1 Introduction

At the risk of some oversimplification, the leading alternatives to the neoclassical / real business cycle model for understanding short run fluctuations are Keynesian models. I phrase this in the plural because there are multiple different versions of the Keynesian model, which differ in terms of how the aggregate supply block of the economy is formulated. Whereas neoclassical models emphasize changes in supply as drivers of the business cycle, feature monetary neutrality, and have no role for activist economic policies, Keynesian models are the opposite – they emphasize demand changes as the source of business cycles (though changes in supply can also have effects on output), money is non-neutral, and there is a role for activist stabilization policies.

Though often caricatured as being fundamentally different from the neoclassical model, modern Keynesian models (which are often called “New Keynesian” models) actually have exactly the same backbone and structure as the neoclassical model. Agents are optimizing and forward-looking. There is a well-defined equilibrium concept. The fundamental difference between Keynesian and neoclassical theories concerns the flexibility of prices and wages. Keynesian theories typically emphasize nominal rigidities, in the sense that the aggregate price level and/or nominal wages may be imperfectly flexible. This imperfect flexibility of prices and wages (sometimes called price and wage “stickiness”) can be motivated via the common experience that the prices of the goods we buy, and the wages we are paid for work, don’t instantaneously change period-to-period in response to changing conditions. This could be because of things like “menu costs” (it is costly to change posted prices for some reason), institutional constraints (wage contracts are set in advance and are difficult to change on the fly), or simply because firms find it costly to pay attention to aggregate conditions and constantly re-evaluate their prices and wages. Whatever the reason why prices and/or wages are sticky, this stickiness will do a couple of important things in the model: (i) it will allow changes in the money supply to have real effects, so that money is non-neutral and (ii) it will mean that the equilibrium response to other shocks will generally be inefficient, in the sense of differing from what a fictitious social planner would choose. The fact that the equilibrium will generally be inefficient gives some justification for activist economic policies designed to stabilize
the business cycle.

In spite of these differences, the core of Keynesian models is the same as the neoclassical model. The household and firm problems are the same as we’ve already studied, aside from the assumptions that prices and wages aren’t freely able to instantaneously adjust each period. Hence, we won’t be writing down any new decision problems and won’t really be doing any new math. We’ll analyze the model using a slightly different set of graphs, but it’s possible to use these same graphs to analyze the equilibrium of the neoclassical model. So, in some sense, we can think of the neoclassical model not as a different model from the Keynesian model, but rather as a special case of the Keynesian model in which prices and wages are fully flexible.

2 The IS-LM-AD Block

The demand side of Keynesian models is characterized by the IS-LM-AD curves. The IS curve stands for “Investment = Saving” and is identical to the $Y^d$ curve that we derived before, it’s simply relabeled to be consistent with Keynesian terminology. The LM curve stands for “Liquidity = Money” and shows the $(r_t, Y_t)$ pairs where the money market is in equilibrium for given values of $M_t$ and $P_t$. The AD curve (which stands for “Aggregate Demand”) is the set of $(P_t, Y_t)$ pairs where we’re on both the IS and LM curves. It is important to note that these curves have nothing to do with the principle difference between Keynesian and neoclassical models (price and wage rigidity). As such, we could also use these curves to summarize the demand side of the neoclassical model.

The relevant optimality conditions concerning the demand side of the model are the household’s consumption function and the firm’s investment demand function. These are identical to what we’ve already encountered:

$$C_t = C(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t)$$

$$I_t = I(r_t, A_{t+1}, q, K_t)$$

Consumption depends on current and future expected net income and the real interest rate. Ricardian Equivalence holds so that the representative household behaves as though the government balances its budget each period. Investment depends negatively on the real interest rate, positively on expected future productivity, positively on the investment shock, and negatively on the current capital stock (which is again predetermined and therefore exogenous). Government spending is chosen exogenously. Total desired expenditure is the sum of desired expenditure by households, firms, and the government, where these spending decisions are chosen according to the optimal consumption and investment demand functions:

$$Y^d_t = C(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) + I(r_t, A_{t+1}, q, K_t) + G_t$$

The IS curve is identical the $Y^d$ curve we had before. It is defined as the set of $(r_t, Y_t)$ pairs where desired expenditure equals income. It can be derived graphically just as did before. You plot
\( Y_t^d \) as a function of \( Y_t \). This is upward-sloping but has slope less than 1 (the MPC is positive but less than 1). You start with a particular \( r_t \), say \( r_t^0 \), which determines the vertical position of the desired expenditure line. You see where this crosses a 45 degree line which shows all points where \( Y_t^d = Y_t \). This gives you an interest rate, output pair consistent with expenditure equaling income. Then you try a different interest rate. Suppose \( r_t^1 < r_t^0 \). This results in higher desired consumption and investment for every level of \( Y_t \), or an upward shift in desired expenditure (blue line). This crosses the 45 degree line at a higher value of \( Y_t \). The reverse is true for a higher interest rate. If you connect the dots in a graph with \( r_t \) on the vertical axis and \( Y_t \) on the horizontal axis, you get a downward-sloping curve/line.

![Graph showing IS curve and LM curve](image)

Shifts of the IS curve are identical to shifts of the \( Y^d \) curve. Any exogenous change which increases desired expenditure for a given level of income will result in the IS curve shifting to the right. This would happen in response to an increase in expected future productivity, \( A_{t+1} \), an increase in the investment shock, \( q \), an increase in current government spending, \( G_t \), a decrease in expected future government spending, \( G_{t+1} \), or a decrease in the current capital stock, \( K_t \).

The LM curve is new. It is really just an alternative graphical representative of the money demand/supply diagram that we’ve already seen. In particular, the LM curve is the set of \((r_t, Y_t)\) pairs where the money market is in equilibrium for given values of the exogenous variable \( M_t \) and the endogenous price level \( P_t \). The money demand function for the household is given by:
As discussed previously, the demand for money depends on the nominal interest rate. I have written this in terms of the real interest rate using the approximate Fisher relationship, where we take expected inflation between \( t \) and \( t+1 \), \( \pi_{t+1}^{e} \), to be exogenously given. Since it is exogenous, most of the time I will treat it as fixed (expected inflation will only change if you are told it is changing). As such, I will typically write the money demand function omitting explicit dependence on expected inflation as \( M_t = P_t M_d(r_t, Y_t) \).

To derive the LM curve, start with given values of \( M_t \) and \( P_t \), call them \( M^0_t \) and \( P^0_t \). We will use the same graphical setup to analyze the money market as before, with money supply vertical and money demand upward-sloping in \( P_t \) (recall that the “price” of money in terms of goods is really \( \frac{1}{P_t} \), so the demand curve sloping up is the result of plotting it against the inverse “price”). Then find the the combination of the real interest rate and output, call it \( (r^0_t, Y^0_t) \), at which the money market is in equilibrium at \( (M^0_t, P^0_t) \). In other words, find the \( (r^0_t, Y^0_t) \) such that the money demand curve crosses the money supply curve at \( P^0_t \). I label this point (a) in the graph below.

Next, let’s suppose that output is higher, at \( Y^1_t > Y^0_t \). Holding the real interest rate fixed, this would pivot/shift the money demand curve out to the right. I label this point (b) in the above curve and show the new money demand curve with a blue line. At \( (r^0_t, Y^1_t) \), the money market would not be in equilibrium at \( (M^0_t, P^0_t) \). Holding the money supply and the price level fixed, if output is
higher the real interest rate must adjust in such a way that the money demand curve crosses the money supply curve at the original point, labeled (a). In other words, $r_t$ needs to change in such a way as to shift the money demand curve in, to undo the outward shift induced by higher $Y_t$. This mean that $r_t$ needs to increase to something like $r^1_t$. I label this point (c) in the graph, and at (c) the quantity of money demand is the same as it was at (a), i.e. $M^d(r^0_t, Y^0_t) = M^d(r^1_t, Y^1_t)$. If we connect the dots in a graph with $r_t$ on the vertical axis and $Y_t$ on the horizontal axis, we get an upward-sloping line. This is the LM curve. Mathematically, the LM curve is the set of $(r_t, Y_t)$ pairs for which $M^0_t = P^0_t M^d(r_t, Y_t)$.

In the graph I write the LM curve as $LM(M^0_t, P^0_t)$. This reflects the fact that the position of LM curve depends on the values of $M_t$ and $P_t$. Suppose that the money supply increases from $M^0_t$ to $M^1_t$. This is shown with the blue line for the new money supply curve in the graph below. The money market would not be in equilibrium at $(M^1_t, P^0_t)$ without a change in either $r_t$ or $Y_t$. Basically, we need $(r_t, Y_t)$ to change in such a way as to shift the money demand curve so that it intersects the new money supply curve at $P^0_t$. Hence, the money demand curve needs to shift to the right. This could occur because of an increase in $Y_t$, a reduction in $r_t$, or some combination thereof. I like to think about shifts as being horizontal, so let’s hold $r_t$ fixed at $r^0_t$. We evidently therefore need $Y_t$ to increase to some new value, called it $Y^1_t$, in such a way that $M^1_t = P^0_t M^d(r^0_t, Y^1_t)$. Since $Y_t$ is higher holding $r_t$ fixed, the entire LM curve must shift to the right whenever $M_t$ increases. This is shown with the blue line below. If the money supply were to decrease, the LM curve would shift to the left.

\[ M^d(r^0_t, Y^0_t) \]  
\[ M^d(r^1_t, Y^1_t) \]  
\[ LM(M^0_t, P^0_t) \]  
\[ LM(M^1_t, P^0_t) \]  

↑ $M_t$: for money market equilibrium at $P^0_t$, must have either ↑ $Y_t$ or ↓ $r_t$, so LM curve shifts right
The LM curve will also shift if the price level changes. Suppose that we hold the money supply fixed at $M^0_t$, but entertain the price level increasing from $P^0_t$ to $P^1_t$. The money market would not be in equilibrium at fixed values of $r_t$ and $Y_t$ given $M^0_t$ and a higher price level, $P^1_t$. Evidently, for the money market to be in equilibrium at $(M^0_t, P^1_t)$, we need the money demand curve to shift in. This requires a reduction in $Y_t$, an increase in $r_t$, or some combination thereof. Since I like to do horizontal shifts, I’m going to hold the real interest rate fixed at $r^0_t$. This means that $Y_t$ must decrease to some value $Y^1_t$. This is shown with the blue liens in the graph below. At this point, we have $M^0_t = P^1_t M^d(r^0_t, Y^1_t)$. Since we have a lower value of $Y_t$ for a fixed $r_t$, evidently the LM curve shifts in whenever $P_t$ increases. If $P_t$ were to decrease, the LM curve would shift right.

A useful rule of thumb to remember is this: the LM curve shifts in the same direction as real balances, $\frac{M_t}{P_t}$. Mathematically, the LM curve is defined as the set of $(r_t, Y_t)$ pairs for which $\frac{M^0_t}{P^0_t} = M^d(r_t, Y_t)$. For fixed $M^0_t$ and $P^0_t$, the right hand side must remain constant. If you increase $Y_t$, you must increase $r_t$ to counteract this and keep demand for real balances fixed. If $\frac{M_t}{P_t}$ goes up, you need demand for real balances to increase, which requires some combination of an increase in $Y_t$ or a decrease in $r_t$ – i.e. the LM curve must shift to the right. This can happen because either $M_t$ goes up or $P_t$ goes down.

The aggregate demand curve (AD) is defined as the set of $(P_t, Y_t)$ pairs where we’re on both the IS and the LM curves. Be careful to distinguish the AD curve from the $Y^d$ curve (which is what we’re now calling the IS curve). We can derive this graphically as follows. Draw the IS-LM.
graph (with \( r_t \) on the vertical axis, and \( Y_t \) on the horizontal axis) and then draw another graph right below this with \( P_t \) on the vertical axis and \( Y_t \) on the horizontal axis (so that the horizontal axes are the same). What connects these two graphs is \( P_t \). Start with a particular value of \( P_t \), call it \( P_t^0 \). Given a value of the exogenous variable \( M_t \), this determines the position of the LM curve. Given values of the exogenous variables which determine the position of the IS curve, we can find the value of \( Y_t \) where the IS and LM curves intersect. Call this \( Y_t^0 \). Now consider a higher value of \( P_t \), call it \( P_t^1 \). As per our discussion above, this results in the LM curve shifting in to the left. This means that the value of \( Y_t \) at which the new LM curve intersects the IS curve will be lower, call it \( Y_t^1 \). Likewise, consider a reduction in the price level to \( P_t^2 \). This would shift the LM curve to the right, which would result in a higher value of \( Y_t \) at which the IS and LM curves intersect, call it \( Y_t^2 \). If we plot these points in the bottom graph with \( P_t \) on the vertical axis and \( Y_t \) on the horizontal axis and connect the dots, we get a downward-sloping curve. This is the AD curve.

The AD curve will shift if there is a change in an exogenous variable which causes either the LM or IS curves to shift. Note that a change in \( P_t \) induces a shift of the LM curve but represents a movement along the AD curve rather than a shift. Let’s start with an exogenous increase in \( M_t \), from say \( M_t^0 \) to \( M_t^1 \). This causes the LM curve to shift to the right for a given price level. Holding the price level fixed, the value of \( Y_t \) at which the IS and LM curves intersect will be higher, say \( Y_t^1 \). Since \( Y_t \) increases for a given \( P_t \) when \( M_t \) increases, the entire AD curve shifts to the right. We can see this in the blue lines in the graph below:
Now, instead suppose that some exogenous variable changes which causes the IS curve to shift to the right. This could be caused by an increase in $A_{t+1}$, an increase in $q$, an increase in $G_t$, a decrease in $G_{t+1}$, or a decrease in $K_t$. The IS curve shifts to the right (shown with the blue line); this increases the level of $Y_t$ at which the IS and LM curves intersect. Since the LM curve is drawn for a given price level, $P_t^0$, this means that the level of $Y_t$ for which we are on both the IS and LM curves is bigger for a given $P_t$. In other words, the AD curve shifts to the right.
As noted above, nothing in the derivation of the IS, LM, or AD curves depends on any assumptions about price or wage stickiness. As such, we could use these curves in either the neoclassical or the Keynesian model.

3 The AS Curve and Equilibrium Effects of Changes in Exogenous Variables

To characterize the equilibrium, we need a description of the supply side of the economy. We will do this graphically with the AS (or “aggregate supply”) curve. The AS curve is defined as the set of \((P_t, Y_t)\) pairs consistent with some notion of labor market equilibrium and the aggregate production function. I say “some notion of labor market equilibrium” because it’s not necessarily labor market clearing in the sense we talked about in the neoclassical model. The chief difference between Keynesian models and the neoclassical models is the shape of the AS curve and what labor market equilibrium actually means. In the neoclassical model, the AS curve is vertical, which means that output is supply determined. In the Keynesian model, the AS curve is upward sloping but not vertical, which gives some scope for demand to influence output. We will consider two different assumptions which generate an upward-sloping AS curve – wage stickiness and price stickiness. Before doing that, I will derive the AS curve in the neoclassical model and show that we could use this new set of graphs to analyze effects of changes in exogenous variables in that model.
3.1 The Neoclassical Model

In the neoclassical model, the supply side of the economy is characterized by a labor demand curve, a labor supply curve, and the production function. These are:

\[ N_t = N^s(w_t, H_t) \]
\[ N_t = N^d(w_t, A_t, K_t) \]
\[ Y_t = A_t F(K_t, N_t) \]

The important thing to note here is that \( P_t \) does not appear in any of these expressions. This means that there is going to be no relationship between \( P_t \) and \( Y_t \) coming from these equations, so the AS curve will be vertical in a graph with \( P_t \) on the vertical axis and \( Y_t \) on the horizontal axis.

The mathematical equations characterizing the equilibrium of the neoclassical model are the same as we had before:

\[ N_t = N^d(w_t, A_t, K_t) \]
\[ N_t = N^s(w_t, H_t) \]
\[ Y_t = A_t F(K_t, N_t) \]
\[ C_t = C(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) \]
\[ I_t = I(r_t, A_{t+1}, q, K_t) \]
\[ Y_t = C_t + I_t + G_t \]
\[ M_t = P_t M^d(r_t, Y_t) \]

This is 7 equations in 7 endogenous variables (\( N_t, w_t, Y_t, C_t, I_t, r_t, \) and \( P_t \)). The exogenous variables are \( A_t, A_{t+1}, K_t, G_t, G_{t+1}, q, \) and \( H_t \). We can graphically characterize the equilibrium using a similar four part graph to what we had before in the neoclassical model. The labor market is in the upper left quadrant, the production function is plotted below that, and the bottom right graph is a 45 degree line reflecting the vertical axis onto the horizontal. The difference relative to our earlier setup is the graph in the upper right quadrant – now we have a graph with \( P_t \) on the vertical axis and \( Y_t \) on the horizontal axis (as opposed to \( r_t \) on the vertical axis). We can experiment with different values of \( P_t \), but since \( P_t \) doesn’t affect the position of the labor demand or supply curves, nor the position of the production function, we will not get a different value of \( Y_t \) for different \( P_t \). So the AS curve will be vertical (just like the \( Y^s \) curve was vertical, but these are different concepts). We can see this below.
We can characterize the full equilibrium of the economy as being on both the AD and AS curves. Being on the AS curve means that we’re on both the labor demand and labor supply curves (as well as the production function), while being on the AD curve implies that we are on both the IS and the LM curves. Graphically:
This picture graphically determines equilibrium values of $Y_t$, $N_t$, $w_t$, $P_t$, and $r_t$. The values of $C_t$ and $I_t$ are then determined by looking at the equations underlying the IS curve. In terms of the equations above, the IS curve summarizes the consumption function, the investment demand function, and the resource constraint. The LM curve summarizes money demand equaling money supply. The AD curve encapsulates both the IS and LM curves. The AS curve summarizes the labor demand and supply curves as well as the production function.
We can use these graphs to think about the effects of changes in exogenous variables. First, consider an exogenous increase in $A_t$. This causes both the labor demand curve and the production function to shift, which induces a rightward movement in the AS curve. I show this with the blue line. We can determine graphically that $Y_t$, $w_t$, and $N_t$ rise, while $P_t$ falls.

To determine what happens to the real interest rate, we have to use the IS-LM curves in conjunction with the AD-AS curves. Because the price level falls, real money balances rise. This
induces a rightward shift of the LM curve. I show that rightward shift in the LM curve with a green line (to differentiate it from the blue line, where I think of the blue line as representing the “direct effect” and the green line the “indirect effect” induced by a lower price level). Since the real interest rate falls and output rises, we can determine that consumption and investment both rise. Even though it’s not necessarily obvious from these curves, the effects on all the endogenous variables are identical to what we had in the other graphical setup (you can see this by looking at the equations).

Next, consider the effects of a labor supply shock, represented by an increase in the exogenous variable $H_t$. The labor supply curve shifts out and there is no change in the production function. With higher $N_t$, we get more $Y_t$ for each $P_t$, so the AS curve shifts right. We can deduce graphically that $Y_t$ and $N_t$ rise, while $P_t$ and $w_t$ fall.
To determine the effect on the real interest rate, we have to use the IS-LM curves in conjunction with the AD-AS curves. The lower price level induces a rightward shift in the LM curve, denoted by the green line. This results in a lower real interest rate. Since the real interest rate is lower and output is higher, both consumption and investment are higher. The changes in the endogenous variables are again identical to what we had before in the different graphical setup.

Now, let’s consider a “demand shock” caused by something which shifts the IS curve (increase
in $A_{t+1}$, $q$, or $G_t$, or decrease in $G_{t+1}$ or $K_t$). This is shown with the blue line in the IS-LM diagram. This causes the AD curve to shift out. Given the vertical AS curve, this results in no change in $Y_t$, $w_t$, or $N_t$, but an increase in $P_t$. The increase in $P_t$ causes the LM curve to shift in. This is shown with the green line. Since there is no change in $Y_t$ from the AD-AS intersection, the LM curve shifts in such that it intersects the new IS curve at the original level of $Y_t$ with a higher $r_t$. How consumption and investment are affected depends on which exogenous variable triggered the shift in the IS curve. The effects are identical to what we saw before.
Finally, consider the effect of an exogenous increase in the money supply, from $M^0_t$ to $M^1_t$. This causes the LM curve to shift right, which induces a rightward shift in the AD curve. These are shown with the blue lines in the diagram below. Since the AS curve is vertical, there is no change in $Y_t$ and an increase in $P_t$. There is no effect on either $w_t$ or $N_t$. The higher $P_t$ causes the LM curve to shift in. Since there is no change in $Y_t$ from the AD-AS intersection, this evidently means that the increase in $P_t$ is sufficient to completely “undo” the rightward shift of the LM curve, so that on net, there is no shift in the LM curve, and hence no change in $r_t$. Mathematically this means that $LM(M^0_t, P^0_t) = LM(M^1_t, P^1_t)$, which means that there is no effect on real balances; in other words, $\frac{M_t}{P_t}$ does not change, so that the price level simply rises proportionately with the money supply. Since neither $r_t$ nor $Y_t$ change, there are no changes in consumption or investment. There are no real effects of a change in the money supply, so money is neutral, just as we saw before.
3.2 Sticky Wage AS

We just saw that we can use the IS-LM-AD-AS curves to analyze the effects of changes in exogenous variables in the neoclassical model. Our real interest here is in analyzing the effects of these changes in Keynesian models.

At a basic level, Keynesian models differ from the neoclassical model in terms of the shape of the AS curve. In the neoclassical model, the AS curve is vertical, so output is supply determined.
In Keynesian models, the AS curve is upward sloping but not vertical, so there is some role for demand. To get the AS upward sloping we have to assume some sort of different structure on the supply side of the economy. The two most popular and straightforward structures are sticky wages and sticky prices. In this subsection we derive the sticky wage AS curve and then examine how the economy reacts to changes in the different exogenous variables.

In the sticky wage model we assume that the nominal wage, $W_t$, is fixed at some exogenous value, $\bar{W}$. You can think of this as being set in advance and unable to change in response to exogenous variables within a period, $t$. The real wage is $w_t = \frac{W_t}{P_t}$ or $W_t \frac{1}{P_t}$. The mathematical equations characterizing the supply side of the labor market are the same as before, though we have an extra condition determining the real wage in terms of the fixed nominal wage and the price level:

\[ N_t = N^d (w_t, A_t, K_t) \]
\[ Y_t = A_t F(K_t, N_t) \]
\[ w_t = \frac{\bar{W}}{P_t} \]

With the nominal wage fixed, it’s going to generally be impossible for the labor market to clear in the way we’ve defined it before. Why is this? Suppose that the price level, $P_t$, increases. With a fixed nominal wage, this reduces the real wage. This makes firms want to hire more labor (labor demand is downward-sloping in the real wage) but makes households want to work less (labor supply is increasing in the real wage). We are going to make the following assumption: we are going to assume that the quantity of labor is determined from the labor demand curve, so we are not necessarily on the labor supply curve. I will typically draw these graphs where $\bar{W}$ is set such that we would simultaneously be on both labor demand and labor supply given exogenous variables, but when an exogenous variable changes we will determine labor from the labor demand curve. In this sense labor demand need not equal labor supply in equilibrium. Mathematically, this involves essentially replacing the labor supply curve with the definition of the real wage in terms of the fixed nominal wage and the price level.

The mathematical equations characterizing the equilibrium of the sticky wage Keynesian model are therefore:

\[ N_t = N^d (w_t, A_t, K_t) \]

---

1 One might question how firms could force workers to work more than they might otherwise want to. One could motivate this via an attachment story – a household may not want to work off of its labor supply curve, but if the household is somehow attached to the firm it may be willing to do so at least for a while so as to avoid getting fired and not having a job in the future. An alternative way to address this problem would be to assume that $\bar{W}$ is always set such that real wage, $\frac{\bar{W}}{P_t}$, is always above the labor market clearing real wage (so that the quantity of labor supplied exceeds quantity demanded at the real wage). Reading quantity off the labor demand curve, the household is working less than it would otherwise like to, so the household would be willing to work more in response to a shock if the firm wants to hire more.
\[ w_t = \frac{W}{P_t} \]
\[ Y_t = A_t F(K_t, N_t) \]
\[ C_t = C(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) \]
\[ I_t = I(r_t, A_{t+1}, q, K_t) \]
\[ Y_t = C_t + I_t + G_t \]
\[ M_t = P_t M^d(r_t, Y_t) \]

Just as in the neoclassical model, this is again 7 equations in 7 endogenous variables \((N_t, w_t, Y_t, C_t, I_t, r_t, \text{and } P_t)\). What is different than the neoclassical model is that we have replaced the labor supply curve with the condition \(w_t = \frac{W}{P_t}\), and have included \(W\) as a new exogenous variable. So in a very basic sense, really all we’ve changed relative to the neoclassical model is that we’ve replaced the labor supply curve with a condition determining the real wage as a function of the price level given the fixed nominal wage.

We graphically derive an AS curve in a way similar to what we did before in a four part graph. Unlike in the neoclassical model, here there is a connection between the price level and the supply side of the model through the effect of the price level on the real wage, given the fixed nominal wage. Start with a value of \(P_t\) in the upper right quadrant, call it \(P^0_t\). For ease of exposition, suppose that given this value of the price level \(W\) is such that the labor market clears at \(w_t = \frac{W}{P^0_t}\) in the sense that we’re simultaneously on both the labor demand and supply curves. Given the real wage \(\frac{W}{P^0_t}\), we determine \(N_t\) from the labor demand curve. Then we plug that \(N_t\) into the aggregate production function (the lower left graph), which then gives us a value of \(Y_t\). Reflecting this over using the 45 degree line in the lower right quadrant, we get a \((P_t, Y_t)\) pair. Now, consider a lower value of the price level, \(P^1_t\). A lower price level means that the real wage increases because the nominal wage is fixed. This effectively causes firms to move “up” the labor demand curve – with a higher real wage, firms want to hire less labor. Less labor plugged into the production function means less output. So we get a new \((P_t, Y_t)\) pair that is to the “southwest” of the original pair. Connecting the dots, we get an upward-sloping (but not vertical) AS curve.\(^2\)

---

\(^2\)Note that in the sticky wage model we are always on the labor demand curve but not on the labor supply curve. As we will see, the reverse will be true in the sticky price model. This permits there to be differences between the quantity of labor supplied and the quantity demanded. If the quantity of labor supplied exceeds the quantity demanded, this sounds a lot like unemployment as it is defined in the data (people who are unemployed are those who would like to work but cannot find work). This is an interpretation one can give to these models but we will not focus on it, instead focusing on the behavior of aggregate output and aggregate labor input.
The IS-LM-AD block is unaffected by wage stickiness. So we can simply draw in the AD curve and look at the IS-LM curves to fully characterize the equilibrium.
The IS curve summarizes the consumption function, the investment demand function, and the resource constraint. The LM curve summarizes the condition that money demand equals supply (which is given exogenously). The AS curve summarizes the labor demand curve, the production function, the condition that the real wage equals the fixed nominal wage divided by the price level.

We can consider the effects of changes in exogenous variables in this model in a conceptually similar manner to what we did before, but the answers are going to be different. Let’s start with
an exogenous increase in $M_t$. This induces the LM curve to shift to the right, which causes the AD curve to shift to the right. Since the AS curve is upward sloping but not vertical, this means that $P_t$ and $Y_t$ both rise. This rise in output is supported because the rising price level pushes down the real wage to $\frac{W}{P_t}$, which induces firms to hire more labor. We can see this in the graph below:

Because the price level is higher, the LM curve must shift back in some, denoted with the green line in the graph. Unlike the neoclassical model, the LM curve does not shift "all the way" back
in since $Y_t$ is higher. In other words, relative to the neoclassical model with a vertical AS curve, the price level does not rise as much, so that real balances, $\frac{M_t}{P_t}$, increase, and the LM curve “on net” shifts right. This means that the real interest rate is lower. A lower real interest rate plus higher output means that both consumption and investment are higher. Working back to the labor market, a higher price level with an unchanged nominal wage means that the real wage is lower. The lower real wage causes firms to hire more labor, so $N_t$ increases and $w_t$ decreases.

Hence, by increasing the money supply a central bank can lower the real interest rate in this model, which stimulates both investment and consumption. A lower real interest rate as the “monetary transmission” mechanism is loosely how people in the real world think about the real effects of monetary policy – central banks are able to manipulate interest rates through their control of the money supply, which induces changes in consumption and investment. What is critical for this to happen in this model is that there is a friction (in this case, the nominal wage being sticky) which keeps the price level from rising as much as it would as in the neoclassical model.

Next, let’s think about what would happen after a shock which shifts the IS curve to the right (which could result because of an increase in $A_{t+1}$, $q$, $G_t$, or a decrease in $G_{t+1}$ or $K_t$). The rightward shift of the IS curve shifts the AD curve to the right, shown with blue lines in the diagram below. With an upward-sloping AS curve, this results in both output and the price level being higher. The higher price level, in conjunction with a fixed nominal wage, results in a lower real wage, which induces firms to hire more labor. So the real wage declines and labor hours increase. The higher price level causes the LM curve to shift in some (shown by the green line), but not so much that output is unchanged. Hence, the real interest rate rises.

3Traditional Keynesian theories emphasize IS shifts as causes of business cycles. One term used by Keynesians is “animal spirits,” which is meant to represent excessive optimism or pessimism. In the model, one interpretation of animal spirits is changes in what people believe $A_{t+1}$ to be. In the neoclassical model this has no effect on output because the AS curve is vertical, but with a non-vertical AS curve it can affect $Y_t$. 

24
We cannot determine what happens to $C_t$ or $I_t$ without knowing what exogenous variable changed in the first place. Suppose that the IS shock were caused by an increase in expected future productivity, $A_{t+1}$. As in the neoclassical model, it would be ambiguous as to what happens to both $C_t$ and $I_t$ – higher $A_{t+1}$ works to make both of these higher and higher $Y_t$ works to make $C_t$ higher, other things being equal, while higher $r_t$ works to make both $C_t$ and $I_t$ lower. Hence, the effect of higher $A_{t+1}$ on these variables is ambiguous.
Suppose instead that the IS shock were caused by an increase in $q$. Higher $q$ has a direct effect that makes $I_t$ higher, but higher $r_t$ has the effect of working to make $I_t$ lower. However, we actually know that $I_t$ must be higher in the new equilibrium. Why is that? We argued that in the neoclassical model $I_t$ would be higher when $q$ goes up, or that the direct effect dominates. In the sticky wage Keynesian model, the increase in $r_t$ after an increase in $q$ is smaller than in the neoclassical model (you can see this by noting that the neoclassical model is a special case of this model with a vertical AS curve). Hence, the indirect effect due to the higher interest rate is even smaller than in the neoclassical model, so we know that $I_t$ must rise. What happens to $C_t$ is ambiguous – higher $Y_t$ works to make consumption bigger, while higher $r_t$ has the opposite effect. We cannot definitely determine what happens to $C_t$ here.

Suppose that the IS shock were caused by an increase in $G_t$. This makes $r_t$ higher, which means that $I_t$ will be lower. Higher $r_t$ works to make $C_t$ lower, higher $G_t$ works to make $C_t$ lower, but higher $Y_t$ works to make $C_t$ higher. Hence, it seems that the effect on $C_t$ is ambiguous. But it turns out it’s not. Back in the equilibrium in an endowment economy material, we argued that output would increase one-for-one with $G_t$ if the real interest rate were held fixed – in the terminology of this new model, the magnitude of the horizontal shift in the IS curve is equal to the change in $G_t$. But since the real interest rate rises in the new equilibrium, the actual change in output is smaller than the change in $G_t$. Put another way, in this model the government spending multiplier is positive (unlike zero in the neoclassical model), but less than one. Since $Y_t$ goes up by less than $G_t$, $Y_t - G_t$ goes down, so perceived current net income falls. Falling current net income exerts a negative effect on consumption. Combined with the higher real interest rate, this means that consumption falls after an increase in $G_t$.

Suppose that the IS shock were caused by an expected reduction in future government spending. Since the real interest rate rises and nothing else relevant for investment has changed, we can deduce that $I_t$ must fall. But since $Y_t$ is higher and current $G_t$ is unchanged, for $Y_t$ to rise and $I_t$ to fall it must be the case that $C_t$ rises.

Next, let’s consider the effects of an increase in $A_t$ in the sticky wage model. The higher $A_t$ has two direct effects – it shifts the labor demand curve to the right, and it shifts the production function up. Holding the price level fixed, labor demand shifting right would result in higher $N_t$. Higher $N_t$ plus higher $A_t$ means higher $Y_t$ for a given $P_t$. In other words, the AS curve shifts to the right. This means that $Y_t$ rises and $P_t$ falls. The fall in $P_t$ induces an outward shift of the LM curve (shown by the green line), so that $r_t$ falls. $r_t$ falling with $Y_t$ rising means that both consumption and investment also rise. We have to work our way back to the labor market. The lower $P_t$ results in a higher real wage, which induces firms to hire less labor. In this model, it turns out to be ambiguous how $N_t$ reacts – it could be higher, lower, or unchanged. In the picture below I’ve drawn it as being unchanged, but in general it is ambiguous. We will return to this point in some more detail later.
A change in $H_t$ has no effects on anything in the sticky wage model. Changes in $H_t$ shift the labor supply curve. But in this model we are not on the labor supply curve, so it is irrelevant for all the other endogenous variables in equilibrium.

The table below summarizes the qualitative effects of changes in various exogenous variables on the endogenous variables in the sticky wage Keynesian model.
Variable: $\uparrow M_t$ $\uparrow A_t$ $\uparrow A_{t+1}$ $\uparrow q$ $\uparrow G_t$ $\uparrow G_{t+1}$ $\uparrow H_t$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Output</th>
<th>Hours</th>
<th>Consumption</th>
<th>Investment</th>
<th>Real interest rate</th>
<th>Real wage</th>
<th>Price level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Hours</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>?</td>
<td>-</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Real interest rate</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Real wage</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Price level</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>

### 3.3 Sticky Price AS

Now we switch gears and motivate a non-vertical AS curve via sticky prices. We assume that the nominal wage is flexible (though in principle it is possible to incorporate both price and wage stickiness at the same time).

The firm side of the model needs to be slightly modified to incorporate price stickiness. For prices to be sticky, firms have to have some price-setting power (which they don’t in a perfectly competitive setup). Suppose that there are a bunch of different firms, indexed by $j = 1, \ldots, J$. They each produce output according to $Y_{j,t} = A_t F(K_{j,t}, N_{j,t})$, where $A_t$ is common across all firms. Differently than our previous setup, we assume that firms have some price-setting power – suppose that the goods they produce are sufficiently different that firms are not price-takers in their output market. Nevertheless, we assume that they do not behave strategically – though firms might be able to adjust their own price, they don’t act as though their price-setting (or production) decisions have any effect on the aggregate price level or output (put differently, the total number of these firms, $J$, is assumed to be sufficiently “large”. Formally, these firms are monopolistically competitive. We can think about aggregate output and prices as essentially weighted-averages of individual firm output and prices. Ultimately, since this is macro, we’re really only interested in the behavior of aggregates. We introduce firm heterogeneity because we need some price-setting power for price-stickiness to make any sense.

Suppose that the demand for each firm’s good is a decreasing function of its relative price:

$$Y_{j,t} = f \left( \frac{P_{j,t}}{P_t}, X_j \right)$$

Here $X_j$ denotes other stuff (like tastes, aggregate income, etc., some of which may be specific to product $j$, some of which may not). The important and relevant assumption is that $f_1 < 0$: demand for the good is decreasing in the relative price.

Now, if all firms could freely adjust prices period-by-period, the relative prices of goods, $\frac{P_{j,t}}{P_t}$, would be determined by tastes and technologies (e.g. different kinds of foods, or electronics becoming cheaper to produce, whatever). Movements in the aggregate price level, $P_t$, would have no effect on demand for products – if $P_t$ doubled but nothing else changed, all firms would just double...
their prices, $P_{j,t}$. This wouldn’t change relative prices, so there would be no change in the demand for goods, and hence there would be no effect of a change in $P_t$ on total output – money would be “neutral” as it is in the benchmark neoclassical model.

Suppose instead that firms have to set their prices in advance based on what they expect the aggregate price level to be. Denote the aggregate expected price level as $P^e_t$. We take this variable to be exogenous. Each individual firm sets its own price to target an optimal relative price based on other conditions specific to its product. Suppose that some fraction of firms cannot adjust their price within period to changes in the aggregate price level, say because of “menu costs” or informational frictions. This means that an increase in the aggregate price level, $P_t$, over and above what was expected, $P^e_t$, will lead these firms to have relative prices that are too low (while firms that can update their prices will have their target relative prices). With a lower relative price, there will be more demand for these goods. The “rules of the game” are that a firm must produce however much output is demanded at its price – the rational for which could be that refusing to produce so as to meet demand would lead to a loss in customer loyalty (or something similar). Therefore, having a suboptimally low relative price means that a firm that cannot adjust its own price must produce more when the aggregate price level is higher than was expected. With some firms producing more than they would like to, aggregate output will rise. Thus, there will be a positive relationship between surprise changes in the price level and the level of economic activity.

Let $Y_{f,t}$ denote the hypothetical amount of output that would be produced in the neoclassical model where prices are flexible (hence the $f$ superscript). This is unaffected by price rigidities – it would be the equilibrium level of output given the real exogenous variables ($A_t, A_{t+1}, G_t, G_{t+1}, K_t, q,$ and $H_t$) in the model where there were no pricing rigidities. Let $Y_t$ denote the actual amount produced. Our story above says that when the aggregate price level increases, output increases, because some firms cannot/don’t adjust their own price, and hence end up producing more than they find optimal. The story from the above paragraph suggests that there ought to be a positive relationship between the gap between $Y_t$ and $Y_{f,t}$ and the gap between the actual and expected price level – the actual price level being higher than expected leads to more production than would take place without price rigidity, whereas the price level being lower than expected leads to less production. We therefore suppose that the aggregate price-output dynamics obey the following Aggregate Supply (AS) relationship:

$$P_t = P^e_t + \gamma(Y_t - Y_{f,t})$$

$0 \leq \gamma \leq \infty$ is a parameter tells us how “sticky” prices are (in essence the fraction of firms than are unable to adjust their price). If $\gamma \to \infty$, then prices are perfectly flexible: we’d have $Y_t = Y_{f,t}$, even if $P_t \neq P^e_t$. If the aggregate price level differs from what was expected, but if all firms can adjust prices freely, then all will do so with no change in relative prices at the micro level. In contrast, if $\gamma \to 0$, then this conforms with all firms having sticky prices – if no firms can adjust their price within period, then the aggregate price level will be equal to what it was expected to equal (the aggregate price level cannot change within period – it is fixed if all firms are unable to
adjust their price). For intermediate cases between $\gamma \to 0$ and $\gamma \to \infty$, the AS curve will be upward sloping in a graph with $Y_t$ on the horizontal axis and $P_t$ on the vertical axis. When $Y_t = Y^f_t$, we will have $P_t = P^e_t$ (except in the case in which the AS Curve is perfectly vertical, with $\gamma \to \infty$).

The figure above plots the AS curve. Regardless of the value of $\gamma$, the AS curve must cross through the point $(P^e_t, Y^f_t)$ – when $P_t = P^e_t$, for the AS curve to hold it must be the case that $Y_t = Y^f_t$. I show three different variants of the AS curve corresponding to different values of $\gamma$. The black line shows the AS curve for an “intermediate” value of $\gamma$. The orange line shows the AS curve for a large value of $\gamma$ – a large value of $\gamma$ corresponds to not many firms having sticky prices, and in the limit as $\gamma \to \infty$ the AS curve is identical to what you get in the neoclassical model. The blue line shows the AS curve for a small value of $\gamma$, which corresponds to prices being quite sticky and the AS curve consequently being relatively flat.

The aggregate production function is the same as it has been before, and is identical to the individual firm production functions:

$$Y_t = A_t F(K_t, N_t)$$

The desired aggregate labor demand for firms is also the same as it was before:

$$N_t = N^d(w_t, A_t, K_t)$$

I put the word “desired” in italics above because this curve ends up being irrelevant for the determination of aggregate employment. Why is that? As mentioned above, the “rules of the game”

\[\text{All the firms have the same form of the production function but may employ different quantities of capital and labor. Under fairly weak assumptions we can aggregate the individual firm production functions to yield an identical aggregate production function to what we had in the flexible price model. You do not need to worry about this.}\]
are that the firms produce however much is demanded at their relative price. If the actual price level is higher than firms expected, some firms have suboptimally low relative prices, which means they have to produce more than they would like to if they were maximizing profits. Therefore, firms are required to hire sufficient labor to produce however much is demanded at their price and must produce more than they would otherwise like if prices were flexible. This means that they are in general off their labor demand curve. The equilibrium concept in the labor market is that the real wage and the level of employment are determined from the household’s labor supply curve, given the level of $Y_t$ consistent with being on both the AD and AS curves. If you compare this to the sticky wage model, an easy way to remember this is that we’re on the labor supply curve in the sticky price model (but not necessarily the labor demand curve), while we’re on the labor demand curve in the sticky wage model (but not necessarily the labor supply curve).

The household side of the model is identical to what we’ve had before. The consumption function, investment demand function, and labor supply function are:

$$C_t = C(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t)$$
$$I_t = I(r_t, A_{t+1}, q, K_t)$$
$$N_t = N^s(w_t, H_t)$$

The full set of equations characterizing the equilibrium is given below:

$$P_t = P^e_t + \gamma(Y_t - Y^f_t)$$
$$N_t = N^s(w_t, H_t)$$
$$Y_t = A_tF(K_t, N_t)$$
$$C_t = C(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t)$$
$$I_t = I(r_t, A_{t+1}, q, K_t)$$
$$Y_t = C_t + I_t + G_t$$
$$M_t = P_tM^d(r_t, Y_t)$$

Just as in the neoclassical and sticky wage Keynesian models, this is 7 equations in 7 endogenous variables. Relative to the neoclassical model, we have replaced the labor demand curve with the AS curve $P_t = P^e_t + \gamma(Y_t - Y^f_t)$. $P^e_t$ is taken to be exogenous and $Y^f_t$ is what output would equal if prices were flexible (i.e. what output would equal in the neoclassical model). So just like as in the sticky wage Keynesian model, relative to the neoclassical model we’re just swapping out one equation with a new one (in this case, the labor demand curve with the AS relationship above; in the sticky wage model, the labor supply curve with the condition determining the real wage given the nominal wage).

We can incorporate the sticky price AS curve with our labor market diagram and production
function in a way similar to what we have done before. If $P_t = P_t^e$, the $Y_t = Y_t^f$ and the labor market equilibrium occurs where labor demand equals labor supply. If $P_t < P_t^e$, however, then $Y_t < Y_t^f$. This means that $N_t$ is smaller than would be the case at the intersection of the labor demand and supply curves. In the sticky price model, we determine the quantity of labor and the real wage off of the labor supply curve, not the labor demand curve. This means that if $P_t < P_t^e$, then $w_t$ is smaller than what it would be if prices were flexible (and consequently labor hours are smaller than they would be if prices were flexible). The reverse would be the case if $P_t > P_t^e$. The diagram below shows how things play out.

Since the household side of the model is the same as we’ve been working with, the IS-LM-AD block is identical to the neoclassical model as well as the sticky wage model. We can graphically depict the full equilibrium of the economy as simultaneously being on the IS and LM curves (which implies being on the AD curve), the AS curve, the production function, and the labor supply curve. Note that we are not necessarily on the labor demand curve, though in the diagram below I imagine that the initial equilibrium level of output and the price level are such that $Y_t = Y_t^f$ and $P_t = P_t^e$, so that labor market equilibrium occurs where the labor demand and supply curves intersect, but
in general this need not be the case. The picture below graphically characterizes the equilibrium.

In terms of the equations given above, the IS curve again summarizes the consumption function, the investment demand function, and the resource constraint. The LM curve summarizes the condition that money demand equals money supply. The AS curve is the equation that is given. We then determine the real wage and quantity of employment using the production function and the labor supply curve.
In terms of the IS-LM-AD-AS curves, there is no *qualitative* difference between the sticky wage and sticky price models. The differences in the models arise because of different assumptions about *why* the AS curve isn’t perfectly vertical and what the notion of equilibrium in the labor market is. In the sticky wage model, the nominal wage is fixed and the quantity of labor is read off the labor demand curve at the $N_t$ consistent with the value of $Y_t$ where the AD and AS curves intersect. In the sticky price model, the price level is sticky and the quantity of labor is read off the labor supply curve given the level of $N_t$ consistent with the $Y_t$ where the AD and AS curves intersect. In other words, if all you care about is the behavior of output, prices, and the interest rate, from a qualitative perspective it does not matter whether the AS curve is not vertical because of sticky prices or sticky wages. But for understanding what happens in the labor market, and understanding optimal economic policy, the reason behind the upward-sloping AS curve will matter, as we will learn later.

Now, let’s go through and analyze how the endogenous variables change in response to changes in exogenous variables. Consider first an increase in the money supply. This shifts the LM curve out (blue line), which in turn causes the AD curve to shift to the right (also a blue line). The outward shift of the AD curve along an upward-sloping AS curve results in increases in both $Y_t$ and $P_t$. The higher $P_t$ causes the LM curve to shift back in some (green line), though not all the way to where it started (unlike what would happen in the neoclassical model). This means that the real interest rate is lower in the new equilibrium. Higher $Y_t$ and lower $r_t$ means that both $C_t$ and $I_t$ are higher in the new equilibrium. Turning to the labor market, since $Y_t$ is higher it must be the case that $N_t$ is higher. Since we are determining labor from the labor supply curve (not the labor demand curve), getting households to supply more labor requires a higher real wage.
Next, consider some change in an exogenous variable that causes the IS curve to shift to the right. This could be caused by an increase in $A_{t+1}$, an increase in $q$, an increase in $G_t$, or a decrease in $G_{t+1}$ (I will not consider the effects of a decrease in $K_t$ here). The IS curve shifts to the right (shown by the blue line). This causes the AD curve to shift to the right as well (also shown by the blue line). The rightward shift of the AD results in higher values of both $Y_t$ and $P_t$. The higher $P_t$ causes the LM curve to shift in some (though not so far that $Y_t$ doesn’t rise), which is shown with
the green line. The real interest rate is therefore higher in the new equilibrium. Since \( Y_t \) is higher but \( A_t \) is unchanged, \( N_t \) must be higher. Since we determine labor from the labor supply curve, it must be the case that \( w_t \) is higher to induce households to work more.

How consumption and investment are affected depends on the exogenous variable which is changing. These effects are going to be qualitatively similar to what we saw in the sticky wage model. When \( A_{t+1} \) increases, the effects on both \( C_t \) and \( I_t \) are ambiguous, though we know that
at least one of them must increase (and they may both increase, in spite of the higher real interest rate). When \( q \) increases, we know that \( I_t \) increases (in spite of the increase in the real interest rate, since \( I_t \) would increase in the neoclassical model, and the real interest rate increases less here). We cannot determine whether \( C_t \) increases or decreases. When \( G_t \) increases, we know that both \( C_t \) and \( I_t \) must decrease. The decrease in \( I_t \) is clear from the increase in \( r_t \). The reason why we know that \( C_t \) decreases is that \( Y_t \) increases by less than \( G_t \), so that \( Y_t - G_t \) declines. Combined with \( r_t \) increasing, we therefore know that \( C_t \) must fall. When \( G_{t+1} \) falls, we know that \( I_t \) falls because \( r_t \) is higher. Since \( Y_t \) is higher but \( G_t \) is not affected, we can deduce that \( C_t \) must increase.

Consider next the effects of an increase in \( A_t \). This causes the AS curve to shift horizontally to the right. The magnitude of the horizontal shift is equal to the change in \( Y_t^f \), which can graphically be determined as the level of \( Y_t \) that would obtain if we were on both the new labor demand and supply curves as well as the new production function. As long as the AS curve is not vertical (and the AD curve not completely horizontal), we see that \( Y_t \) will increase and \( P_t \) will fall. Graphically, the increase in \( Y_t \) is smaller than the horizontal shift of the AS curve – put another way, \( Y_t \) increases by less than it would if prices were flexible. The lower price level causes the LM curve to shift right, so that the real interest rate is lower. A lower real interest rate plus higher output means that both \( C_t \) and \( I_t \) are higher in the new equilibrium. Turning to the labor market, the level of employment must be consistent with the level of \( Y_t \) where the AD and AS curves intersect. The equilibrium real wage is then read off the labor supply curve at this level of \( N_t \). As drawn here, we actually get a decline in the real wage and a decline in \( N_t \). These effects are technically ambiguous (in a way similar to how the effects of a productivity shock on labor hours were ambiguous in the sticky wage model). The real wage and labor hours could rise, and it would be more likely that they do if the AD curve is very flat (or the AS curve very steep). We will return to this point below.
Finally, consider the effects of a labor supply shock, manifested as an increase in $H_t$. In the sticky wage model this shock had no effect on the equilibrium, since we weren’t on the labor supply curve. In the sticky price model it will. The increase in $H_t$ raises $Y^F_t$. The horizontal shift in the AS curve is equal to the increase in $Y^F_t$. We can determine this by finding the level of $Y_t$ which would obtain if $N_t$ were determined by the intersection of the labor demand curve and the new labor supply curve associated with the higher $H_t$. Because the AS curve shifts out, in the new
equilibrium $Y_t$ is higher and $P_t$ is lower. That being said, unless the AS curve is vertical (or the AD curve perfectly horizontal), the increase in $Y_t$ is smaller than the increase in $Y_t^f$ (i.e. the increase in $Y_t$ is smaller than the horizontal shift of the AS curve, in a way similar to what we saw for the case of an increase in $A_t$ above). The lower price level causes the LM curve to shift to the right, which results in a lower real interest rate. A lower real interest rate plus higher output means that both $C_t$ and $I_t$ are higher in the new equilibrium. Turning back to the labor market, the new level of $N_t$ must be consistent with the $Y_t$ where the AD and AS curves intersect. This is smaller than the new $N_t$ would be if prices were flexible (e.g. the AS were vertical). We determine the real wage off of the new labor supply curve at the new equilibrium level of $N_t$. We see that $w_t$ is smaller in the new equilibrium.
The table below summarizes the qualitative effects of changes in various exogenous variables on the endogenous variables in the sticky price Keynesian model.
4 Comparing the Sticky Price and Sticky Wage Models: The Cyclicality of the Real Wage

In thinking about the similarities and differences between the sticky price and wage models, a useful rule of thumb to remember is that in the sticky wage model labor is determined from the labor demand curve at the real wage equal to the fixed nominal wage divided by the price level, whereas in the sticky price model labor and the real wage are determined off of the labor supply curve at a value of $N_t$ consistent with the $Y_t$ where the AD and AS curves intersect. Aside from the fact that labor supply shocks don’t have any equilibrium effects in the sticky wage model (since we are not on the labor supply curve in general), from a qualitative perspective there is no difference in terms of the IS-LM-AD-AS diagrams and the qualitative movements in $Y_t$, $C_t$, $I_t$, $P_t$, and $r_t$ in response to changing values of exogenous variables. Because the AS curve is not vertical in both models, demand shocks can have effects on output, and changes in the money supply can have real effects.

The differences in the models arise in terms of what happens in the labor market, and in particular what happens to the real wage after shocks. In the sticky wage model, positive shocks to aggregate demand (either from an increase in $M_t$; increases in $A_{t+1}$, $q$, or $G_t$; or decreases in $G_{t+1}$) cause output to rise. For output to rise absent a change in $A_t$ or $K_t$, labor hours must rise. Since labor is determined off of the labor demand curve, to induce firms to hire more labor the real wage must fall. In other words, conditional on demand shocks, in the sticky wage model the real wage and output move in opposite directions. This is different in the sticky price model. Output rises in response to positive demand shocks, and so $N_t$ must rise to support this. But labor is determined from the labor supply curve, not the labor demand curve, in the sticky price model. To induce households to work more the real wage must rise. In other words, in the sticky price model the real wage and output move in the same direction conditional on aggregate demand shocks.

If you go back to the notes on the neoclassical model, I presented some evidence on correlations of aggregate variables in the data. There we saw that the real wage is procyclical in the sense that it is positively correlated with output (i.e. they tend to be high together or low together). The correlation is not overwhelmingly positive (it’s about 0.15), but I argued that this correlation

<table>
<thead>
<tr>
<th>Variable:</th>
<th>$\uparrow M_t$</th>
<th>$\uparrow A_t$</th>
<th>$\uparrow A_{t+1}$</th>
<th>$\uparrow q$</th>
<th>$\uparrow G_t$</th>
<th>$\uparrow G_{t+1}$</th>
<th>$\uparrow H_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Hours</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Consumption</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>?</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Investment</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Real interest rate</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Real wage</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Price level</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
probably understates the actual procyclicality of the real wage because of things like the composition bias. If you take as given that the real wage is procyclical, does this provide any insight into which variant of the Keynesian model might better fit the data? To the extent to which you think aggregate demand shocks are an important driver of output, it does. Since the sticky price model predicts a positive correlation between real wages and output conditional on demand shocks, this would seemingly be a better-fitting model than the sticky wage model. It’s largely for this reason that the class of “New Keynesian” models developed in academia in the 1980s and 1990s emphasize price stickiness as the key nominal rigidity, not wage stickiness. More modern variants of the model used at the frontiers of academic research often feature both wage and price stickiness, but a model with sticky wages alone will not do a good job of producing a procyclical real wage conditional on demand shocks.

5 Supply Shocks in the Keynesian Model

Loosely speaking, we can think about there being two kinds of shocks (“shocks” = change in an exogenous variable) that affect output: supply shocks (things which shift the AS curve) and demand shocks (things which shift the AD curve). In the neoclassical model the AS curve is vertical, which means that demand shocks cannot affect output. One key difference between the Keynesian and neoclassical models is that both variants of the Keynesian model feature a non-vertical AS curve, which allows output to react to demand shocks.

As we saw above, supply shocks can and do affect output in the Keynesian model. For the rest of this section, let’s focus on a change in productivity, \( A_t \), as the supply shock (since changes in \( H_t \) don’t affect the AS curve in the sticky wage model). Whereas in the neoclassical model an increase in \( A_t \) causes \( N_t \) to rise, in both variants of the Keynesian model the effect on \( N_t \) is ambiguous (in the graphs above I showed \( N_t \) as not changing after an increase in \( A_t \) in the sticky wage model and as falling after an increase in \( A_t \) in the sticky price model). I want to explore this point about the ambiguous effect of a change in \( A_t \) on \( N_t \) in the Keynesian model a little more carefully here.

Let’s begin with the sticky wage Keynesian model. I want to consider the effects of an increase in \( A_t \) on \( N_t \) (and other variables) in that model. To make the point as clear as possible, I’m going to do so with two AD curves. One is relatively steep (black line) while the other is relatively flat (red line). The effects of an increase in \( A_t \) are shown in the following diagram, which is explained in more detail below. For ease of exposition, I omit the IS-LM diagram here.
(a) Original equilibrium, where equilibrium output equals flexible wage output  
(b) New flexible wage equilibrium  
(c) New sticky wage equilibrium when AD is flat (red line)  
(d) New sticky wage equilibrium when AD is steep (black line)  

$N_t$ and hence $Y_t$ could go up by more (point (c)) or less (point (d)) after an increase in $A_t$ than they would if wages were flexible.

In the figure, the black lines show the initial curves (as noted, the alternative “flat” AD curve is shown by the red line, and I assume that it is associated with the same original equilibrium as the “steep” AD denoted by the black line). For point of comparison, I also plot in the hypothetical AS curve that would exist if wages were flexible, denoted by $AS^f$. The initial equilibrium is denoted by point (a) in the diagram. Suppose that there is an increase in $A_t$. This causes the labor demand curve to shift to the right and the production function to shift up. The new “flexible wage” AS
curve, \( AS'' \) (shown in blue) can be determined as the level of \( Y_t \) consistent with the intersection of the new labor demand curve and the labor supply curve and with the production function. Hence, \( AS' \) shifts to the right, just as it would in the neoclassical model using these graphs. We determine the new level of \( Y_t \) if wages were flexible where the new vertical \( AS' \) curve intersects the AD curve, labeled (b) in the diagram.

Now, let’s think about what happens when wages are sticky. The labor demand curve and production shift out and up. But here labor is read off of the labor demand curve only (we are not on the labor supply curve). For a fixed price level, this implies a higher level of \( N_t \) than we would get with flexible wages. This means that the AS curve shifts to the right (labeled \( AS' \) and shown in blue). Importantly, the sticky wage AS curve shifts horizontally to the right more than the flexible wage AS curve does. What drives this is the assumption of being on only labor demand – for a fixed price level, the real wage doesn’t change in the sticky wage model, which means firms would increase \( N_t \) more than if wages were flexible.

The fact that the AS curve shifts more to the right with sticky wages than with flexible wages does not imply that output rises by more after an increase in \( A_t \) relative to the neoclassical model. We can see this clearly with two cases. The black AD curve is relatively steep. The new sticky wage AS curve intersects this AD curve at a higher value of \( Y_t \), but it is lower than the new equilibrium level of \( Y_t \) that would emerge with flexible wages. This is labeled as point (d) in the diagram. Since output would rise by less than it would with flexible wages, hours must also go up by less. This could involve no change in hours (which is how I’ve drawn the picture), a reduction in hours, or an increase in hours that is smaller than what would happen if wages were flexible. The red line considers a relatively flat AD curve. Here we see that the new equilibrium level of output is higher than it would be with flexible wages, as labeled in the diagram with point (c). Output being higher than it would be with flexible wages means that hours must go up, and must go up more than they would if wages were flexible.

You can think of it this way. The magnitude of the effect of a positive shock to \( A_t \) in the sticky wage model will depend on how steep the AD curve is. If the AD curve is sufficiently flat, then output could go up by more than it would if wages were flexible (which in turn means that hours go up by more than they would in the neoclassical model). If the AD curve is sufficiently steep, then output might go up by less than it would if wages were flexible (which in turn means that hours go up by less than they would in the neoclassical model, and may in fact decline). So the sign of the effect of an increase in \( A_t \) on \( N_t \) is genuinely ambiguous, as is the effect of an increase in \( A_t \) on \( Y_t \) relative to what would happen to \( Y_t \) in the neoclassical model. Since the price level always falls after an increase in \( A_t \) in the sticky wage model, the real wage must go up after an increase in \( A_t \).

Now let’s think about the effects of an increase in \( A_t \) in the sticky price model. As I did above, I show these effects in a diagram with two AD curves with different slopes – the black AD curve is relatively steep and the red AD curve is relatively flat. I assume that both of these AD curves cross the original AS curve at the same point. The original equilibrium is denoted by point (a).
(a) Original equilibrium, where equilibrium output equals flexible wage output
(b) New flexible price equilibrium
(c) New sticky price equilibrium when AD is flat (red line)
(d) New sticky price equilibrium when AD is steep (black line)

\[ N_t \] could go up (point(c)) or down (point (d)) after an increase in \( A_t \) with sticky prices. It cannot go up by more than what would happen if prices were flexible.

As I did with the sticky wage model, I also show the hypothetical effects of what would happen if prices were flexible. This is denoted by the vertical AS curve, \( AS^f \). An increase in \( A_t \) causes the labor demand curve to shift to the right and the production function to shift up. The new position of the \( AS^f \) curve, denoted \( AS'^f \) and shown in blue, is determined as the level of \( Y_t \) consistent with being on both the labor demand and supply curves and the production function. The flexible price level of output increases. This is denoted by point (b) in the diagram.
Now, let’s consider what would happen with sticky prices. The AS curve would shift horizontally to the right by the change in $Y_f^t$. In other words, the horizontal shift of the AS curve in the sticky price model is the same as the horizontal shift of the hypothetical AS curve if prices were flexible. But because the AS curve in the sticky price model is not vertical, the change in equilibrium $Y_t$ in the sticky price model is always smaller than it would be if prices were flexible. This is true whether the AD curve is relatively flat (red AD curve, new equilibrium denoted by point (c)) or relatively steep (black line, new equilibrium denoted by point (d)). Since output necessarily goes up by less in the sticky price model relative to the flexible price model, the increase in $N_t$ is necessarily smaller than it would be if prices were flexible. It is true that the flatter is the AD curve, the more output increases in the sticky price model after an increase in $A_t$, but it cannot go up by more than it does in the flexible price model. If the AD curve is relatively flat, then output goes up by relatively a lot, which means it is likely that $N_t$ increases in the sticky price model (and that the real wage increases). But if the AD curve is relatively steep, then it is possible that $N_t$ declines (and hence so too does $w_t$). Hence, the effect of an increase in $A_t$ on $N_t$ (and $w_t$) in the sticky price model is ambiguous. Whether $N_t$ (and $w_t$) go up or down depends on the steepness of the AD curve. In any event, $N_t$ (and $w_t$) will increase by less in the sticky price model than it would in the flexible price neoclassical model.

In both the sticky price and wage models, it is conceivable that $N_t$ declines after a productivity improvement (increase in $N_t$). Is there any empirical evidence to support this? It turns out there is. A number of papers seek to empirically identify surprise changes in $A_t$ and assess their impact on endogenous variables like $N_t$. Many of these papers find that $N_t$ declines when productivity improves, a finding which is inconsistent with the neoclassical model but potentially consistent with the Keynesian model (either the sticky wage or sticky price version). Gali (1999) uses a restriction that only productivity changes can impact output in the “long run” and finds that productivity improvements are associated with reductions in hours worked. Basu, Fernald, and Kimball (2006) construct a “purified” measure of total factor productivity (TFP) meant to proxy for the model-based $A_t$. The “purification” refers to the fact that they try to control for unobserved input variation, which they argue is important and contaminates traditional measures of TFP like the one I produced in the neoclassical model notes. They find that improvements in their purified TFP measure are also associated with declines in total hours worked. Both Gali (1999) and Basu, Fernald, and Kimball (2006) argue that this is strong evidence against the neoclassical model and points towards Keynesian theories. There does exist some countervailing evidence that argues that

---


6The basic idea of unobserved input variation is that measured $K_t$ and $N_t$ may be poor measures of true capital and labor input. Suppose that we are in a Keynesian model and output goes up due to a positive demand shock. Firms may work their capital and machines “harder” in such a way that actual $K_t$ and $N_t$ rise by more than what we can observe in the data. This would mechanically make it look like $A_t$ is increasing, even though it’s really not. These (and other) authors argue that unobserved input variation is primarily responsible for the strong positive correlation between measured TFP and output that we saw in the last set of notes, not actual changes in productivity occurring at the same time as fluctuations in output.

hours increase after improvements in $A_t$ in a way consistent with the implications of the neoclassical model.

When comparing the Keynesian model to the neoclassical model, there are some nice dichotomies that are easy to remember. In the neoclassical model, only supply shocks (changes in $A_t$ or $H_t$) can affect output. In the Keynesian model (either the sticky price or sticky wage version), demand shocks can matter too. In the sticky price model, supply shocks (changes in either $A_t$ or $H_t$) have smaller effects on $Y_t$ and other real variables relative to a neoclassical model. In the sticky wage model, labor supply shocks have no effect on real variables, and these effects are therefore smaller than they would be if wages were flexible. The effects of changes in $A_t$ on $Y_t$ in the sticky wage model may be smaller or larger than in the neoclassical model depending on the slope of the AD curve. To make things easy to remember, we will hereafter assume that the AD curve is sufficiently steep so that output rises by less after an increase in $A_t$ in the sticky wage Keynesian model than it would in the neoclassical model. This means that we can draw the following conclusion: relative to the neoclassical model, demand shocks have bigger real effects and supply shocks smaller real effects in the Keynesian model (either the sticky price or sticky wage version).

6 Sticky Prices and Wages: Empirical Evidence

Relative to the neoclassical model, the key friction in Keynesian theories is nominal rigidity – prices and/or wages are imperfectly flexible. This imperfect flexibility allows demand shocks to have real effects and changes the way that supply shocks impact the real side of the economy. As we will see, Keynesian theories also have different normative implications for economic policy than does the neoclassical model, where there is no justification for activist policies.

If we want to take Keynesian theories seriously, we would like to get a sense of whether or not there is any empirical evidence to support price and/or wage stickiness. It turns out that there has been a decent amount of research into this area. Bils and Klenow (2004) is a comprehensive study that makes use of unpublished data on prices of over 350 categories of goods. They find evidence that prices are sticky – the median duration between prices changes across all varieties of goods is roughly six months, or two quarters. This is broadly consistent with the notion that at least some prices do not react instantaneously to changing aggregate conditions as in our simple sticky price model. There is great heterogeneity in frequency of price duration across different varieties of goods – some goods have prices which change daily (e.g. gasoline), while there are other goods whose prices change on average only every couple of years (e.g. newspapers). While there is thus some good evidence that prices are sticky, some neoclassical economists have countered that the observed level of stickiness is not sufficiently long for price stickiness to be important over the medium term (frequencies of 1-3 years).

There is also evidence on the importance of wage rigidity. Barattieri, Basu, and Gottschalk

---

(2014) argue that nominal wages adjust on average only once a year or so, which in terms of
duration between changes is significantly longer than for prices. This is also broadly consistent
with the sticky wage model. There are some potential issues here. In particular, what may be
macroeconomically relevant is wage rigidity for new hires, not wages of existing hires. There is
some evidence that new hire wages adjust quite a lot and rather frequently.

Nevertheless, given all this evidence, as well as the empirical evidence that demand shocks
matter, most modern macroeconomic models incorporate at sticky prices or sticky wages, and
often use both at the same time. In that sense, some version of the Keynesian model (a little more
sophisticated than what we’ve done here, but I’ve provided you with the basic gist) has more or
less become the “standard” model that academic macroeconomists and central bankers use. As I
stated at the beginning, it’s important to emphasize that we shouldn’t think of this model as wholly
different from the neoclassical model. Rather, the neoclassical model can be thought of as a special
case of a Keynesian model in which there is no nominal rigidity. In that sense, the neoclassical
model is a building block of Keynesian models and it is useful to understand that model well, even
if you don’t necessarily take its implications all that seriously.

7 Dynamics: From Short Run to Medium Run

Price and/or wage stickiness are fundamentally “short run” phenomena. By that I mean that
while there may be frictions that prevent the instantaneous adjustment of prices and/or wages to
changing aggregate conditions, eventually prices and wages should be able to adjust. This is also
consistent with the empirical evidence – while there is some good evidence that prices and wages
are in fact sticky, they’re not sticky forever.

We want to briefly discuss how the economy ought to “dynamically” adjust to being away from
its flexible price/wage level. I put “dynamically” in quotes because we’re not doing dynamics in
the way we did in the Solow model. Here we only have two periods, and I don’t even want to
think about adjustments across periods (we really just have the \( t + 1 \) in there to motivate that
what happens today depends on what people think will happen in the future). But I do want to
think about forces that will be at work if the economy finds itself in an equilibrium that does not
 correspond with what the equilibrium would be if prices and wages were flexible. The basic gist
is going to be this. If the economy finds itself at an equilibrium where \( Y_t \neq Y_t^f \) (where \( Y_t^f \) is the
level of output that would obtain if prices and/or wages were fully flexible), then the AS curve is
going to shift in such a way as to force the equilibrium to move towards \( Y_t^f \). This will be true in
both the sticky wage and sticky price models. When thinking about these features, I’m going to
imagine this shift of the AS curve occurring within period \( t \). We can take a liberal notion of how
long \( t \) is – if you like, think about a period as lasting 3-4 years. The economy may find itself in
an equilibrium away from \( Y_t^f \) for 1-2 years (think about this as the “short run”), but then in years
3-4 and the AS will shift to make the equilibrium correspond with \( Y_t^f \) (think about this as the

\[ \text{Barattieri, Alessandro, Susanto Basu, and Peter Gottschalk. 2014. “Some Evidence on the Importance of Sticky}
\]}

\[ \text{Wages.” American Economic Journal: Macroeconomics 6(1): 70-101.} \]
“medium run”). The “long run” corresponds to frequencies like decades, which we thought about in the Solow Model.

Let’s first start with the sticky wage version of the Keynesian model. Suppose that the economy initially sits in an equilibrium in which \( Y_t^0 < Y_t^f \). \( Y_t^f \) is the level of output that would obtain if we were at the intersection of the labor demand and supply curves. This is denoted by point (b) in the graph below. The actual equilibrium is denoted by point (a). If output is below its flexible wage level, this means that \( N_t \) is lower than it would be if wages were flexible. Because we are always on the labor demand curve in the sticky wage model, this must mean that the real wage is higher than it would be with flexible wages.

Now, let’s think about the incentives that actors in the economy face should the economy find itself in a position like this. For output to be below its flexible wage level, the real wage is higher than is optimal. In terms of the figure, there is an excess supply of labor at the initial real wage – the quantity of labor supplied (which is not what is relevant for output, since we are not on the labor supply curve) exceeds the quantity of labor demanded at this wage. This means that there ought to be downward pressure on the nominal wage – an excess supply of something ought to drive down the price of that thing (in this case, the wage). In other words, we would expect that, over time as it is able to adjust, the nominal wage ought to adjust downward. A downward adjustment in the nominal wage would work to shift the AS curve to the right – a downward change in \( W \) represents a movement down the labor demand curve for a given price level, resulting in more employment and hence more output for each price level, i.e. an outward shift of the AS curve. Over time, the nominal wage will adjust to some new level, call it \( W' \), in such a way that the AS curve will shift so as to intersect the AD curve at \( Y_t^f \). In other words, we would expect the nominal wage to adjust in such a way as to shift the AS curve to “close the gap” in the sense of eliminating any difference between equilibrium output and its flexible wage level. The new sticky wage equilibrium in the “medium run” (point (c)) ought to converge to the flexible wage equilibrium. The outward shift of the AS curve (shown with the purple line) results in a fall in the price level. Something similar would happen (but in reverse) if we happened to find ourselves in an initial equilibrium in which \( Y_t > Y_t^f \): the nominal wage would eventually adjust up, the AS curve would shift in so as to “close the gap,” and the price level would rise.
Next, let's think about how dynamics would play out in the sticky price Keynesian model. The diagram below shows a situation in which the initial equilibrium is such that output is above what it would be if prices were flexible, i.e. $Y_t^0 > Y_t^f$. The sticky price equilibrium is denoted by point (a) and the hypothetical flexible price equilibrium by point (b). If output is higher than it would be if prices were flexible, it must mean, from the AS curve, that $P_t > P_t^e$: in other words, the price level is higher than firms expected it to be. This is the case in the diagram, with $P_t^0 > P_t^e$. For
output to be higher than it would be with flexible prices, it must also be the case that $N_t$ is higher than it would be with flexible prices. Since we are always on the labor supply curve in the sticky price model, this means that the real wage is higher than the point where the labor supply and demand curves intersect.

Now, let’s think about forces that would be at work if the economy were to find itself in a situation such as this. If $P_t > P_t^e$, then firms were surprised (on the up side) in terms of what
they expected prices to be. Fool me once, shame on you. Fool me twice, shame on me. Firms that were surprised will eventually update their expectations of the price level to conform with reality. In other words, $P^e_t$ will increase over the medium run to something like $P^e_t'$. An increase in the expected price level works to shift the AS curve to the left (or up, if you prefer). This is shown by the purple line in the graph. This will happen until the AS curve shifts in so that equilibrium output equals what it would be if prices were flexible, at point (c). At this point, the new equilibrium price level level is higher and equal to what firms expected it to be. Put another way, price level expectations adjust in such a way as to “close the gap” between equilibrium output and its hypothetical flexible price level. In the process the actual price level rises. The reverse would happen if we started out in an equilibrium in which output was below its flexible price level – the price level would be lower than firms expected, price expectations would decline, the AS curve would shift out to “close the gap,” and the price level itself would fall.

To summarize, in either the sticky wage or sticky price variants of the Keynesian model, over the “medium run” the AS curve will shift in such a way as to restore equilibrium at the flexible wage/price equilibrium. This suggests that there ought to exist a relationship between the “output gap,” $Y_t - Y^f_t$, and changes in the price level. This forms the basis of the “Phillips Curve.” Generically, a Phillips Curve shows a relationship between some measure of real economic activity (an output gap or sometimes an unemployment gap) and changes in nominal prices (typically inflation or sometimes wage inflation). Generically, in terms of our models we can think of the Phillips Curve looking something like:

$$\pi_t = \varphi (Y_t - Y^f_t)$$

Our models tell us that the parameter $\varphi > 0$: a positive output gap ought to put upward pressure on prices ($\pi_t$ is inflation, defined as the percentage change in the price level). This begs the question: do we see such a relationship in the data? This is not a particularly easy question to answer because we don’t observe $Y^f_t$, so it is difficult to know what the “output gap” is at any point in time. We have to rely on proxies. I tried out two different ones. In one, I simply define $Y^f_t$ as the HP trend value of output (recall again that the HP trend is essentially a two-sided moving average). In another, I download data from the CBO on “potential output” and use that as a measure of $Y^f_t$. Using these two different measures of $Y^f_t$, I construct an empirical measure of the output gap and do a scatter plot of that with inflation, defined as the percentage change in the GDP price deflator. The scatter plots, along with best-fitting regression lines, are shown below:

---

10One should be aware that many presentations of Phillips Curves plot the inflation rate against an unemployment gap. To the extent to which unemployment is negatively related to the output gap (there is an empirical regularity related to this called “Okun’s Law”), we would expect a negative relationship between inflation and the unemployment gap if there is a positive relationship between inflation and the output gap. Since we are not focusing on unemployment in this course, I express the Phillips Curve as a positive relationship between an output gap and inflation. So don’t get confused when you see a downward-sloping Phillips Curve with the unemployment gap on the horizontal axis.
We see that for either proxy for $Y_t^f$, there does in fact seem to exist a positive relationship between the output gap and inflation, just as our models would predict. This provides some empirical validation for the basic Keynesian model (either the sticky wage or sticky price version).

It is important to know how long the dynamic response of the AS curve to deviations of $Y_t$ from $Y_t^f$ takes when thinking about optimal monetary policy (as we will see). Neoclassical economists tend to think that prices and wages adjust relatively quickly, so that the “medium run” approaches quickly, whereas Keynesian economists think that price and wage rigidity is more important, implying a longer period of adjustment so that the “medium run” is further off in the future. To the extent to which deviations of $Y_t$ from $Y_t^f$ are undesirable, how long you think this adjustment from “short run” to “medium run” takes informs how active you think economic policy ought to be, as we will see next when discussing optimal monetary policy within the context of the Keynesian model.

References