1 Introduction

Among mainstream academic economists and policymakers, the leading alternative to the real business cycle theory is the New Keynesian model. Whereas the real business cycle model features monetary neutrality and emphasizes that there should be no active stabilization policy by governments, the New Keynesian model builds in a friction that generates monetary non-neutrality and gives rise to a welfare justification for activist economic policies.

New Keynesian economics is sometimes caricatured as being radically different than real business cycle theory. This caricature is unfair. The New Keynesian model is built from exactly the same core that our benchmark model is – there are optimizing households and firms, who interact in markets and whose interactions give rise to equilibrium prices and allocations. There is really only one fundamental difference in the New Keynesian model relative to the real business cycle model – nominal prices are assumed to be “sticky.” By “sticky” I simply mean that there exists some friction that prevents $P_t$, the money price of goods, from adjusting quickly to changing conditions. This friction gives rise to monetary non-neutrality and means that the competitive equilibrium outcome of the economy will, in general, be inefficient. By “inefficient” we mean that the equilibrium allocations in the sticky price economy are different than the fictitious social planner would choose.

New Keynesian economics is to be differentiated from “old” Keynesian economics. Old Keynesian economics arose out of the Great Depression, adopting its name from John Maynard Keynes. Old Keynesian models were typically much more ad hoc than the optimizing models with which we work and did not feature very serious dynamics. They also tended to emphasize nominal wage as opposed to price stickiness. Wage and price stickiness both accomplish some of the same things in the model – they mean that the equilibrium is inefficient and that money is non-neutral. But nominal wage stickiness implies that real wages may be countercyclical, which is inconsistent with the data. For this and other reasons, New Keynesian models tend to emphasize price stickiness (though many of these models also feature wage stickiness, too).

The New Keynesian framework is the dominant paradigm for thinking about fluctuations and policy. A nice aspect of the model is that, at its core, it is the same as the real business cycle
model. Though the graphs that we’ll use to analyze the model look different, we could use the new set of graphs that we’re about to use to think about the real business cycle model as well (with a parameteric restriction that would make the Phillips Curve, to be introduced below, vertical). In that sense, what we’re about to do is quite general.

2 Household

The household side of the model is exactly the same as we’ve had before. There are many, identical households. We can therefore model it as there being a single household that takes prices as given. Households get utility from consumption, labor, and holdings of real money balances. They face the same budget constraints that we’ve already seen.

The solution of the household problem implies exactly the same consumption function, labor supply function, and money demand function (where the money demand function makes use of the Fisher relationship, with says that $i_t = r_t + \pi_{t+1}^e$, where we take expected inflation to be an exogenous constant). These are:

$$N_t = N^*(w_t, r_t)$$

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

$$M_t = P_t M^d(r_t + \pi_{t+1}^e, Y_t)$$

Labor supply is assumed to be increasing in the wage (substitution effect dominates income effect), and increasing in the real interest rate (when $r_t$ goes up, the household would like to save more, so it wants to earn more income as well as consume less). Households again behave as though the government balances its budget each period – in other words, Ricardian Equivalence holds. Consumption is increasing in current perceived net income, with $0 < MPC < 1$ denoting the partial derivative with respect to current net income. Consumption is also increasing in perceived future net income, where, as before, we treat expected future income as effectively exogenous (e.g. we avoid the complications associated with feedback effects into future income). Finally, consumption is assumed to be decreasing in the real interest rate. Money demand is (i) proportional to the price level, (ii) decreasing in the current nominal interest rate (so decreasing in the real interest rate and the rate of expected inflation between $t$ and $t + 1$), and (iii) increasing in the level of current income.

These conditions are the same as we had before, so we will not discuss them in any further depth.

3 Firms and Price-Setting

The firm side of the model is different than we had before. Suppose that there are a bunch of different firms, indexed by $i = 1, \ldots, L$. They each produce output according to $Y_{i,t} = A_t F(K_{i,t}, N_{i,t})$, 

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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, \( L \), 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:

\[
Y_{i,t} = f\left( \frac{P_{i,t}}{P_t}, X \right)
\]

Here \( X \) denotes other stuff (like tastes, aggregate income, etc). 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, \( \frac{P_{i,t}}{P_t} \), 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, \( P_{i,t} \). 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”.

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 \( P^e_t \). Each firm individual 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 firms 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 these firms must produce more. 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 our standard, flexible price model. This is unaffected by price rigidities – it would be the equilibrium level of output given the real exogenous variables \( (A_t, A_{t+1}, G_t, G_{t+1}, K_t, q) \) 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 “Phillips Curve” (or sometimes called an “AS” (for “aggregate supply”) 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 Phillips 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 Phillips Curve is perfectly vertical, with $\gamma \to \infty$):
The value of $\gamma$ determines the slope of the Phillips Curve (PC). When $\gamma$ is large, the curve is steep. This means that it would take a large change in the aggregate price level to generate a given change in output – when $\gamma$ is large, not many firms have sticky prices, so it would take a large change in the aggregate price level to generate much change in aggregate output (because only a few firms end up with suboptimally low relative prices). In contrast, if $\gamma$ is small, many firms have sticky prices. It therefore takes a smaller change in the aggregate price level to generate a given change in output – the curve is flatter. Two different Phillips Curves are shown below. In either case, when $Y_t = Y_t^f$, we have $P_t = P_t^e$. 
Especially when thinking about dynamics, it is helpful to think about the “long run” versus “short run” Phillips Curves. In the “long run,” prices are flexible – given sufficient time, all firms will be able to adjust their posted prices relative to expectation and will achieve their desired relative price. Hence, in the “long run,” we will have $Y_t = Y_t^f$ regardless of the price level. The basic idea here is that, over a sufficiently long horizon, there will be no price stickiness. Hence, the “long run Phillips Curve” (LRPC) will be a vertical line at $Y_t^f$, which, to reiterate, is the hypothetical level of output that would be produced if prices were flexible. The short run Phillips Curve (PC) must cross the LRPC when $P_t = P_t^e$. If prices were perfectly flexible, with $\gamma \to \infty$, then the short run and long run Phillips Curves would coincide at $Y_t^f$. 
What will shift the Phillips Curve? Mathematically, the Phillips Curve plots a relationship between $P_t$ and $Y_t$, holding $P_t^e$ and $Y_t^f$ fixed. Hence, changes in $P_t^e$ or $Y_t^f$ will result in shifts of the Phillips Curve. An increase in $Y_t^f$ will shift both the PC and the LRPC horizontally to the right, by the same amount (such that the short run and long run curves would cross at $P_t = P_t^e$).
An increase in the expected price level, in contrast, would effectively shift the short run Phillips Curve up (with no change in the LRPC). Holding $Y_t$ fixed, higher $P^e_t$ translates into higher $P_t$ (equivalently, you could think about an inward horizontal shift).
In summary:

1. Firms produce differentiated goods. The demand for their good is a decreasing function of its relative price, $\frac{P_{i,t}}{P_t}$.

2. If firms could freely adjust prices, then their relative price would be determined by things like tastes and technology. Any change in the aggregate price level would have no effect on relative prices – if $P_t$ doubled, all firms would just double $P_{i,t}$. With no change in relative prices, there would be no relationship between the aggregate price level and the amount of output produced. Money would be neutral.

3. Suppose that firms post prices in advance based on what they expect the aggregate price level to be, $P_t^e$.

4. Only a subset of firms can adjust their pre-set prices in response to changing economic conditions. This means that prices are “sticky”. This could be due to “menu costs” (it is costly/impossible to change a posted price) or informational frictions (individual firms don’t observe the aggregate price level perfectly).

5. Suppose that the aggregate price level goes up relative to what was expected. Those firms that can adjust their prices do so proportionally to the change in the aggregate price level. But at least some firms cannot. Since these firms cannot adjust their $P_{i,t}$, their effective relative
price falls when $P_t$ goes up. A lower relative price means more demand for their good. The “rules of the game” are such that they will produce enough to meet demand. Since some firms end up producing more because their relative prices are suboptimally low, aggregate output goes up when the aggregate price level goes up relative to where firms expected it.

6. The Phillips Curve is $P_t = P^e_t + \gamma(Y_t - Y^f_t)$. It is upward-sloping in a graph with $P_t$ on the vertical axis and $Y_t$ on the horizontal axis. $\gamma$ is a measure of how sticky prices are and governs the slope – if prices are not very sticky (most firms can adjust price within period), the Phillips Curve is steep. If prices are very sticky, then $\gamma$ is small and the Phillips Curve is flat.

7. The Phillips Curve shifts out whenever $Y^f_t$ increases or $P^e_t$ decreases.

8. The “long run” Phillips Curve (LRPC) is a vertical line at $Y_t = Y^f_t$. In the long run, all firms can adjust their prices, so output is independent of the price level.

Now, we haven’t mentioned labor demand yet, and with good reason. As noted above, the “rules of the game” are that firms must produce however much output is as demand at their price. Effectively, when firms have pricing power, they don’t choose labor to maximize profit directly. Rather, they choose their price to maximize profit given the demand for their good, and then hire sufficient labor (given their inherited stock of capital and exogenous level of productivity) to produce the output demanded at their relative price. If prices were flexible, you could think about the problem either way – hiring labor to maximize profit would imply an optimal price, whereas choosing an optimal price (what I described above) would imply an optimal choice of labor. If prices are sticky, there is no optimization going on – firms just have to hire as much labor as is necessary to produce the output that is demanded at their price.

Effectively, this is a long-winded way of saying that, to the extent to which prices are sticky, output is “demand-determined.” Output will be determined by the intersection of the Phillips Curve with a new curve called the AD curve described below. Given that level of output, firms will have to hire as much labor as necessary to produce that level of output. This means that labor demand is now longer to hire labor up until the point at which the marginal product of labor equals the real wage. Rather, firms just hire enough labor to meet demand, regardless of the wage. This means that the aggregate labor demand curve is a vertical line and depends on the level of aggregate output (as well as the level of $A_t$ and $K_t$). The “aggregate” production function is the same as we’ve had before: $Y_t = A_tF(K_t, N_t)$.\(^1\) Given $Y_t$, which will be determined below, as well as $K_t$ and $A_t$, which are exogenous, this equation implicitly determines $N_t$ independently of the wage. Hence, labor demand is vertical in a graph with $N_t$ on the horizontal axis and $w_t$ on the vertical. It shifts out whenever (i) $Y_t$ goes up, (ii) $A_t$ goes down, or (iii) $K_t$ goes down. The latter two effects result because, if $A_t$ or $K_t$ go down, but $Y_t$ is unaffected, you need more $N_t$ to produce a given level of $Y_t$.

\(^1\)Given individual production functions of this type, you can actually show this mathematically that it aggregates up, at least under certain conditions
The picture above shows labor demand in the sticky price model. The salient point here is that, one prices are sticky, we think about labor demand as being determined by output, not by the marginal product of hiring an additional unit of labor.

4 The IS-LM-AD Curves

The Phillips Curve characterizes the “supply” side of the economy. To characterize the “demand” side, we’re going to introduce a new curve and relabel an old one.

4.1 The LM Curve

In the real business cycle model, money was neutral, and we determined the price level “last” after all real variables were determined. Because of price stickiness, money will no longer be neutral, and we determine nominal prices simultaneously with real variables. We are going to introduce a new curve, which is called the “LM curve”. The “L” stands for “liquidity” (or money demand) and the “M” stands for “money” (or money supply). The LM curve is a plot showing all combinations of \( r_t \) and \( Y_t \) for which the money market is in equilibrium (money demand equals money supply), for given levels of money supply, \( M_t \), and the price level, \( P_t \). This definition of the LM curve does not rely upon any notion of price stickiness. We could have defined and used this curve earlier in the flexible price model.
The figure below describes the graphical derivation of the LM curve. Proceed as follows. Start with some hypothetical interest rate-output combination, \((r_t^0, Y_t^0)\), in the right panel in a graph with \(r_t\) on the vertical axis and \(Y_t\) on the horizontal axis. This determines a “position” of the money demand curve in a graph with \(P_t\) on the vertical axis and \(M_t\) on the horizontal axis. Suppose that the price level, \(P_t^0\), and the money supply, \(M_t^0\), are initially such that the money market is in equilibrium (demand = supply). Call this point (a). Now, suppose that we keep the real interest rate at \(r_t^0\), but increase output to \(Y_t^1\). This would cause the money demand curve to pivot to the right, where at a given price level there would now be more demand for money. Call this point (b). For a given \(P_t\) and \(M_t\), the money market is not in equilibrium at point (b). Holding the money supply and price level fixed, with this new higher level of \(Y_t\), the only way the money market can remain in equilibrium is if \(r_t\) goes up (which would have the effect of “pivoting in” the money demand curve). Call this point (c), which, in the money-demand supply graph, is the same position of money demand as at the original output and interest rate combination. Hence, if \(Y_t\) is higher, then \(r_t\) must be higher for the money market to be in equilibrium holding \(P_t\) and \(M_t\) fixed. This means that the LM curve is upward-sloping, as shown below.

As you can see from the labeling above, the LM curve is drawn holding fixed levels of the price level, \(P_t\), and the money supply, \(M_t\). Hence, changes in either of these will cause the LM curve to shift. Start from an initial point (a), with \(r_t^0, Y_t^0, P_t^0,\) and \(M_t^0\). First, suppose that there is an increase in the money supply, from \(M_t^0\) to \(M_t^1\). This shifts the money supply curve to the right.
Now, holding $P_t$ fixed at $P^0_t$, if neither $r_t$ nor $Y_t$ were to change, the money market would not be in equilibrium. For a given price level, to be in equilibrium in the money market given the new higher money supply, we need the money demand curve to pivot out. This could occur if either (i) $Y_t$ goes up or (ii) $r_t$ goes down (or some combination of the two). I like to think about this as a horizontal curve shift, so suppose that $Y^1_t$ is the new level of $Y_t$ that would cause the money market to be in equilibrium for $r_t$ fixed at $r^0_t$ (i.e. this is the new level of $Y_t$ that would cause the money demand curve to pivot so that the money market is in equilibrium with $M^1_t$ at $P^0_t$). Call this point (b). This means that the LM curve shifts out whenever $M_t$ increases. We see this below.

Now, a change in the price level (holding $M_t$ fixed) will also shift the LM curve. Suppose that the price level decreases, from $P^0_t$ to $P^1_t$. For given values of $r_t$ and $Y_t$ (e.g. $r^0_t$ and $Y^0_t$), money supply would exceed demand at a lower price level. To restore equilibrium in the money market, we’d need the money demand curve to pivot out. This could occur if either $Y_t$ increases or $r_t$ decreases, or some combination of the two. Since I like to think about horizontal shifts of curves, I pick out the new level of $Y_t$, call it $Y^1_t$, that would lead the money demand curve to pivot sufficiently far to the right to restore equilibrium in the money market at the new lower price level. Call this point (b). Similarly to the case of an increase in the money supply, we see that a decrease in the price level also causes the LM curve to shift out.
In summary:

1. The LM curve shows the combinations of \((r_t, Y_t)\) where the money market is in equilibrium, holding fixed the quantity of money supplied, \(M_t\), and the price level, \(P_t\). It is upward-sloping.

2. The LM curve shifts out if \(M_t\) increases or \(P_t\) decreases.

3. An easy way to remember this is that the LM curve shifts out of if the quantity of real money balances, \(\frac{M_t}{P_t}\), increases.

4. The definition and graphical derivation of the LM curve in no way depend upon price stickiness. We could have derived the LM curve in exactly the same way in the flexible price model.

4.2 The IS Curve

The IS curve stands for “Investment = Saving.” It is exactly the same thing as what we have been calling the \(Y^d\) curve. It shows the set of \((r_t, Y_t)\) pairs for which expenditure equals income, given optimizing behavior by households and firms.

Total desired expenditure in the economy, \(Y_t^d\) is the sum of desired expenditure by households (consumption), firms (investment), and the government (government spending). The functions
describing optimal behavior are as we have seen. Desired consumption is a function of desired income. Mathematically:

\[ Y_t^d = C(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) + I(r_t, A_{t+1}, q) + G_t \]

Here I have imposed Ricardian Equivalence, whereby the household behaves as though the government balances its budget each period. The marginal propensity to consume, MPC or \( \frac{\partial C}{\partial Y} \), is between 0 and 1. This means that graphing desired expenditure against income (expenditure is \( Y_t^d \), and income is \( Y_t \), we get an upward-sloping line with slope less than one. We assume that desired expenditure is positive even at zero current income (because of the components of expenditure which do not depend on income, as well as from expected future income). This means that the desired expenditure line must cross a 45 degree line along which \( Y_t^d = Y_t \) exactly once. In any equilibrium expenditure must equal income.

To derive the IS curve (which is the same thing as what we have been calling the \( Y^d \) curve, not that the “position” of the desired expenditure line in \( (Y_t, Y_t^d) \) space depends on the real interest rate. When \( r_t \) goes up, desired expenditure is smaller at every level of income – the desired expenditure line shifts down, and the point where \( Y_t^d = Y_t \) is lower. The converse is true when \( r_t \) goes down. Connecting the dots, we get a downward-sloping curve, just as we have seen before. This is shown below:

![](image.png)

The IS/\( Y^d \) curve will shift whenever anything other than \( r_t \) leads to a change in desired expen-
diture. This includes changes in $G_t$ (increases in which cause the IS curve to shift out one-for-one, as per earlier arguments), $G_{t+1}$ (increases in which cause the IS curve to shift in), or increases in $q$ or $A_{t+1}$ (which cause the IS curve to shift out to the right by stimulating desired investment).

4.3 The AD Curve

The AD, or “Aggregate Demand,” curve shows combinations of $(P_t, Y_t)$ for which the economy is both on the LM curve (money market clears) and the IS/$Y^d$ curve (goods market clears). In other words, the IS-LM curves are the building blocks of the AD curve.

What connects the IS-LM curves (which show combinations of $(r_t, Y_t)$ for which the goods and money markets clear) is the price level. As we showed above, the price level affects the position of the LM curve. Changes in the price level leads to shifts in the LM curve. Shifts of the LM curve combined with the IS curve imply different levels of $Y_t$ associated with different levels of $P_t$.

We can graphically derive the AD curve. Draw two graphs on top of one other, where the upper graph has $r_t$ on the vertical axis and $Y_t$ on the horizontal axis, and with the lower plot having $P_t$ on the vertical axis and $Y_t$ on the horizontal axis. Suppose that we initially start with a price level, $P^0_t$, and all other determinants of the IS and LM curves are held fixed. This price level determines a position of the LM curve. The intersection of the LM and IS curves determines a combination of $r_t$ and $Y_t$, call it $r^0_t$ and $Y^0_t$. Bringing this point down, we get a point $(P^0_t, Y^0_t)$. Now, suppose that we have a higher price level, $P^1_t$. This causes the LM curve to shift in, as we saw above. This means that the $Y_t$ where the new LM and IS curves cross is lower, $Y^1_t$. Consider then a lower price level, $P^2_t$. This shifts the LM curve out, meaning that the $Y_t$ where the IS and LM curves cross is higher, $Y^2_t$. Connecting the dots, we get a downward-sloping curve, which we call the AD curve.
What will shift the AD curve? The AD curve will shift if anything other than $P_t$ causes either the LM curve or the IS curve to shift. This includes $M_t$ (which shifts the LM curve), and $G_t$, $G_{t+1}$, $q$, and $A_{t+1}$ (which shift the IS curve). Below I show how the AD curve shifts to the right if the money supply increases:
In this picture, the LM curve shifts right for a given price level, meaning that the $r_t$, $Y_t$ combination where the IS and LM curves intersect is “down and to the right.” The higher $Y_t$ for a given $P_t$ means that the entire AD curve shifts out to the right.

Next, consider an increase in $G_t$, decrease in $G_{t+1}$, increase in $q$, or increase in $A_{t+1}$ (or a decrease in uncertainty). Any of these would cause the IS curve to shift right. This means that the level of $Y_t$ where these curves intersect (for a given $P_t$) is higher, meaning that the AD curve shifts to the right.
In summary:

1. The AD curve shows \((P_t, Y_t)\) pairs where both the money market (LM) and goods market (IS/\(Y^d\)) clear.

2. A higher \(P_t\) shifts the LM curve in, leading to a level of \(Y_t\) where the IS and LM curves intersect that is lower. Therefore, the AD curve slopes down.

3. The AD curve shifts whenever anything other than \(P_t\) shifts the IS or LM curves. This includes \(M_t\) (LM shift), as well as \(G_t, G_{t+1}, q, or A_{t+1}\) (IS shifts).

4. Nothing about the IS, LM, or AD curves depends on price stickiness. We could have used these exact same curves to summarize our earlier model where prices were flexible. It’s just a different graphical way of characterizing goods demand, money demand, and money supply.

5 **Short Run Equilibrium**

Equilibrium in the economy occurs when we’re on both the AD and the PC curves. Being on the AD curve means that the money and goods markets both clear. Being on the PC summarizes the revised firm side of the model with price rigidity. Being on both the PC and AD curves jointly determines the price level and output. Once we know the level of output, we know the position of the labor demand curve, and we can then determine the equilibrium quantity of employment and the real wage. In that sense, the labor market is the “last” thing we look at, whereas with flexible prices it was the first.

The position of the IS and LM curves, and hence the position of the AD curve, is determined by the exogenous variables related to the demand side of the model: \(A_{t+1}, G_t, G_{t+1}, q, K_t, and\)
uncertainty. In determining the position of the PC curve, we need to know (i) \( P^e_t \) and (ii) \( Y^f_t \). We take \( P^e_t \), the expected price level, to be exogenous. The level of \( Y^f_t \) would be determined by the intersections of the \( Y^d \) and \( Y^s \) curves in a hypothetical flexible price economy, given the values of the exogenous variables.

Mathematically, the conditions characterizing the equilibrium are:

\[
N_t = N^s(w_t, r_t) \\
C_t = C(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) \\
I_t = I(r_t, A_{t+1}, q, K_t) \\
Y_t = A_t F(K_t, N_t) \\
Y_t = C_t + I_t + G_t \\
P_t = P^e_t + \gamma(Y_t - Y^f_t) \\
M_t = \pi^e_t (r_t + \pi^e_{t+1}, Y_t) \\
r_t = i_t - \pi^e_{t+1}
\]

As in the real business cycle model, there are 8 equations. There are 8 endogenous variables: \( Y_t, C_t, I_t, N_t, r_t, w_t, i_t, \) and \( P_t \). Seven of the eight equations are identical to what we had before. The new equation is the Phillips Curve expression, which replaces the labor demand condition that firms should hire labor up until the point at which the wage equals the marginal product. We can de facto think about \( Y^f_t \) as being exogenous here (in reality, \( Y^f_t \) would be determined given the values of other exogenous variables in the flexible price version of the model). The exogenous variables of the model are the same as before: \( A_t, G_t, G_{t+1}, q, K_t, M_t, \pi^e_{t+1} \), and now a new one, \( P^e_t \). The IS curve summarizes consumption demand, investment demand, and total goods demand \((Y_t = C_t + I_t + G_t)\). The LM curve summarizes money demand, the Fisher relationship, and the exogenous money supply. The AD curve summarizes both the IS and LM curves. The Phillips Curve summarizes the pricing side of the model. The Phillips curve plus the AD curve determine \( Y_t \) and \( P_t \). Given \( P_t \) and other exogenous variables, we know the positions of the IS and LM curves, which determines the composition of output and \( r_t \). Given \( Y_t \) and the exogenous values of \( A_t \) and \( K_t \), we determine employment from the production function. Given that level of employment, we then determine the real wage from the labor supply expression. In contrast to the RBC model, where we looked at the labor market “first,” in the NK model we figure out output first, and then find the level of \( N_t \) consistent with that and the \( w_t \) consistent with the household being on its labor supply curve.

We run into an irritating complication. With the exception of \( M_t \), all of the exogenous variables which affect the AD curve \((A_{t+1}, G_t, G_{t+1}, q, K_t, \) and any uncertainty about the future) would also affect the hypothetical \( Y^f_t \). This means that, other than \( M_t \), any of the exogenous variables which affect the AD curve should also affect the PC curve. This means that there isn’t a clear dichotomy between “demand” shocks and “supply” shocks (other than \( M_t \), which only affects the
AD, and $A_t$, which only affects the PC).

We’re heretofore going to ignore these effects. In other words, from here on out, assume that exogenous variables which affect the IS curve ($A_{t+1}$, $q_t$, $G_t$, and $G_{t+1}$) do not impact $Y^f_t$. This means that changes in these exogenous variables will not lead to shifts in the PC. We could get this literally if we assumed that labor supply were not sensitive to $r_t$: this would mean that the $Y_s$ curve was vertical, so changes in these exogenous variables would not impact $Y^f_t$. More generally, we can think of this as an approximation wherein the effects of changes in these exogenous variables on $Y^f_t$ are sufficiently small that we can safely ignore the effects on the PC and focus on these exogenous variables as “demand” shocks which only impact the AD.

We will split exogenous variables into three camps for this model. The first camp is monetary. Changes in $M_t$ will affect the AD curve. The second is supply – think changes in $A_t$. This will lead to changes in $Y^f_t$ and hence shifts of the PC and the LRPC. The third camp are IS shocks: as noted above, these are changes in $G_t$, $G_{t+1}$, $A_{t+1}$, $q_t$ or uncertainty. Changes in these variables impact the IS curve and lead to shifts in the AD curve. We assume that they do not lead to shifts in the PC, as in the paragraph above.

The picture above shows the IS-LM and AD-PC equilibrium. Jointly, the intersection of these curves determine $r_t$, $P_t$, $Y_t$, and the components of $Y_t$. Once we know $r_t$ and $Y_t$, we know the positions of the labor supply curve (same as it ever was) and the modified, vertical labor demand curve. This allows us to compute the equilibrium levels of $N_t$ and $w_t$, as shown below.
An equilibrium is a set of prices \((r_t, w_t, \text{ and } P_t)\) and quantities \((Y_t, C_t, I_t, \text{ and } N_t)\), given \(M_t, A_t, A_{t+1}, q, G_{t+1}, G_t, P^e_t, \text{ and } \pi^e_{t+1}\), such that the money, goods, and labor markets simultaneously clear. We have three sub-markets that must clear, so we have three prices that do the clearing.

Next, let’s go through the effects of changes in the exogenous variables. I’ll split these into three categories, the same as above. First, we’ll consider a monetary shock. Second, a supply shock. Third, an IS shock.

5.1 Monetary Shock

First, consider an exogenous increase in \(M_t\). This has the effect of shifting the LM curve to the right, and hence also the AD curve to the right. There is no effect on \(Y_t^f, P^e_t\), or any of the components of the IS curve, so only the LM and AD curves shift. These are shown by the blue lines in the picture below. For a given price level, the new quantity of goods demanded exceeds the quantity supplied from the Phillips Curve. Hence, the price level, \(P_t\), must rise to the point where the new AD curve intersects the PC curve. Call these new points \(Y_t^1\) and \(P_t^1\). There is now an “indirect” effect on the LM curve in that the higher price level causes it to shift back in part-way. This makes the quantity of output in the IS-LM graph coincide with the quantity from the intersection of the AD-PC curves. As long as the PC is not vertical, output increases, so the LM curve does not shift back in all the way. Put differently, on net an increase in \(M_t\) leads to an increase in \(\frac{M_t}{P_t}\), real money balances, so on net the LM curve has shifted out. Hence, on net,
we have $Y_t$ higher, $P_t$ higher, and $r_t$ lower. $r_t$ lower, plus $Y_t$ higher, means that $C_t$ and $I_t$ both increase. Here the “monetary transmission mechanism” is that the monetary expansion lowers real interest rates, which stimulates consumption and investment.

In the picture above, note that if the Phillips Curve were vertical (such as would be the case in the “long run”), there would be no real effect of the monetary expansion. The LM curve would still shift right, causing the AD curve to shift right, but with a vertical PC, the price level would rise such that there would be no effect on real balances, $\frac{M_t}{P_t}$, and therefore no net effect on the position of the LM curve. There would be no change in the real interest rate, no change in $Y_t$, and no change in $C_t$ or $I_t$. Just as we saw before, the only effect of an increase in $M_t$ would be a proportional increase in the price level. Here you can see that this new graphical setup can also be used to study the flexible price model we had already considered.

Now, back to the case in which the PC is upward-sloping, not vertical, what happens in the labor market? Higher $Y_t$ means that aggregate labor demand increases – the vertical labor demand curve shifts to the right. A lower real interest rate leads to the labor supply actually shifting in. An inward shift of labor supply, and an outward shift of the vertical labor demand curve, means that $N_t$ and $w_t$ are both higher in the new equilibrium.
In summary, then, an increase in \( M_t \) leads to a decrease in \( r_t \) and increases in \( w_t, P_t, Y_t, C_t, N_t, \) and \( I_t \). With the exception of \( P_t \), these movements will all be larger the flatter is the Phillips Curve (e.g., the stickier are prices). In the extreme case in which the Phillips Curve is perfectly vertical, nothing but the price level would react.

### 5.2 Supply Shock

Next, suppose that we have a “supply” shock that increases \( Y_t^f \) but has no effect on the IS, LM, or AD curves (e.g., an increase in \( A_t \)). There is no “direct” effect (holding the price level fixed) on the LM or IS curves, and hence no effect on the AD curve. The Phillips Curve shifts out to the right because of the increase in \( Y_t^f \), by an amount horizontally equal to the increase in \( Y_t^f \) (which is the amount by which the LRPC shifts out to the right). This results in the price level fall, from \( P_t^0 \) to \( P_t^1 \). Output increases, from \( Y_t^0 \) to \( Y_t^1 \). Note that the increase in \( Y_t \) is less than the horizontal shift of the PC (in other words, \( Y_t \) increases by less than \( Y_t^f \)). The lower price level translates into an outward shift of the LM curve. The LM curve intersects the unaffected IS curve at a lower real interest rate, \( r_t^1 \), and a level of \( Y_t \) consistent with the intersection of the PC and AD curves. The lower real interest rate, plus higher output, mean that \( C_t \) and \( I_t \) are higher.
It is difficult to determine what happens in the labor market. The lower real interest rate causes labor supply to shift to the left. Other things being equal, this would work to raise the real wage. The effect on labor demand is unclear. On the one hand, $Y_t$ is higher, but on the other, so is $A_t$, which means that firms need less labor to produce a given amount of output. Hence, we cannot sign the shift in the $N^d$ curve – it could shift out or it could shift in. Hence, we cannot determine what happens to $w_t$ or $N_t$ with any certainty.

We can say the following, however. We know that $N_t$ goes up by less (or down by more) after an increase in $A_t$ than it would if prices were flexible. If prices were flexible, the PC would be vertical, there would be a bigger change in $Y_t$, a bigger drop in $P_t$, and a bigger drop in $r_t$ (and hence bigger increases in $C_t$ and $I_t$). Another way to put this is that output does not rise by “enough” relative to what it would if prices were flexible. The reason is that higher $A_t$ puts downward pressure on prices. Since some firms cannot adjust their prices, they end up with relative prices that are too high, and consequently produce less than they would otherwise like. In the extreme case of prices being perfectly rigid ($\gamma \to 0$), there would be no effect of the supply shock on $Y_t$ or any other real variables. With $Y_t$ not rising, and $A_t$ higher, we would know that the vertical labor demand curve would shift in (you’d need less labor to produce a given amount of output with productivity higher).
5.3 Demand Shock

Next, consider some exogenous change which affects the IS curve, but not $Y_t^f$. As per the discussion above, this could represent exogenous changes in $A_{t+1}$, $G_t$, $G_{t+1}$, $q$, or uncertainty, assuming the $Y^s$ curve is vertical, or at least sufficiently close to vertical so that the changes in $Y_t^f$ are sufficiently small so as to be able to safely ignore the effects on the PC. The effects on the IS-LM and AD-PC curves are shown below:

The IS curve shifts to the right. This would raise $Y_t$ for a given $P_t$: in other words, the AD curve shifts horizontally to the right. The AD curve shifting right, with no shift in the PC, means that we end up with higher $Y_t$ and higher $P_t$. The increase in $Y_t$ is smaller than the horizontal shift in the AD (unless the PC is perfectly flat). The higher price level leads to an inward shift of the LM curve, so that the $Y_t$ where the IS-LM curves intersect is the same as where the AD-PC curves intersect. We end up with $Y_t$, $P_t$, and $r_t$ all higher. How $C_t$ and $I_t$ are affected depends on what shock is driving the IS shift – if $q$ is going up, $I_t$ would be higher; whereas if it is $G_t$, then $C_t$ and $I_t$ will both be lower. Hence, all we can say generically is that the effects on $C_t$ and $I_t$ of an IS shock are ambiguous.

Lastly, go to the labor market. Since output is higher, firms need to hire more labor, so the vertical labor demand curve shifts right. The higher real interest rate stimulates labor supply. Hence, we know that $N_t$ will go up, but it is unclear what will happen to the real wage. It could go up or go down.
Finally, since we have implicitly assumed that the $Y^*$ curve is vertical (so that things which shift the IS curve have no effect on $Y_t^f$, and hence the position of the PC curve), note that these IS shocks have larger effects on output the flatter is the Phillips Curve. Were the Phillips Curve vertical (prices flexible), there would be no effect. Hence, there is a certain symmetry with the case of a supply shock (where we argued that the effect on $Y_t$ was smaller the stickier were prices). The stickier are prices (the flatter the PC), the bigger the effects of IS shocks on $Y_t$. The intuition for this is that these shocks lead to increases in the price level, which causes some firms to get stuck with relative prices that are too low, and hence these firms end up producing more than they would otherwise find optimal. In other words, with price stickiness, “demand” side shocks have larger effects on output than they would if prices were flexible, with the opposite the case for supply shocks.

The table below summarizes the effects on the endogenous variables for (i) a monetary shock, (ii) a supply shock, and (iii) a positive shock to the IS curve.

<table>
<thead>
<tr>
<th>Variable:</th>
<th>↑ $M_t$</th>
<th>↑ $A_t$ (Supply)</th>
<th>IS Shock (positive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_t$</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>$P_t$</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>$r_t$</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>$C_t$</td>
<td>+</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td>$I_t$</td>
<td>+</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td>$N_t$</td>
<td>+</td>
<td>?</td>
<td>+</td>
</tr>
<tr>
<td>$w_t$</td>
<td>+</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

Let’s quickly compare these qualitative co-movements with what we observe in the data (see the last set of notes, on real business cycle theory). The basic facts are: quantities tend to co-move positively with output, the real wage is procyclical but not as strongly as quantities like consumption or investment, the real interest rate is essentially uncorrelated with output, and the price level if mildly countercyclical.

We observe kind of a mixed bag here. A change in $A_t$ (supply shock) produces the “right” co-movements in terms of $P_t$, $r_t$, $C_t$, and $I_t$. That said, price stickiness makes it less likely that $N_t$ and $w_t$ increase when $A_t$ goes up; and with a sufficient amount of price-stickiness $N_t$ is in fact likely to go down. Monetary shocks do pretty well in producing movements in endogenous variables that look like what we observe in the data, with the exception of $P_t$. IS shocks get $Y_t$ and $N_t$ to move together, but produce movements in $r_t$ and $P_t$ that aren’t perfectly consistent with the data. Positive IS shocks may lead to increases in $w_t$ though, which is more consistent with the data than we observe in the flexible price model. While none of these shocks does a perfect job of accounting for movements in endogenous variables relative to what we see in the real world, we can draw the following conclusion. *Price stickiness improves the ability of “demand” shocks to account for fluctuations (“demand” meaning either monetary shocks or IS shocks), and makes it harder for...*
“supply” shocks (changes in \( A_t \)) to account for empirically observed business cycles. In terms of IS shocks, we get smaller increases in \( r_t \) and at least have the possibility that \( w_t \) rises after a positive shock which raises \( Y_t \), unlike in the flexible price model. Monetary shocks can have real effects here, whereas they have no real effect in the flexible price model. Finally, supply shocks have smaller effects on \( Y_t \) the stickier are prices, and therefore are less likely to lead to positive co-movement between \( Y_t \) and \( N_t \).

Below is a summary about how to work through exogenous changes in the NK model:

1. Start in the IS-LM diagram. Figure out if the IS or LM curves shift, holding the price level fixed. This will tell you if the AD curve shifts or not, and in which direction.

2. Then ask yourself whether the PC shifts. This will occur if \( Y_t^f \) changes (recall caveat discussed extensively above) or if \( P^e_t \) were to change.

3. Combine the AD and/or PC shifts to determine a new equilibrium level of \( Y_t \) and \( P_t \).

4. Take the new \( P_t \) and adjust the position of the LM curve in such a way that \( Y_t \) intersection lines up. Determine the new \( r_t \) at the point at which the IS and LM curves intersect. Combine the changes in \( r_t \) and \( Y_t \), along with the change in the exogenous variable, to try to figure out how \( C_t \) and \( I_t \) are affected (you may not be able to).

5. Finally, go to the labor market. Given the \( Y_t \) you found, determine what \( N_t \) needs to be. This determines the position of the vertical labor demand curve. Then given \( r_t \), determine the position of labor supply. Combine labor supply and demand to determine \( w_t \).

6 Dynamics

The exercises above are awfully “static” in the sense that no thought is given to price adjustment. In the “short run” firms may have to keep their preset price, but after a while pricing rigidities should be irrelevant. In this section we think about the dynamic responses to the same shocks we looked at in the previous section.

The basic idea of dynamics is that \( P_t \neq P^e_t \) (i.e. firms being surprised by the aggregate price level) will lead to subsequent adjustment of price expectations that will shift the Phillips Curve. In particular, it seems natural that if firms were surprised by an aggregate price level that is higher than expected, \( P_t > P^e_t \), then, when given the opportunity, firms will update their price expectations. This would lead to the Phillips Curve shifting in/up. In contrast, if firms are surprised with lower than expected prices, \( P_t < P^e_t \), they will do the opposite: expected prices will fall, which will shift the Phillips Curve out.

Now in terms of thinking of these dynamics, a complication arises in the sense that we really ought to be formal about the number of time periods. Instead of doing that, we’re going to engage in a bit of a hand-waiving exercise. Think about a period, \( t \), as having multiple “parts” (e.g. a day has morning, afternoon, and night; a year has 12 months or four quarters). To be as specific
as possible, let’s divide a period, \( t \), into two parts: call them the “short run” and the “medium run.” In the “short run,” \( P_t^e \) is fixed. In the “medium run,” expected prices will adjust based on movements in actual prices, in such a way \( P_t = P_t^e \), so that we’re always at \( Y_t^{ff} \). This is another way of saying that money can only be non-neutral for a short period of time.

The way we’ll go through these dynamic exercises is as follows:

1. Go through and do the exercise as above. Figure out how \( Y_t \) and \( P_t \) will change based on shifts of the AD or PC curves. Think about this as happening in the first “half” of period \( t \).

2. If \( P_t < P_t^e \), assume that \( P_t^e \) adjusts up in such a way that the PC shifts in/up in such a way that the equilibrium level of \( Y_t \) is equal to \( Y_t^{ff} \). Think about this is occurring in the second “half” of period \( t \).

We’re going to go through and do these exercises for a monetary shock, a supply shock, and an IS/demand shock. I use black lines to denote the original curve positions, blue lines to denote the “short run” effects of the shock (i.e. what happens in the first “half” of \( t \)), red lines to denote the intermediate or indirect effects of price changes on the position of the LM curve, and green lines to denote what happens in the “medium run” (i.e. the second “half” of period \( t \)).

### 6.1 Monetary Shock

Suppose that there is an exogenous increase in \( M_t \). From our earlier analysis, we know that this leads to an outward shift of the LM curve for a given price level, as indicated by the blue LM curve below. This results in an outward shift of the AD curve. This results in an increase in the price level to \( P_t^1 \), and an increase in output to \( Y_t^1 \). The increase in output is smaller than the horizontal shift of the AD curve, so that the increase in the price level has a secondary or indirect effect on the LM curve, pushing it back in slightly so that the quantities of \( Y_t \) align at \( Y_t^1 \). This is no different than that which we have already done.
What’s new here is the green part. We see in the picture that $P_t > P_t^e$: put differently, firms have been fooled. Fool me once, shame on you. Fool me twice, shame on me. Firms react by raising their expected price, and hence their posted prices, in the second “half” of the day. This results in an inward shift of the PC. The magnitude of the inward shift is such that the PC intersects the new AD curve at the original equilibrium level of $Y_t^0$ (which we implicitly assume is equal to $Y_t^f$, which is unaffected by $M_t$). This increase in the expected price level, leading to the inward shift of the PC, results (relative to the first “half” of period $t$) in a reduction in output and an increase in $P_t$. The increase in $P_t$ results in an inward shift of the LM curve, in such a way that the outputs align in both pictures. Since we return to the original level of output, the LM curve returns to its initial position (albeit with different levels of $M_t$ and $P_t$).

We see here that, in the “medium run,” money is neutral. The change in $M_t$ has no effect on $Y_t$, no effect on $r_t$, and hence no effect on $C_t$ or $I_t$. With no effect on $Y_t$ or $r_t$, there is no “medium run” impact on the positions of the labor supply or the vertical labor demand curves, and hence no change in $N_t$ or $w_t$. In other words, we’re back to the monetary neutrality case we saw before — the only effect of a change in $M_t$ is to change $P_t$, with no real consequences. In the “short run” (e.g. the first half of the period $t$), money is not neutral because prices are imperfectly flexible (the Phillips Curve is no vertical): this means that the increase in $M_t$ results in a temporary reduction in $r_t$, which stimulates consumption and investment and hence output.
6.2 Supply Shock

Next, consider a positive supply shock that raises \( Y_t^f \) but has no effect on the AD curve (e.g. an increase in \( A_t \)). This has no “direct” impact on the IS or LM curves. It results in an outward shift of both the PC and the LRPC, by an amount horizontally equal to the change in \( Y_t^f \). This is shown in the graph by the blue lines, with \( PC_1 \) denoting the new Phillips Curve. Because the AD curve is not perfectly horizontal, in the new equilibrium, actual output increases by less than the horizontal shift in the PC, to \( Y_t^1 \). The price level falls to \( P_t^1 \), which is lower than \( P_t^e \). The lower price level works to shift the LM curve out (red line), so that the real interest rate is lower and the quantity of output aligns with the AD-PC intersection. This is identical to what we saw above.

Now, let’s think about the dynamics. The price level is lower than what is expected, but we also have equilibrium output lower than the new \( Y_t^f \) (in the picture, \( Y_t^1 < Y_t^2 \)). Firms being surprised on the downside results in them lowering \( P_t^e \). This results in an outward shift of the PC, by an amount such that it intersects the AD curve at \( Y_t^2 \), which is the new flexible price level of output. This results in a further decrease in the price level, which results in an outward shift of the LM curve so that the quantities of output align.

Put differently, in the “short run” (the first “half” of the period), output under-reacts to the supply shock. This happens because the price level is unable to fully react because of price stickiness. In the “medium run,” firms adjust price expectations, in such a way that we have \( Y_t = Y_t^f \).
6.3 IS Shock

Finally, let’s consider a shock to the IS curve (change in \( A_{t+1}, G_t, G_{t+1}, \) or \( q \)) which has no effect on \( Y_t^f \), and hence no effect on the PC (see discussion above). From our earlier discussion, we know how things will play out in the “short run.” The IS curve shifts out to \( IS_1 \). This raises the quantities of goods demand at a given price level, resulting in an outward shift of the AD curve. The outward shift of the AD curve, along with an upward-sloping (but not vertical) PC means that \( Y_t \) and \( P_t \) both go up. The increase in \( Y_t \) is smaller than the outward shift of the AD (unless the PC is perfectly horizontal). The increase in the price level has an indirect effect wherein it results in an inward shift of the LM curve, so that the quantities of output in the upper and lower graphs align. The real interest rate rises.

\[
\begin{align*}
\text{LM}(P_t^0) & \quad \text{IS}_0 \\
\text{LM}(P_t^0) & \quad \text{PC}_0 \\
\text{IS}_1 & \quad \text{AD}_1
\end{align*}
\]

Let’s think about the dynamics at work. In the new short run equilibrium, we have \( Y_t^1 > Y_t^f \), and \( P_t > P_t^e \). Firms have been surprised by higher than expected prices. They react in the second half of the day by increasing their price expectation, which has the effect of shifting the Phillips Curve in, to \( PC_1 \). The magnitude of this shift is such that the PC intersects the new AD at \( Y_t^f \), which has not changed. The higher price level resulting from this inward PC shift works to shift the LM curve in even more, so that the quantities of output in the upper and lower diagrams align. The real interest rate ends up higher.

What’s going on here is that output expands by “too much” (relative to the flexible price level of output, \( Y_t^f \)) because of price rigidity – in the short run, the price level cannot rise by enough, so
the real interest rate rises by “too little,” and output expands by more relative to $Y_t^f$ (which does not change, by construction). This is the mirror image of what happens in response to a supply shock – output responds by too little to a supply shock, and by too much after a demand shock, when prices are sticky (the Phillips Curve is not vertical). But in the “medium run,” (the second half of the period), prices are effectively not rigid – firms can update their expected prices in such a way that the actual price level will be what they expect, and we’ll have $Y_t = Y_t^f$. Hence, price stickiness is a “short run” friction that makes the equilibrium level of output differ (at least for the first half of the period) from $Y_t^f$.

6.4 The Limits of Monetary Expansion

The introduction and study of these “dynamics” (simple and contrived enough as they are) allows us to address some potentially interesting policy questions.

Can the central bank get the economy to produce more than $Y_t^f$? As we have seen above, the answer is “yes,” at least in the short run. When the central bank increases $M_t$, $P_t$ increases, but not by enough because some firms are stuck with their old price. In essence, monetary neutrality works by “fooling” firms into producing too much. But we have seen that there is a limit to this process. While the central bank can temporarily boost output through monetary policy, in the medium run all that happens is that prices rise.

What would happen if the central bank tried to permanently keep output high (say because of political pressure)? It would have to continually increase the money supply: in our graphs, this would represent continual outer shifts of the AD. But these continual outer shifts of the AD would be met by continual inward shifts of the PC as firms adjust their price expectations. Hence, the “cost” of trying to expand output above its “potential” level ($Y_t^f$) is higher prices. The cost of trying to continually do this is continually higher prices (e.g. high and rising inflation). Eventually, if the central bank tried to do this enough, firms would catch on, and would build these price increase expectations into their price-setting, and monetary expansion would have no real effects – it would just result in inflation. Bottom line: the central bank cannot permanently stimulate output by printing more money. To the extent to which it can do so in the short run (because of price rigidity), the cost is higher prices. Trying to continually increase the money supply in such a way as to further stimulate output would result in further price level increases, which would eventually be factored into price-setting expectations, making monetary policy ineffective in stimulating output.

6.5 Costly Disinflation and Credibility

Suppose that, for whatever reason, a central bank would like to bring the price level down (or more generally, create a “disinflation” – a slow down in the rate of growth in prices). As we have seen above, the central bank can do this by reducing the money supply. This results in an inward shift of the LM curve, and a resulting inward shift of the AD curve. The inward shift of the AD curve along an upward-sloping PC curve means that both $P_t$ and $Y_t$ fall. In other words, the “cost” of bringing prices down is lower output. We can see this in the picture below:
Is there a way in which the central bank could bring about a reduction in prices without having to incur a loss in output? Yes, at least in principle. In essence, what leads to the output loss from the monetary contraction is that firms are surprised by the lower than normal price level – when the price level ends up lower than expected, some firms end up with relative prices that are too high, and total production goes down. If the central bank could achieve an expected reduction in the price level, this output loss may be able to be avoided.
The picture above shows a situation in which a reduction in the money supply, $M_t$, is met by a simultaneous reduction in the expected price level, $P^e_t$. The reduction in the expected price level works to shift the Phillips Curve out to right. I have drawn the Phillips Curve shift such that, combined with the AD shift from the monetary contraction, there is no change in output. We’ve taken $P^e_t$ to be exogenous up until now, but suppose that it is in some way possible for the central bank to “manage” expectations. For example, if the central bank could credibly commit to reducing the money supply in the future, expected prices would react, and the central bank could lower the money supply without incurring an output loss.

For this kind of experiment, credibility becomes key. For expected prices to fall, firms have to believe that the central bank will actually lower the money supply in the future. You can imagine why this kind of announcement may not be credible. Suppose, for example, that the central bank were to announce that it is going to lower the money supply in the next period. Expected prices would react, and when next period rolls around, the Phillips Curve would shift out. If the Fed then reneged on its promise to lower the money supply, output would actually rise (the outward shift of the PC with no shift of the AD would generate this). For political reasons, the central bank may like output rising, and then may choose, when the future rolls around, to not actually reduce the money supply. But if firms know (or think) that the central bank will renege, then they won’t expect lower prices in the first place – they won’t believe the central bank, and the central bank will not be able to engineer a reduction in prices without incurring an output loss as in the case of an unexpected reduction in the money supply.
For this reason, central bank credibility is considered very important. Because what firms expect the aggregate price level to be is so important for the position of the Phillips Curve, it is important that the central bank have the credibility that it will in fact do what it says it will do. Because credibility is so important, it is widely agreed (at least among academic economists) that central bank independence is really important. This independence refers to independence from fiscal/political authorities. Politicians like it when output is high – in the story of the paragraph above, if there are political pressures on the central bank, they may renege on their promise to lower the money supply, which would erase any credibility they may have.

Bottom line: a central bank can do a better job of bringing prices down if it can credibly convince firms (and households) in the economy that it will be able to commit to future policy actions (e.g. lowering the money supply). This credibility will be stronger the more independent a central bank is from the political process, since politicians typically view output being high as a good thing.

7 Optimal Monetary Policy

We have so far taken $M_t$ to be exogenous, meaning that there is no reaction of monetary policy to economic conditions. In reality, we know that the central bank reacts to external conditions. In this section we study optimal monetary policy in our basic model.

From the perspective of the New Keynesian model, we’ve effectively been taking $Y_t^f$ as exogenous – it is determined by the same exogenous variables we face here, but in a different, hypothetical model. To the extent to which the central bank can control the money supply, it can also control the level of output and the price level relative to the expected price level (changes in the money supply lead to different positions of the AD curve along the upward-sloping PC). What level of output, and what price level, would the central bank want to target? From our discussion of the real business cycle model, we know the answer for the level of output: the central bank would want $Y_t = Y_t^f$. Why? Because we know that $Y_t^f$, the hypothetical equilibrium level of output under flexible prices, is exactly the same level of output that would emerge as the solution to a fictitious social planner’s problem. The price level at which $Y_t = Y_t^f$ is, given the construction of the Phillips Curve, $P_t = P_t^e$. The intuition for this is straightforward – if the actual price level is what was expected, then there is no effect of price stickiness, as no firms will find it desirable to adjust their price anyway. This gives rise to something that is sometimes called the “Divine Coincidence”: in this New Keynesian model, a policy of price stability (so that $P_t = P_t^e$) promotes the optimal level of real economic activity.

We can think about optimal monetary policy in the following way. Suppose there is some exogenous shock that would shift the AD or PC curves, resulting in a new equilibrium level of $Y_t$ and $P_t$. To the extent to which the new equilibrium level of $Y_t$ differs from $Y_t^f$, the central bank should adjust the money supply in such a way that the AD curve shifts “again” so as to make the new equilibrium level of $Y_t$ exactly equal to $Y_t^f$.

I will use the following color coding scheme below. Black lines are the original positions of curves. Blue lines show the “direct” effects of exogenous changes. The red lines shown the “indirect” effect.
in the IS-LM diagram of a different price level. Orange lines show how the central bank should shift curves so as to bring about the optimal equilibrium. The purple lines in the IS-LM diagram show the “indirect” effects of the central bank actions on the price level.

I first consider how the central bank ought to respond to a “supply” shock, and then look at the how they ought to react to an IS shock. As we will see, the optimal response to a positive supply shock is to increase $M_t$ in such a way that $P_t$ need not fall. In that case, it is optimal to have procyclical monetary policy: the money supply moves in the same direction as output. In the case of an IS shock, the reverse is true. The IS shock would lead to output rising above $Y_t^f$ and the price level rising. The central bank ought to react to that by reducing the money supply. In that sense, monetary policy ought to be countercyclical: it needs to move $M_t$ in the opposite direction from that which $Y_t$ would move.

7.1 Positive Supply Shock

Suppose that the economy initially sits in an equilibrium in which $P_t = P_t^e$ and $Y_t = Y_t^f$. Suppose that there is an exogenous increase in $Y_t^f$ (from $Y_t^0$ to $Y_t^2$, coming from an increase in $A_t$. This would have the effect of shifting both the PC and LRPC horizontally to the right by the same amount (blue lines). Along a downward-sloping AD curve, actual output would increase by less than the increase in $Y_t^f$, to $Y_t^1$ and the price level would fall to $P_t^1$. The falling price level would shift the LM curve out (red line) to make the $Y_t$ at the IS-LM intersection align with the $Y_t$ at the AD-PC intersection.
Now, how should monetary policy react to this? As noted above, we would like to get the equilibrium level of output equal to the new hypothetical flexible price level of output. In other words, we’d like to get \( Y_t = Y_t^2 \). To do this, we need to shift the AD curve out, so that it intersects the new PC at the new LRPC. This involves an increase in the money supply. The orange line in the IS-LM diagram shows the required horizontal shift of the LM, relative to the point \((M_t^0, P_t^1)\). This would cause the AD curve to shift horizontally, as shown by the orange line. It would intersect the new PC at \( Y_t^2 \), the new hypothetical level of output under flexible prices (corresponding to the position of the new vertical LRPC). This involves a higher price level relative to \( P_t^1 \), which leads to an indirect shift of the LM curve (purple line) so that the output levels in the two diagrams correspond. The new equilibrium price level where output is at potential is exactly the price level that was expected. As stated above, by stabilizing the price level, the central bank stabilizes output about its potential.

### 7.2 IS Shock

Next, suppose that there is positive shock to the IS curve. The economy initially sits in an equilibrium at \((P_t^0, Y_t^0)\). We assume that the IS shock has no effect on \( Y_t^f \), and hence no effect on the PC or LRPC. The IS shock would lead to the AD curve shifting horizontally to the right, resulting in increases in both \( Y_t \) (to \( Y_t^1 \)) and \( P_t \) (to \( P_t^1 \)). The higher price level makes the LM curve shift in (red line) so as to intersect the IS curve at the “right” level of output.
Now, how should the central bank react? Since $Y_t^f$ hasn’t changed, we’d like $Y_t$ to not change either. In other words, we need to change $M_t$ in such a way as to shift the AD curve back in. This necessitates reducing the money supply. Reducing the money supply shifts the LM curve in for a given price level (orange line), which shifts the AD curve back in to its original starting position. The lower price level (relative to $P_t^1$) has a secondary indirect effect on the LM curve, so that it shifts slightly back out to the right (purple line) intersecting the new IS curve at the original level of output. In the new equilibrium neither $Y_t$ nor $P_t$ are affected, though $r_t$ is higher. This is exactly the same outcome that would obtain if prices were flexible.

### 7.3 Summary

Because of price rigidity, the PC is not perfectly vertical. This means that supply shocks (changes in $A_t$) have equilibrium effects on $Y_t$ that are “too small” relative to what would happen with flexible prices, whereas “demand” shocks to the IS curve have effects that are too large. Optimal monetary policy can achieve the optimal level of output by moving $M_t$ in response to exogenous shocks in such a way as to stabilize the price level at the expected price level. If the central bank can engineer $P_t = P_t^e$, then the AD curve will intersect the PC at $Y_t^f$, and the equilibrium allocation will be efficient (the same as a social planner would choose) in spite of the underlying pricing friction.

To figure out how monetary policy should react to a shock, go through the following steps.

1. Figure out how the shock will affect $Y_t^f$, $Y_t$, and $P_t$. A supply shock causes the PC to shift
right. Along a downward sloping AD curve, this means that $Y_t$ will rise, but not by the full amount of the increase in $Y_t^f$. The price level, $P_t$, will fall relative to $P_t^e$. If there is a shock to the IS curve (which, by assumption, has no effect on $Y_t^f$), then the AD curve shifts to the right, with $Y_t$ rising relative to $Y_t^f$ and $P_t$ also rising relative to $P_t^e$.

2. Move the money supply, $M_t$, in such a way that the equilibrium level of $Y_t$ (where the AD intersects the PC) is equal to $Y_t^f$. Equivalently, this means that we need to move $M_t$ in such a way to make $P_t = P_t^e$.

3. In the case of the positive supply shock, $Y_t$ does not rise by enough and $P_t$ falls. This means we want to increase the money supply.

4. In the case of a positive IS shock, $Y_t$ rises by too much relative to $Y_t^f$, and $P_t$ rises. It is optimal to respond with contractionary monetary policy by reducing $M_t$.

5. Achieving price stability means that output will be stabilized about potential, $Y_t^f$, which is optimal.

6. A simple way to think about this is as follows. If aggregate prices are stable (relative to expectation), then the underlying price stickiness friction at the firm level is irrelevant. Hence, the objective for monetary policy is to move $M_t$ in response to other exogenous shocks in such a way that price level doesn’t move – so if an external shock would raises $P_t$, the central bank wants to lower $M_t$ (which would work in the other direction); whereas in response to a shock which would lower $P_t$, the central bank wants to raise $M_t$.

7. Since the central bank would like to implement $Y_t = Y_t^f$, and changes in $M_t$ change $Y_t$ but not $Y_t^f$, it is not optimal to have exogenous changes in $M_t$. $M_t$ should only react to other exogenous changes.

8 Zero Lower Bound

As we have previously noted, while real interest rates can be negative, nominal interest rates cannot. Nominal interest rates in the US have been at or very near zero for the last five years. This is sometimes referred to as the “Zero Lower Bound.” What are the implications of the zero lower bound for the analysis of the New Keynesian model?

The zero lower bound affects the LM curve. In particular, when the nominal interest rate has hit zero, the real interest rate gets “stuck” at the negative of the expected rate of inflation. In other words, the LM curve becomes horizontal at $r_t = -\pi_{t+1}^e$. With the LM curve horizontal, changes in the price level have no effect on the position of the LM curve, and hence no effect on the $Y_t$ at which the IS and LM curves intersect. This means that the AD curve becomes vertical at the zero lower bound.
An example economy in which the zero lower bound binds is shown below. In particular, I assume that the vertical AD curve intersects the PC curve at a level of $Y_t < Y_t^f$ (which, by construction given the expression for the PC, means that $P_t < P_t^f$).

A situation like this can become very problematic. As we saw a couple of sections ago, the normal adjustment process when $Y_t < Y_t^f$ would be for expected prices to fall, which would shift out the PC curve. With the AD curve vertical, an outward shift of the PC curve would in fact lead to $P_t$ falling, but it would have no effect on $Y_t$. In fact, if we were to endogenize expected inflation, $\pi_{t+1}^e$, the problem would get even worse. Falling prices would create deflationary expectations. Given a nominal interest rate fixed at zero, this would actually lead to an upward shift of the horizontal LM curve, and an inward shift of the AD curve. Put differently, if we find ourselves with the nominal interest rate fixed at zero and output below potential, there is the possibility that output can get “stuck” at $Y_t < Y_t^f$: the normal price adjustment process won’t work. Further, the pricing dynamics can actually exacerbate the problem: we can get into a “deflationary spiral” in which expected inflation keeps declining, leading to higher and higher real interest rates, and even lower levels of output.

Another term for this setup is sometimes also called the “Liquidity trap.” It is a “trap” in the sense that the economy can’t easily get itself out of this situation the way it normally would. Having periods of output being persistently below potentially is certainly something that policy makers would prefer to avoid. One way to avoid the situation of nominal interest rates getting to
zero is having a higher long run level of average inflation. As we argued earlier in the class, excess money growth over output growth determines average inflation over long horizons, which in turn determines expected inflation. The real interest rate is determined by trend growth and preferences (the extent to which households discount the future). Hence, the level of the nominal interest rate (in the long run) moves one-for-one with the level of inflation. Committing to more inflation in the long run has the effect of raising average nominal interest rates, which reduces the probability of running into a situation in which the nominal rate hits zero. Of course, the tradeoff here is that, for a variety of different reasons, people typically don’t like inflation. So the long run inflation target that a central bank takes needs to balance the costs of inflation with the benefit that higher average inflation reduces the incidence of hitting the zero lower bound.

The zero lower bound also introduces complications for the conduct of monetary policy. As we saw above, in our model it is optimal for monetary policy to adjust the money supply in such a way so as to lead to the equilibrium level of output being equal to the hypothetical level of output that would obtain if prices were flexible, $Y^f_t$. When the nominal interest rate is zero and the LM curve is horizontal, changes in the money supply don’t have any effect. So another reason that the ZLB is costly (aside from the fact that you can easily get stuck there, potentially in a “deflationary trap”) is that it becomes impossible to conduct optimal monetary policy according to the normal channels.

Below, I show how (i) supply and (ii) IS shocks impact the equilibrium assuming that we are in a zero lower bound regime in which output is already too low relative to potential. Finally, I consider one potential “escape” channel from the zero lower bound: the engineering of expected inflation. We will see that the zero lower bound exacerbates the effects of price stickiness – supply shocks have smaller effects on real variables and IS shocks have bigger effects.

### 8.1 Supply Shock at the ZLB

First, suppose that we’re initially sitting in the zero lower bound and are hit with a positive shock to $Y^f_t$ (from an increase in $A_t$). As before, this will lead to outward shifts in both the PC and LRPC. But since the AD curve is vertical, there will be no effect on $Y_t$. The lower price level that obtains will have no effect on the position of the LM curve, and hence no effect on the real interest rate or the components of output. The only real variables affected will be related to the labor market, where $N_t$ and $w_t$ will both decrease.
We can see that the effects of the positive supply shock at the zero lower bound are even smaller than they are away from the zero lower bound with sticky prices, which are in turn smaller than they are under flexible prices. In other words, the zero lower bound exacerbates the effects of sticky prices on the equilibrium effects of a supply shock – output and other real variables respond by less than they would absent the zero lower bound.

8.2 IS Shock at the ZLB

Next, consider a shock to the IS curve. This could come from an increase in $A_{t+1}$, $G_t$, or $q$, or decreases in $G_{t+1}$, $K_t$, or uncertainty. Assume that the IS curve shifts to the right. Along a flat LM curve, the AD curve will shift to the right, by an amount equal to the horizontal shift of the IS curve. Since the AD curve is vertical, output increases by the amount of the shift in the AD curve. The price level rises, but this has no secondary effect since the LM curve is horizontal.
An important take-away point here is that a shock to the IS curve has even bigger effects on output than it would absent the zero lower bound – output increases by the full amount of the direct rightward shift of the IS curve. Intuitively, the reason this happens is that there isn’t an accompanying increase in the real interest rate resulting from an IS shock. For example, suppose that there is an increase in government spending. Since we assume that Ricardian Equivalence holds and that households behave as though the government balances its budget period by period, we know that the horizontal shift of the IS curve is equal to the change in government spending. If there were no change in the real interest rate, neither $C_t$ nor $I_t$ would react – there would be no change in $r_t$ and no change in $Y_t - G_t$. Under our normal assumption of an upward-sloping LM and downward-sloping AD, there would be some crowding out of private expenditure – the real interest rate would rise, so $Y_t$ would rise by less than the increase in $G_t$ (the “multiplier”) would be less than one), and both $C_t$ and $I_t$ would decline. At the zero lower bound, there is no crowding out. This means that IS shocks, including fiscal policy shocks, have much larger effects at the zero lower bound than they do otherwise.

8.3 Escaping the ZLB: Inflation Expectations

As I noted above, one problem with the ZLB is that changes in the money supply don’t affect the AD curve and therefore have no effect on the economy. Put differently, the “normal” channel of monetary policy isn’t viable. Is there any way for monetary policy to affect the equilibrium of the
economy? Is there a way to escape the ZLB?

At the ZLB, the LM curve becomes perfectly horizontal at negative of the rate of expected inflation. We’ve been treating expected inflation as an exogenous constant, though above I talked about the possibility of a deflationary expectations spiral. Suppose that there were some way for the central bank to “manage” expected inflation. What would happen if the central bank could credibly commit to higher future inflation? What effects would that have in the present?

The picture below shows what happens if there is an increase in expected inflation. Mechanically, we treat this to be an exogenous change, though we can think of ways in which a central bank might engineer this (more on this below). The higher rate of expected inflation shifts the horizontal LM curve down. This means it intersects the IS curve at a higher level of $Y_t$. Since the AD curve is vertical, this means that the AD curve shifts right. The AD curve shifting right along an upward-sloping PC means that equilibrium output increases. Since there is no change in the nominal rate, higher expected inflation means that the real interest rate is lower. A lower real rate, plus higher output, means consumption is higher. A lower real rate means that investment is higher. Higher output means that the vertical aggregate labor demand curve shifts right, with $N_t$ increasing. A lower real rate means that labor supply shifts in. This combined with the outward shift of the vertical labor demand curve would mean that the real wage is higher. Finally, the outward shift of the vertical AD curve along the upward-sloping PC means that the nominal price level, $P_t$, also increases. Higher expected inflation leads to higher prices in the present, and is in that sense somewhat “self-fulfilling.”
A lot of the “non-standard” monetary policies which have been undertaken in the last several years can be boiled down to trying to engineer inflation expectations, leading to effects similar to those shown in the picture above. We’ll be studying those in more depth when we study the Great Recession.