

Lecture Notes: Chapter 11: Extending the Sticky-Price Model

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The Money Stock and the Money Market: The LM Curve

The intersection of the IS and LM curves determines short-run equilibrium values of real GDP when the money stock is fixed. But in today's world, central banks manipulate the money stock to peg interest rates. They don't hold the money stock fixed.

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But if you need the full IS-LM analysis, here it is. Recall three facts about business and household demand for money, where "demand for money" is economist-speak for the quantity of readily-spendable liquid assets held in one's portfolio:

- Money demand is proportional to total nominal income $P \times Y$.
- Money demand has a time trend, the result of slow changes in banking-sector structure and technology.
- Money demand is *inversely* related to the nominal interest rate.

Money demand is inversely related to the nominal interest rate because the nominal interest rate is the opportunity cost of holding money. Money balances earn effectively zero real interest, and over time they lose their power to purchase real, useful goods and services at the rate of inflation π . If money balances were sold and the proceeds put into some other investment, they would earn the prevailing market real interest rate r . Thus the opportunity cost of holding wealth in the form of money is the nominal interest rate $i = r + \pi^e$: the sum of the real interest rate r and the expected inflation rate π^e .

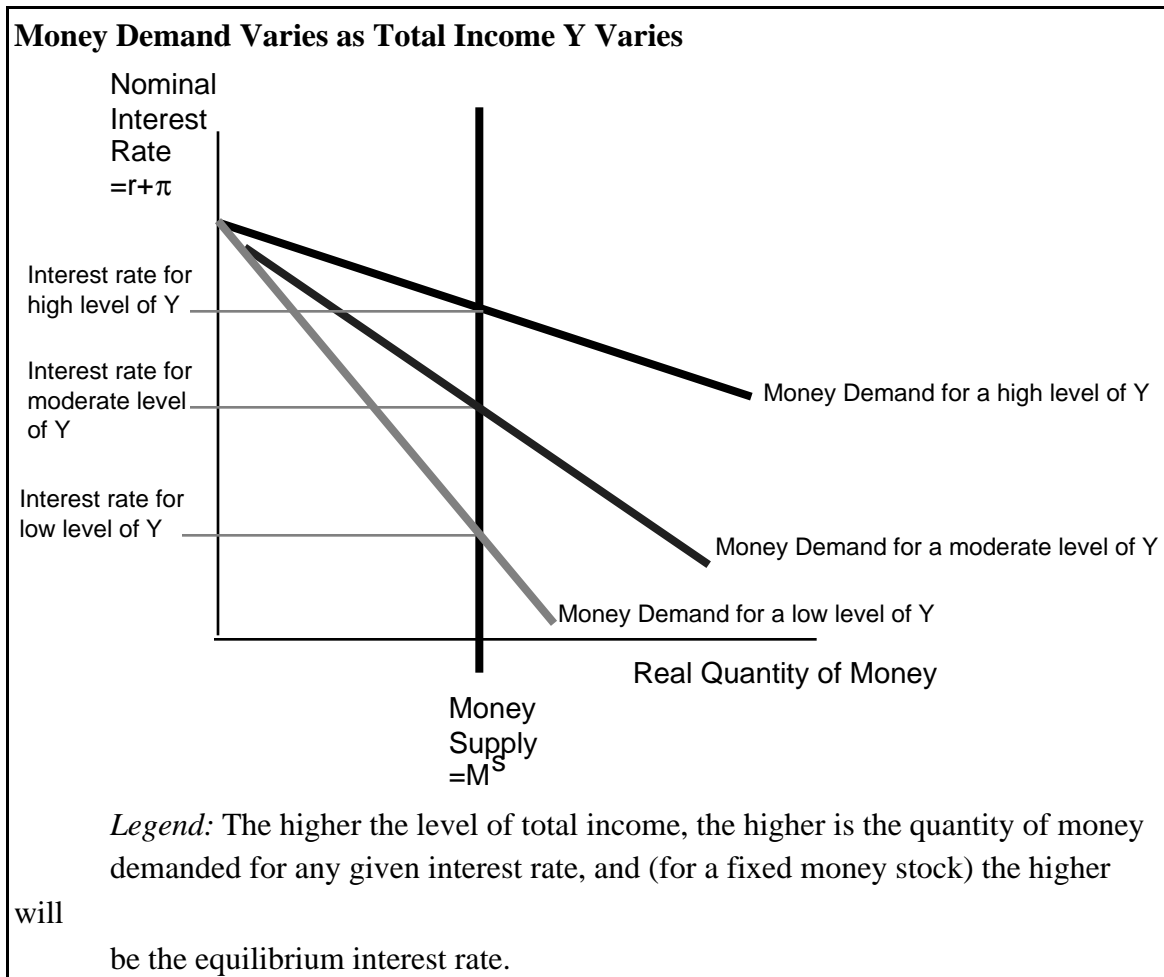
To keep our model simple, we ignore the time trend in velocity and write the demand for money as the function:

$$\frac{M^d}{P} = \frac{Y}{V_0 + V_i \times (r + \pi^e)}$$

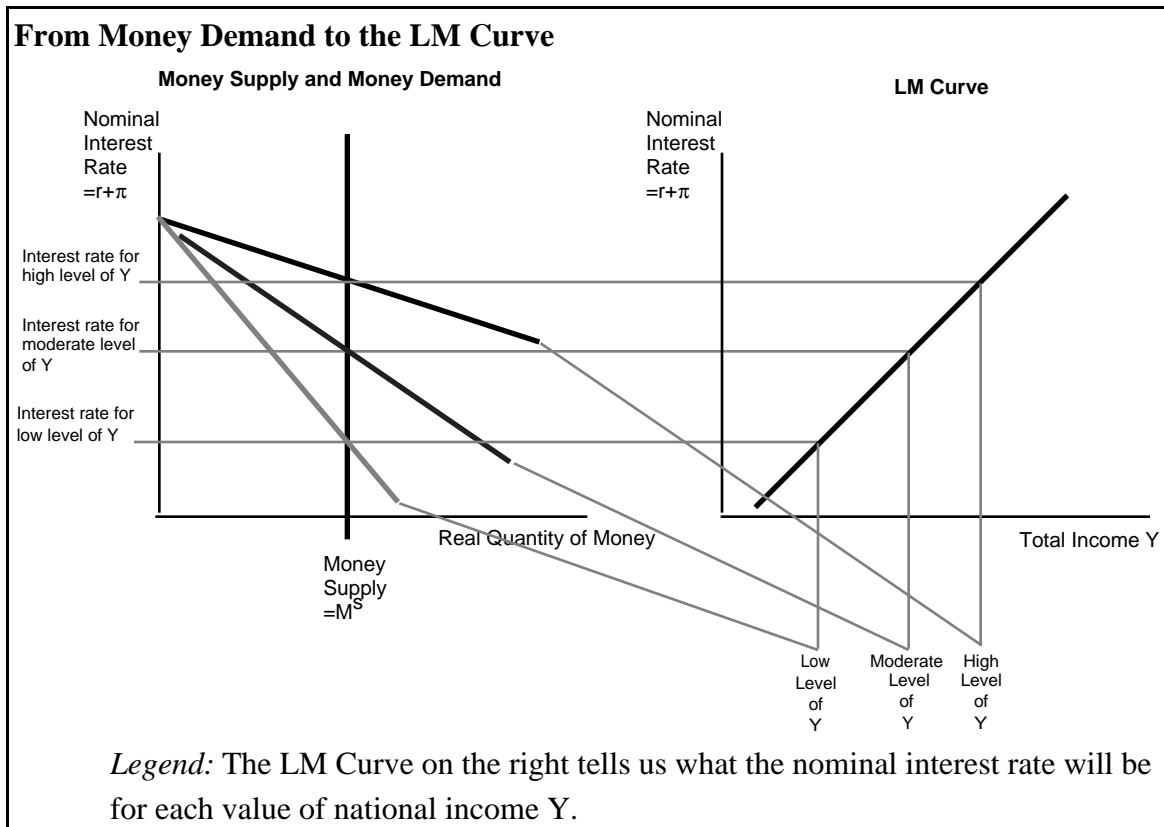
Because the left hand side is the nominal money stock divided by the price level, this equation represents real money demand—a demand for an amount of liquid power to purchase goods and services, rather than a demand for a stack of dollar bills. This equation shows that money demand is proportional to real GDP Y : the higher is real GDP, the more real money balances people wish to hold. The plus sign in front of the V_i parameter means that velocity is an increasing function of the nominal interest rate, and thus money demand is a decreasing function of the nominal interest rate. The higher is the nominal interest rate, the higher is the opportunity cost of holding money, and the lower is the real quantity of money demanded.

The LM Curve

If the money stock is constant, then the fact that demand for money depends on real GDP Y means that the equilibrium nominal interest rate varies whenever real GDP Y varies. At each possible level of total income Y , there is a different curve showing money demand as a function of the nominal interest rate, as Figure 11.2 shows. With a fixed money supply, each of these money demand curves produces a different equilibrium nominal interest rate. If real GDP Y rises and the money supply M^s does not, the nominal interest rate must rise too if the money market is to remain in equilibrium. With higher incomes, households and businesses want to hold more money. But if the money supply does not increase, then in aggregate their money holdings cannot grow. Something must curb their demand for liquid cash holdings and so keep money demand equal to money supply, and that something is a higher nominal interest rate, a higher opportunity cost of holding money.



If we draw another diagram with the nominal interest rate $i=r+\pi$ on the vertical axis and the level of total income Y on the horizontal axis. For each possible value of Y on the x-axis, plot the point whose y-axis value is the equilibrium nominal interest rate, as in Figure 11.3. The result is the LM curve the economy's current level of the real money stock M^s/P . The LM curve slopes upward: at a higher level of real GDP Y , the equilibrium nominal interest rate is higher.



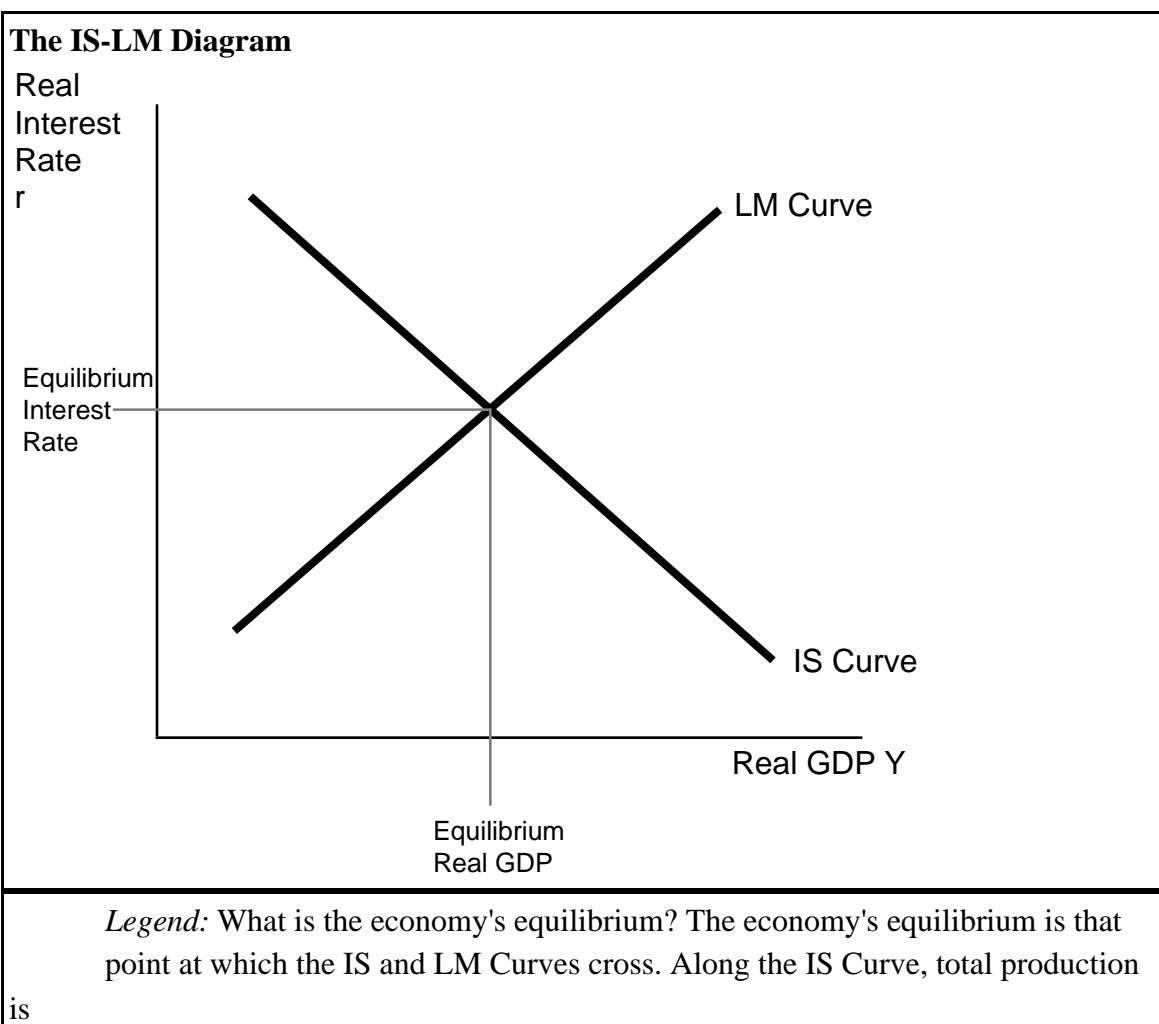
The equation for the LM curve is simply the money demand function rewritten with the real GDP by itself on the left-hand side:

$$Y = (V_0 + V_i \times (r + \pi^e)) \times \left(\frac{M}{P} \right)$$

This equation tells us that monetary policy changes that increase the nominal money supply shift the LM curve to the right: the same equilibrium nominal interest rate i corresponds to a higher level of real GDP Y . Monetary policy changes that decrease the nominal money supply shift the LM curve in and to the left. Similarly, a decline in the price level boosts the real money supply (M/P) and shifts the LM curve out to the right. A rise in the price level decreases the real money supply (M/P) and shifts the LM curve in to the left.

The IS-LM Framework

As long as we know the expected inflation rate, the fact that the nominal interest rate is equal to the real interest rate plus the expected inflation rate means that we can plot the IS and LM curves on the same set of axes, as in Figure 16.4. This is called the IS-LM diagram. The equilibrium level of real GDP and of the interest rate is at the point where the IS curve and the LM curve cross. At that level of real GDP and total income Y and the real interest rate r , the economy is in equilibrium in both the goods market and the money market. Aggregate demand is equal to total production, so inventories are stable (that's what the IS curve indicates); and money demand is equal to money supply (that's what the LM curve indicates). Box 11.1 shows how to calculate the economy's equilibrium position for some specific parameter values of the sticky-price model.



equal to aggregate demand. Along the LM Curve, the quantity of money demanded by households and businesses is equal to the money stock. Where the curves cross both the goods market and the money market are in balance.

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Aggregate Demand

Modern central banks, however, do not fix the money stock and then sit by passively watching the business cycle. So the derivation of the aggregate curve in the section above is a little distant from modern macroeconomies. Once we recognize that modern central banks play an active role in managing the macroeconomy, the analysis of aggregate demand is somewhat different. Modern central banks pay a lot of attention to the inflation rate. When the inflation rate rises, the central bank tends to increase the real interest rate to try to reduce aggregate demand and cool off inflation.

Stanford economist John Taylor, [currently on leave at the Treasury Department as Undersecretary for International Affairs](#), has a simple model of how central banks act, called the *Taylor rule*. According to the Taylor rule, the central bank has a *target* value π^* for the inflation rate, and an estimate r^* of what the normal real interest rate should be. If inflation is higher than its target value, the central bank raises the real interest rate above r^* ; Whenever inflation is lower than its target value, the central bank lowers the interest rate below r^* according to a rule:

$$r = r^* + \phi'' \times (\pi - \pi^*)$$

where the parameter ϕ'' determines how aggressively the central bank reacts to inflation.

We take the Taylor rule, the model of how the central bank acts, and substitute its expression for the determinants of the real interest rate into the IS-curve equation:

$$Y = \frac{A_0}{1 - MPE} - \frac{I_r + X_\varepsilon \varepsilon_r}{1 - MPE} \times r$$

to obtain:

$$Y = \left[\frac{A_0}{1 - MPE} - \frac{I_r + X_\varepsilon \varepsilon_r}{1 - MPE} \times r^* \right] - \frac{\phi'' \times (I_r + X_\varepsilon \varepsilon_r)}{1 - MPE} \times (\pi - \pi')$$

This equation is too complex to work with, so once again it is useful to simplify. Define Y_0 to be the level of real GDP when the real interest rate is at its long-run normal value r^* :

$$Y_0 = \frac{A_0}{1 - MPE} - \frac{I_r + X_\varepsilon \varepsilon_r}{1 - MPE} \times r^*$$

And define a new parameter ϕ' , the Greek letter “phi” with one apostrophe attached to it, to be:

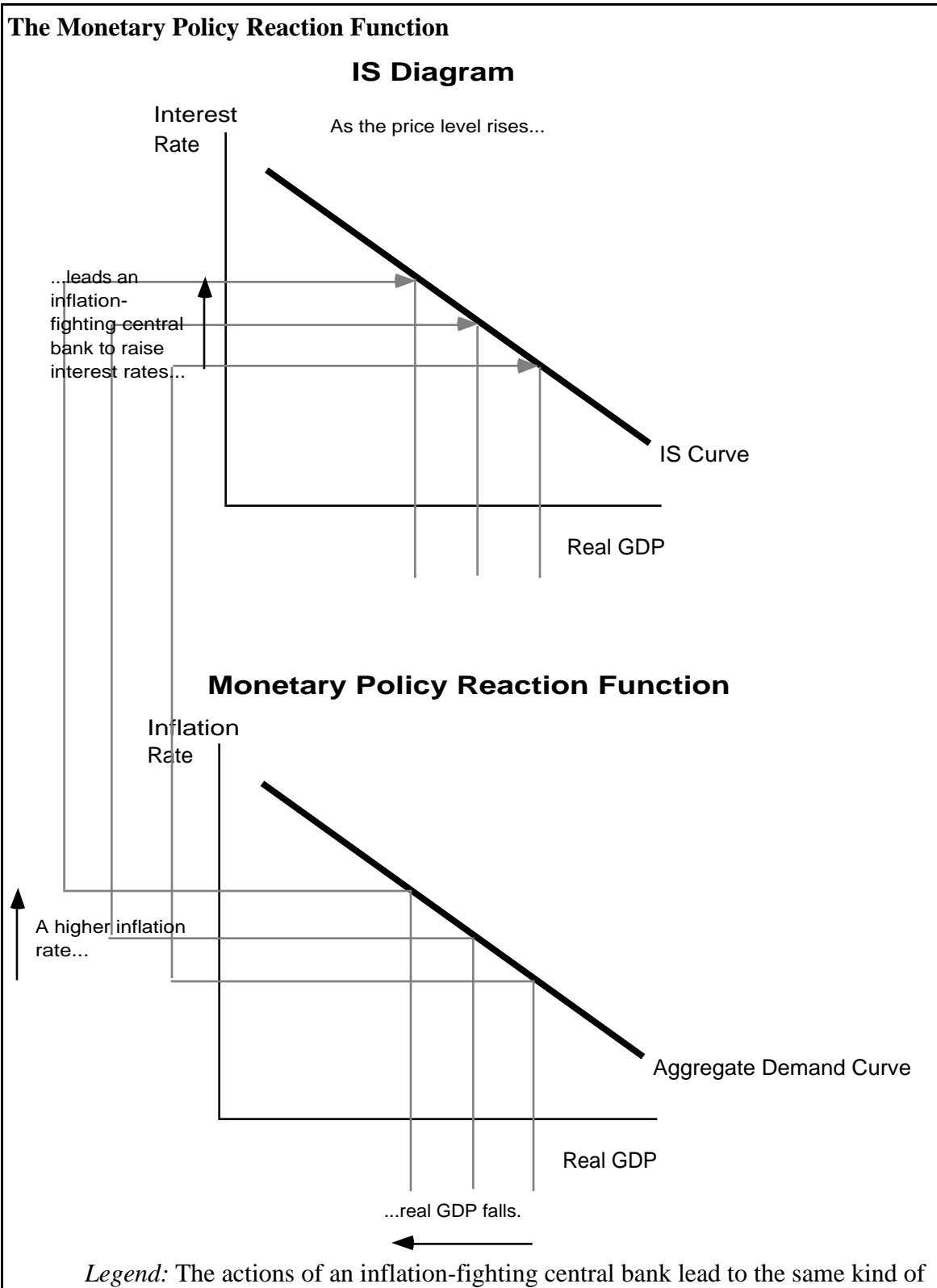
$$\phi' = \frac{\phi'' \times (I_r + X_\varepsilon \varepsilon_r)}{1 - MPE}$$

Then we can write our combination of the Taylor rule and the IS curve in the simple looking form:

$$Y = Y_0 - \phi' \times (\pi - \pi')$$

which is called the *monetary policy reaction function*, and which is shown in Figure 11.18.

This monetary policy reaction function looks akin to the aggregate demand curve of the previous section. When prices increase—in this case, when inflation is higher than the central bank wants it to be—real GDP declines. There are, however, differences. The aggregate demand curve of the previous section was a relationship between the price *level* and real GDP. This monetary policy reaction function is a relationship between the inflation rate and real GDP. The aggregate demand curve assumed that the Federal Reserve sat like a potted plant while the business cycle proceeded. The monetary policy reaction function assumes that the Federal Reserve is engaged in the economy, trying to manage it to keep inflation close to the inflation target. Last, the monetary policy reaction function is a good model of how central banks actually behave.



downward-sloping relationship between prices and output as in the previous section. But in this case it is a higher inflation rate, not a higher price level, that associated with lower real GDP.

Once again, however, this monetary policy reaction function offers a glimpse into how over time adjustments in prices and wages might carry the economy from the sticky-price equilibrium in which there is unemployment and a gap between GDP and potential output back to the flexible-price equilibrium in which real GDP is equal to potential output. If real GDP is less than potential output, inflation might fall over time, and the central bank reducing interest rates in response to low inflation would carry the economy down and to the right along the monetary policy reaction function, increasing real GDP. If real GDP is greater than potential output, inflation might rise over time, and the central bank raising interest rates in response to high inflation would carry the economy up and to the left along the aggregate demand curve, reducing real GDP.

Aggregate Supply

Inflation is an increase in the general, overall price level. An increase in the price of any one particular good--even a large increase in the price of any one particular good--is not inflation. Inflation, then, is an increase in the price of just about everything. Together, the prices of all or nearly all goods and incomes rise by approximately the same proportional amount.

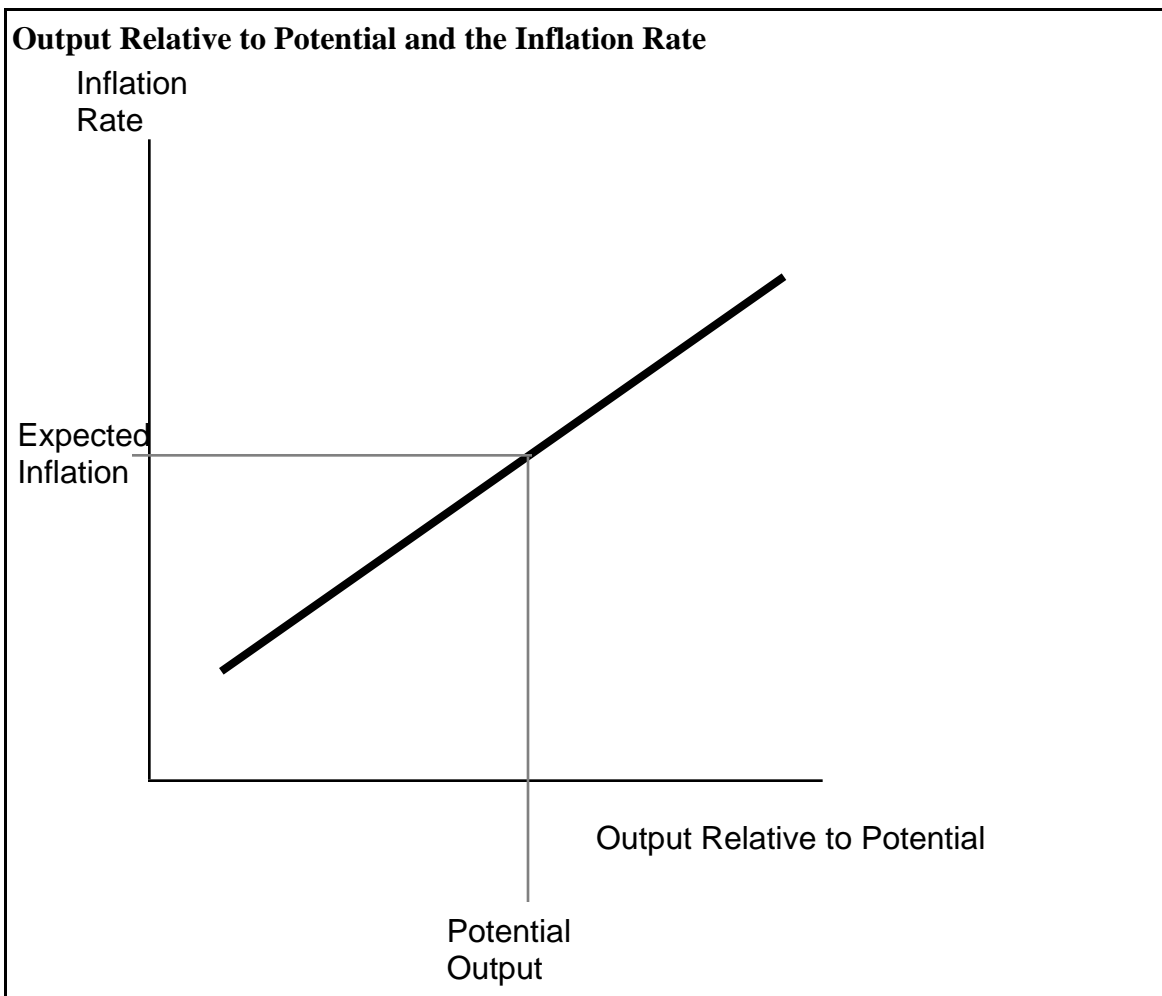
Whenever real GDP is greater than potential output, inflation is likely to be higher than people had previously anticipated. Thus inflation is likely to accelerate. Conversely, whenever the level of real GDP is below potential output, then inflation is likely to be lower than people had previously anticipated. The inflation rate is likely to fall toward zero--and perhaps prices will begin to fall in deflation.

Economists call this correlation between real GDP (relative to potential output) and the rate of inflation (relative to its previously-expected value) the short-run *aggregate supply* curve. One way to write the short-run aggregate supply curve is as:

$$\frac{Y - Y^*}{Y^*} = \theta \times \left(\frac{P - P^e}{P^e} \right)$$

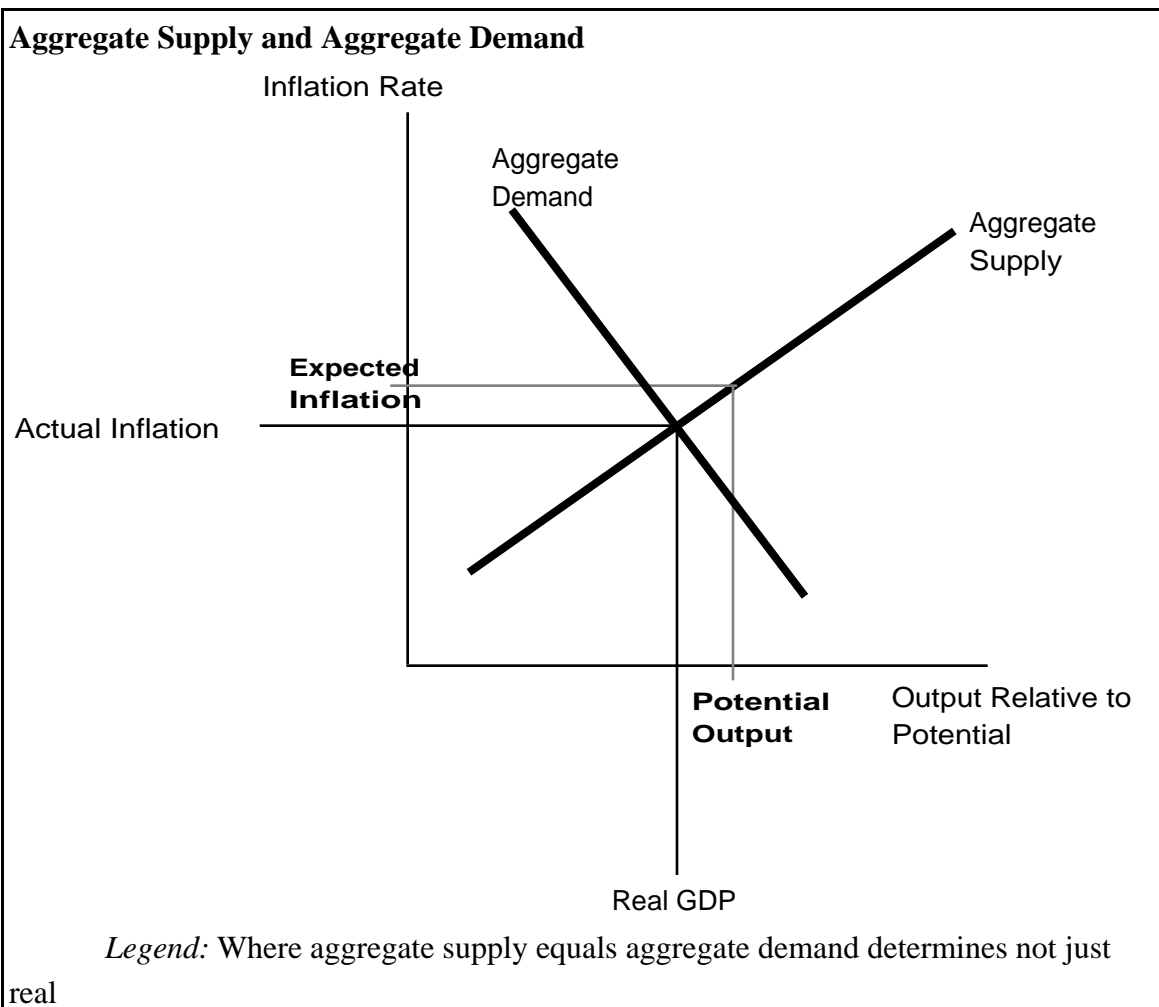
That is, the proportional deviation of real GDP Y from potential output Y^* is equal to the parameter θ (the Greek letter “theta”), which represents the slope of the short-run aggregate supply function, times the proportional deviation of the price level P from its anticipated level P^e . But since the inflation rate π is simply the proportional rate of change of the price level, we can replace the expression $((P - P^e)/P^e)$ with the actual inflation rate π minus the expected inflation rate π^e :

$$\frac{Y - Y^*}{Y^*} = \theta \times (\pi - \pi^e)$$



Legend: When production is higher than potential output, prices will be higher than businesses, consumers, and workers had anticipated--and inflation will be higher than expected inflation.

The aggregate supply curve slopes upward because a higher inflation rate calls for the more intensive use of resources and thus a higher level of production. A higher inflation rate either reduces the real money stock by raising the price level directly and thus increases the real interest rate, or induces the central bank to raise the real interest rate, and so cuts aggregate demand. Where aggregate supply and aggregate demand are equal—where the two curves cross—is the current level of real GDP and the current inflation rate.



GDP but also the price level and the inflation rate.
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Short-Run Aggregate Supply

There are many reasons why high levels of real GDP should be associated with higher inflation and a higher price level.

First, when demand for products is stronger than anticipated, firms raise their prices higher than they had previously planned. When aggregate demand is higher than potential output, demand is strong in nearly every single industry. Nearly all firms raise prices and hire more workers. Employment expands beyond its average proportion of the adult population and the unemployment rate falls below the "natural" rate of unemployment--the rate at which the rate of inflation is stable. High demand gives workers extra bargaining power, and they use it to bargain for higher wage levels than they had previously planned. Unions threaten to strike, knowing that firms will have a hard time finding replacement workers. Individuals quit, knowing they can find better jobs elsewhere. Such a high-pressure economy generates wages that rise faster than anticipated. Rapid wage growth is passed along to consumers in higher prices and accelerating inflation. Thus high real GDP generates higher inflation.

Second, when aggregate demand is higher than potential output, individual economic sectors and industries in the economy quickly reach the limits of capacity: Bottlenecks emerge. Confronted with a bottleneck--a vital item, part, or process where production cannot be increased quickly--potential purchasers bid up the price of the bottlenecked item. Since a car is useless without brakes, it is worth it for car manufacturers to pay any price for brake assemblies if they are in short supply. Such high prices signal to the market that the bottleneck industry should expand, and triggers investment that in the end boosts productive capacity. But developing bottlenecks lead to prices that increase faster than expected--thus to accelerating inflation.

To some degree the puzzle is not why high levels of real GDP (and low levels of unemployment) are associated with higher prices and inflation, but why the association is as weak as it is.