x \approx 0$:

$$g_x \approx \ln(1 + g_x)$$

- Since $\ln(1 + g_x) = \ln(x_{t+1}) - \ln(x_t)$:

$$\boxed{g_x \approx \ln(x_{t+1}) - \ln(x_t)}$$

Exercises

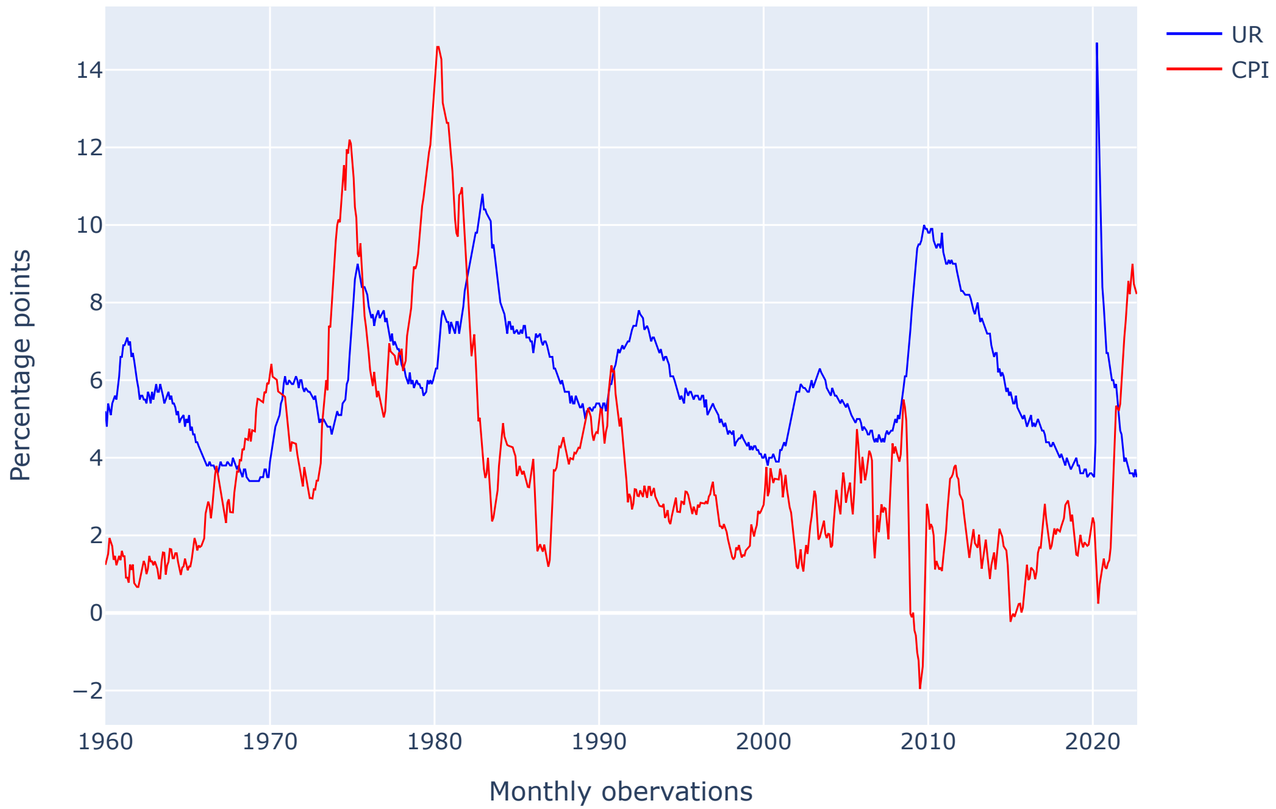
1. Inflation vs. unemployment

This will focus on the Phillips curve's relationship between inflation and unemployment. We will use the data in the file "ASdata.csv" which includes monthly observations covering the US economy from 1960 to 2022.

a. In Fig 1, we plot the ***time series*** of two variables: the inflation and the unemployment rates. Can we infer if there is any kind of relationship between those two aggregates by looking at the time series?

1. Inflation vs. unemployment

Fig 01. Inflation Rate (CPI) versus Unemployment Rate (UR): USA (1960--2022)



- CPI seems more volatile than UR
- Apart from the 70's, they seem symmetric
- A time-series is not the best visual choice to show cross-relationship

1. Inflation vs. unemployment

Fig 02. Inflation versus Unemployment: USA (1960--2022)

b. In Fig 2 we plot the **cross-plot** between those two aggregates. Can you spot any relationship between those two variables that may resemble the “Phillips Curve”?

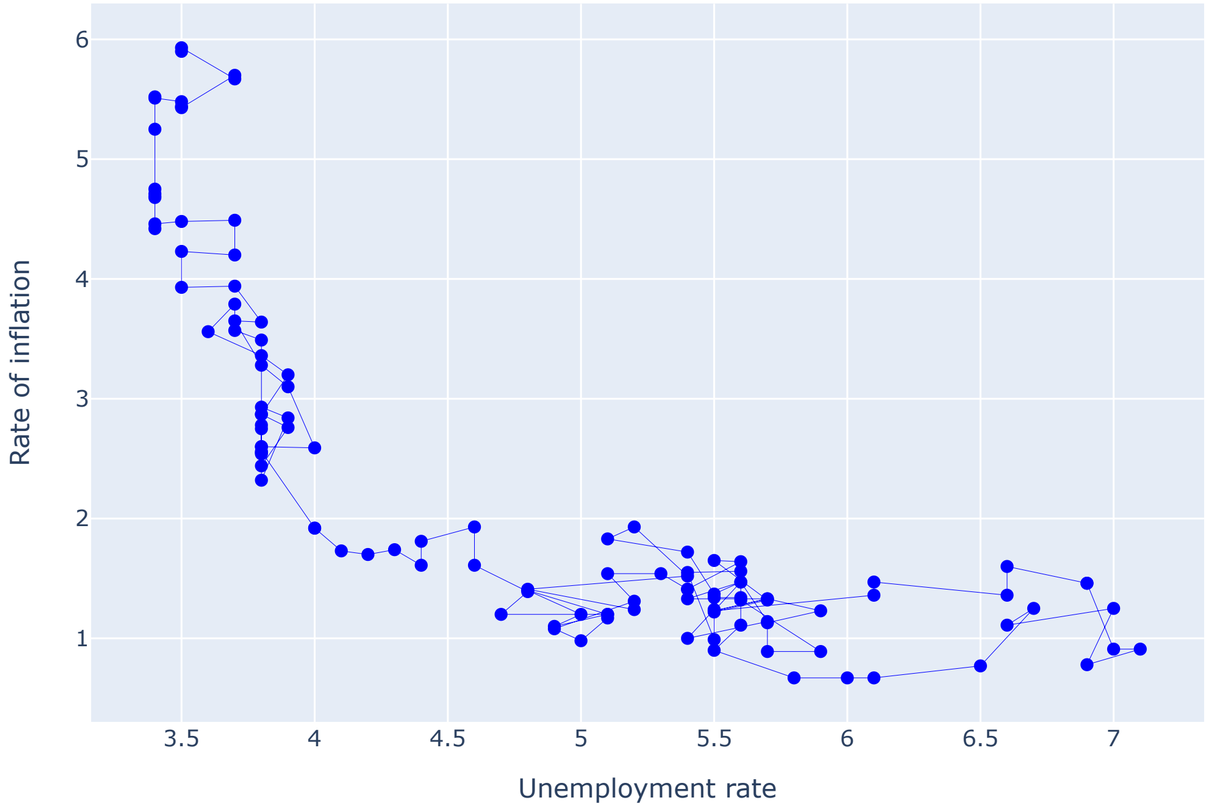
1. Inflation vs. unemployment

Fig 02. Inflation versus Unemployment: USA (1960--2022)

- **Phillips Curve**:
  $\pi = \pi^e - \omega\left(U - U_n\right) + \rho$
- Stable negative relationship between inflation π and unemployment U
- The plot does not show such a relationship, *for the entire period*

1. Inflation vs. unemployment

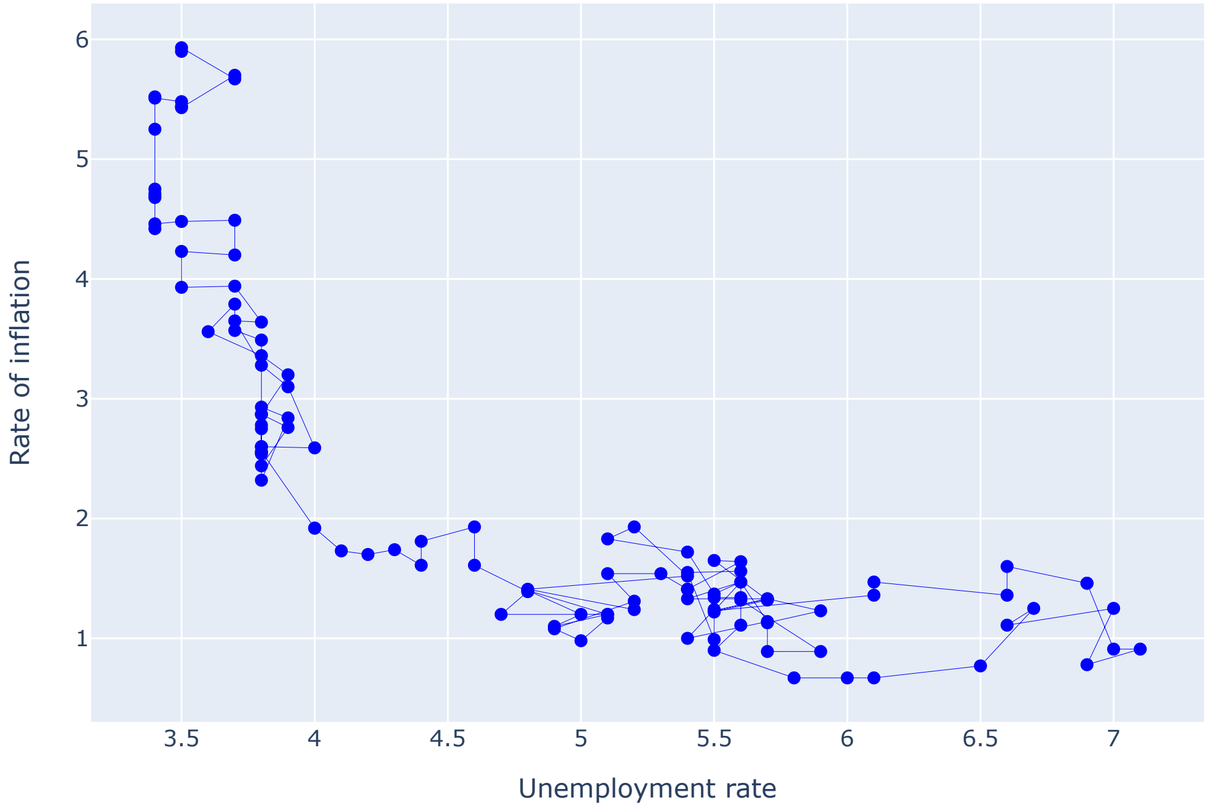
Fig 03. Inflation versus Unemployment: USA 1960s



c. Fig 3 presents the relationship for the 1960s. Do you see an apparent Phillips curve over there?

1. Inflation vs. unemployment

Fig 03. Inflation versus Unemployment: USA 1960s



- Now we see it
- Oil prices remained extremely stable (so $\Delta\rho = 0$), and inflation expectations were low ($\pi^e = 0$)

1. Inflation vs. unemployment

d. In Figs 4 and 5, we get the relationship for the 1970s and the 1980s. What conclusions can we put forward?

Fig 04. Inflation versus Unemployment: USA 1970s

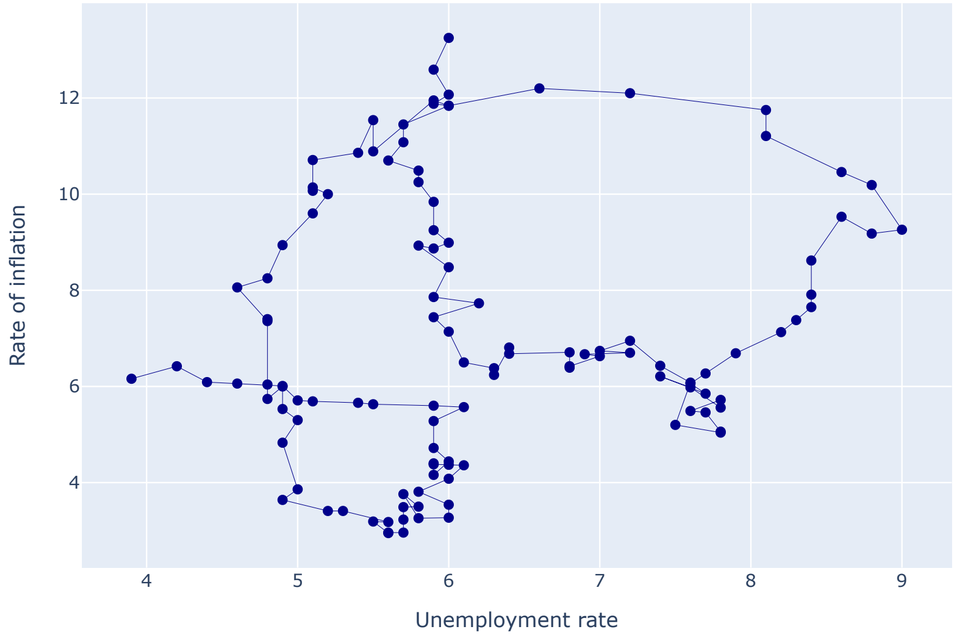
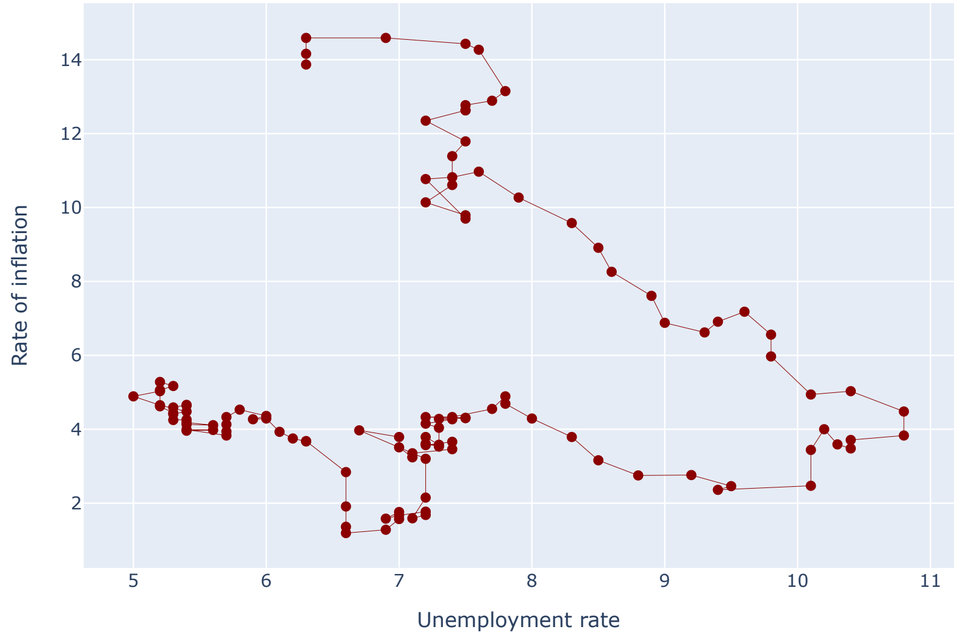


Fig 05. Inflation versus Unemployment: USA 1980s



1. Inflation vs. unemployment

- In the **1970s**, the Phillis Curve seems to be a *"Philips Cloud"*
  - The two first oil price shocks (in 1973 and 1979)
  - A war in the Middle East
  - Significant increases in inflation expectations
- In the **1980s**, the Phillips Curve seems to have *two slopes*
  - Oil prices went down systematically during the decade
  - Paul Volker (Fed's Chairman) gave an ice bath to inflation (at the political cost of President Carter failing the re-election)

1. Inflation vs. unemployment

e. Finally, in Figs 6 and 7, we get the relationship for the 2000s and 2010s. What conclusions can we put forward?

Fig 06. Inflation versus Unemployment: USA 2000s

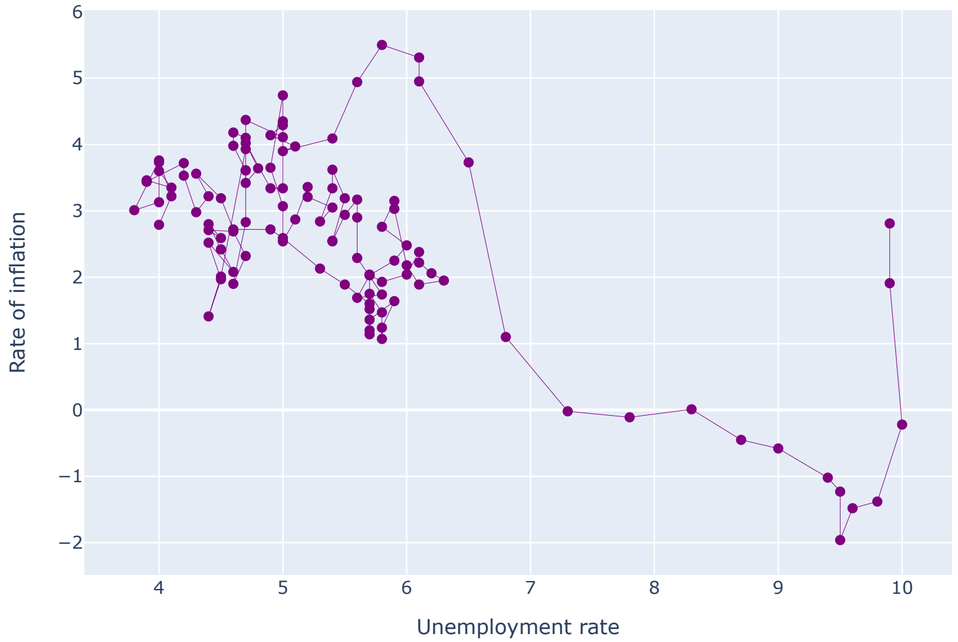
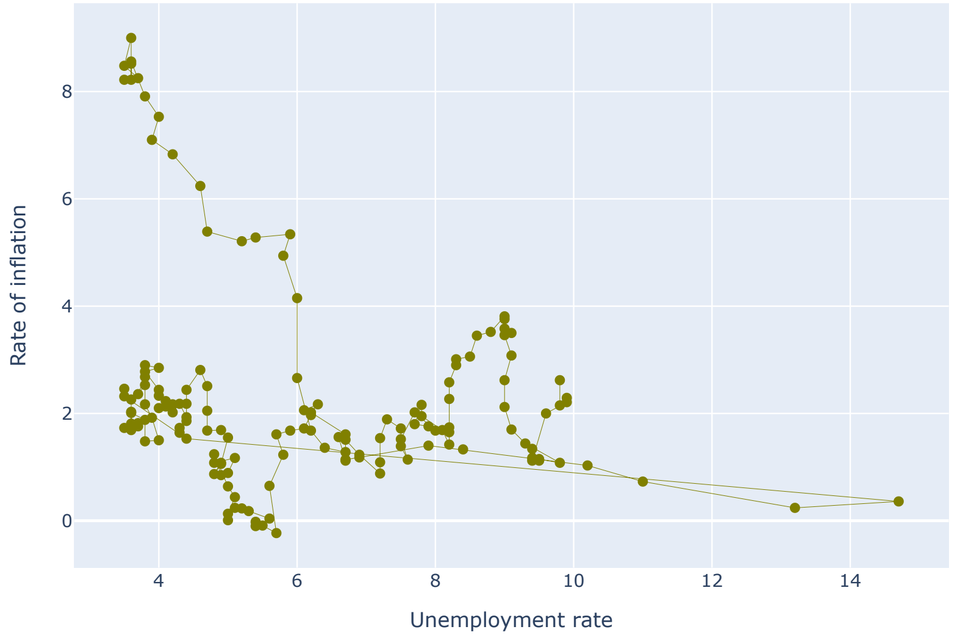


Fig 07. Inflation versus Unemployment: USA 2010-2022



1. Inflation vs. unemployment

- **Since 2000** the Phillips Curve seems *erratic*
  - Instability in oil prices
  - The biggest financial crisis (2008-2014)
  - A large war in the Middle East
  - The Covid-19 pandemic
  - And now a war in Europe of unknown repercussions
- *Too many shocks*

2. Inflationary expectations

Consider the following equations, which describe the expectations-augmented Phillips Curve:

$$\pi = \pi^e - \omega\left(U - U_n\right), \quad \omega = 1.2, \quad \pi_t^e = \pi_{t-1}$$

Assuming that, in this economy, the natural unemployment rate $U_n = 4\%$, current unemployment is $U = 4\%$, current inflation is $\pi = 2\%$, and expected-inflation is $\pi^e = 2\%$:

a. What happens to inflation over the next nine years if the central bank tries to bring the unemployment rate down to 3%, starting next year?

2. Inflationary expectations

- $U^T = 3\% \quad > \quad U_n = 4\%$
- Using the Phillips Curve with adaptive expectations for inflation, we can analyze the effect on inflation

$$\pi_1 = 2\% - 1.2 \times (3\% - 4\%) = 3.2\%$$
$$\pi_2 = 3.2\% - 1.2 \times (3\% - 4\%) = 4.4\%$$
$$\vdots$$

- An **inflation spiral** will emerge

2. Inflationary expectations

b. What do we call this type of inflation dynamics?

- **Inflationary expectations**
- This results from the Central Bank trying to achieve a rate of unemployment systematically below its natural level

2. Inflationary expectations

> **c.** The monetary authorities have a target value for inflation: $\pi^T = 2\%$. Is this target value compatible with 3% unemployment? What is the option available to the monetary authorities for achieving that target?

- $U = 3\%$ will cause an inflation spiral incompatible with $\pi^T = 2\%$
- Remember the Phillips Curve expression with adaptive expectations: $\pi = \pi_{t-1} - \omega\left(U - U_n\right) + \rho$
- Then, we need several periods of $U > U_n$ to push inflation down

3. Deflationary expectations

> Assume the same information as in the previous exercise.
>
> **a.** What happens to inflation over the next nine years if the central bank tries to increase the unemployment rate up to 5%, starting next year?

```
begin
    T3  = 9
    ω3  = 1.2
    U3  = 5
    Uₙ3 = 4

    π3  = zeros(T3)
    π3[1] = 2

    for t = 1:(T3-1)
        π3[t+1] = π3[t] - ω3 * (U3 - Uₙ3)
    end
```

$$\boldsymbol{\pi} = \begin{bmatrix} 2.0 \\ 0.8 \\ -0.4 \\ -1.6 \\ -2.8 \\ -4.0 \\ -5.2 \\ -6.4 \\ -7.6 \end{bmatrix}$$

3. Deflationary expectations

b. What do we call this type of inflation dynamics?

- **Deflationary spiral**
- Central bank is keeping a recession for 9 years

3. Deflationary expectations

> **c.** The monetary authorities have a target value for inflation: $\pi^T = 2\%$. Is this target value compatible with 5% unemployment? What is the option available to the monetary authorities for achieving that target?

- The answer is the opposite of part c. in the previous exercise
- $U = 5\%$ will cause a deflation spiral incompatible with $\pi^T = 2\%$
- Several periods of $U < U_n$ will be needed to restrain inflation from going down

4. The US labor market is too hot

> *“The labor market is too hot for the Fed [the unemployment rate falling to 3.5%]. I think it keeps them on a pretty aggressive tightening path. I expect another 75 basis point hike in November. They can hopefully moderate and reduce the size of rate hike to 50 basis points in December,”*
>
> — Kathy Bostjancic, chief U.S. economist at Oxford Economics, 7 October 2022.

According to the concept of the Pillips Curve, what does it mean “the labor market is too hot for the Fed”?

4. The US labor market is too hot

- Again, the Phillips Curve expression with adaptive expectations is: $\pi = \pi_{t-1} - \omega\left(U - U_n\right) + \rho$
- By *"too hot labor market"* we usually understand a *demand higher than the supply*, so $U < U_n$
- This pushes $\pi \uparrow$ and so $\pi^e \uparrow$
- For the Fed to fight this inflationary pressure it will need to cause a recession ($U \uparrow$)

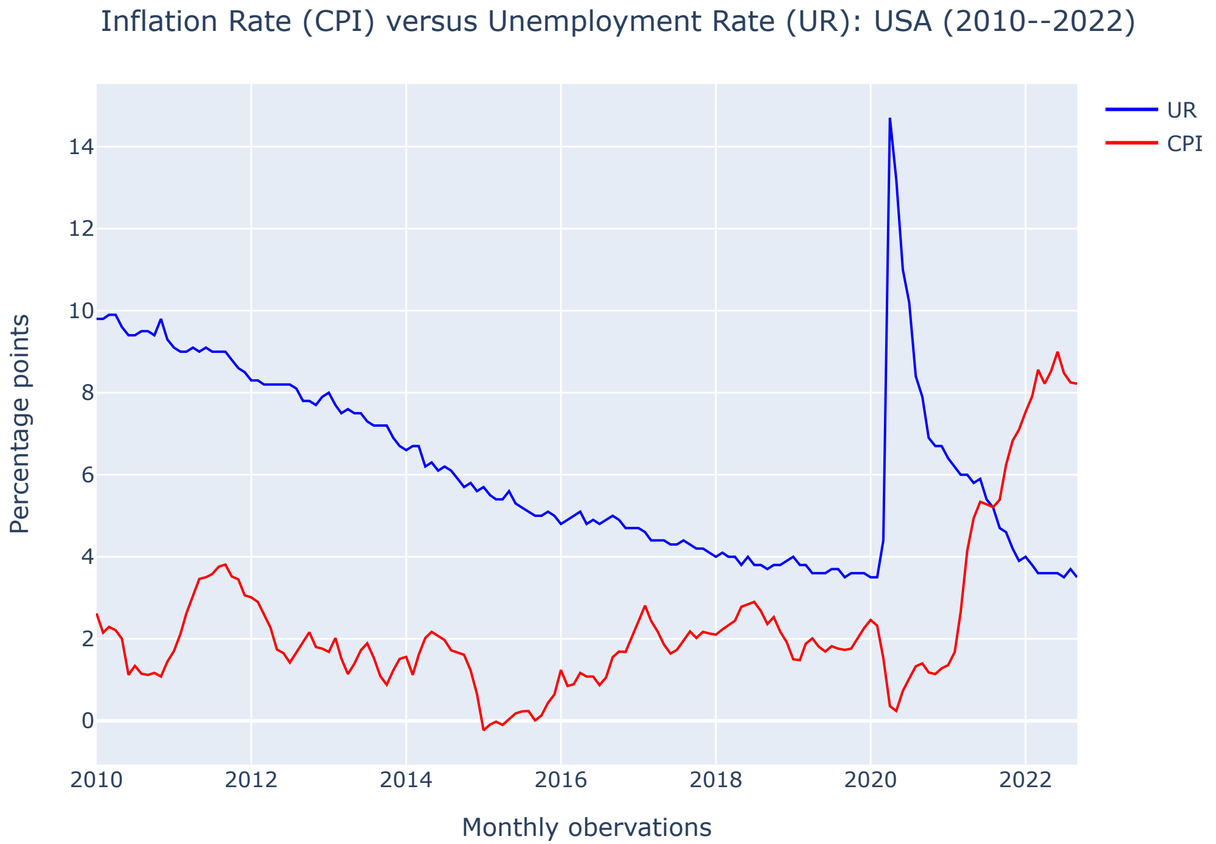
5. Is the US labor market too hot?

> *"Most seers believe the US labor market is overly strong. Federal Reserve Chair Jerome Powell recently described it as "extremely tight" and "out of balance", with demand for workers far outstripping supply. I beg to differ."*
>
> — Gary Shilling, Bloomberg, 4 October 2022

As usual, in macroeconomics, there is a massive controversy about the current situation of the US labor market. If the US labor market were "so hot", how can it be that real wages have been declining since 2021? Or how can the participation rate still be below the pre-pandemic level?

5. Is the US labor market too hot?

We do not have much space here, but just a hint in the following figure: in February 2020 (before the pandemic started), unemployment as 3.5% and inflation was 2.46%; in September 2022, unemployment was 3.5% (!!), while inflation reached 8.22%. How is this compatible with a too-hot labor market?



5. Is the US labor market too hot?

Gary Shilling does not see how the two facts can be conjugated to deliver such a message:

"My analysis indicates that current labor market stringency isn't due to robust demand for workers but because Americans are limiting the supply after the pandemic. After staying at home for two years due to the lockdowns, many people became accustomed to working remotely and putting in fewer hours while others dropped out, retiring early. In late September, office occupancy as measured by workers at actual desks was only 47.5% of early 2020, according to Kastle Systems."

6. Cyclical unemp. & the output-gap

Using the file “US_Data_May2021.csv”, in this we will deal with the Okuns’ law for the USA, during the period between 1960.Q1 and 2019.Q4.

a. In Fig 6.1 and 6.2 we plot the evolution of the unemployment rate, its trend, and cyclical rate of unemployment. What is cyclical unemployment? How can we obtain it?

Fig 6.1. US Unemployment and its Trend (1960.Q1--2019.Q4)

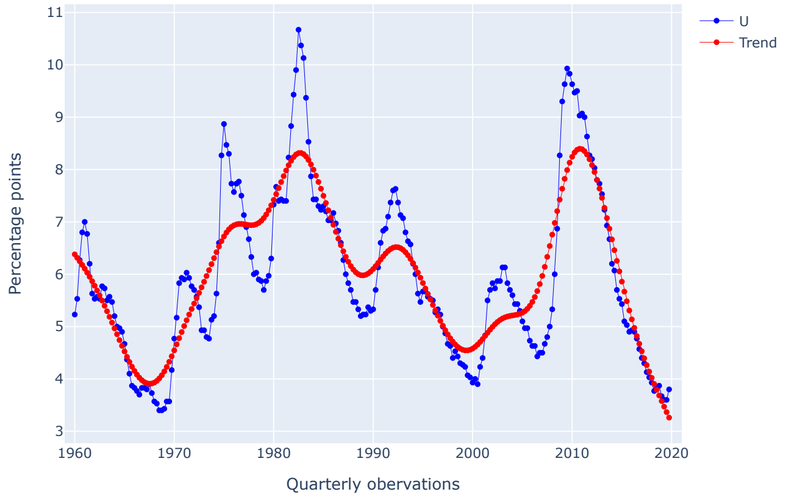
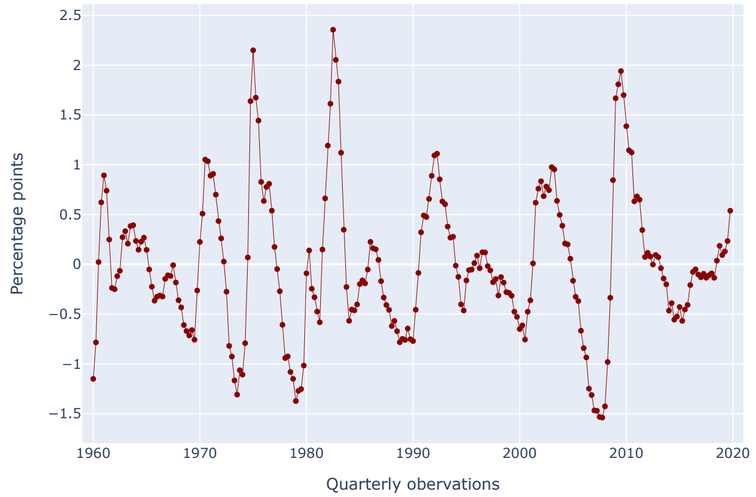


Fig 6.2. US Cyclical Unemployment (1960.Q1--2019.Q4)



6. Cyclical unemp. & the output-gap

- Cyclical unemployment is caused by **business cycles**
  - In a *boom*, actual unemployment will be below its long-term trend
  - In a *recession*, the opposite
- It is the only type of unemployment that *can be reduced (or increased) trough policy measures*
- It is obtained by the *difference between the actual unemployment rate and its long-term trend*

6. Cyclical unemp. & the output-gap

b. In Figures 6.3 and 6.4, we plot the evolution of the real GDP, its trend, and the output gap. What is the output gap? How can we obtain it?

Fig 6.3. GDP and its Trend (1960.Q1--2019.Q4)

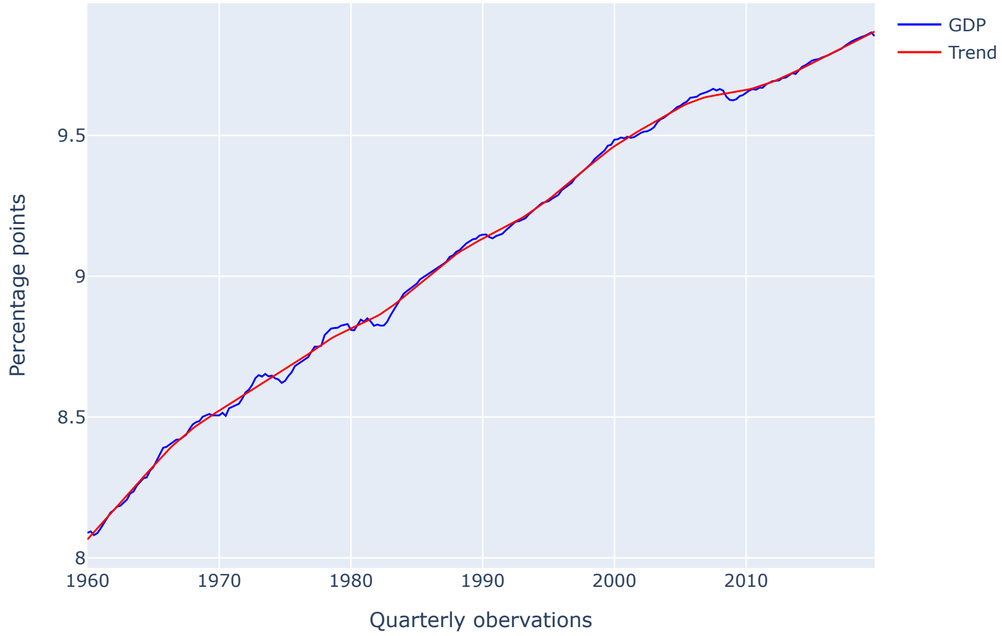
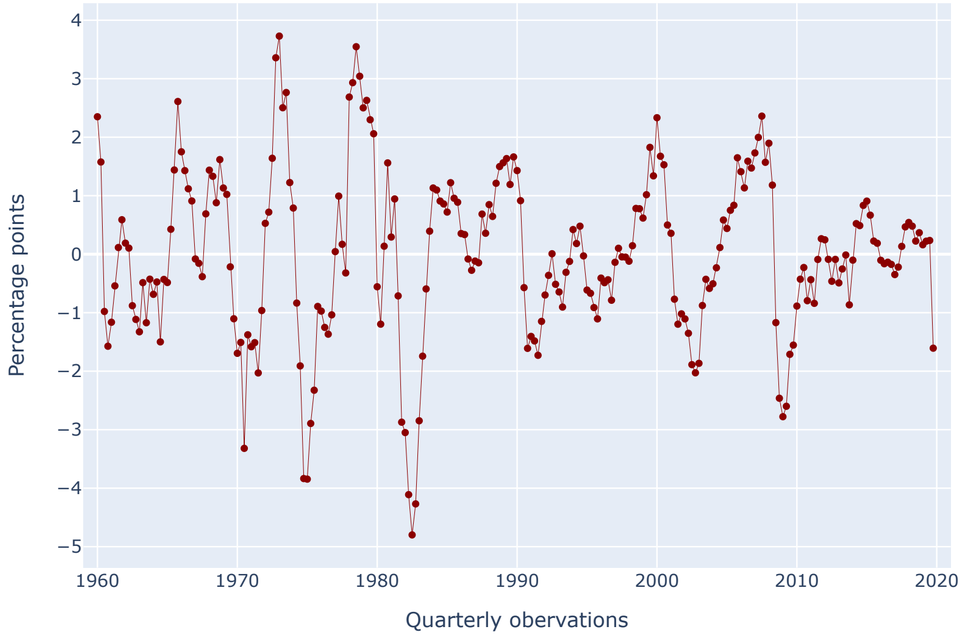


Fig 6.4. Output Gap (1960.Q1--2019.Q4)



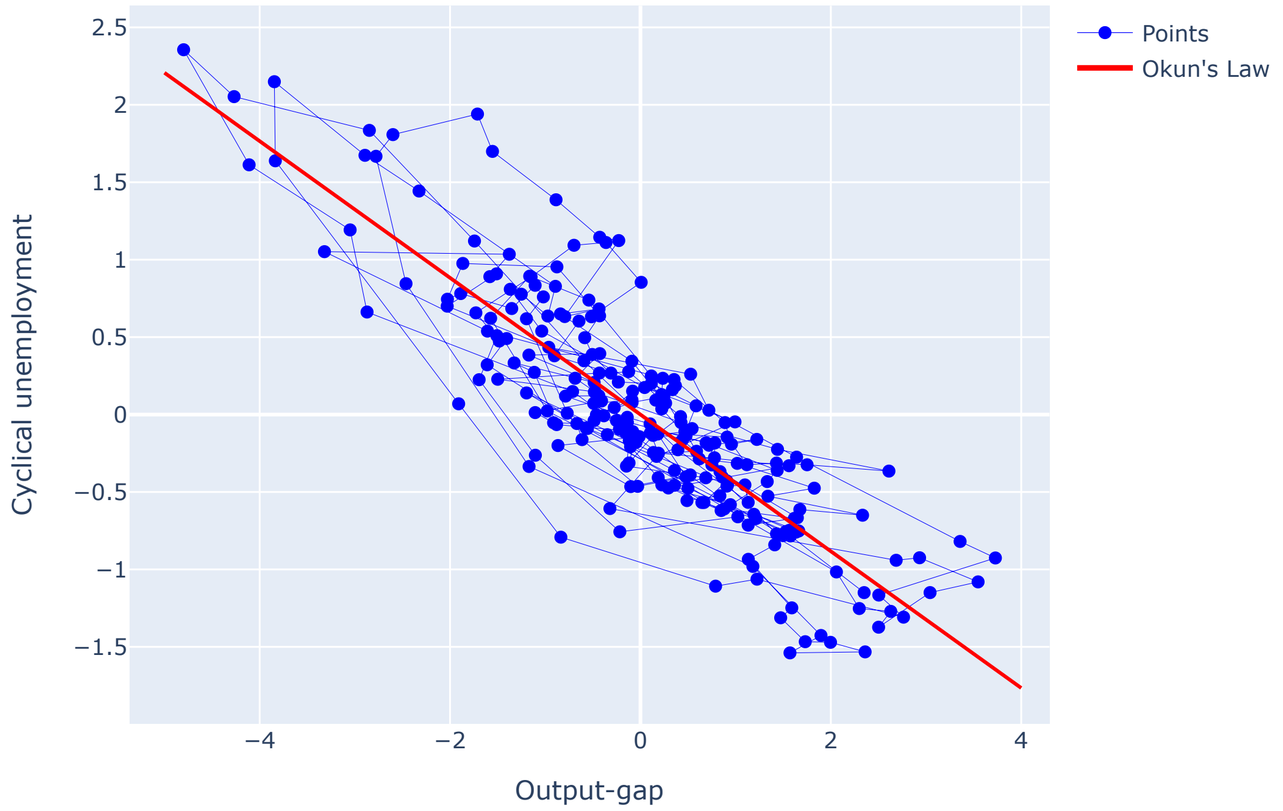
6. Cyclical unemp. & the output-gap

- The output gap is the *percentage deviation* of **real GDP** from its **long-term trend**
  - Recessions correspond to highly negative values
  - Booms corresponde to highly positive values
- The trend is statistically determined, usually applying the *Hodrick-Prescott (HP) Filter*

6. Cyclical unemp. & the output-gap

c. Fig 6.5 displays Okun's law for the US. For the period under consideration (1960.Q1-2019.Q4), the Okuns's law has an intercept equal to 0 and a slope equal to -0.441393 (see figure below). What is this law? How do we obtain it?

Fig 6.5. The Okun's Law: USA (1960.Q1--2019.Q4)



6. Cyclical unemp. & the output-gap

- **Okun's law** is an *empirical fact*, a statistical regularity
- If the economy loses 1% of the output gap, cyclical unemployment tends to increase by (around) 0.5% (-0.44 to be precise)
- It is obtained through a *linear regression* over data points of the variables (output gap and cyclical unemployment)

7. The Okun's law

From the textbook.

Suppose the Okun's law can be expressed according to the following formula:

$$U - U_n = -0.5(Y - Y^P).$$

Assuming that potential output grows at a steady rate of 2.5% and that the natural rate of unemployment remains unchanged:

a Calculate by how much unemployment increases when real GDP decreases by one percentage point.

7. The Okun's law

- First, notice that:

$$\Delta U - \Delta U_n = -0.5 \left(\Delta Y - \Delta Y^P \right)$$

- If $\Delta Y^P = 2.5\%$ and $\Delta U_n = 0\%$, and if $\Delta Y = -1\%$, then:

$$\Delta U = -0.5(-1\% - 2.5\%) = +1.75\%$$

7. The Okun's law

b. Calculate by how much real GDP increases when unemployment decreases by two percentage points.

- Recall that: $\Delta U - \Delta U_n = -0.5\left(\Delta Y - \Delta Y^P\right)$
- If $\Delta Y^P = 2.5\%$, $\Delta U_n = 0\%$, and $\Delta U = -2\%$, then:

$$-2\% - 0\% = -0.5(\Delta Y - 2.5\%) \Leftrightarrow$$
$$\Leftrightarrow \Delta Y = 3.25\%/0.5 = +6.5\%$$

8. The short-run AS curve

> *From the textbook.*
>
> Assuming that the Okun's law is given by $U - U_n = -0.5(Y - Y^P)$ and that the Phillips curve is given by $\pi = \pi^e - 0.6(U - U_n) + \rho$
>
> **a.** Obtain the short-run aggregate supply curve if expectations are adaptive, inflation was 3% last year, and potential output is \$10 trillion (assume $\rho = 0$).

We obtain the short-run AS substituting Okun's law inside the Phillips Curve with adaptive expectations:

$$\pi = 3 + 0.6 \times 0.5(Y - 10) + 0 \Leftrightarrow$$
$$\Leftrightarrow \pi = -3 + \times 0.3Y$$

8. The short-run AS curve

> **b.** Calculate inflation when output is \$8, \$10, and \$12 trillion dollars.

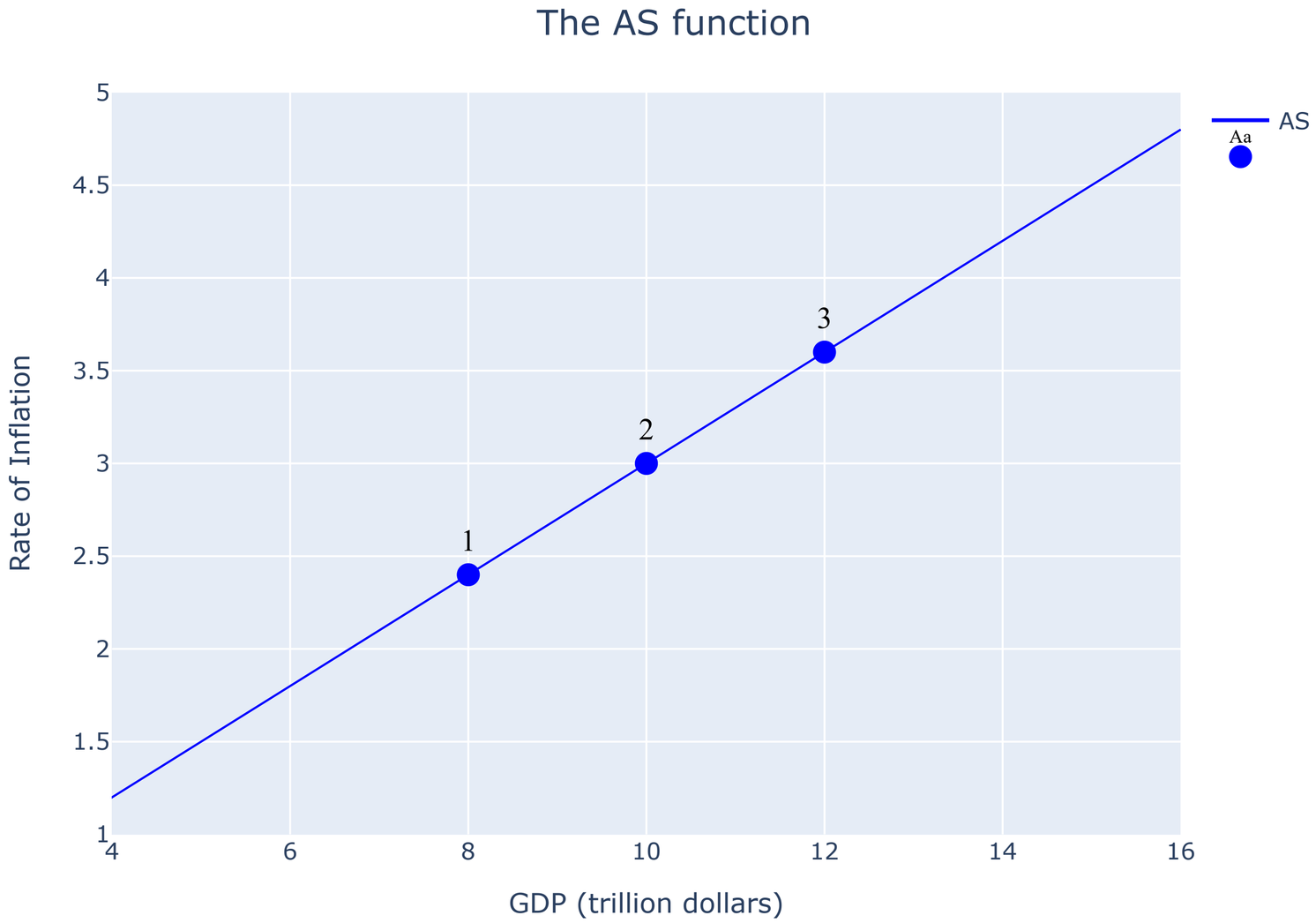
As shown in the Notebook:

```
begin
    inflation(gdp) = 3.0 .+(0.6 .* 0.5).*(gdp .- 10.0)  # this function represents the AS cur
    gdp = [8 , 10 , 12]                                 # this vector contains the values of
    inflation(gdp)                                      # this line prints the values of infl
end
```

$$\boldsymbol{Y} = \begin{bmatrix} 2.4 & 3.0 & 3.6 \end{bmatrix}$$

8. The short-run AS curve

c. The figure below plots the short-run AS curve with three points. What happens to the unemployment rate when we move from points 1 to 2 and 3?



8. The short-run AS curve

- Moving from points 1 to 2 and 3 means that the inflation rate is increasing
- *By the Phillips Curve*, if inflation increases, the unemployment rate declines *cœteris paribus*
  - There are no supply shocks
  - No changes in inflation expectations
  - Potential real GDP remains constant

9. Oil prices and inflation

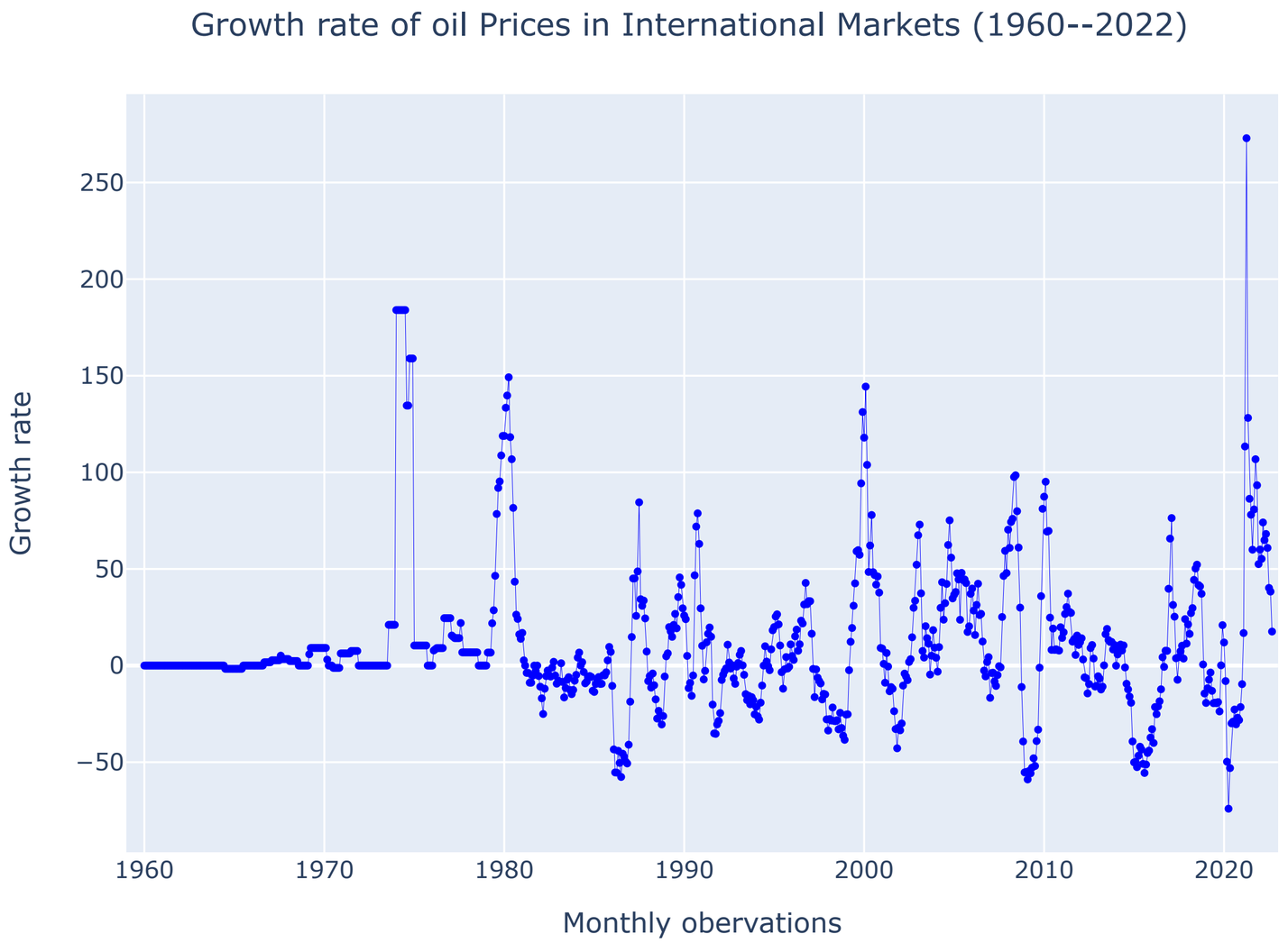
a. In the following figure, we plot the evolution of oil prices since the 1960s. Mention three aspects that may be relevant for the analysis of inflation in a market economy.

9. Oil prices and inflation

1. Oil prices were very stable until the *mid-1970s*
2. *From 1980 to around 2000*, oil prices displayed a mild downward trend
3. From *early 2000 onwards*, oil prices have been tremendously unstable

9. Oil prices and inflation

b. In the following figure, we show the annual growth rates of oil prices. Do you see anything peculiar in that figure that may have a crucial impact on inflation?

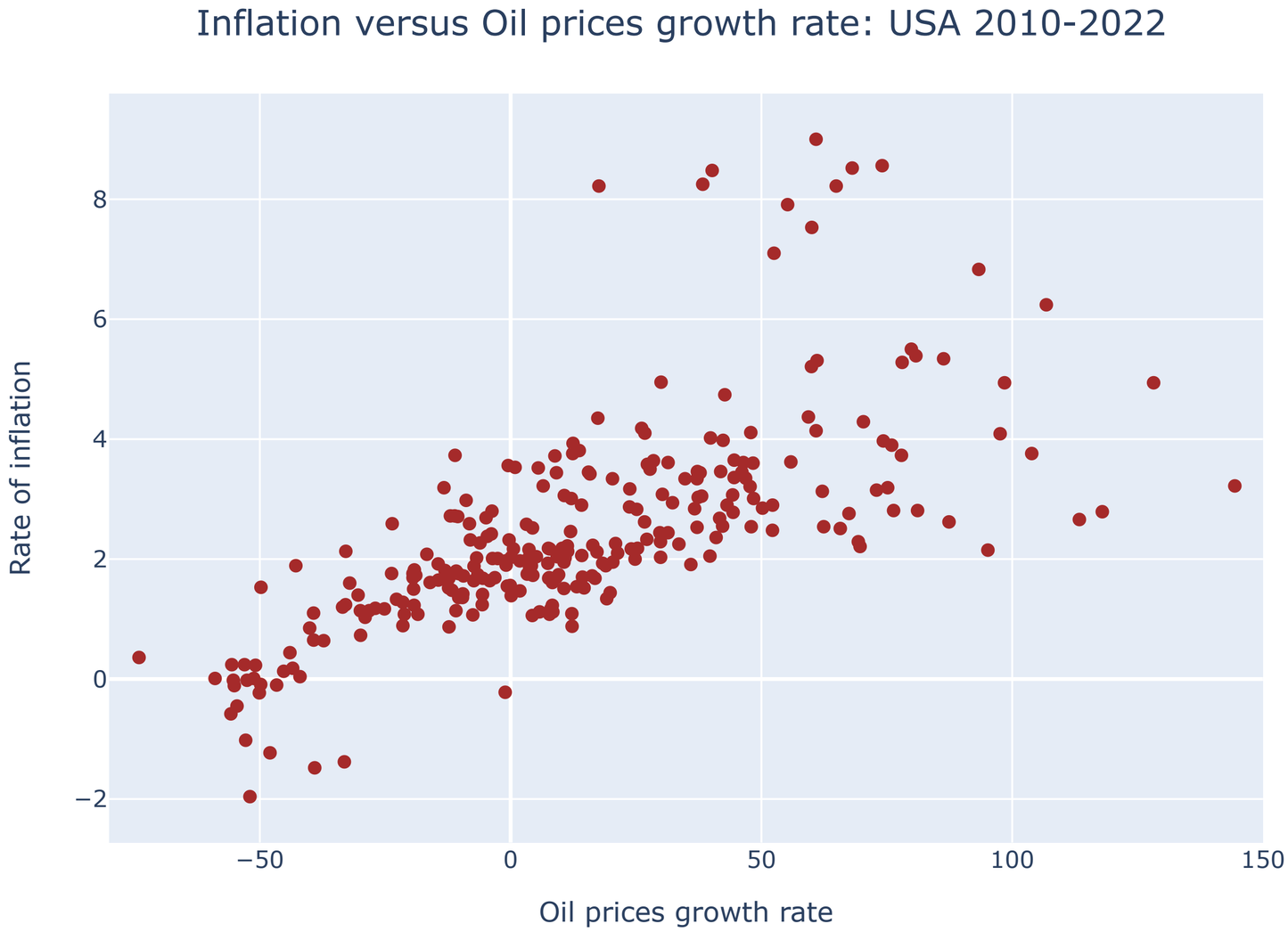


9. Oil prices and inflation

- Annual growth rates of oil prices go far more than 50% often (sometimes even greater than 100%, like in April 2021, with a growth rate of 272%)
- Negative growth rates close to -50% are also not uncommon
- Since the entire world economy is dependent on oil, these swings in oil prices create **instability in production costs**, leading to *inflationary (or deflationary) pressures* hard to manage

9. Oil prices and inflation

c. In the following figure, we show the relationship between inflation and the growth rate of oil prices for the period 2000-2022. What kind of relationship between those two variables do we have in that figure?



9. Oil prices and inflation

- There is a **positive relationship** between the growth rate of oil prices and the inflation rate
- *The causality* is also clear: higher growth rates of oil prices will be translated into higher inflation rates
- If oil prices do not go down, it seems complicated to control inflation just by increasing short-term interest rates

10. A comprehensive exercise

Consider the AS function as described in the slides and textbook:

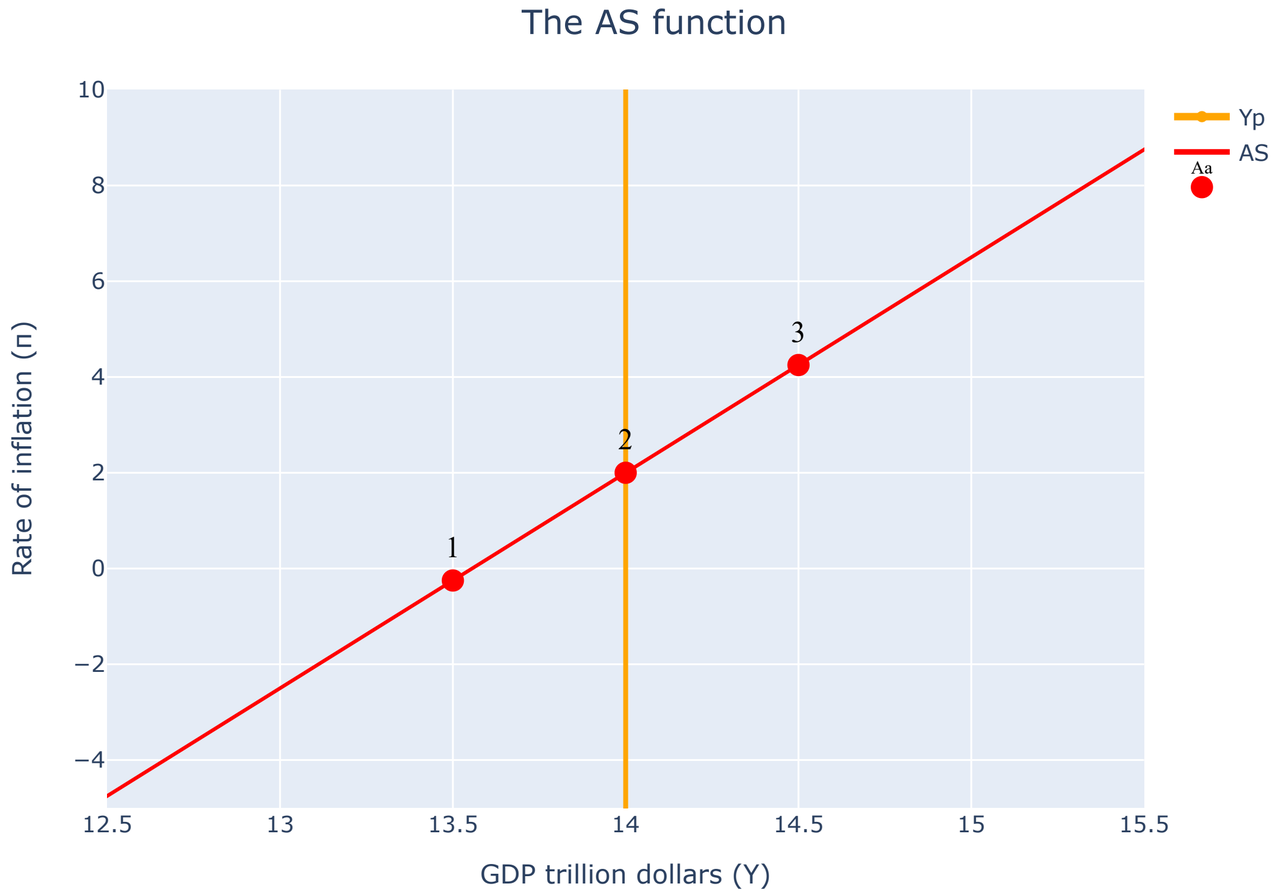
$$\pi = \pi^e + \gamma \left(Y - Y^P \right) + \rho.$$

The following information is known:

$$\gamma = 4.5 \quad , \quad Y^P = 14.0 \quad , \quad \pi^e = 2.0 \quad , \quad \rho = 0.0$$

10. A comprehensive exercise

a. In the following figure, we plot the short-run AS curve for the values of GDP between 12.5 and 15.5. We also plot the long-run AS curve. What do they represent?



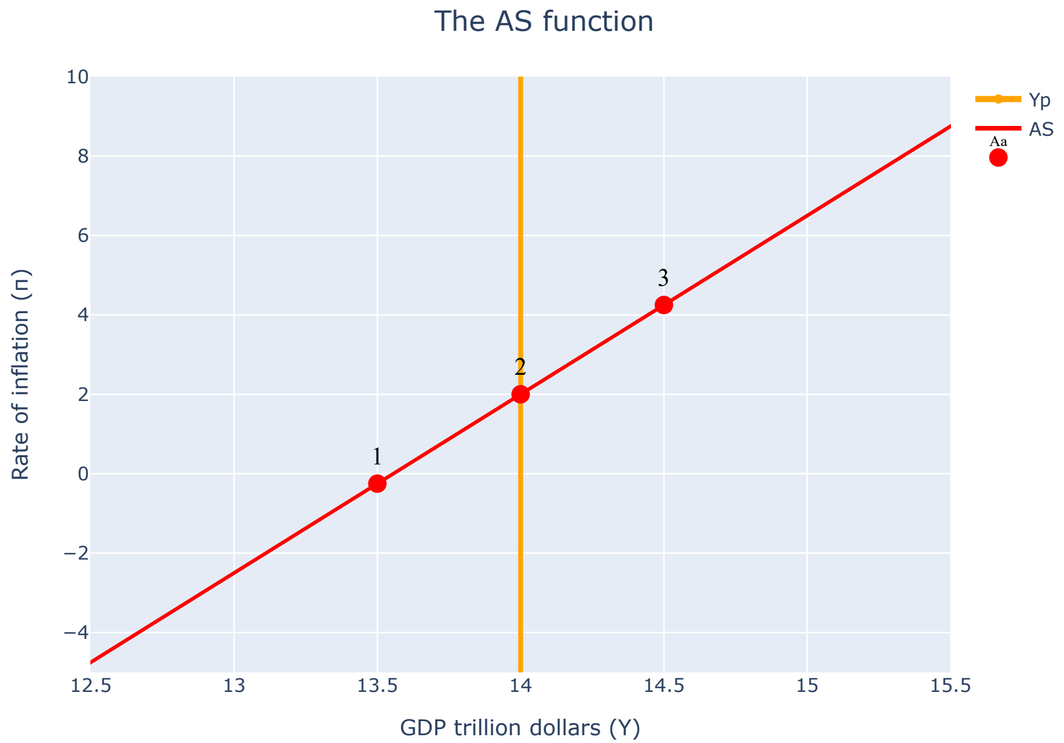
10. A comprehensive exercise

- The **short-term AS curve**: level of *real GDP* for each level of *inflation*
  - Assumes constant: π^e, Y^P *and* ρ
  - Shows a *trade-off between inflation and real GDP*
- The **long-term AS curve**: level of *potential real GDP*
  - Shows *no trade-off between inflation and real GDP*
  - Potential GDP may change for other (more structural) reasons

10. A comprehensive exercise

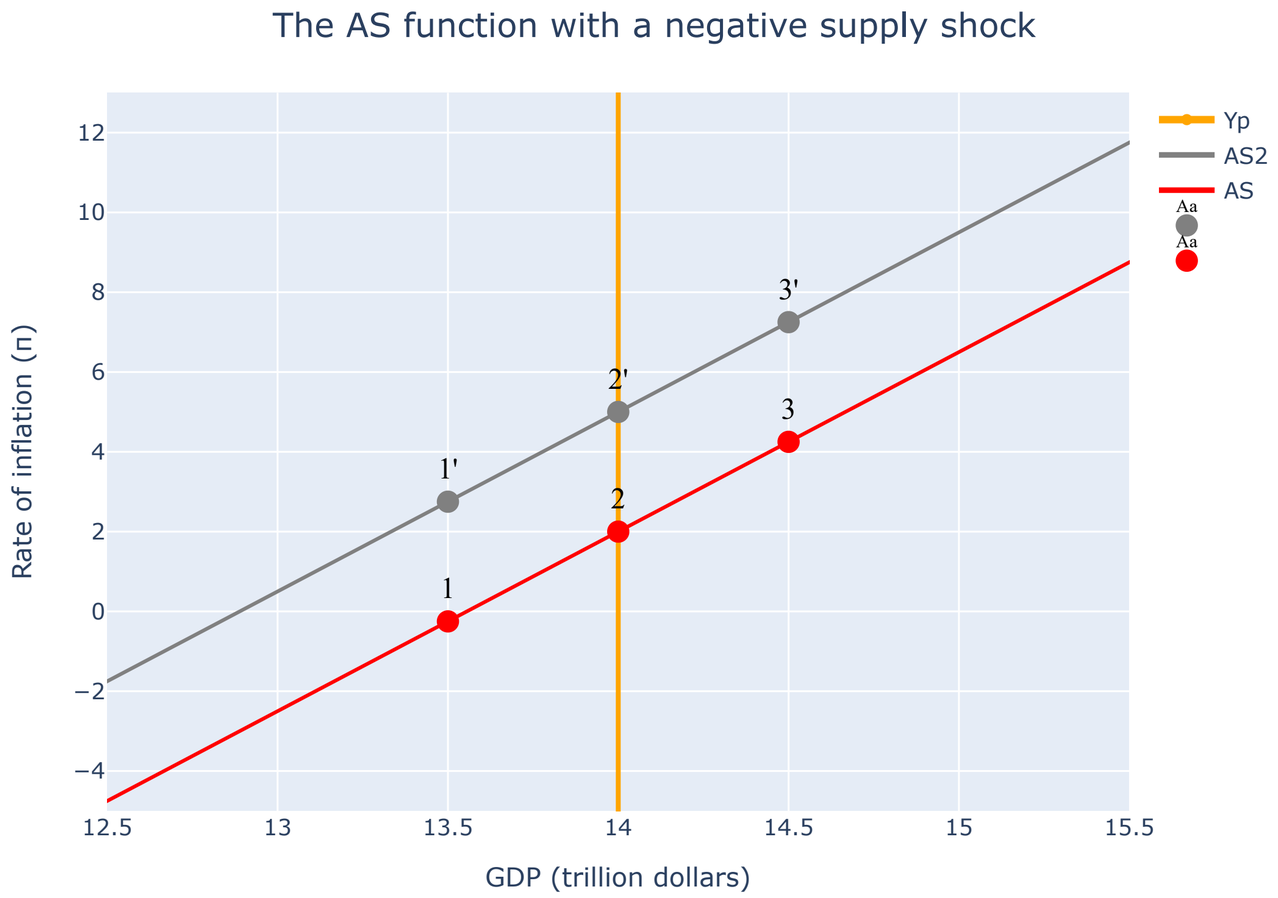
b. What makes the economy move from points 1 to 2 and 2 to 3?

- *From 1 to 2:* inflation increases by 2p.p. (0% to 2%)
- *From 2 to 3:* inflation increases by 2p.p (2% to 4%)



10. A comprehensive exercise

c. Suppose there is a shock in oil prices such that $\rho = 3.0$. Using the slider ρ8c below, represent the impact of this shock upon the initial functions.

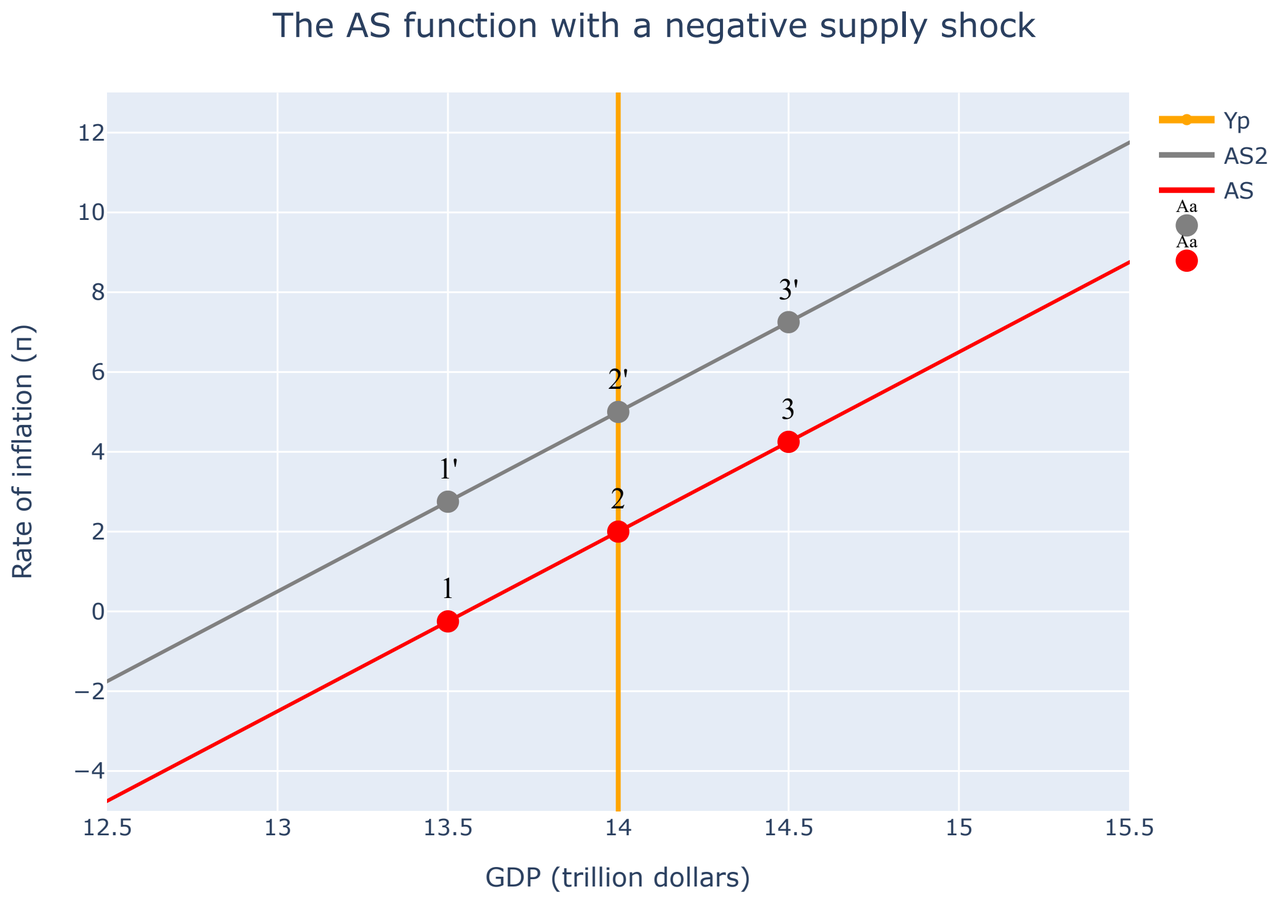


10. A comprehensive exercise

- There is no information on whether the shock is temporary or permanent: in principle, is *temporary* (remember previous exercise)
- The **short-run AS** function will be affected.
- The increase in oil prices, *shifts the short-run AS curve to the left*
- *For every level of real GDP*, the economy will display higher inflation

10. A comprehensive exercise

d. Is this oil price shock a positive or a negative type of shock?



10. A comprehensive exercise

- Be careful with the words chosen to frame a particular exercise!
- We will consider this type of shock to be **negative**, because it *reduces GDP* for every level of inflation
- Accordingly, a *negative supply shock* means *inflation will go up*, whereas a *positive supply shock* means *inflation will go down*