Notes on the IS-MP-AS (AS/AD) Model

Econ 110

This mini-text is an introduction to a canonical, "Keynesian" model of business cycles. The first part focuses on the idea of an "Aggregate Demand" relationship, which is presented somewhat informally in the textbook. By giving more structure to the aggregate demand curve, we can think more about the channels by which policy affect the economy, and how the microeconomics of household and firm behavior generate macroeconomic outcomes. Adding explicit structure also makes it more transparent to think about adding alternative features into the model. It will also allow us to introduce the concept of "multipliers" which is at the heart of applied macroeconomic policy analysis and advice.

The model has a lot of moving parts, so we introduce them in stages. At first, we will focus on the determination of aggregate consumption, investment, and income for a particular real interest rate. We'll call this a "partial equilibrium" relationship because it takes all the prices in the economy as given.

We'll then show that when the interest rate varies, income will also vary in a systematic way. We'll call the resulting relationship between these two variables the "IS" (Investment-Savings) Curve. We'll assume that monetary policy also relates real interest rates to output and inflation. The equilibrium between the investment-savings relationship and the monetary policymakers' actions will determine an equilibrium relationship between inflation and output, which we'll call the aggregate demand (AD) curve.

Finally, we'll motivate an aggregate supply (AS) relationship which explains short run production decisions as a function of inflation. The equilibrium between short-run aggregate supply and aggregate demand will determine the economy-wide level of inflation and production/income/GDP. The classical case fo monetary neutrality is a special version he classical dichotomy holds, although we'll see how that is, in some ways, a special case of the model we'll consider. This will let us use our model to talk about real effects of monetary policy and how fiscal policy may also play a role in stabilizing the economy.

This is a (hard copy) version of the notes available at `https://people.carleton.edu/~estruby/ASAD/`. The electronic version has some embedded links, color, and nicer formatting, but this version has blanks for the exercises you should work out.

Contents

1 Components of aggregate demand

In this section, we'll talk about the components of "aggregate demand" – the things that people spend their money on. We'll think about it in terms of some simple equations that describe peoples' behavior in the aggregate.

1.1 Consumption and saving

We'll assume a closed economy, although we will explicitly include government spending and taxes.

We start with consumers. As we've seen earlier in the course, households consider a number of different factors when they're making consumption plans – including things like their permanent income and interest rates.

For our basic model, we'll focus on current disposable income (current income minus taxes). For mathematical simplicity, we'll assume that aggregate consumption is a linear function of disposable income. Notice that since aggregate household income is total income for the economy, disposable income is just aggregate real GDP Y minus aggregate taxes T, which we'll assume are "lump sum," so that the aggregate consumption function is

$$C(Y,T) = a + b \cdot (Y - T)$$

The assumption we're making says that the "C" part of the GDP accounting identity is a function of real GDP and real taxes minus transfers. We'll call this expression the *aggregate consumption function.*

a in the aggregate consumption function is called "autonomous consumption." It is a catch-all variable for any consumption that occurs which is unrelated to the current level of disposable income. For example, if (in the aggregate) household wealth matters for income, it's captured in a.

b , the slope of the aggregate consumption function, is the marginal propensity to consume (MPC). It has the natural interpretation of the amount that consumption increases for every additional dollar of disposable income the household receives.

Assuming that all disposable income is consumed or saved, we can also define an aggregate saving function, which will also be linear. (To see this, note that $Y - T = C + S$, substitute the aggregate consumption function in for C, and solve for S.)

$$S(Y,T) = -a + (1 - b) \cdot (Y - T)$$

If you're feeling concerned about the intercept of this savings function being negative, remember that borrowing is like negative saving. For certain levels of GDP and net taxes, the household sector is a net borrower, and for others, they are net savers.

Sketch the aggregate consumption and savings functions described by the lines you worked out above.

1.2 Investment and government spending

Given that we've assumed a closed economy, we know that all output can be assigned to three uses: Household consumption (C), Government purchases (G), and investment I.

Remember that investment has many components: residential investment, business fixed investment, and inventories. We will simplify by assuming there are two kinds: **planned investment** and **unplanned inventory changes**, which happen when consumers buy more or less of the firms' output than expected.

We will assume planned investment is mainly determined by the interest rate r. When r is high, it is expensive to borrow. All else equal, investors want to borrow less because few projects have a high enough return to have a positive net present value. The reverse is true when r is low.

What might cause planned investment to change besides interest rates (that is, what could be sources of shifts in the investment curve at a given real interest rate r)?

Unplanned investment does not directly depend on the interest rate. It is merely the result of the fact that consumers may buy more or less than firms anticipated in a given period.

Overall investment is therefore

$$I(r) = PI(r) + \text{Unplanned inventory changes}$$

This means we can write the overall uses of income as the sum of consumption, investment, and government spending:

$$Y = C(Y, T) + PI(r) + \text{Unplanned inventory changes} + G$$

2 Partial equilibrium and the "Keynesian Cross"

You probably noticed that, in the last section, C depended on Y. But we also know that Y depends on C. So you're probably wondering how to deal with the circular nature of what we're doing. That's what this section is about.

We will assume (temporarily) that real interest rates r are fixed. In the real world, r changes of course – we'll get to it in a bit!

We'll define planned spending as consumption plus planned investment plus government purchases:

$$\text{Planned spending}(Y, r, T, G) = C(Y, T) + PI(r) + G$$

We will define *partial equilibrium* as the situation where planned spending is equal to *actual spending* Y. Formally:

Definition 1 (Partial equilibrium). *Given an interest rate r, a level of lump sum taxes T and a level of government spending G, the economy is in partial equilibrium when the following is true:*

1. *Consumers are behaving according to their consumption function $C(Y, T)$*
2. *Given the interest rate, planned investment is described by the investment function $PI(r)$*
3. *There is no unplanned investment, so: $I(r) = PI(r)$ and hence*

$$\textit{Planned Spending}(Y^{PE}, r, T, G) = Y^{PE} = C(Y^{PE}, T) + PI(r) + G$$

Y^{PE}, the partial equilibrium level of output, is the Y that solves the above equation.

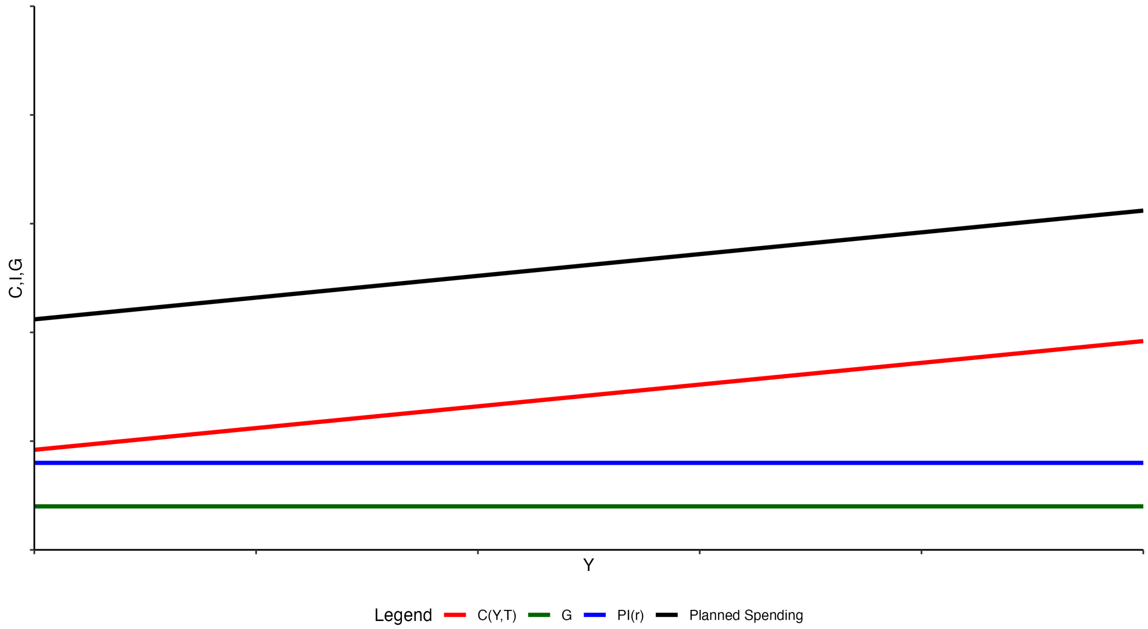
This is "equilibrium" because we're considering what all of the agents in the economy do optimally given a fixed interest rate when they have no reason to change their behavior. But we have not specified how interest rates are determined, which is why we call it "partial."

What if we were "out of equilibrium?" In that case, there is an unplanned increase or decrease in inventories. Firms would adjust their production accordingly, decreasing production if aggregate spending is too high and pushing it downwards (and vice versa). We'll focus on the situation where peoples' plans are consistent with what actually happens and peoples' behavior is described by the equations we set up.

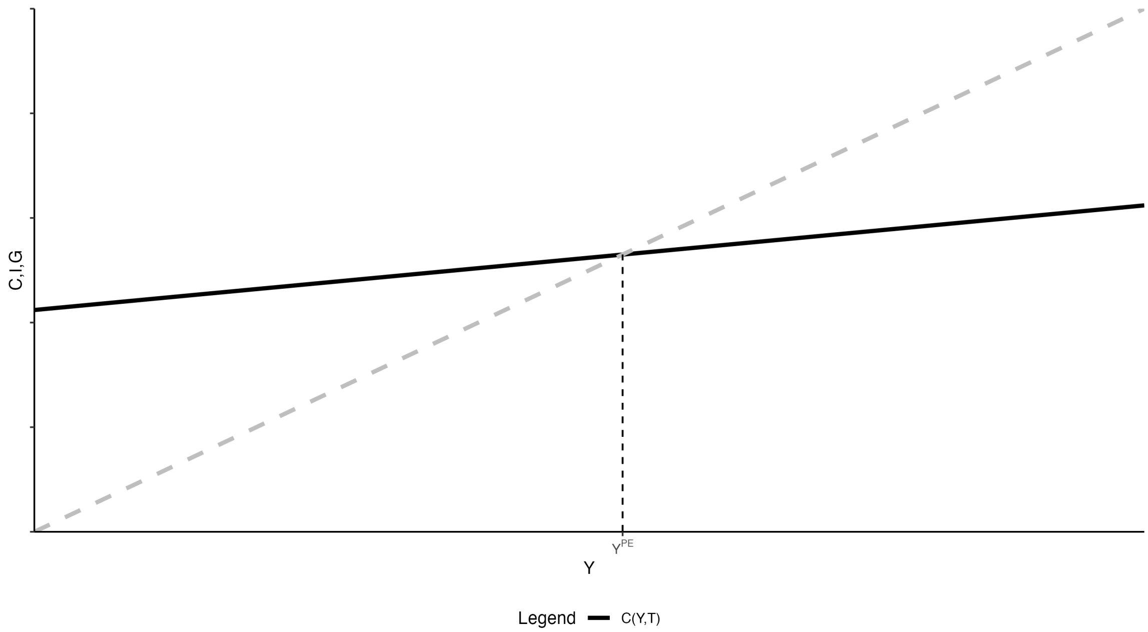
Show that, in partial equilibrium, investment is equal to household saving $S(Y^{PE}, T)$ plus public saving $T - G$. (Use the fact that $Y = C + I + G$ and $Y = C + S + T$)

Next, we'll show how to find the partial equilibrium level of output graphically and algebraically.

First, graph for planned spending and its components. Notice that because we assumed G was given, it's just a number. Similarly, r is fixed, so $PI(r)$ is also just a number, and as a result $G + I(r)$ is just a straight line. C depends positively on Y so the consumption function is upward sloping. Since planned spending is $C + PI + G$, the planned spending function is parallel to the consumption function, but higher.

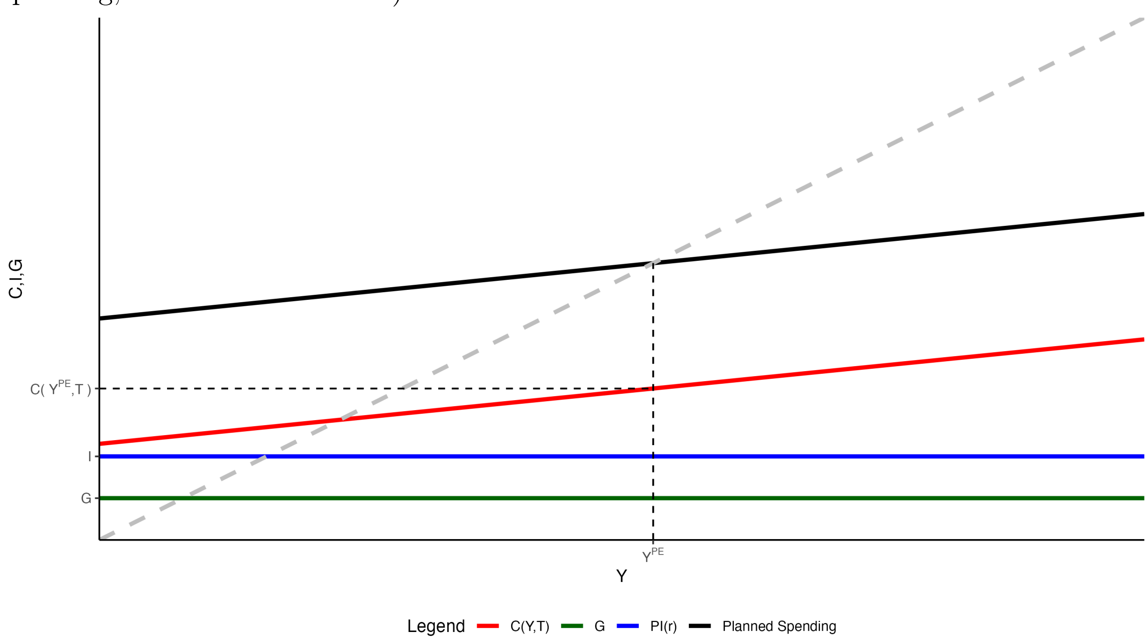


To find the partial equilibrium level of output, we use a graphical representation called the "Keynesian cross." Plotting planned spending as a function of Y, and then drawing a 45 degree line out of the origin of the graph. This 45 degree line is like the line $Y = Y$ - it increases by 1 every time Y increases by 1. These graphs will intersect at one point, which is the only point where $Y = PS(\cdot)$. But that's exactly our definition of partial equilibrium!



One way of thinking about this is that we know that consumption depends on output and output depends on consumption, etc. There's one level of consumption and output that are consistent with one another – the intersection of the 45 degree line and the planned spending line.

Adding back the components of the planned spending function, we can also show the partial equilibrium levels of the other variables (although for investment and government spending, this is kind of trivial).

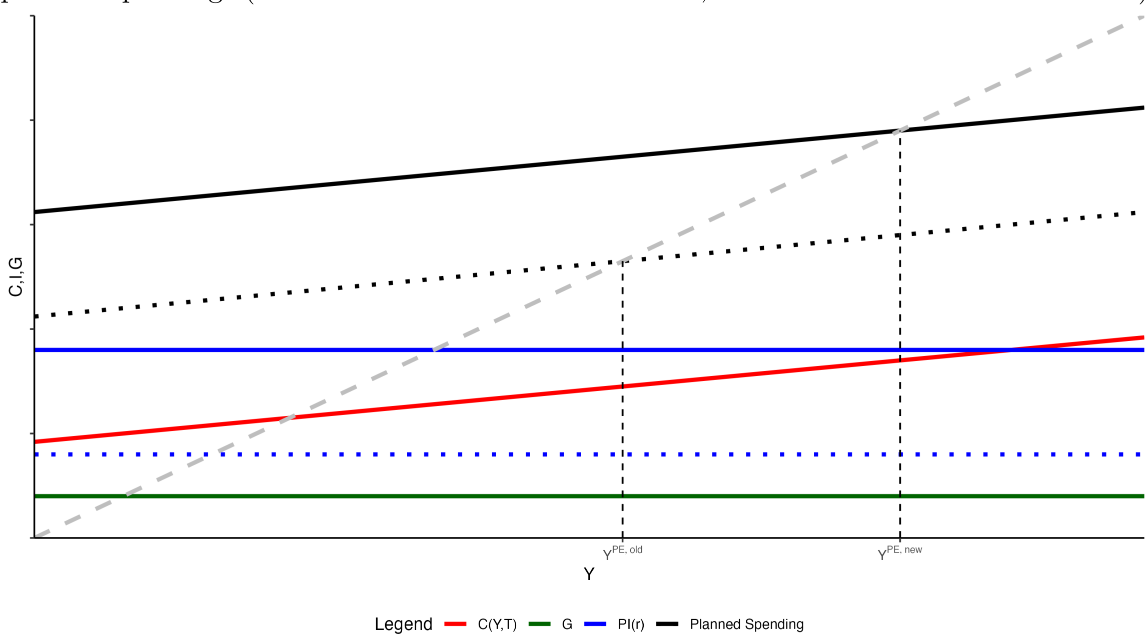


Now that we know how to (graphically) solve the model in partial equilibrium, we'll show off the multiplier idea.

3 Multipliers

Now that we know how to solve the model, a natural question is "what happens when something changes?" Given what we've seen in previous models (such as the Solow model) and in the data, it especially makes sense to wonder what effects changes investment (I) have. And given its centrality in business cycle policy and political discussion, we'd also be interested in understanding the effects of fiscal policy (taxes and government spending).

Suppose that investment increases for some reason by an amount ΔI. Graphically, this shifts up both the I and planned spending curves – at any given level of Y, we have more planned spending. (The old curves are the dotted lines, the new curves are the solid ones)



Notice that the increase in Y is more than we might have expected – in particular, it's bigger than the increase in I. This isn't just because of a trick of how the graph is generated, but actually a result of the model!

Show algebraically that Y^{PE} is equal to

$$Y^{PE} = \frac{1}{1-b}(a - b \times T + I + G)$$

(Hint: Start with the fact that $Y = C(Y,T) + I + G$, substitute for $C(Y,T)$ and solve for Y^{PE})

A numerical example: Suppose that $a = 500, b = .5, PI(r) = 200 - 25 \cdot r, T = 100, G = 100$ and $r = 4$. Calculate I, Y and C. (You'll want to do them in that order!) Then suppose that the interest rate falls by 1 (e.g., $r = 3$). Calculate the new I, Y and C.

Show, algebraically, that *in general*, in this model, any change in output will be larger than the change in investment; $\Delta Y^{PE} > \Delta I$.

The mechanism behind the multiplier is the fact that, in this model, an increase in investment causes an increase in Y, but an increase in Y feeds back into C, which feeds back into Y again, etc.

This is unlike the Solow model, where we assumed output was essentially fixed (at a given moment of time), and changes in I were 100% offset by a change in C. Here, all the components of final demand determine Y.

The investment multiplier depends on the MPC (the parameter b of the consumption function). Explain the intuition for why a larger marginal propensity to consume implies a larger multiplier effect.

Derive an expression for ΔY^{PE} in terms of b, and $\Delta T, \Delta G$ and ΔI. What are the multipliers for a change in taxes or a change in government spending? What is the intuition for each?

4 The Investment-Savings (IS) Curve

Sketch what would happen to planned expenditure and output if r changes, and in a separate graph, sketch the relationship between r and Y (now without the superscript, since we're letting r vary). The relationship between r and Y is called the "IS" curve (IS stands for "investment and savings") Then show how a change in G will impact the IS curve, based on how it affects partial equilibrium output at a given interest rate.

The negative relationship between the r and Y is the "Investment-Savings curve" (IS curve). It tells us what the equilibrium level of output is for a given r. (It's called this because it reflects a particular equilibrium between investment and aggregate savings. A given r changes investment; we need savings and investment markets to clear, and only one Y will do it, all else equal).

As you might expect, changes in r, all else equal, lead to movements along the IS curve. Changes in other variables, holding r fixed, *shift* the IS curve.

We could also assume that I is a linear function of real interest rates, that is

$$I = d - hr$$

In this expression, h represents how responsive I is to a change in the real interest rate (so if r goes down by 1%, I increases by h dollars). d captures other factors that affect investment at any given interest rate – such as confidence or beliefs about the future.

Given that assumption, we can derive an analytical expression for the IS curve.

Recall that in partial equilibrium, $PI(r) = I$. Using the assumption that $C = a + b(Y - T), I = d - hr, Y = C + I + G$ and given G and T, show that

$$Y = \frac{1}{1-b}(a - bT + G - hr)$$

This is the expression for the IS curve. What is its slope (e.g., what's $\Delta r / \Delta Y$?)

Notice, however, this is not enough to tell us what r and Y actually occur; we have only one curve. Short of assuming the interest rate is always fixed, we don't have enough information. In the next section, we'll introduce another curve to pin down r and Y.

In the online version of this text, there's an interactive application which lets you select parameters for the different components of demand, and show how changes in those parameters affect the IS curve. This may be helpful for checking your work as you practice using the model, and developing intuition about the different parameters. It's also available at the following web address: `https://shinyapps.carleton.edu/estruby/IS_compare/`

5 The monetary policy (MP) curve

In the previous section, we found a downward-sloping relationship between real interest rates and final demand. In this section, we'll (finally!) introduce monetary policy to this model.

We showed that monetary policymakers can affect the economy through open market operations. We also discussed that monetary policymakers in the United States typically think about and discuss their policy in terms of a target Federal Funds rate. We will embed this idea into our model.

In theory, the Fed manages the economy by looking through a complicated set of data series and forecasts. However, the economist John Taylor noted that, at least since the mid-1980s, the Federal Reserve's policy is often summarized through a simple linear relationship. This relationship is now known as the "Taylor Rule." We'll assume that the Fed follows a "Taylor Rule" in our model:

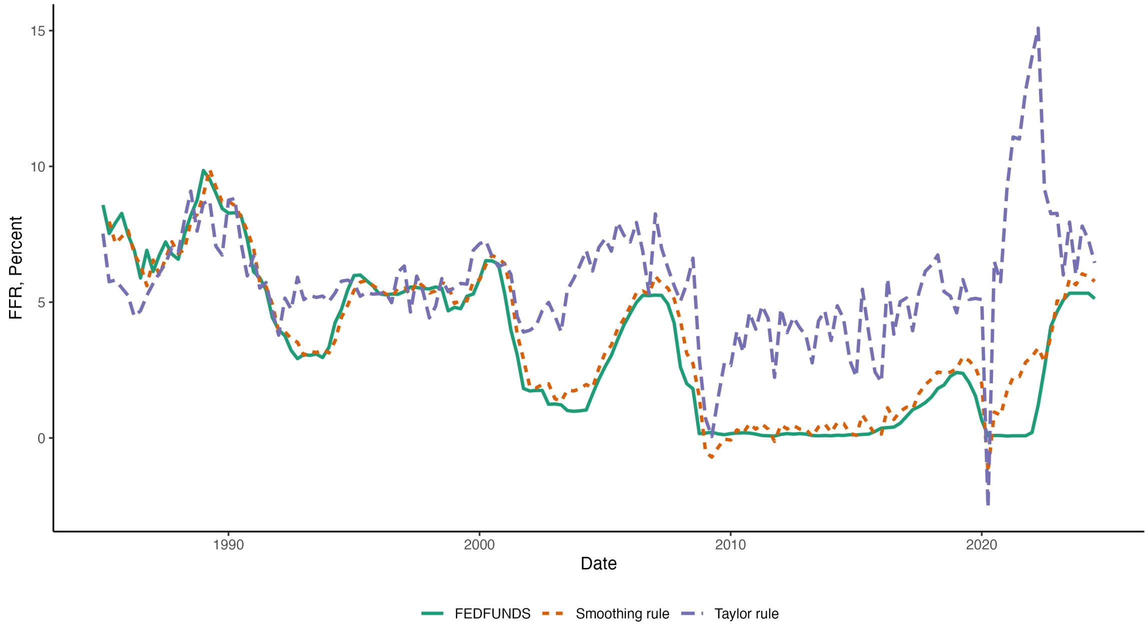
Assumption 1 (Assumptions about monetary policy)**.** *We assume the Federal Reserve sets a nominal interest rate *target* based on the policy rule*

$$i^{FED} = r^* + \pi^* + \alpha \times (Y - Y^N) + \beta \times (\pi - \pi^*)$$

$\alpha > 0, \beta > 1$.

Y is the level of output (GDP), Y^N is the long run level of output ("potential GDP"), $Y - Y^N$ is the "output gap",π is the rate of inflation, π^* is the inflation target, and r^* is the long-run "natural rate" (the real interest rate when $Y = Y^N$).

What are some realistic numbers for α and β? And how well does the Taylor rule describe policy in practice? We can see in the plot below the actual FFR, and the prescriptions of two Taylor rules: One which includes "smoothing" (e.g., the idea that the Fed usually makes small changes to the FFR at any given time) and one that doesn't (which was Taylor's original rule).



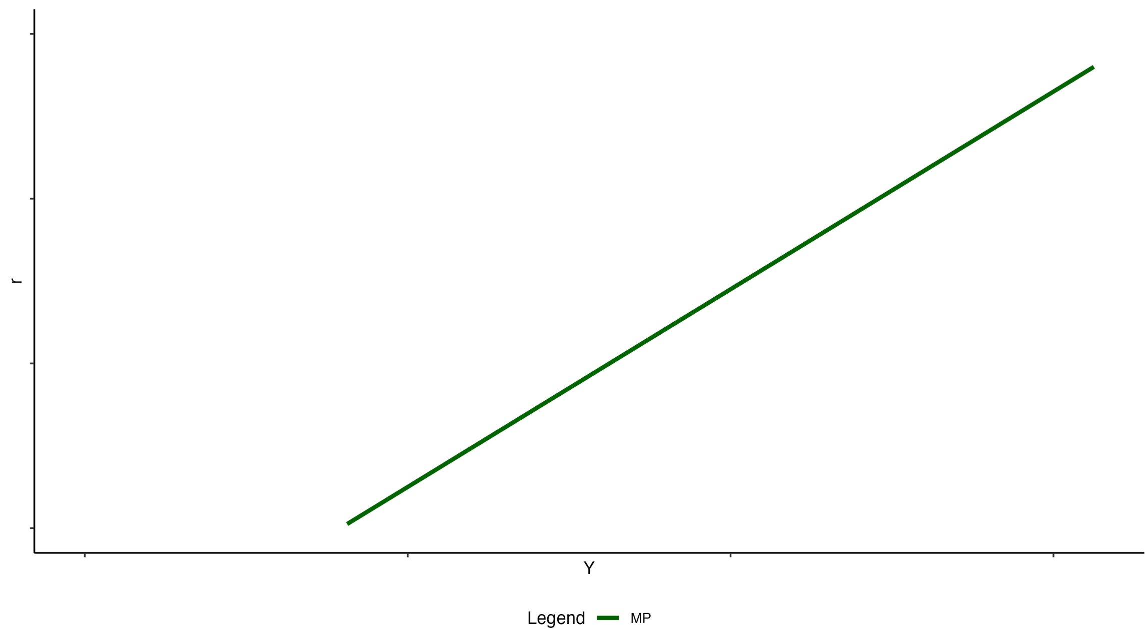
As we can see, the original Taylor rule's ability to mach the data isn't perfect.[1]. But a rule of this type does a decent job of matching data in the real world (if we add some smoothing). Since our model doesn't have any dynamics, it's okay to focus on the output gap and inflation gap terms. However, we will modify the rule in two respects.

First, notice that the Taylor rule tells us about **nominal** interest rates, but the IS curve is in terms of **real** interest rates. We can adjust nominal to real by subtracting inflation. Second, we will add a "shock" term to the rule. The resulting equation is the monetary policy curve, or MP curve.

Definition 2 (Definition of MP curve)**.** *The interest rate r is*

$$r = r^* + \alpha \times (Y - Y^N) + (\beta - 1) \times (\pi - \pi^*) + \epsilon$$

ϵ ("epsilon") is a "shock" term. It captures all the reasons real interest rates might be different from what the Taylor rule prescribes, including monetary policymakers violating the rule, or financial market conditions which lead interest rates to change at a given level of output.



Now, you might be able to see why we wanted to assume that $\beta > 1$ in this expression. If π increases by 1%, then $\beta > 1$ implies that the Fed will increase nominal interest rates by *more* than 1%. This means, by the Fisher equation, r increases. The response of the Fed to an increase in inflation is to *raise* real rates, an idea known as the "Taylor Principle".

[1]Some economists, including Taylor, argue that this is a bad thing – they *should* be following the rule, but aren't

Graphically, What is the effect on the MP curve of an increase in ϵ? an increase in Y^N? an increase in π?

6 The Aggregate Demand (AD) curve

The IS and MP curves are a relationship between real interest rates and output. But they also link output and **inflation** which is the other key business cycle variable we're interested in – how does the overall change in prices affect real quantities, if at all? The classical model suggested it didn't, and we're finally in a position to examine that question with this demand-driven model. The MP curve relates interest rates to inflation, and the IS and MP curves relate output to interest rates.

6.1 Graphical equilibrium

In particular, the equilibrium between IS and MP shows Y and r for a *given* π. When π changes, that will shift the MP curve, and hence change Y. That means, holding fixed all the other stuff that shifts IS and MP, we can trace out a relationship between Y and π.

Depict the equilibrium relationship between r and Y using the IS curve and the Fed's policy rule by tracing out the effects of changes in π on Y. This is the aggregate demand (AD) curve.

Graphically, what happens to the IS, MP, and AD curves when government spending increases?

Graphically, what happens when taxes increase?

Graphically, what happens when ϵ increases?

Graphically, what happens if there is a decrease in desired consumption at any level of income? (This is a decrease in a)

Because the road to this point has been a little winding, it's worth reminding ourselves of the overall plot.

- The consumption and investment functions, along with given fiscal policy variables, give tell us what level of spending on goods and services is consistent with agents' investment and savings decisions at any given r.
- The monetary policy rule tells us what level of r is consistent with the Fed's policy actions, given Y^N, ϵ and, critically, π.
- Equilibrium between the IS and MP curves tells us what level of Y and r we have for a *given* π. This is a single *point* on the aggregate demand curve; it tells us what the final demand for goods and services is, consistent with economic agents' actions.
- But if inflation changes, the Fed changes interest rates. In particular, the Fed raises interest rates when π goes up. This, all else equal, lowers the equilibrium level of Y.
- The end result is that the aggregate demand curve is downward sloping – higher π is associated with lower Y.

In other words, the AD curve slopes downward *because* of our assumptions about how the Fed reacts, and because of our assumptions about how IS is determined.We could change the story; problem set questions will ask you to change a number of the assumptions and see how that does (or does not) affect the aggregate demand curve.

6.2 Analytical results

Because our model is relatively simple – it's linear after all! – we can solve for the mathematical expression for the AD curve.

The AD curve describes an equilibrium relationship between the IS and MP curves. Using the IS equation:

$$Y = \frac{1}{1-b}(a - b \times T + (d - hr) + G)$$

and the MP equation

$$r = r^* + \alpha \times (Y - Y^N) + (\beta - 1) \times (\pi - \pi^*) + \epsilon$$

Show that the AD equation is

$$Y = \frac{1}{1-b+h\alpha} \times \left[a - bT + d + G - hr^* + h\alpha Y^N - h(\beta-1)(\pi - \pi^*) - h\epsilon\right]$$

Given

$$Y = \frac{1}{1-b+h\alpha} \times \left[a - bT + d + G - hr^* + h\alpha Y^N - h(\beta-1)(\pi - \pi^*) - h\epsilon\right]$$

We can also write this in "changes" form. In particular, let's study the effect of a change in government spending, holding fixed T and ϵ, but allowing π to vary.

$$\Delta Y = \frac{1}{1-b+h\alpha} \times (\Delta G - h(\beta-1)\Delta\pi)$$

Notice that whether a change in G increases or decreases GDP depends, critically, on the sign and size of $\Delta\pi$. $h(\beta-1)$ is a positive number, and $1-b+h\alpha$ is also positive. But the AD curve alone doesn't tell us how inflation changes – only that an increase in inflation, all else equal, is associated with lower output.

We need an aggregate supply curve to complement our aggregate demand curve. Adding that will allow us to (1) embed a purely real, long-run model as a special case (2) Consider short-term monetary non-neutrality.

7 Aggregate supply

In the last section, we found an expression for aggregate demand:

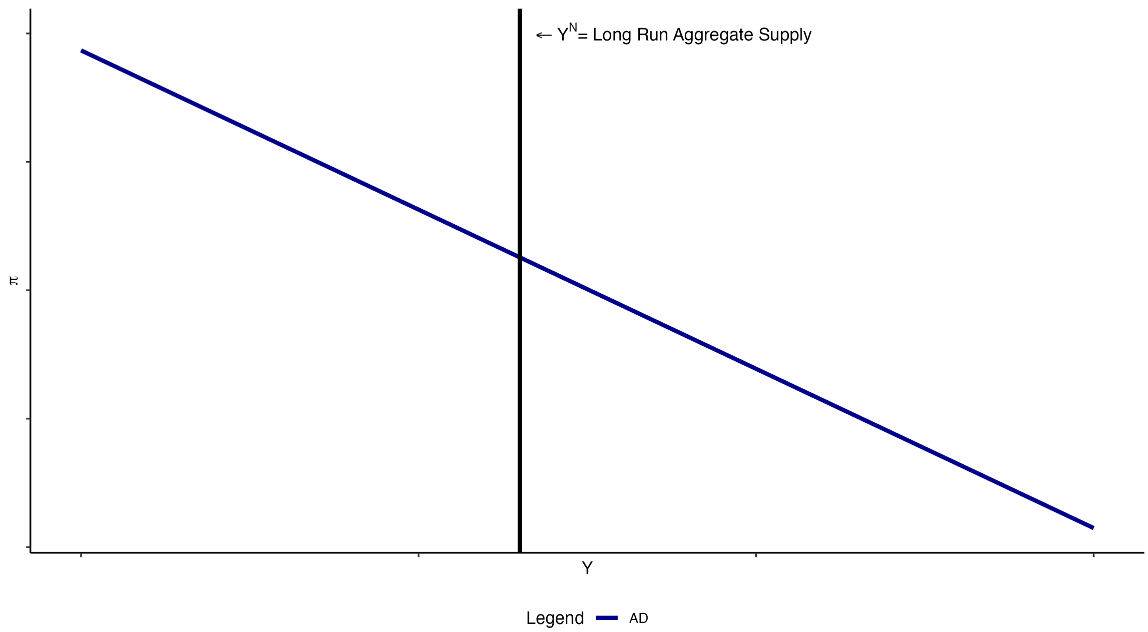
$$Y = \frac{1}{1-b+h\alpha} \times \left[a - bT + d + G - hr^* + h\alpha Y^N - h(\beta-1)(\pi - \pi^*) - h\epsilon\right]$$

Given Y, we could solve for π. Alternatively, given π, we could solve for Y. But to know what Y and π are simultaneously, we need to do a little more work. We'll develop two versions: one that we'll call the "long-run" version, which is really a re-statement of the classical model. The second is a "short-run" version, which is closer to what's in the textbook. Having both versions is helpful because it helps us think about how the short run becomes the long run.

7.1 Long run: The return of the classical model

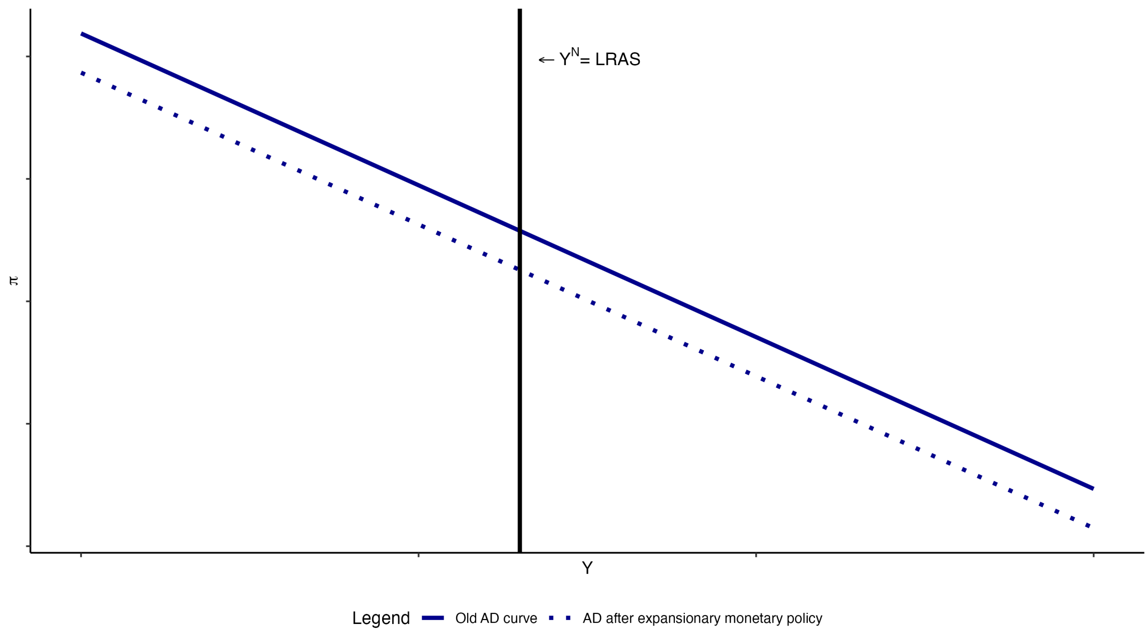
We already defined Y^N as *potential GDP*. We can think about this as the level of GDP we expect the economy to return to in the long run, given the quantity of factors of production and production technology.

One way of thinking about the macroeconomy is similar to the classical model: assume that output is determined by Y^N, and aggregate demand determines the rate of inflation. This yields a vertical "long run aggregate supply curve." The macroeconomic equilibrium is determined by the inflation level that, all else equal, keeps output on this long-run aggregate supply curve (graphically, the intersection of AD and LRAS).

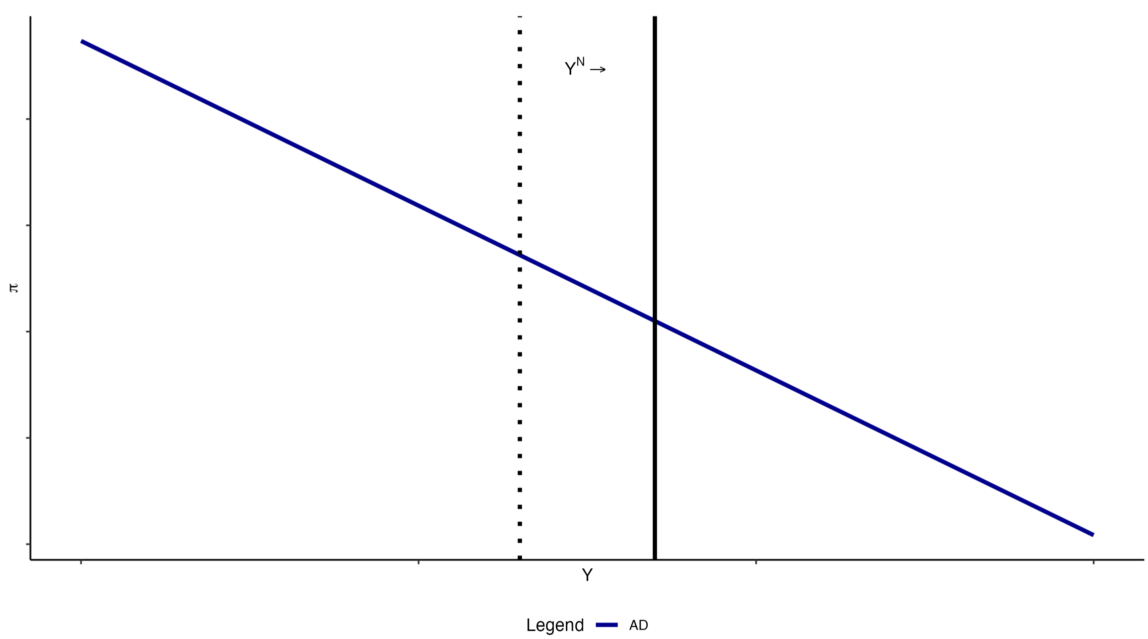


Essentially, the long run aggregate supply curve assumes a particular kind of monetary neutrality: the rate of inflation has nothing to do with the level of output. Aggregate GDP, at the end of the day, must be at the level determined by the available factors of production and technology; prices will adjust to make that the case, and changes to the money supply don't affect it. A change in aggregate demand may have an effect on what quantities of C, I, or G we end up with, but those also lead to price adjustments so that $Y = Y^N$.

For instance, suppose that the Federal Reserve attempted to increase the money supply. We know from our earlier work that this will, all else equal, lower nominal interest rates. (In terms of model variables, this shifts the MP curve downward without a change in Y or π – it's a decrease in ϵ). But if we are on the LRAS curve, we also know that the increase in money will *also* be offset by an increase in inflation, which keeps nominal interest rates exactly the same. Real activity is unaffected, prices are higher.



By emphasizing this as a long-run outcome, we're essentially saying that aggregate demand determines the rate of inflation, but the supply side of the economy determines output. Government policy that attempts to affect aggregate demand can't affect Y. The government could only affect output in the long run by affecting Y^N – say, by investing in productive capital or choosing policies that result in greater efficiency. These things *shift* the Y^N curve.



Notice that, consistent with the quantity equation logic, an increase in LRAS (shift to the right, the solid line) will lower inflation if money doesn't adjust enough to keep that from happening.The punchline is that the IS-MP-AS (AS/AD) model we've developed contains the classical model as, more or less, a special case. However, we need not assume monetary neutrality, and in the next subsection, we'll relax that assumption. This will allow the economy to be (temporarily) off the long-run aggregate supply curve.

7.2 The short run

We've seen reasons to expect monetary neutrality doesn't hold at all times. Here, we'll relax the assumption of pure neutrality by focusing on one possible story: that wages do not adjust freely. (This was one story that Keynes proposed, and while it is not the only possible one, it's fairly intuitive).

To generate intuition: Suppose we have profit-maximizing firms who hire workers as one possible input into production. Over short horizons, it's not possible to adjust all of their factors of production, but if they want to adjust how much they produce, they can hire or fire workers. The fact that some factor of production – say, the number of computers and desks available for workers – is fixed means that they face diminishing marginal returns to labor.

The firm decides whether to hire or fire a worker (or, to have a worker work an additional hour) by comparing the benefit to the firm – the marginal revenue generated by the worker for an hour of work – to the marginal cost – the wage. If the worker produces \$200 in revenue in an hour of work, and they cost \$15 an hour, it is "worth it" to the firm to hire them – they keep \$185 in profits.

Diminishing marginal returns implies that the amount produced by each worker falls as the number of hours of work increases, so at some point, we have the condition

$$\text{Price of the firm's output} \times \text{Marginal Product of Labor} = \text{Wage}$$

Now we introduce the idea of **sticky wages.** Suppose that wages are negotiated on infrequently – the worker and the firm agree to a contract that says the worker will receive \$15 in *nominal* dollars for every hour of work, and the contract is re-negotiated every year. That means that the right-hand side is fixed in advance. How do firms and workers negotiate? Well, part of what will affect their negotiations is the *real* wage they expect – that is, how much they expect inflation to change between now and their next contract. Call $\bar{\mathrm{W}}(\pi^e)$ the fixed nominal wage they negotiate on as a function of π^e, the expected rate of inflation. Profit maximization implies:

$$\text{Price of the firm's output} \times \text{Marginal Product of Labor} = \bar{\mathrm{W}}(\pi^e)$$

Now, what happens if prices in the economy generally change? The price of the firm's output is one of those prices – so if π is rising, then we'd expect the price of the firm's output to go up. That implies firms are getting a good deal – they're earning more revenues, but the cost of workers isn't changing. (Real wages are going down!). What should they do in that case? Hire more workers! But hiring more workers means the marginal product of labor will fall over until the benefit of hiring workers is equal to the cost.

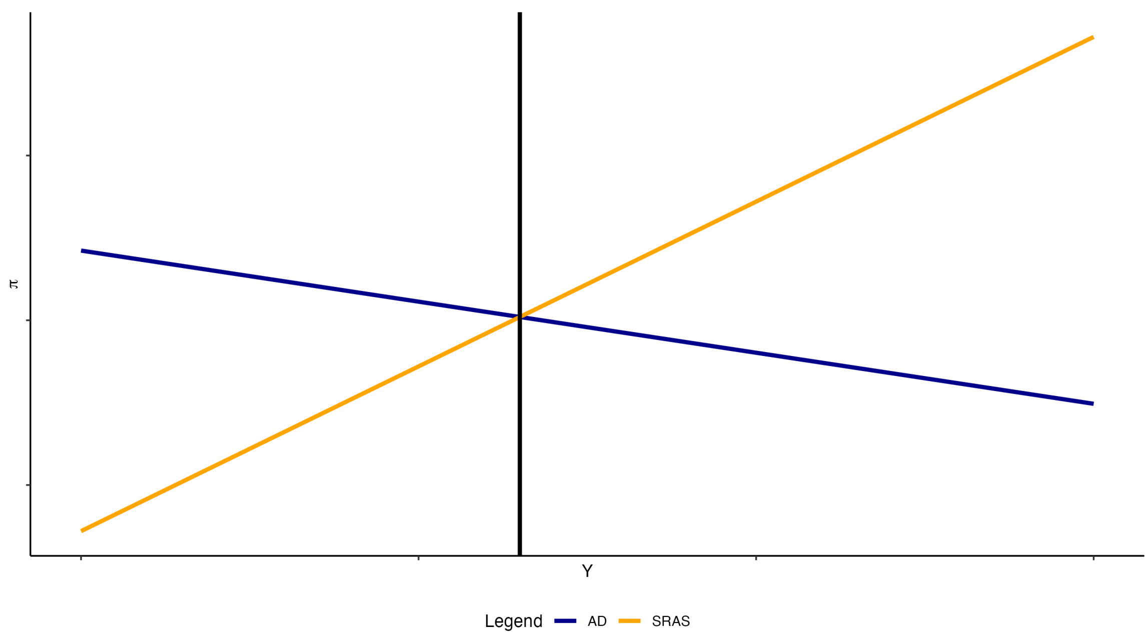
This holds for a single firm. Over the entire economy, we'd expect that the timing of wage negotiation, its flexibility, etc, might differ for different firms. So, handwaving a little bit, we'll summarize the relationship between prices and production as follows: When inflation is higher than expected, firms have a greater incentive to produce. We summarize this relationship in the following expression:

$$\text{SRAS: } Y = Y^N + \kappa(\pi - \pi^e)$$

κ (a greek letter 'kappa') is greater than zero, and summarizes how much firms produce above potential when prices are unexpectedly high (and vice versa). If κ is large, output is very responsive. On the other hand, the limiting case is when wages also respond perfectly to price changes, in which case $Y = Y^N$ always and $\kappa = 0$. Over time, inflation expectations adjust, workers re-negotiate wages, and firms will once again produce at the "natural" sustainable level.

To sum up:

- If wages are sticky, and are set by firms' price expectations ...
- then when inflation is higher than expected, firms marginal costs are not increasing, but their marginal benefits are ...
- ... so they want to produce more.
- The adjustment of inflation expectations, and the related setting of wages, brings the economy back to the long-run level of production where $Y = Y^N$.



What shifts short-run aggregate supply? We've got two possibilities: (1) Changes in the long-run level of production in the economy of firms (that is, changes in Y^N) and (2) changes in firms' expectations about inflation (π^e)., holding fixed the *actual* level of inflation

Let's dig into that second one. If firms and workers expect that prices will increase in the future, then wages go up *today* (when they negotiate). However, firms' prices haven't actually increased yet. So firms are paying a higher cost without getting a higher benefit; optimally, they cut back on production. All else equal, an increase in expected inflation shifts SRAS to the left.

8 Equilibrium and graphical analysis

Now that we have aggregate supply and aggregate demand, we can define equilibrium. But we need to be a *little* careful, because we seem to have two supply curves and one demand curve.

Definition 3 (Definition of equilibrium in the AS-AD model)**.** *Equilibrium is the level of output Y and inflation π at the point where the aggregate demand curve equals *short run* aggregate supply, $AD = SRAS$.*

In the long run, since $Y = Y^N$, SRAS and AD must intersect at the long-run aggregate demand curve. This is where $\pi = \pi^e$.

*The transition from a short-run equilibrium to the long-run equilibrium occurs either through a change in fiscal or monetary policy (shifting AD) *or*, if not through policy, through a change in inflation expectations π^e.*

When we're analyzing events in the AS-AD model, we should try to be systematic about it, using something like the following procedure:

1. Decide whether the event affects aggregate demand, short run aggregate supply and/or long-run aggregate supply;

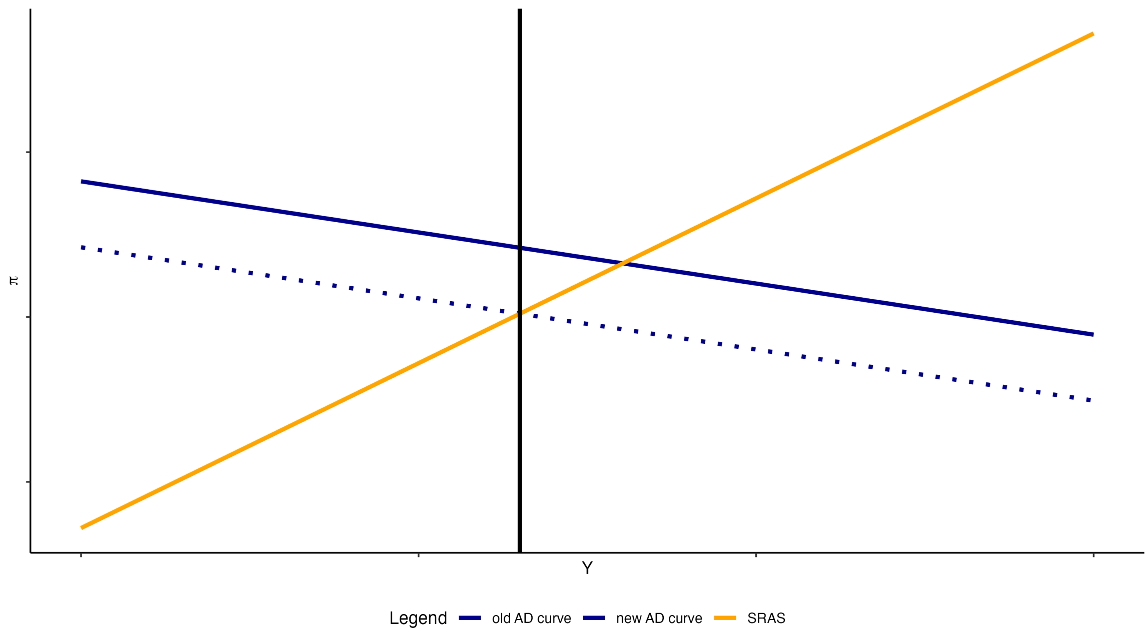
2. Shift the appropriate curve, and find the equilibrium level of inflation and output in the short run where AD = SRAS3.

3. Explain how (1) if policymakers do nothing, inflation expectations adjust; (2) if policymakers act, what they do to shift aggregate demand.It's easiest to see how this works through an example.

8.1 Example: A change in aggregate demand

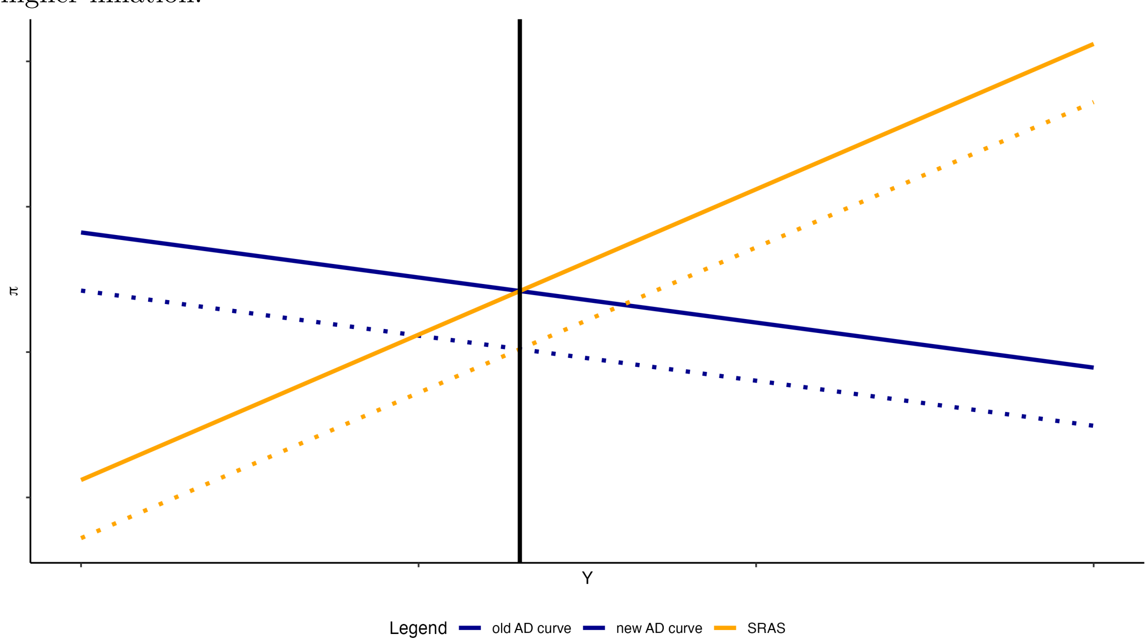
Suppose that investors decided that now was a good time to expand their firms – say, by investing in new factories or equipment. What effect would this wave of optimism have on the economy? Let's apply the procedure above:

1. Firms' investment decisions affects their demand for investment; hence, this should shift AD. (In the long run, it could arguably affect Y^N, but we can set that aside – remember that capital might take awhile to get running, and it's okay for this qualitative model to focus on the main, most important, effect). In particular, it likely increases output at any given level of inflation. (I would think of this as a change in the d parameter of the investment function).

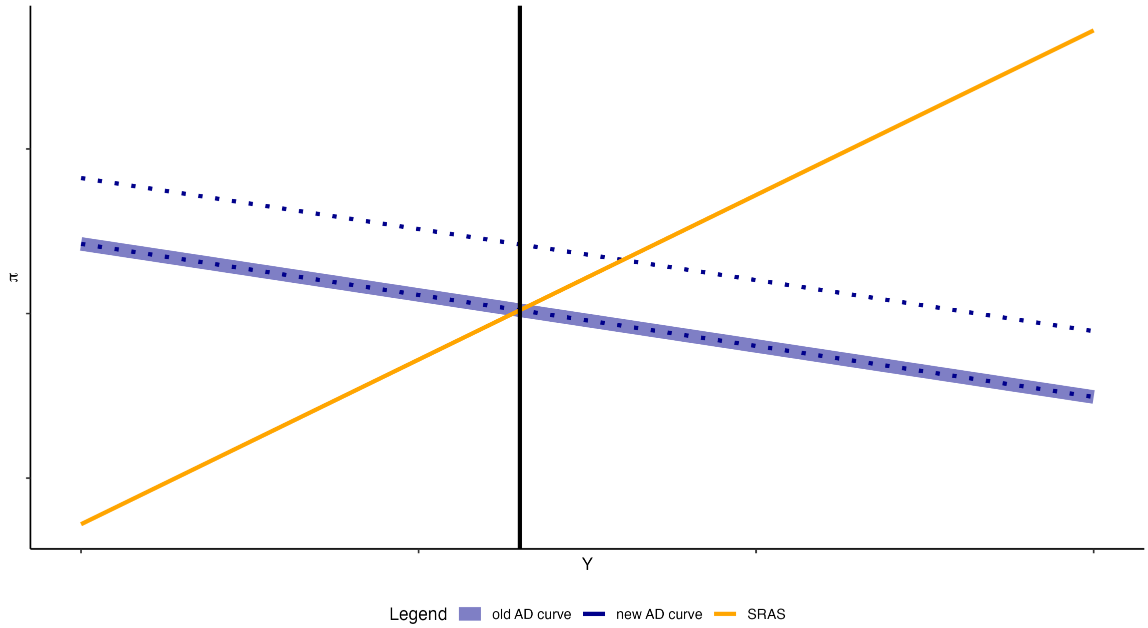


2. As is clear from the above, the short-run equilibrium is the intersection of the solid blue and orange lines. The expansion in investment raises output, but also leads to an increase in inflation. (The increase in inflation is what induces production to meet the higher demand).

3. Now, the question is: how do we get back to the long run? If policymakers do nothing (holding G,T,ϵ fixed), then the higher-than-expected inflation doesn't stay higher-than-expected forever. Eventually, workers renegotiate wages to reflect the new high rate of price changes. This reduces the firms' incentives to produce above potential GDP, shifting SRAS to the left. In the long run, equilibrium is at potential GDP, but with permanently higher inflation.



On the other hand, policymakers may want to avoid higher inflation. If so, they could directly affect aggregate demand by cutting government spending, increasing taxes, and/or engaging in contractionary monetary policy. Any of these could shift AD back to its original position!



A List of equations and variables

This is just a short list of variables that are used in the text. If I've forgotten any, let me know!

Linear aggregate consumption function

$$C = a + b(Y - T)$$

Linear aggregate savings function:

$$S = -a + (1 - b)(Y - T)$$

MPC:

$$b$$

MPS:

$$(1 - b)$$

Linear investment function:

$$I = d - hr$$

In partial equilibrium:

Investment multiplier:

$$\frac{\Delta Y}{\Delta I} = \frac{1}{1 - b}$$

Government spending multiplier:

$$\frac{\Delta Y}{\Delta G} = \frac{1}{1 - b}$$

Tax multiplier:

$$\frac{\Delta Y}{\Delta T} = \frac{-b}{1 - b}$$

Central Bank Policy Rule ("Taylor Rule") for nominal rates:

$$i^{Fed} = r^* + \pi^* + \alpha(Y - Y^N) + \beta(\pi - \pi^*)$$

Real interest rate (MP curve):

$$r = i^{Fed} - \pi + \epsilon = r^* + \alpha(Y - Y^N) + (\beta - 1)(\pi - \pi^*) + \epsilon$$

AD curve equation (where IS = MP):

$$Y = \frac{1}{1 - b + h\alpha}\left[a + d - bT + G - h(r^* + \pi^*) + h\alpha Y^N - h \times (\beta - 1) \times (\pi - \pi^*) - h\epsilon\right]$$

Greek letters Δ - capital delta – generically, the change in a variable

α - lower case alpha – the weight on the output gap in the Taylor Rule

β - lower case beta – weight on inflation gap in the Taylor rule.

ϵ - lower case epsilon – interest rate "shock" (deviation from the Taylor rule)

B An important algebraic fact: the "write it as changes" trick

With this model, we'll mainly work with systems of linear equations. If you need a refresher, you should check out sections 3 and 5 of the math review document.This isn't really a trick, but a fact about algebra: Suppose that

$$X = q + mY + nZ$$

And use Δ to indicate a change in a variable, e.g. ΔX is a change in X. Suppose q is a constant. That means if X is changing, it is because of some change in either Y or Z. This implies

$$X + \Delta X = q + m(Y + \Delta Y) + n(Z + \Delta Z)$$

Notice that we can then write:

$$X + \Delta X - X = q + m(Y + \Delta Y) + n(Z + \Delta Z) - (q + mY + nZ)$$

and hence

$$\Delta X = m\Delta Y + n\Delta Z$$

This is handy if we want to calculate how much X changes with Z changes, all else equal: just use the "changes" version of the expression with $\Delta Y = 0$.If you've taken calculus, this may seem slightly familiar. We can think of our linear model as describing the linearized, approximate behavior of a more complicated model (e.g., using the tangent lines around some value to approximate the behavior of the potentially more complicated system). The way we calculate "changes" is by taking total differentials.