1 A Closed Economy Model[1]

1.1 National Income Accounts

The measure of aggregate output in the national income accounts is **gross domestic product**, or GDP. We can measure GDP in three different but equivalent ways:

1. From the production side: GDP equals the value of the final goods and services produced in the economy during a given period. The important word here is final. We want to count only the production of final goods, not intermediate goods.

2. Also from the production side: GDP is the sum of value added in the economy during a given period. The value added by a firm is defined as the value of its production minus the value of the intermediate goods used in production.

3. From the income side: GDP is the sum of incomes in the economy during a given period.

The three ways to measure GDP give the same number.[2] We use Y to refer to GDP. Depending on the context, we refer to Y as output, production, value added, or income.

1.2 The Market for Goods and Services

Goods and Services

The economy produces many goods and services. We are only interested in aggregate production, so we construct a representative basket of goods and services and treat that basket as the single aggregate good in the economy. Output Y is the number of baskets of goods produced.

The Price Level

The price in dollars of one basket of goods is denoted by P. We refer to P as **the price level**.

[1] This document based on Blanchard (2024).
[2] We ignore measurement error.

Equilibrium in the Goods Market

Demand is given by:

$$Z \equiv C + I + G, \tag{1.1}$$

where Z is demand; C is aggregate consumption; I is investment in physical capital; and G is government spending.

Consumption C is an increasing function of **disposable income** $Y_D \equiv Y - T$:

$$C = C(\underset{(+)}{Y_D}), \tag{1.2}$$

where Y is income and T are taxes. The plus sign below Y_D signifies that the function $C(Y_D)$ is increasing in Y_D. We note that we have abused notation in equation (1.2): the symbol C on the left-hand side is a number while the symbol C on the right-hand side is a function. We will use the same abuse of notation throughout.

Investment I is a decreasing function of the **real interest rate,** r and an increasing function of income Y:

$$I = I(\underset{(-)}{r}, \underset{(+)}{Y}).$$

From now on, we ignore the dependence of investment on Y and simply write:

$$I = I(\underset{(-)}{r}).$$

We highlight that investment I is *not* investment in financial assets. It is investment in *physical capital* such as machines and buildings. Similarly, when we use the word capital in this context, we always mean *physical* capital, not *financial* capital (money invested in some financial assets).

Using $C = C(Y - T)$ and $I = I(r)$ in equation (1.1) gives:

$$Z = C(Y - T) + I(r) + G, \tag{1.3}$$

so Z is an increasing function of Y and G and a decreasing function of T and r.

The **supply of goods** is simply domestic production Y.

The equilibrium condition in the goods market is that the supply goods Y equals the demand for goods Z. We can write this as:

$$\underbrace{Y}_{\text{supply}} = \underbrace{C(Y-T)+I(r)+G}_{\text{demand}}. \tag{1.4}$$

We think of this equation as determining the equilibrium level of Y given T and r and G.

Table 1.1 lists the exogenous variables of the model in alphabetical order. Table 1.2 lists the endogenous variables in alphabetical order, together with the equations that determine them.

Goods market: exogenous variables

Variable	Description
G	government spending
r	real interest rate
T	taxes

Table 1.1

Goods market: endogenous variables and equations

Variable	Description	Equation	Type of equation
C	consumption	$C = C(\underset{(+)}{Y_D})$	Behavioral
I	investment	$I = I(\underset{(-)}{r})$	Behavioral
Y	income, production	$Y = C + I + G$	Equilibrium condition
Y_D	disposable income	$Y_D \equiv Y - T$	Identity
Z	demand for goods	$Z \equiv C + I + G$	Identity

Table 1.2

Example 1.1. We use the following functions:

$$C(Y-T) = 1 + \frac{1}{2}(Y-T), \tag{1.5}$$

$$I(r) = 2 - r. \tag{1.6}$$

Our goal is to solve the model, that is, express all endogenous variables in terms of exogenous variables only.

Plugging equations (1.5) and (1.6) into equation (1.4) gives:

$$Y = \underbrace{1 + \frac{1}{2}(Y-T)}_{C(Y-T)} + \underbrace{2-r}_{I(r)} + G.$$

Solving for Y gives Y in terms of exogenous variables:

$$Y = \frac{1}{1-\frac{1}{2}}\left(1 + 2 - \frac{1}{2}T - r + G\right) = 2\left(3 - \frac{1}{2}T - r + G\right). \tag{1.7}$$

The rest of the endogenous variables can be found by plugging in equation (1.7) into the equations from Table 1.2. □

Saving

Private saving, denoted by S^p is defined as the part of disposable income that is saved rather than consumed:

$$S^p \equiv Y_D - C.$$

Government saving, denoted S^g is defined similarly to private saving. The government's "income" is its tax revenue, T while its "consumption" is government spending:

$$S^g \equiv T - G.$$

National saving, sometimes called aggregate saving or just **saving**, is denoted by S and defined by:

$$S \equiv S^p + S^g.$$

The two types of saving we have defined, private and government, add up to national saving, denoted by S

$$S = S^p + S^g.$$

Using equation (1.4) and the equations for saving above, we get

$$I = S. \tag{1.8}$$

In a closed economy investment is always equal to saving. Equation (1.8) is where the name "IS" of the IS curve comes from.

The government's **budget deficit** is defined as $G - T$ which also equals the negative of government saving $G - T = -S^g$. Using the equations for saving given above, equation (1.8) can be written as:

$$S^p = I + (G - T). \tag{1.9}$$

Equation (1.9) states that private saving can take one of two forms: investment in physical capital I and purchases of government debt $G - T$. Investing in physical capital is saving because it involves foregoing some consumption today (equal to the amount invested) in order to have more consumption in the future (equal to the additional consumption that can be produced in the future with the additional physical capital).

When the budget deficit is positive the government is spending more than its income because $G > T$. Where does it get the difference? It gets it by borrowing from the private sector using government bonds. The private sector purchases the government bonds today, and the government repays bondholders in the future. Thus, budget deficits act as saving for the private sector, who consumes less today in order to have resources to buy government bonds, in exchange for higher future consumption when bonds pay out.

1.3 The Money Market

Real money demand is denoted by M^d/P. We assume the real money demand is given by:

$$\frac{M^d}{P} = \mathcal{L}(\underset{(-)}{i}, \underset{(+)}{Y}),$$

where $\mathcal{L}$ is a function that is decreasing in the **nominal interest rate** i (indicated by the minus sign below the i), and increasing in income Y (indicated by the plus sign under the Y). The **real money supply** is denoted by M^s/P.

The equilibrium level of real money, also called the **real money stock**, or the **real money balance**, is denoted by M/P. The real money stock is determined by the equilibrium condition in the money market that real money supply is equal to real money demand, $M^s/P = M^d/P$:

$$\frac{M^s}{P} = \mathcal{L}(i, Y). \tag{1.10}$$

Two models for the money market

We consider two different models for the money market. The money demand function $M^d/P = \mathcal{L}(i, Y)$ and the equilibrium condition $M^s/P = M^d/P$ are the same in both models. What differs is how the central bank behaves. Table 1.3 summarizes the two models, which are presented in more detail next.

Money market: two models

Model	Exogenous variable	Endogenous variable	Money market equilibrium
1	M^s	i	$M^s/P = \mathcal{L}(i, Y)$ determines i
2	i	M^s	$M^s/P = \mathcal{L}(i, Y)$ determines M^s/P

Table 1.3

Model 1: Exogenous money supply In this model, we assume that the real money supply M^s/P is exogenous while the nominal interest rate i is endogenous. We interpret this model as the central bank picking the money supply. The equilibrium condition $M^s/P = M^d/P$ determines the endogenous money demand and the behavioral equation $M^d/P = \mathcal{L}(i, Y)$ then determines the nominal interest rate.

This model is sometimes called the “old LM” or “classical LM” model. The idea is that the central bank's defining property is the ability to "print money". When the central bank prints money and uses it to buy bonds, money supply increases. In equilibrium, money demand must equal money supply, so money demand must increase. For money demand to increase, the nominal interest rate must go down so that people find bonds less attractive, prompting them to sell bonds in exchange for money. In the new equilibrium, the central bank holds more bonds, and the private sector holds more money.

Table 1.4 lists the exogenous variables for model 1. Table 1.5 lists the endogenous variables for model 1, together with the equations that determine them.

Money market Model 1: exogenous variables

Variable	Description
M^s/P	real money supply
Y	income

Table 1.4

Money market Model 1: endogenous variables and equations

Variable	Description	Equation	Type of equation
M^d/P	real money demand	$M^d/P = \mathcal{L}(\underset{(-)}{i}, \underset{(+)}{Y})$	Behavioral
i	nominal interest rate	$M^s/P = M^d/P$	Equilibrium condition

Table 1.5

Model 2: Exogenous nominal interest rate This model assumes that the nominal interest rate i is the exogenous variable, while the real money supply is determined endogenously. Now, instead of picking the real money supply, the central bank picks the nominal interest. Given the exogenous nominal interest rate i and the exogenous level of income Y; the real money demand is determined by $M^d/P = \mathcal{L}(i, Y)$. The real money supply is then determined by the equilibrium condition $M^s/P = M^d/P$.

This model is sometimes called the "new LM" model. Just as in Model 1, this model also takes into account the central bank's ability to print money. However, it also recognizes that the central bank has a monopoly on money creation, which allows it to pick not only the quantity of money (the money supply) but also the price of money (the nominal interest rate). Operationally, the way that the central bank "picks" the nominal interest rate is by allowing people to deposit money in central bank accounts—in the same way that you deposit money in your own checking account at your bank—that earn the interest rate chosen by the central bank. The central bank can pay any interest it chooses, since it can always print any amount of money needed to do so.

Table 1.6 lists the exogenous variables for model 2. Table 1.7 lists the endogenous variables for model 2, together with the equations that determine them.

Money market Model 2: exogenous variables

Variable	Description
i	nominal interest rate
P	price level
Y	income

Table 1.6

Money market Model 2: endogenous variables and equations

Variable	Description	Equation	Type of equation
M^d/P	real money demand	$M^d/P = \mathcal{L}(\underset{(-)}{i}, \underset{(+)}{Y})$	Behavioral
M^s/P	real money supply	$M^s/P = M^d/P$	Equilibrium condition

Table 1.7

Example 1.2. We use the following function for $\mathcal{L}$:

$$\mathcal{L}(i, Y) = 2 + Y - 0.2i. \tag{1.11}$$

The goal is to solve both money market models, that is, to express all the endogenous variables in terms of exogenous variables only.

Model 1 The equilibrium condition for the money market is that real money demand M^d/P equals real money supply M^s/P. Since real money supply is exogenous, and $M^d/P = M^s/P$ already expresses money demand only as a function of exogenous variables.

Now we find i in terms of exogenous variables. Plugging equation (1.11) into equation (1.10) gives:

$$\frac{M^s}{P} = 2 + Y - 0.2i.$$

Solving for i gives:

$$i = 10 - 5\frac{M^s}{P} + 5Y. \tag{1.12}$$

Model 2 Now the nominal interest rate is exogenous. Real money demand in terms of exogenous variables is immediately given by $M^d/P = \mathcal{L}(i, Y) = 2 + Y - 0.2i$. Equating this real money demand to real money supply gives

$$\frac{M^s}{P} = 2 + Y - 0.2i,$$

which expresses the real money supply as a function of exogenous variables only. □

1.4 The IS-LM Model

The Expected Price Level

The **expected price level** denoted by P^e is the price level that we expect will prevail in some future period. You can think of it as our best guess of what the actual price level will be once we get to that future period. For example, let's use t to denote the current period (the present). In the current period, the price level is P_t. This current price level P_t is known at time t since we construct it by looking at currently available prices. The next period $t + 1$ is in the future. The actual or **realized** price level P_{t+1} that will prevail at $t + 1$ is not known at t. The future price level P_{t+1} will only be known at $t + 1$. However, in the present (at time t), we do have some expectations of what P_{t+1} will be, which is the expected price level P^e_{t+1}. We form these expectations at time t. Therefore, unlike the realized future price level P_{t+1}; the future expected price level is known in the present, at time t.

1.5 Inflation

Inflation denoted by π is the percentage change in the price level P over some period:

$$\pi_t \equiv \frac{P_t}{P_{t-1}} - 1. \tag{1.13}$$

For example, if the period t is the year 2025 and the period $t-1$ is the year 2024; π_t is the inflation rate in 2025, the percentage change in the price level between 2024 and 2025.

Expected inflation denoted by π^e is the expected percentage change in the price level over some period that is, at least in part, in the future. For example, if t is the current period, expected inflation for the period $t+1$ is:

$$\pi^e_{t+1} = \frac{P^e_{t+1}}{P_t} - 1, \tag{1.14}$$

and expected inflation for $t+2$ is:

$$\pi^e_{t+2} = \frac{P^e_{t+2}}{P^e_{t+1}} - 1.$$

We follow the convention that whenever we omit the time index subscript for a variable, then that variable corresponds to the current period. For example, if t is the current period, then π and π_t both denote inflation in the current period. We also follow the convention that whenever we omit the time index subscript for the expectation of a variable, the expectation is about the value of the variable in the next period. For example, if t is the current period, then π^e is the same as π^e_{t+1}. When necessary, we disambiguate by just stating in words what period is the current one, and what future period expectations refer to.

The Fisher Equation

The real interest rate r and the nominal interest rate i are related by:

$$r = i - \pi^e, \tag{1.15}$$

where π^e is expected inflation. Equation (1.15) is called the **Fisher equation**.

The IS Curve

Plugging the Fisher equation (1.15) into the equilibrium condition for the goods market in equation (1.4) gives the **IS relation**:

$$Y = C(Y - T) + I(i - \pi^e) + G. \tag{1.16}$$

The **IS curve** is the set of points (Y, i) that satisfy equation (1.16) when we plot them with values of Y in the horizontal axis and values of i in the vertical axis. Figure 1.1 shows a generic IS curve. The IS curve is always downward sloping. Despite its name, the IS curve is not necessarily curve and can certainly be a (downward sloping) straight line.

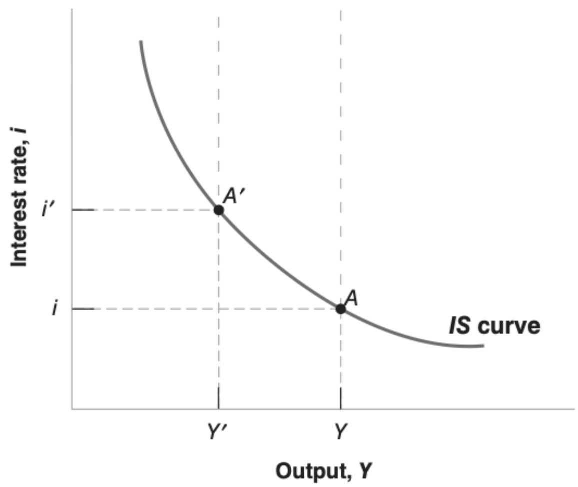


Figure 1.1: The IS curve

Example 1.3. The goal is to derive the IS curve. Using equation (1.7) and the Fisher equation, we get:

$$Y = 2\left(3 - \frac{1}{2}T - i + \pi^e + G\right).$$

Solving for i gives:

$$i = \underbrace{3 - \frac{1}{2}T + \pi^e + G}_{\text{intercept}} + \underbrace{\left(-\frac{1}{2}\right)}_{\text{slope}} Y, \tag{1.17}$$

which we recognize as the equation for a line with intercept $3 - \frac{1}{2}T + \pi^e + G$ and slope $-1/2$. The slope of this line is negative. We note that the only reason to solve for i explicitly is to make plotting the IS curve easier. We still think of the IS as determining Y for given values of i and of all other exogenous variables. When T or π^e or G change, the intercept of the IS changes. In this case, we say the IS shifts. If the intercept goes down, the IS shifts to the left; if the intercept goes up, the IS shifts to the right. We say the IS shifts left and right, rather than up and down, because we are thinking of how Y changes for given values of i (and a given value of i is a horizontal line, so higher or lower Y for that given value of i is the same as moving left or right along that horizontal line). □

The LM Curve

Equation (1.10) is called the **LM relation** (where the L is for "liquidity" and the M is for "money").

The **LM curve** is the set of points (Y, i) that satisfy equation (1.10) when we plot them with values of Y in the horizontal axis and values of i in the vertical axis. Despite its name, the LM curve is not necessarily curve and can certainly be a straight line.

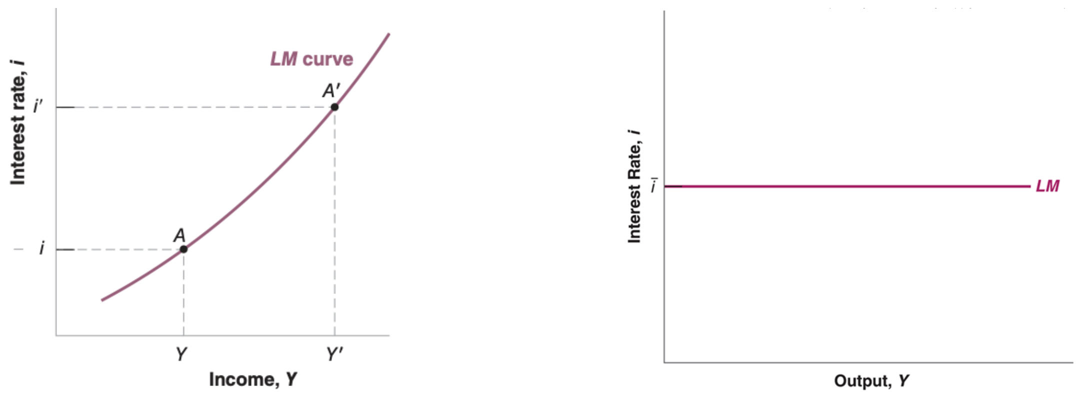
In model 1, the LM curve is upward sloping because an increase in Y increases money demand and, with M^s exogenous, equilibrium requires a higher i. Figure 1.2(a) shows a generic upward sloping model 1 LM curve.

In model 2, the LM curve is a horizontal line because i is exogenous, and hence does not change with Y. Figure 1.2(b) shows a model 2 flat LM curve.

Example 1.4. The goal is to derive the LM curve.

Model 1 If we use the function L from equation (1.11), we already found in the last section that:

$$i = \underbrace{10 - 5\frac{M^s}{P}}_{\text{intercept}} + \underbrace{5}_{\text{slope}} Y, \tag{1.18}$$



(a) Model 1: Upward sloping (b) Model 2: Flat

Figure 1.2: The LM curve

which we recognize as the equation for a line with intercept $(10 - 5M^s/P)$ and slope 5. When any of M^s or P change, the intercept of the LM changes. In this case, we say the LM shifts. If the intercept goes up, the LM shifts up; if the intercept goes down, the LM shifts down. We say the LM shifts up and down, rather than left and right, because we are thinking of how i changes for given values of Y.

Model 2 The equation for the LM curve is

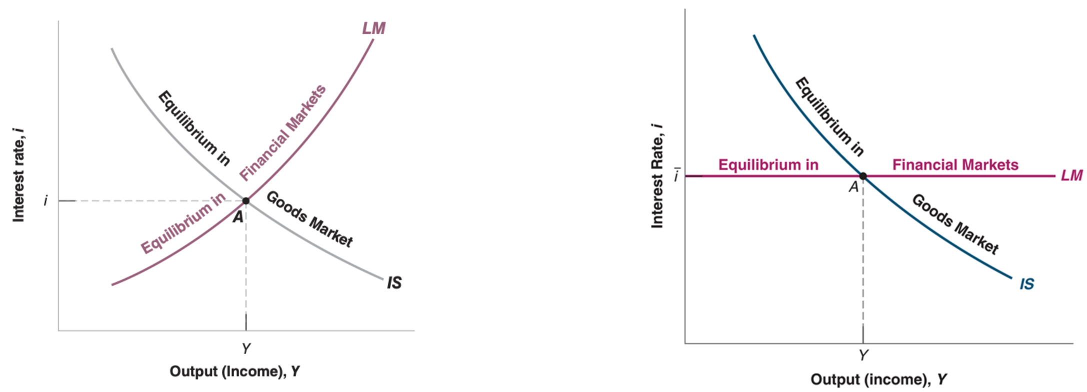
$$i = \bar{\imath}, \tag{1.19}$$

where $\bar{\imath}$ is the exogenous level of the nominal interest rate. □

<u>Combining IS and LM</u>

Points in the IS curve are combinations of Y and i that are consistent with equilibrium in the goods market. Points in the LM curve are combinations of Y and i that are consistent with equilibrium in the money market. The unique pair (Y, i) at the intersection of the IS and LM curves are therefore the values of Y and i that are consistent with equilibria in both the goods and money markets. Figure 1.3(a) shows the IS and LM curves together in one graph for model 1, and Figure 1.3(b) shows the same for model 2.

Just as we thought of the IS as determining Y given i and of the LM as determining i given Y. We now think of Y and i as being jointly determined by the IS and the LM—that is, by



(a) Model 1 (b) Model 2

Figure 1.3: IS-LM equilibrium

equilibrium in both the goods and money markets.

Table 1.8 lists the exogenous variables of the IS-LM model for model 1 in Table 1.3. Table 1.9 lists the endogenous variables for model 1, together with the equations that determine them. Tables 1.10 and 1.11 show the same but for model 2.

IS-LM Model 1: exogenous variables

Variable	Description
G	government spending
M^s/P	real money supply
T	taxes
π^e	expected inflation

Table 1.8

Example 1.5. **Model 1.** We start with the IS from equation (1.17) and the LM from equation (1.18):

$$\text{IS curve: } i = 3 - \frac{1}{2}T + \pi^e + G - \frac{1}{2}Y, \tag{1.20}$$

$$\text{LM curve: } i = 10 - 5\frac{M^s}{P} + 5Y. \tag{1.21}$$

IS-LM Model 1: endogenous variables and equations

Variable	Description	Equation	Type of equation
C	consumption	$C = C(\underset{(+)}{Y - T})$	Behavioral
i	nominal interest rate	$M^s/P = M^d/P$	Equilibrium condition
I	investment	$I = I(\underset{(-)}{i - \pi^e})$	Behavioral
M^d/P	real money demand	$M^d/P = \mathcal{L}(\underset{(-)}{i}, \underset{(+)}{Y})$	Behavioral
r	real interest rate	$r = i - \pi^e$	Identity
Y	income, production	$Y = C + I + G$	Equilibrium condition

Table 1.9

IS-LM Model 2: exogenous variables

Variable	Description
G	government spending
M^s/P	real money supply
T	taxes
π^e	expected inflation

Table 1.10

IS-LM Model 2: endogenous variables and equations

Variable	Description	Equation	Type of equation
C	consumption	$C = C(\underset{(+)}{Y - T})$	Behavioral
i	nominal interest rate	$M^s/P = M^d/P$	Equilibrium condition
I	investment	$I = I(\underset{(-)}{i - \pi^e})$	Behavioral
M^d/P	real money demand	$M^d/P = \mathcal{L}(\underset{(-)}{i}, \underset{(+)}{Y})$	Behavioral
r	real interest rate	$r = i - \pi^e$	Identity
Y	income, production	$Y = C + I + G$	Equilibrium condition

Table 1.11

We now find the equilibrium values of i and Y: that is, the values of i and Y at the intersection of the IS and the LM curves. First, equate the right-hand side of equation (1.20) to the right hand side of equation (1.21):

$$3 - \frac{1}{2}T + \pi^e + G - \frac{1}{2}Y = 10 - 5\frac{M^s}{P} + 5Y.$$

Second, solve for Y to get:

$$Y = -\frac{14}{11} + \frac{10}{11}\frac{M^s}{P} - \frac{1}{11}T + \frac{2}{11}\pi^e + \frac{2}{11}G. \tag{1.22}$$

Last, plug Y into equation (1.20) or equation (1.21) and re-arrange to get the equilibrium value of i:

$$i = \frac{5}{11}\left(8 - \frac{M^s}{P} - T + 2\pi^e + 2G\right). \tag{1.23}$$

Model 2. The IS is the same as in model 1. The LM given in equation (1.19):

$$\text{IS curve: } i = 3 - \frac{1}{2}T + \pi^e + G - \frac{1}{2}Y, \tag{1.24}$$

$$\text{LM curve: } i = \bar{\imath}. \tag{1.25}$$

The equilibrium nominal interest rate is already expressed in terms of the exogenous variable $\bar{\imath}$. Plugging $i = \bar{\imath}$ into the IS curve and solving for Y gives Y in terms of exogenous variables only:

$$Y = 6 - T + 2\pi^e + 2G - 2i.$$

□

1.6 The Labor Market

Unemployment

Let L be the economy's **workforce** or **labor force** and N be the number of people in the workforce who are employed. Then the **unemployment rate** is defined by:

$$u \equiv \frac{L - N}{L}. \tag{1.26}$$

Production Function

The only factor of production is labor[3]. The aggregate **production function** is:

$$Y = N. \tag{1.27}$$

Price-setting

Since the only factor of production is labor, the nominal marginal cost for firms producing goods and services is the **nominal wage** W. If markets were perfectly competitive, firms would set the price P equal to marginal cost W and make zero profits. In the real world, there is market power and firms tend to set prices above marginal cost. We capture this idea by the following **price-setting relation**:

$$P = (1 + m)W, \tag{1.28}$$

where m is the **markup**. This price setting relation says that firms set the price of the goods that they sell to always get a profit rate of m. To see that the markup m is equal to the

[3] This is not as restrictive as it sounds: we are assuming that labor is the only factor of production that adjusts within the time horizons we are considering and ignoring the other factors because they remain unchanged.

profit rate, start by defining the profit rate by

$$\frac{\text{profit}}{\text{cost of production}}.$$

Each unit sold costs W to produce and sells for P. The profit per unit is $P - W$. Hence the profit rate for one unit is

$$\frac{P-W}{W} = \frac{(1+m)W - W}{W} = m.$$

Selling more units raises profits (the numerator) and costs of production (the denominator) proportionally, leaving the profit *rate* unchanged.

There are many factors that can affect the markup, including:

- The cost of production. If the cost of production increases, producers may pass some or all of the cost increase to consumers in the form of higher markups. An important example is the price of oil. When the price of oil increases, costs of production increase even keeping the nominal wage constant.
- Monopoly power. If a firm's monopoly power increases, it can increase the price even keeping labor and other production costs unchanged. Many different channels can influence the degree of monopoly power. For example, making it more difficult for new firms to enter markets increases the monopoly power of incumbent firms. More stringent anti-trust regulation, in contrast, should reduce monopoly power.

Wage-setting

Wages are set according to the following **wage-setting relation**:

$$W = P^e F(\underset{(-)}{u}, \underset{(+)}{z}). \tag{1.29}$$

In this wage setting relation the variable P^e is the expected price level (the price level we expect to hold in the future). The variable u is the unemployment rate. The variable z is a catch-all variable that captures all other elements that influence wages other than P^e and u. The function F is decreasing in u and increasing in z. That the function F is increasing in z is just a convention. There are therefore three elements that determine the wage are

P^e and u and z. We briefly explain why they matter for wages:

- Expected price level. The expected price level P^e is an important determinant of the nominal wage because what people and firms really care about is not the nominal wage but the real wage. Workers value money because of the goods and services they can buy with it, not for its own sake. If my nominal wage is $1,000,000 but the price of one apple is $10,000,000, I am not so happy with my gigantic nominal wage. We use P^e rather than P because after wages are set, they usually remain fixed (or close to fixed) for some time, with wage contracts renegotiated only infrequently. So the relevant price level is the one that will prevail between now and the future time when the wage is renegotiated rather than just the current price level. goods and services that one can afford after W is set are better captured by W/P^e.

- Unemployment. The wage setting equation says that when unemployment is high, wages are low. The reasoning is that when unemployment is high, employers have more bargaining power, since someone seeking a job must compete with a larger pool of unemployed workers. Conversely, when the unemployment rate is low, it is workers who have higher bargaining power, as many firms have to compete to hire among the smaller pool of unemployed people. A conceptual weakness of the unemployment rate as an indicator of the relative bargaining power of workers and firms is that it is based solely on information about the status of workers (employed or unemployed) and does not directly incorporate information on the hiring needs of employers. But the labor market involves costly search by employers for workers as well as by workers for jobs. In principle at least, a given unemployment rate could be consistent with either a strong labor market, with upward pressure on wages, or a weak labor market and low wage pressure, depending on whether job openings are plentiful or scarce. An alternative indicator of bargaining power that takes into account the state of workers and of firms is the ratio of the **vacancy rate** (job listings reported by employers divided by the labor force) denoted by v to the unemployment rate u. The ratio v/u is called **labor market tightness**. However, the notion of labor market tightness is more general. In periods when firms want to hire a lot of workers, unemployment is relatively low, there is upward pressure on wages and many unfilled job vacancies, we say the labor market is **tight**. Conversely, when there are a lot of people looking for jobs, firms are not looking to hire as much, vacancies are filled quickly, and there is a downward pressure on wages, we say that the labor market is **slack**. Thus, conceptually, what we would really like to include in the wage-setting equation (1.29) is a good measure of overall labor market tightness rather than simply unemployment. Using v/u is one good option.

- Other factors. The other factors are defined so that the convention that F is increasing in z applies. Examples of factors that enter z are:
  - Unemployment insurance, the payment of unemployment benefits to workers who lose their jobs. If u and P^e are given then higher unemployment benefits make unemployment less painful, so employers must offer a higher wage to attract workers (in this case higher unemployment benefits are associated with a higher z).
  - The minimum wage. An increase in the minimum wage may increase not only the minimum wage itself, but also wages just above the minimum wage, leading to an increase in the economy-wide average wage W at a given unemployment rate.
  - Employment protection laws, which makes it more expensive for firms to lay off workers. Such a change is likely to increase the bargaining power of workers covered by this protection (laying them off and hiring other workers is now more costly for firms), increasing the wage for a given unemployment rate.
  - Worker's productivity. If workers can produce more output in the same amount of time, their labor is more valuable, which allows them to bid for higher wages.

Table 1.12 lists the exogenous variables of the labor market model. Table 1.13 lists the endogenous variables together with the equations that determine them.

Labor market: exogenous variables

Variable	Description
L	labor force
m	markup
P^e	expected price level
Y	production
z	catch-all variable for factors that affect the nominal wage

Table 1.12

Labor market: endogenous variables and equations

Variable	Description	Equation	Type of equation
N	employment	$Y = N$	Behavioral
P	price level	$P = (1 + m)W$	Behavioral
u	unemployment rate	$u = \frac{L-N}{L}$	Identity
W	nominal wage	$W = P^e F(\underset{(-)}{u}, \underset{(+)}{z})$	Behavioral

Table 1.13

Example 1.6. One example for the function F is:

$$F(u,z) = 1 - \frac{1}{4}u + z. \tag{1.30}$$

The goal is to solve the model.

The production function (1.27) immediately gives N as a function of the exogenous Y. Combining equations (1.26) and (1.27) gives u in terms of exogenous variables only:

$$u = \frac{L-N}{L} = 1 - \frac{N}{L} = 1 - \frac{Y}{L}. \tag{1.31}$$

Plugging equation (1.31) into (1.30) gives:

$$F(Y,z) = 1 - \frac{1}{4}\left(1 - \frac{Y}{L}\right) + z. \tag{1.32}$$

Plugging equation (1.32) into equation (1.29) gives:

$$\frac{W}{P^e} = \frac{3}{4} + \frac{1}{4}\frac{Y}{L} + z.$$

Solving for W we get W in terms of exogenous variables only:

$$W = \left(\frac{3}{4} + \frac{1}{4}\frac{Y}{L} + z\right)P^e.$$

Last, plugging into equation (1.28) gives P in terms of exogenous variables only:

$$P = (1+m)\left(\frac{3}{4} + \frac{1}{4}\frac{Y}{L} + z\right)P^e.$$

□

1.7 The Phillips Curve

Aggregate Supply

Combining (1.28) and (1.29) gives:

$$P = (1+m)P^e F(u,z). \tag{1.33}$$

We can re-write equation (1.33) as a relation between P and Y instead of P and u. As in the last example, combining equations (1.26) and (1.27) gives equation (1.31). Equation (1.31) says that lower unemployment is associated with higher output because it takes more employed people to produce more output. Using (1.31) in (1.33) gives:

$$P = (1+m)P^e F\left(1 - \frac{Y}{L}, z\right). \tag{1.34}$$

Equation (1.34) is called the **aggregate supply relation**, or AS relation for short. We think of the AS relation as determining the price level P for a given value of Y.

Figure 1.4 shows a generic AS curve. Just like all the other "curves", the AS curve can be a straight line. The AS curve is always upward sloping. Changes in the markup m and the expected price level P^e and the labor force L and the catch-all variable z shift the AS curve up and down.

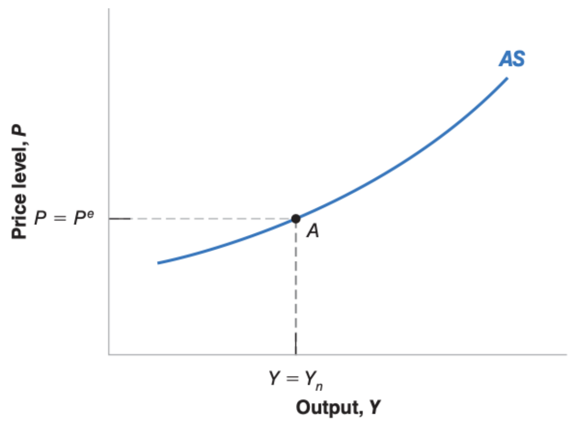


Figure 1.4: The AS curve

From now on, we assume a specific functional form for the function F:

$$F(u, z) = 1 - \alpha u + z, \tag{1.35}$$

where α is a positive parameter (a positive number taken as given). Plugging equation (1.31) into (1.35) gives:

$$F\left(1 - \frac{Y}{L}, z\right) = 1 - \alpha\left(1 - \frac{Y}{L}\right) + z. \tag{1.36}$$

Using equation (1.36) in equation (1.34) and re-arranging gives the AS curve:

$$P = \underbrace{(1+m)P^e(1 - \alpha + z)}_{\text{intercept}} + \underbrace{\frac{(1+m)P^e\alpha}{L}}_{\text{slope}} Y, \tag{1.37}$$

which we recognize as the equation of a line with intercept $(1+m)P^e(1-\alpha+z)$ and slope $(1+m)P^e\alpha/L$. When any of m or P^e or α or z change, the intercept of the AS curve changes and the AS shifts up and down.

Linearization

The definitions of inflation and expected inflation in equations (1.13) and (1.14) imply that

$$P_t = (1+\pi_t)P_{t-1},$$
$$P_t^e = (1+\pi_t^e)P_{t-1}.$$

Adding time subscripts to equation (1.37) and plugging in the last two equations gives:

$$1+\pi_t = (1+m)(1+\pi_t^e)\left(1+z-\alpha+\frac{\alpha}{L}Y_t\right). \tag{1.38}$$

Distributing the product and subtracting 1 from both sides, we get

$$\pi_t = \pi_t^e + m + z - \alpha\left(1-\frac{Y_t}{L}\right) + \text{second order terms}, \tag{1.39}$$

where the second order terms are terms with cross-products of π_t^e and m and $u_t = 1-Y_t/L$. Since π_t^e and m and u_t are relatively small numbers (say, between 0 and 0.2), their cross products are small enough to be ignored and still get a good approximation. Ignoring these second order terms gives the **Phillips curve**:

$$\pi_t = \pi_t^e + m + z - \alpha + \frac{\alpha}{L}Y_t. \tag{1.40}$$

Figure 1.5 shows a generic Phillips curve (PC for short), where the vertical axis plots $\pi_t - \pi_t^e$ and the horizontal axis plots Y_t. Just like all the other "curves", the PC curve can be a straight line. The PC curve is always upward sloping. The variables π_t^e and m and z and α shift the PC up and down, while α and L change the slope of the PC.

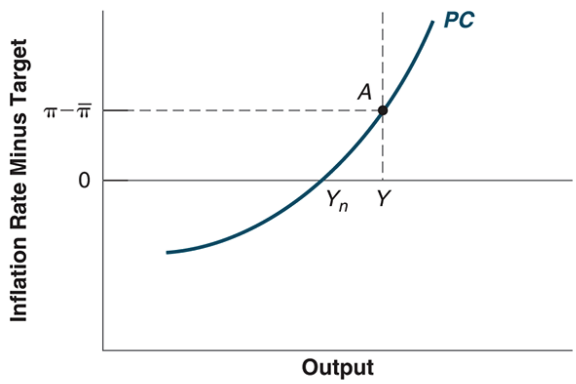


Figure 1.5: The Phillips curve

1.8 IS-LM-PC Model

The IS-LM-PC model combines equilibrium in the goods market (the IS relation), equilibrium in the money market (the LM relation), and equilibrium in the labor market (the Phillips curve, PC).

The model

Adding time subscripts, the IS relation in (1.16) becomes

$$Y_t = C(Y_t - T_t) + I(i_t - \pi_t^e) + G_t, \tag{1.41}$$

where we have used the Fisher equation (1.15) to write the real interest rate as $r_t = i_t - \pi_t^e$.

The LM relation in (1.10) with time subscripts becomes

$$\frac{M_t^s}{P_t} = \mathcal{L}(i_t, Y_t). \tag{1.42}$$

The PC in (1.40) remains unchanged.

Together with the definition of inflation in (1.13), equations (1.41), (1.42), and (1.40) determine the joint behavior of output Y_t and the nominal interest rate i_t and inflation π_t over time. Given an initial price level, the path of inflation can be used to infer the path of the price level P_t.

The natural rate of unemployment and potential output

The **natural rate of unemployment** denoted u^n is defined as the unemployment rate when inflation equals expected inflation, $\pi_t = \pi_t^e$. From (1.40) with $\pi_t = \pi_t^e$ we get

$$u^n \equiv \frac{m+z}{\alpha}. \tag{1.43}$$

The level of output when $\pi_t = \pi_t^e$ is called **potential output**, and is given by

$$Y^n \equiv L(1-u^n) = L\left(1 - \frac{m+z}{\alpha}\right). \tag{1.44}$$

The difference $u_t - u^n$ is called the **unemployment gap** and $Y_t - Y^n$ is called the **output gap**.

Using equations (1.43) and (1.44), we can rewrite the Phillips curve in gap form:

$$\pi_t - \pi_t^e = -\alpha(u_t - u^n), \tag{1.45}$$

or, using the output gap,

$$\pi_t - \pi_t^e = \frac{\alpha}{L}(Y_t - Y^n). \tag{1.46}$$

Equations (1.45) and (1.46) say that unemployment below its natural level and output above potential are associated with inflation above expected inflation.

Expected inflation

Thus far, expected inflation has been taken as exogenous. A behavioral equation that makes expected inflation endogenous—a model of expected inflation—is

$$\pi_t^e = (1-\theta)\bar{\pi} + \theta\pi_{t-1}, \tag{1.47}$$

where θ is a parameter between 0 and 1, and $\bar{\pi}$ is another parameter that we refer to as the **inflation target**. We say that inflation expectations are **anchored** when $\theta = 0$ and **deanchored** when $\theta = 1$.

When $\theta = 1$ the Phillips curve (1.46) is called the "accelerationist" Phillips curve:

$$\pi_t - \pi_{t-1} = \frac{\alpha}{L}(Y_t - Y^n). \tag{1.48}$$

Equation (1.48) implies that whenever output is above its natural level, inflation increases over time, and whenever output is below its natural level, inflation decreases over time. In contrast, when $\theta = 0$ the Phillips curve is

$$\pi_t - \bar{\pi} = \frac{\alpha}{L}(Y_t - Y^n),$$

and inflation increases when the output gap $Y_t - Y^n$ increases, and decreases when the output gap decreases.

The difference between anchored and deanchored inflation expectations is of first-order importance for monetary policy. Consider a scenario in which the economy is in a boom, with unemployment below its natural rate and output above potential. The PC implies that, in this case, inflation is above expected inflation. Imagine monetary policy increases the interest rate over time and stops when unemployment is equal to its natural rate and output is equal to potential. With anchored expectations, the increasing interest rate makes inflation decrease over time as the output gap goes down. When output reaches potential, inflation equals the inflation target $\pi = \bar{\pi}$ so inflation ends up below its initial level. With deanchored expectations, inflation *increases* over time as output goes down, since the output gap is always positive along the path. When output reaches potential, inflation stops increasing. In contrast to the case of anchored expectations, inflation ends up above its initial level.

1.9 Sticky Prices

In the real world, **prices are sticky**: we do not see the price of individual goods changing instantaneously in response to evolving economic conditions, with prices of many individual goods unchanged for months at a time despite fluctuations in economic conditions. In addition, not all prices change at the same time. The stickiness of prices and the lack of synchronization in price changes across firms imply that the aggregate price level changes slowly over time.

Why are prices sticky? One reason is that changing prices is costly. The physical costs of changing prices are called **menu costs**, (think of a restaurant that has to print new menus when it changes prices). There are other reasons why prices are sticky: computing the new price and deciding to change prices can be time-consuming, especially in large companies; the necessary information about economic conditions may take time to get to firms and be digested; even when economic conditions change, if a firm's competitor does not change prices, it may be better to not change prices to remain competitive, etc.

1.10 The Short Run, the Medium Run, and the Long Run

We now want to think about how the economy evolves over time. It is useful to make the conceptual distinction between the short run, the medium run, and the long run.

- **The short run**: What happens to the economy from year to year. Movements in output are primarily driven by "movements in demand", that is, by equilibrium in the goods market. Firms are willing to supply any quantity at the given prevailing price.
- **The medium run**: What happens to the economy over a decade or so. In the medium run, the economy tends to return to the level of output determined by structural "supply factors", that is, by equilibrium in the labor market. Firms supply an amount of output equal to potential, and prices adjust to make the goods market be in equilibrium.
- **The long run**: What happens to the economy over a half century or longer. In the long run, what dominates is not fluctuations, but growth. Long-term growth is determined, among other things, by the growth rate of productivity, the education system, the saving rate, demographics, the rule of law, and the quality of institutions.

The short run, medium run, and long run can also be characterized by how prices behave:

- In the short run the price level P is fixed. In other words, P can be treated as exogenous in the short run. We can think of the short-run price level as being inherited from past decisions, and the short run as the time horizon over which changes in the sticky price level are small enough that they can be ignored.
- The medium run can be thought of as the amount of time it takes for all price changes to occur or, equivalently, for prices to behave as if they were not sticky at all. If prices

are not changing, then the price level must equal the expected price level and inflation must equal expected inflation. Therefore, the conditions $P = P^e$ and $\pi = \pi^e$ can be taken as the *definition* of the medium run.

- In the long run, we have **neutrality of money**: only real variables (rather than nominal ones) determine economic outcomes. The price level P and inflation π are irrelevant in the long run.

Medium-run adjustment

The Phillips curve (1.45) describes how inflation responds to the output gap. Suppose output is above its natural level $Y_t > Y^n$. Then (1.45) implies $\pi_t > \pi_t^e$ so the price level rises faster than expected. A higher price level reduces real money balances M_t^s/P_t; shifting the LM curve up in subsequent periods. This raises the nominal interest rate and lowers output, pushing output back toward Y^n.

Conversely, if output is below its natural level $Y_t < Y^n$ inflation is lower than expected. As the price level rises more slowly (or falls), real money balances increase, shifting the LM curve down and pushing output up toward Y^n.

In the medium run, once the economy reaches a situation in which output equals its natural level $Y_t = Y^n$; the Phillips curve implies that inflation equals expected inflation $\pi_t = \pi_t^e$. In that case, there is no systematic pressure for inflation to accelerate or decelerate.

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