3 The 3-equation model and macroeconomic policy

3.1 Overview

In Chapter 1, we focused on the way shocks to aggregate demand produce fluctuations in output and employment. In Chapter 2, we looked at how supply-side features of the economy determine the constant inflation equilibrium. Then, at the end of Chapter 2, we put these supply- and demand-side elements together. This produced a picture of an economy affected by both demand and supply-side shocks, which are amplified by the multiplier process and dampened by households' and firms' ability to tide themselves over through borrowing when their current income falls. In contrast to the generally slow-moving shifts in equilibrium unemployment, actual unemployment rises and falls in accordance with business cycles largely driven by fluctuations in aggregate demand.

In the model as laid out in Chapter 2, there was no policy intervention to prevent the gap between the real wage workers expect to secure (on the *WS* curve) and the real wage firms are prepared to pay (on the *PS* curve) from producing ever-increasing inflation when unemployment is lower than the equilibrium rate. This incompatibility between the claims of workers and firms—and hence the inflationary pressure in the economy—could in principle be resolved in two ways:

1. First, by supply-side institutional change or policies to raise equilibrium output by either shifting the *WS* curve downwards or shifting the *PS* curve upwards. Examples of this include policies to weaken the bargaining power of workers by worsening the living conditions they would face if they lost their jobs (brought about, for instance, by lowering unemployment benefits). Another example is an institutional change which increases bargaining restraint by unions. One policy which might shift the *PS* curve upwards would be the promotion of more competition, thus reducing the mark-up on product prices.
2. Second, by the use of demand management policy to reduce employment and output to the level consistent with a $WS - PS$ equilibrium, where inflation will be constant. This policy lever takes supply-side institutions and policies as given.

In this chapter, the focus is on the second set of policies mentioned above. This means that we do not deal here with supply-side policies that aim to influence equilibrium

unemployment (that is postponed to Chapter 15, which can be read immediately after this chapter). Here, we begin with unemployment at its equilibrium rate (the $WS - PS$ intersection), where the output gap is zero and inflation is constant. If, at this point, the economy suffers a shock, how would the policy maker respond so as to stabilize it at its constant-inflation level?

Shortly, we will look in more detail at how demand management policy is implemented to stabilize the economy (for example by raising aggregate demand in the face of a negative demand shock or dampening it in the face of a positive demand shock). But, before that, we need a little more background information about the policy regime and its recent history. During the 1990s, many countries around the world adopted a new macroeconomic policy regime known as inflation targeting. It means that the government gives responsibility to the central bank to stabilize the economy by adopting a specific target for the annual rate of inflation, the most commonly adopted rate being 2%. To help clarify the reasons why these changes in regime and policy have taken place it would be useful to answer three related background questions:

1. Why do governments often define the central bank's responsibility as the control of inflation?
2. Why, in any case do governments regard inflation as a problem which needs to be controlled?
3. Why do governments hand over the problem of keeping inflation low and stable to the makers of monetary policy (the central banks) rather than controlling inflation themselves?

Regarding the first of these questions, we have already seen that the rate of unemployment at which inflation is constant depends on structural features of the labour market and the goods market. It is these structural features which determine the positions of the *WS* and *PS* curves in the supply-side model. But, since the central bank does not have policy instruments with which it can change these supply-side economic features, it is clearly not the right policy maker to be charged with reducing equilibrium unemployment. The government will have to do this, in ways which are discussed in Chapter 15.

We shall see, however, that there is one important way in which the central bank's behaviour does affect unemployment. A central bank that is given responsibility for maintaining high employment as well as keeping inflation close to its target level would be less inclined to support policies of rapidly cutting inflation through pushing unemployment up sharply. In Chapter 13, we return to the question of how variation in the behaviour of different central banks around the world can be represented in the model.

The second preliminary question is why policy makers are concerned about inflation at all. One reason why governments might pursue low inflation is that the level of inflation is a key priority for voters. Governments might have to pay a large electoral price if they fail to control inflation. The importance the US general public gives to inflation is highlighted in a 1997 paper by Shiller, who surveys both economists and members of the public in the US about their views on inflation. Table 3.1 shows that the general public (more than economists) see controlling inflation as a national priority. We shall look in more detail at the factors that lie behind voters' concerns with inflation in the next subsection.

Table 3.1 Public attitudes on the importance of preventing high inflation.

Do you agree that preventing high inflation is an important national priority, as important as preventing drug abuse or deterioration in the quality of our schools?

	Fully agree		Undecided		Completely disagree	
US all	52%	32%	4%	8%	4%	n=117
Economists	18%	28%	11%	26%	18%	n=80

Source: Survey data from Shiller (1997).

This leaves the third preliminary question: why, in the inflation-targeting regime, is stabilization policy placed in the hands of the central bank rather than the government? This question is best broken down into two separate parts.

The first part is: why is monetary policy chosen over fiscal policy as the primary tool for stabilization policy? There are both practical and political economy reasons why monetary policy is the preferred stabilizer even when both monetary and fiscal policy are available. Firstly, changing public expenditure or taxation normally involve lengthy parliamentary processes, and there is no equivalent to the gradual adjustment possible through quarter-point changes in the interest rate at monthly intervals. Secondly, fiscal policy is inherently political since it involves the use of tax revenue, a fact which is captured by the classic refrain of struggles for democracy: 'No taxation without representation'. Monetary policy is viewed as more neutral and does not so obviously create winners and losers, making it a less contentious policy instrument for use in short-run demand management.

The second part is: why does the government cede control of monetary policy to an independent central bank? The government can potentially gain an electoral advantage by controlling monetary policy. For example, they could raise output above the equilibrium or change politically sensitive mortgage interest rates in the run-up to an election. In light of this, why have governments around the world chosen to delegate control of monetary policy to a committee of independent experts? It is because governments lack low inflation credibility, which translates into higher inflation. The political pressures to manipulate interest rates for electoral gain are the source of this credibility deficit. Independent central banks are free from these pressures so are more likely to deliver low and stable inflation. To the extent that voters care about inflation and sound macroeconomic management, this provides the incentive for the government to relinquish control of this policy lever. These arguments have been persuasive among both left- and right-wing policy makers, as illustrated by the fact that one of the very first acts of the British Labour Party when it came to power in 1997 was to make the Bank of England independent.

The discussion in Chapter 1 brought out the extent to which households are able to limit the costs to them of fluctuations in income that arise from shocks to the economy through smoothing their consumption. Nevertheless volatility remains and the policy maker aims to provide additional stabilization. We shall see in the course of this chapter how the central bank responds to a range of shocks: its interest rate decisions affect aggregate demand and the output gap, guiding the economy back to the medium-run equilibrium with low steady inflation as its objective.

3.1.1 The role of the central bank in stabilization

Since the early 1990s a growing number of central banks have been assigned the task of stabilizing the macro-economy around a low target rate of inflation. This is known as an inflation-targeting monetary policy regime. In response to a surge in inflation, we would expect to see the central bank raise the interest rate; this would lower interest-sensitive spending, such as spending on housing, machinery and equipment, due to the increase in the interest rate (in other words, in the cost of borrowing). The cut back in investment would lead in turn to lower aggregate demand and a fall in output. Unemployment would go up and inflationary pressure would diminish.

In 1997, the year in which the Bank of England was made independent, the Bank's Chief Economist, Mervyn King, who later became Governor, explained:[1]

> [M]onetary policy can be described in terms of two policy variables—a medium-term inflation target and a response of interest rates to shocks that create fluctuations in inflation and output. The overriding objective of monetary policy is to ensure that on average inflation is equal to the target. But such a target is not sufficient to define policy. There is a subordinate decision on how to respond to shocks as they occur.

Figure 3.1 provides a schematic overview of the macro model, including the policy maker. On the left hand side, the role of the demand and supply sides are summarized. The

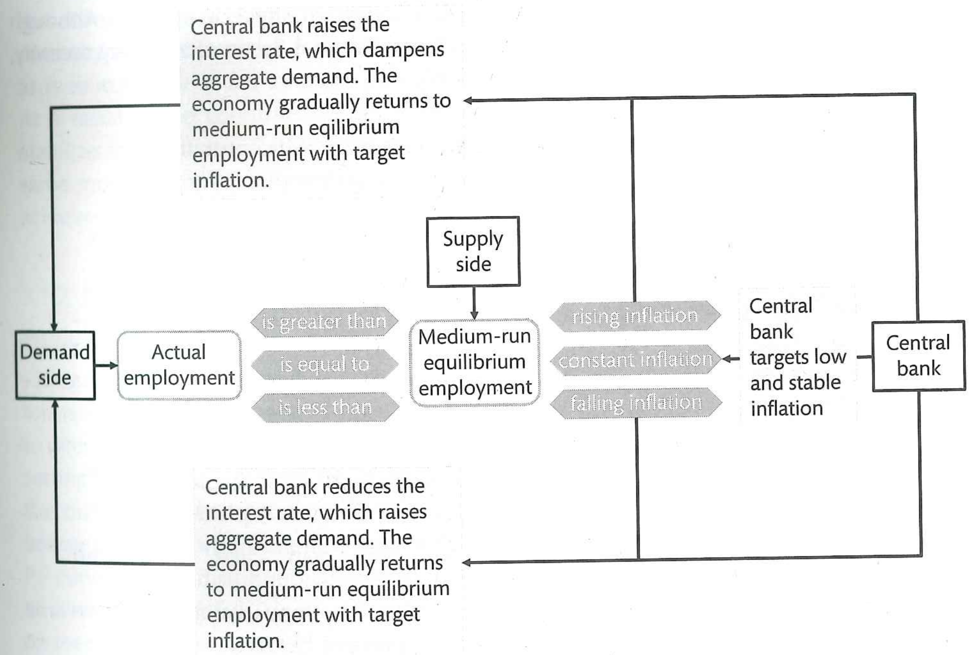


Figure 3.1 Schematic overview of the macro model.

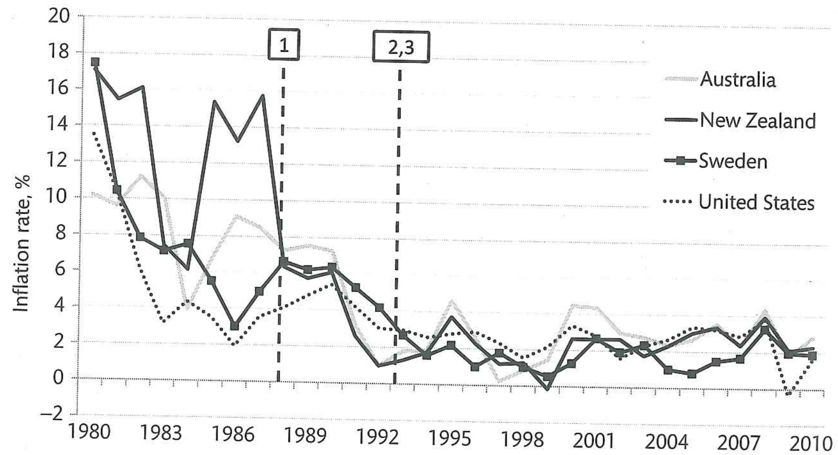
[1] Excerpt taken from: Mervyn King, 29th October 1997, *The Inflation Target 5 Years On*, speech delivered at the LSE. He became the Governor of the Bank of England in 2003.

components of aggregate demand determine the level of output and employment in the goods market equilibrium. The structural features of the economy on the supply side determine the equilibrium rate of unemployment at which inflation is constant. The third panel shows the implications for inflation: if unemployment is at the equilibrium rate, then inflation will remain constant and the central bank will do nothing. If unemployment is below the equilibrium rate, inflation is rising and vice versa for unemployment above it. An increase in inflation above the central bank's target will trigger intervention by the central bank: it will raise the interest rate. Equivalently, a fall in inflation below target will trigger an easing of monetary policy with a lower interest rate.

The outside arrows depict the feedback from the central bank's monetary policy rule to aggregate demand. This illustrates how a central bank uses a monetary policy rule to hold inflation close to a low target value.

Figure 3.2 shows the course of inflation in a selection of developed economies since 1980. The chart shows that a period of high and volatile inflation was followed by one where inflation was lower and more stable. The introduction of inflation targeting regimes was part of the evolution of the policy framework, where from the end of the 1970s, governments used macroeconomic policy to squeeze inflation out of the economy by depressing aggregate demand.

The shift from high to low inflation shown in the chart began before the large fall in the oil price in 1986 and the gradual emergence of low-cost (especially Chinese) manufacturers into world markets, which subsequently also had a significant effect on inflation. Although formal inflation targeting was not adopted by the US Federal Reserve until very recently,



Dates inflation targeting was first adopted:
1. Reserve Bank of New Zealand—April 1988
2. Sveriges Riksbank (the Swedish central bank)—January 1993
3. Reserve Bank of Australia—March 1993

Note: The US had no formal inflation target over this period, but did adopt a target of 2% in January 2012.

Figure 3.2 Inflation rates—before and after the adoption of inflation targeting: 1980–2010.

Source: IMF World Economic Outlook, September 2011.

its inflation behaviour was similar to the other countries shown in Figure 3.2, where its date of introduction in New Zealand, Australia and Sweden is shown. The move towards formal or informal inflation targeting is frequently identified with the beginning of the 'Great Moderation' (the period of unprecedented macroeconomic stability shown in Figure 1.3 in Chapter 1).

There are, however, two very important situations in which the central bank cannot be relied on to stabilize shocks by changing the interest rate as described above. The first of these situations is when the economy experiences such a large negative demand shock that even when the central bank cuts the nominal interest rate all the way to zero this is not low enough to stimulate a revival of aggregate demand. With a nominal interest rate of zero, the real interest rate, which is the one relevant to the investment decisions of firms, is not low enough to stimulate interest-sensitive spending. This problem of the *zero lower bound* is closely related to the possibility that the economy can become caught in a *deflation trap*, where it enters a vicious cycle of falling output and inflation. Once the usual channel of monetary stabilization is shut down, the central bank can try to stimulate the economy using other policies, such as quantitative easing, or it can share responsibility for stabilization with fiscal policy. The cases of the zero lower bound and the role of fiscal policy as stabilizer are addressed later in this chapter. We leave a discussion of quantitative easing until Chapter 7.

The second case in which monetary policy cannot be used to achieve stabilization is when the economy has a fixed exchange rate. This is easy to see in the setting of a common currency area such as the Eurozone: member countries of the Eurozone all use the euro as their currency and they share a single central bank, the European Central Bank (ECB). As a result, these countries do not have their own monetary policy maker which could stabilize shocks that are specific to their country. Because all Eurozone countries have the same monetary policy, any stabilization of shocks to a particular country would have to be achieved by the use of fiscal policy (a case explained in Chapter 12).

3.1.2 **Inflation and deflation**

Rising inflation and distributional conflict

Rising inflation reflects distributional conflict as different social groups (wage setters/employees and price setters/employers) seek to protect their interests. In an economy in which groups such as unions can influence nominal wages and where firms have price-setting power, a situation of rising inflation reflects inconsistent claims by these groups on the output per head produced in the economy. In other words, when unemployment is below the equilibrium rate, the gap between the real wage on the *WS* curve and on the *PS* curve reflects distributional conflict and causes inflation to rise. As shown in Chapter 2, as unemployment falls, workers become more powerful in the labour market and are able to secure a higher expected real wage: this is the reason the *WS* curve is upward-sloping. But firms will seek to secure their profit margin by setting prices accordingly—leaving a gap between the higher real wage workers expect on the *WS* curve and the unchanged real wage on the *PS* curve.

A similar logic applies with efficiency wage-setting: the conflict of interest between the two sides of the labour market means that the wage employers need to pay to get workers

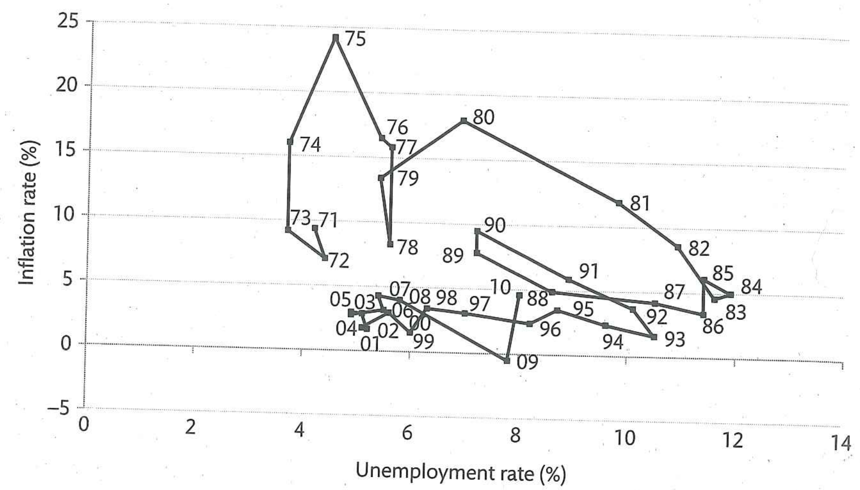


Figure 3.3 UK inflation and unemployment: 1971–2010.

Source: UK Office for National Statistics (data accessed February 2012).

to work sufficiently hard (given the state of the labour market) may differ from the wage that is consistent with the profit margin firms seek. Lower unemployment reduces the cost of job loss and raises the efficiency wage. This pushes inflation up.

Rising inflation produces social tension as frustration mounts. As we shall see, inflationary episodes of this kind have frequently been followed by painful periods of disinflation, where a period of output below equilibrium (accompanied by high unemployment) is required to bring inflation down.[2]

The empirical evidence suggests that periods of disinflation to bring down inflation from moderate rates (up to double digit rates per annum) have involved significant costs in OECD economies where this has occurred. Figure 3.3 shows the path of inflation and unemployment in the UK between the early 1970s and 2010. The high level of inflation in the 1970s was tackled by tight monetary policy from 1979. The process of getting inflation down from a higher level to the targeted one is known as disinflation. It is likely to be a costly process, involving a period of high unemployment to squeeze inflation out of the system. The costs of high unemployment include the direct waste of resources, the erosion of skills and increased vulnerability to mental illness that comes with long spells of unemployment, and the damage to the functioning of families and communities. Figure 3.3 shows that reducing inflation from rates above 20 to below 5% was associated in the British economy with a rise in unemployment from 4 to 12% during the disinflationary episode.

The benefits of low and stable inflation

The survey on public attitudes to inflation summarized in Table 3.2 shows that the main reason the US public dislike inflation is due to the erosion of living standards that are believed

[2] An early formal model of equilibrium unemployment and of the inflation process as one of conflicting distributional claims is in Rowthorn (1977).

to accompany high inflation. We can relate this to an aspect of the dynamics of the *WS-PS* model. The US public's biggest complaint about inflation accords with the outcome of the *WS-PS* model in an inflationary environment, in the sense that rising inflation leads to the persistent frustration of workers' real wage expectations.

In the model in Chapter 2, we used the simplest case regarding the timing of wage and price setting. If firms are able to adjust prices immediately after wages have been set, rising inflation reflects a situation in which the real wage wage setters require is systematically frustrated (in other words, the expected real wage of workers as indicated by the *WS* curve is above the real wage on the *PS* curve). In this simple case, the real wage outcome is on the *PS* curve, not on the *WS* curve. If there are lags in price setting as well as in wage setting, then the real wage lies between the *PS* and *WS* curves and neither wage nor price setters are fully satisfied. This case is more realistic because the empirical evidence suggests that real wages are mildly pro-cyclical, which means that when there is a positive output gap the real wage ends up between the *WS* curve and the *PS* curve (that is, higher than at the constant inflation equilibrium) and vice versa for a negative output gap.

Table 3.2 reveals a divergence between what the public and the economists view as the most significant costs of inflation. Whereas the public appear to worry about their real incomes being eroded by inflation, economists do not see this as much of a concern and place more stress on the interference that high inflation creates for the ability of prices to convey information. Periods of high inflation are also often ones with volatile inflation. To see why this matters, consider an economy with technical progress in which innovation takes place unevenly across sectors. In sectors with rapid innovation, prices will be falling relative to prices in other sectors where technology is more stagnant (think of the falling prices of computing power). These are economically significant changes in *relative prices* and should lead to a reallocation of resources in the economy. Volatile inflation can therefore distort resource allocation to the extent that it masks these relative price changes. In short, volatile inflation has adverse real effects on the economy that are hard to avoid.

When inflation is high, people also want to hold less money. This is because inflation acts as a tax on holding money balances, eroding their real value over time. The so-called inflation tax imposes inefficiencies because it distorts behaviour: people spend more time managing their financial assets incurring what are referred to as 'shoe-leather costs'. Other

Table 3.2 What is peoples' biggest gripe with inflation?

Which of the following comes closest to your biggest gripe about inflation:

1. Inflation causes a lot of inconveniences: I find it harder to comparison shop, I feel I have to avoid holding too much cash, etc.
2. Inflation hurts my real buying power, it makes me poorer.
3. Other.

	1	2	3	
US all	7%	77%	15%	n = 110
Economists	49%	12%	40%	n = 78

Source: Survey data from Shiller (1997).

firms incur costs as a consequence of the need for frequent price changes costs ('menu costs').

The optimal rate of inflation

Given the costs associated with high inflation can we infer that the optimal rate of inflation is zero or even negative? In thinking about the optimal inflation rate, think about the following: the return on holding notes and coins is zero so with any positive inflation rate, the return in real terms, i.e. after controlling for inflation, is negative. The negative real return leads people to waste effort economizing on their money holdings (shoe leather costs again) and this is inefficient given that it is virtually costless to produce money.

If we follow the logic of this argument, then with a positive real rate of interest, for the *nominal* interest rate to be zero, inflation would have to be negative (i.e. prices falling, which is called deflation). This was Milton Friedman's view of the optimal rate of inflation: the rate of deflation should equal the real rate of interest, leaving the nominal interest rate equal to zero.[3] Friedman's rule ensures that people avoid shoe leather costs, but is this sufficient to say that deflation is optimal?

The danger of deflation

An important reason why central banks target a low but positive inflation rate—most commonly 2%—is that they wish to prevent the economy from falling into a deflation trap, a problem which can emerge when weak aggregate demand leads inflation to fall and eventually become negative. When aggregate demand is very weak, the central bank will want to reduce interest rates in order to stimulate interest-sensitive spending like investment. This can push the nominal interest rate close to its lower bound of zero. But when a nominal interest rate close to zero is combined with falling prices (deflation), this implies a positive real interest rate which may be too high to stimulate private sector demand and get the economy back to equilibrium. Continued weak demand will make inflation more negative, thereby pushing the real interest rate up. This is exactly the opposite of what the central bank wants, which is to reduce the interest rate sufficiently to escape the deflation trap.

In addition, deflation increases real debt burdens. Debts are typically denominated in nominal terms, with borrowers having to pay back a fixed amount each period. If wages (and prices) are falling every period then the burden of the debt increases as a proportion of income. This will lower households' disposable income and squeeze firm's profits, exerting a drag on economic growth and slowing down recovery.

Deflation poses a third problem related to the apparent difficulty in cutting nominal wages. If workers are particularly resistant to nominal wage cuts, then a positive rate of inflation creates the flexibility needed to achieve changes in *relative* wages. For example, if, due to a fall in demand for one kind of labour, a real wage cut is required it can be achieved with an inflation rate of, say, 2% p.a. with the nominal wage left unchanged in the sector where the real wage cut is necessary. This argument is referred to as inflation's role in 'oiling the wheels of the labour market'.

[3] See Friedman (1969).

Central bank independence and inflation targeting coincided with the achievement of a low and stable inflation environment as reflected in Fig. 3.2. This helped to reinforce the virtues of a 2% inflation target and central banks have not seriously considered changing to a higher target. In fact, the US Federal Reserve, which has historically avoided having an official inflation target, announced at the start of 2012 that it was joining other developed economies in targeting 2% inflation.[4]

3.1.3 Introduction to the 3-equation model

Figure 3.1 puts together the demand and supply sides of the economy and shows the role an inflation-targeting central bank can play in responding to a shock that takes the economy away from equilibrium. What the inflation-targeting central bank does is to raise the interest rate in response to inflation which is above the target rate in order to dampen aggregate demand and to lower the interest rate when inflation falls below the target rate.

A crucial characteristic of a modern monetary policy regime is that the central bank is forward looking. The central bank forecasts inflation by analysing what is going on in the economy and it must take into account the lags between changes in the interest rate it uses for policy purposes and the impact of that rate on economic activity. The importance of forecasting and lags for the work of central banks is highlighted in the monetary policy strategy document of the Sveriges Riksbank (the Swedish central bank):[5]

> It takes time before monetary policy has a full impact on inflation and the real economy. Monetary policy is therefore guided by forecasts for economic developments.

When three things are known—what the central bank is trying to achieve, how it thinks about the constraints it faces arising from the behaviour of the private sector, and how it implements its policy—this information will provide a skeletal model enabling an analysis of how the bank will respond to a variety of shocks to the economy. These responses to shocks can then be summarized in the form of a simple monetary policy rule. This rule sits at the heart of the 3-equation model, which is produced by adding the Monetary Rule (MR), curve to the *IS* curve from the demand side and the Phillips curve (*PC*) from the supply side.

We now turn to each of the three questions in turn to pin down how monetary policy is conducted within the 3-equation framework:

1. What is the central bank trying to achieve? It is assumed that its aim is to use monetary policy to stabilize the economy, which means keeping the economy close to equilibrium output and keeping inflation close to its targeted rate. The central bank may be penalized if it fails to meet its inflation target. In the UK, for example, if the inflation rate diverges more than one percentage point above or below the 2% target then the Governor of the Bank of England is obliged to write an open letter to the Chancellor of the Exchequer explaining the reasons for the bank's failure and a plan for returning inflation to target. This is, at the least, embarrassing for the Governor and costly in terms of the central bank's

[4] Federal Reserve FOMC statement of longer-run goals and policy strategy, January 25th 2012.
[5] Excerpt taken from: Sveriges Riksbank, 2010, *Monetary policy in Sweden*.

reputation. The closer is the economy to having output at equilibrium and inflation on its target, the lower is the reputational cost to the bank.

2. What forces prevent the central bank from achieving its target? This is essential information in order to assess the prospects of economic stabilization. As seen in Chapters 1 and 2, the economy is affected by shocks to demand and supply, which affect output and inflation. An unforeseen boom, for example, which takes output above equilibrium, will increase inflation above the target as the position of workers in the labour market strengthens. This aspect of wage behaviour is captured in the Phillips curve (*PC*). The central bank has to take into account behaviour, including the persistence of inflation, when it designs its response to the initial shock to the economy.
3. How does the central bank translate its objectives into monetary policy? It uses a monetary policy rule. This can be represented in the same diagram as the Phillips curves, that is, in a diagram with output on the horizontal axis and inflation on the vertical axis. This will demonstrate how the central bank will choose its preferred policy response given the constraint it faces from the behaviour of wage and price setters, which is captured by a particular Phillips curve.

To implement its preferred policy response in practice, the central bank diagnoses the shock and its forecast effect on inflation and output. It uses this, together with its preferences for stabilization, to estimate the output gap it is trying to achieve. The *MR* curve illustrates the central bank's best response to the shock. It then uses the relationship between the interest rate and output in the *IS* curve to implement that choice.

An example—a consumption boom

The example of a consumption boom is used to show how the model works. Figure 3.4 shows how the central bank analyses a shock of this kind.

The shock has its initial positive impact on output and employment (shown by the rightward shift of the *IS* curve and the movement from *A* to *B* in the *IS* diagram). By following the diagrams in Fig. 3.4 from top to bottom, we can see that the labour market impact of the consumption boom is reflected in a disturbance of the initial constant-inflation equilibrium. At the first wage-setting round following the fall in unemployment, wage and price inflation will rise from the target inflation rate of 2%. As illustrated in the wage-setting and price-setting diagram, the shock has opened up a gap of 1% between the prevailing (low) real wage and the (high) real wage consistent with the tighter labour market following the consumption boom. This means that workers will get a 2% wage rise to compensate them for the erosion of their real wages due to last period's inflation and an additional 1% increase to bring their real wage up to the level indicated by the wage-setting curve. In this case, wages rise by 3% and firms automatically raise their prices by 3% to protect their profit margins; in other words, inflation rises to 3%.

The increase in inflation from 2% to 3% is shown by the movement along the Phillips curve from *A* to *B*. Here, we need to take into account the fact that the higher inflation of 3% will become embedded in the expectations of wage setters. For the next wage-setting round—the one the central bank must anticipate in taking its stabilization decision—expected inflation of 3% will mean that the relevant Phillips curve facing the central bank is the one labelled '*PC* (expected inflation = 3%)'. Given this forecast of inflationary behaviour, the central bank

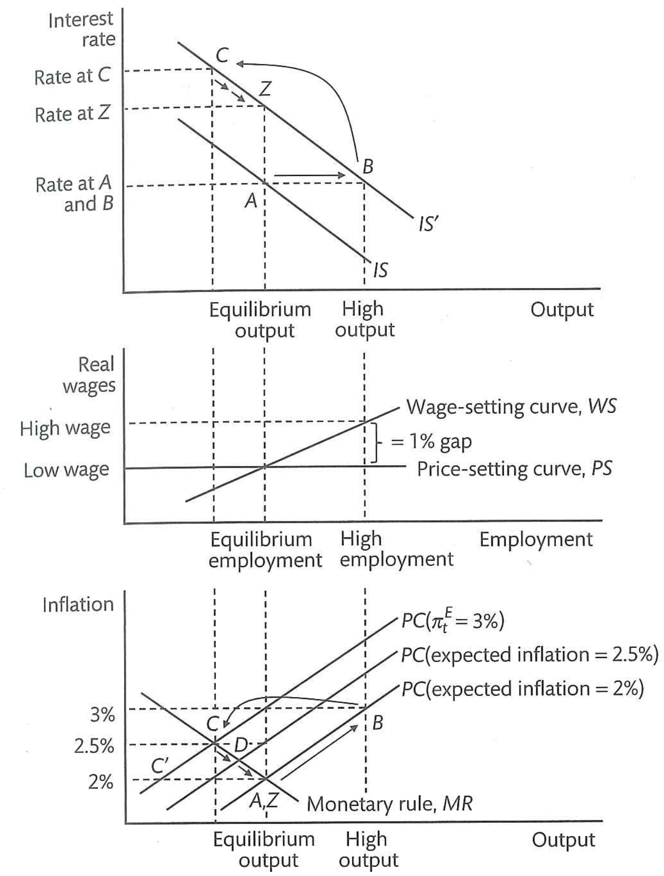


Figure 3.4 The 3-equation model: the adjustment of the economy to a permanent demand shock.

chooses its best response to the situation—the place on the new *PC* where it would like to locate. Its preference is likely to be for a balanced response—making progress in getting inflation back toward target but not imposing a harsh recession—such as at point C. This is a point on the *MR*, which shows the central bank's optimal output-inflation pair for any Phillips curve it faces.

In the top panel of the diagram is the *IS* curve. If the central bank takes the view that in the absence of any response on its part the consumption boom would persist, it will need to choose the interest rate shown by point *C* in order to dampen aggregate demand sufficiently to move the economy onto the path which leads to the inflation target. Once the economy is on the *MR* curve at point *C*, inflation will come down as forecast. Lower inflation will then shift expected inflation down. We can see this in the shift of the Phillips curve downwards to '*PC*(expected inflation = 2.5%)'. The central bank will choose point *D* as its best response to the new inflation environment it faces and will adjust the interest rate down from its peak. In the subsequent periods, the central bank will continue to guide the economy along the *MR* curve by reducing the interest rate as inflation returns to the target rate. The adjustment process finishes when the economy is back at equilibrium output and target inflation (point *Z*.).

There will, however, be a higher interest rate at the new equilibrium, as shown in the *IS* diagram (the top panel of Fig. 3.4). A reduced level of investment is needed to offset the persistent consumption boom.

A summary of modern inflation-targeting central banking

Central bank thinking on monetary policy in the era of inflation targeting was succinctly summarized by Glenn Stevens, the Assistant Governor of the Reserve Bank of Australia in a speech in 1999, in which he lists the six key things that have been learnt about monetary policy after 200 years of thought by economists and others:[6]

1. monetary policy affects principally, or only, prices [and not economic activity] in the medium term;
2. it affects activity in the short term;
3. because of lags, policy has to look forward;
4. but the future is uncertain, as is the impact of policy changes on the economy;
5. expectations matter, so giving people some idea of what you are trying to do, and acting consistently, is useful;
6. and an adequate degree of operational independence for the central bank [from the government] in the conduct of monetary policy is important.

3.2 Modelling

In the previous two chapters, we have built simple models of the demand and supply sides of the economy. The primary aim of this chapter is to add the policy maker to the model of the macro-economy. This gives the three curves in the graphical model based on the three equations that give the model its name:

1. *IS* curve.
2. *PC* curve.
3. *MR* curve.

This section extends the introduction to the 3-equation model by setting out in more detail how the central bank goes about achieving its objective of keeping inflation at target. This gives the *monetary rule*, or *MR* curve, which determines the output gap the central bank should set in order to stabilize the economy following an economic shock. We go on to use the 3-equation model to analyse a range of shocks in Section 3.3.

3.2.1 **The 3-equation model**

The first task of this section is to derive the *MR* curve, which shows the chosen output gap of the central bank in response to any economic shock. The *MR* curve shows the path along which the central bank seeks to guide the economy back to target inflation (and equilibrium output). The mathematical derivation of the model is shown in the Appendix.

[6] Source: Mr G.R. Stevens, Assistant Governor of the Reserve Bank of Australia, 20 April 1999, *Six Years of Inflation Targeting*, speech to the Economic Society of Australia, Sydney. Square brackets indicate additions to the text made by the authors.

The basic method for deriving a monetary policy rule involves the following steps:

1. Define the central bank's preferences in terms of a utility (or loss) function to capture the costs it incurs of being away from the inflation target and from equilibrium output. This produces the policy maker's indifference curves in output-inflation space and shows what the policy maker would like to do—i.e. to be close to the inflation target at equilibrium output.
2. Define the constraints faced by the policy maker from the supply side of the economy: these are the Phillips curves, which are also shown in output-inflation space. These show the 'objective' trade-off between inflation and unemployment in the short run and pin down what it is feasible for the central bank to achieve.
3. Derive the best response *monetary rule* in output-inflation space: this is the *MR* curve. For a given Phillips curve that it faces, the *MR* shows the central bank's desired output-inflation combination.
4. Once the central bank knows where it wants to be by using the *MR* curve, it uses the *IS* curve to implement that choice, since the *IS* curve shows the interest rate that will deliver the central bank's chosen level of output. The interest rate is the central bank's policy lever for influencing aggregate demand.

The central bank's preferences

Where do the central bank's preferences come from? A pragmatic way of thinking about how to model this is to infer their preferences from their behaviour. From the empirical analysis of the behaviour of the US central bank, the Federal Reserve, the economist John Taylor inferred a monetary policy rule. The famous Taylor Rule can be derived from a model in which the central bank minimizes fluctuations from the inflation target and the size of the output gap. Since our aim is to throw light on the way central banks behave, we use this loss function.

In this subsection, we use the central bank's loss function (i.e their utility function) to derive indifference curves representing the trade-off in its preferences between inflation being away from its target and output being away from equilibrium. Looking first at inflation, we assume that it wants to minimize fluctuations around the inflation target π^T:

$$(\pi_t - \pi^T)^2.$$

A loss function is just like a utility function except that the higher the loss, the worse it is for the central bank. This loss function has two implications. First, the central bank is as concerned to avoid inflation below its target as it is inflation above its target. If $\pi^T = 2\%$ the loss from $\pi_t = 4\%$ is the same as the loss from $\pi_t = 0\%$. In both cases $(\pi_t - \pi^T)^2 = 4$. Second, it attaches increased importance to bringing inflation back to its target the further it is away from π^T; the loss from $\pi_t = 6\%$ is 16, compared to the loss of 4 from $\pi_t = 4\%$.

We turn now to the central bank's second concern of keeping output close to equilibrium. We assume the central bank seeks to minimize the gap between y_t and y_e—remembering that it has no way of controlling y_e itself—in order to aid it in achieving its inflation target.

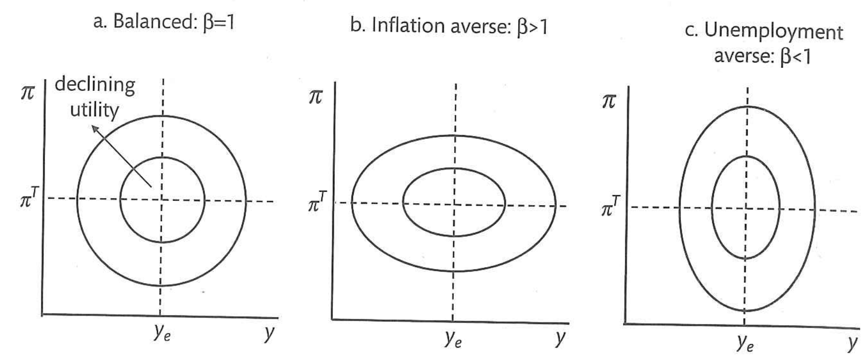


Figure 3.5 Central bank loss functions: utility declines with distance from the 'bliss point'.

The central bank's loss as a result of output being different from its target of y_e is $(y_t - y_e)^2$.

Note that this loss function also assumes a symmetrical attitude to positive and negative deviations—in this case, from the equilibrium level of output. The most straightforward way of thinking about this is that the central bank understands the model and realizes that inflation is only constant at $y_t = y_e$. If $y_t < y_e$ then this represents unnecessary unemployment that should be eliminated. If $y_t > y_e$, this is unsustainable and will require costly increases in unemployment to bring the associated inflation back down. Whenever the economy is disturbed, the central bank sees its task as steering the economy back to this constant-inflation output level.

Adding the two loss functions together, the central bank's loss function is:

$$L = (y_t - y_e)^2 + \beta(\pi_t - \pi^T)^2, \qquad \text{(central bank loss function)}$$

where β is the relative weight attached to the loss from inflation. This is a critical parameter: a $\beta > 1$ will characterize a central bank that places less weight on deviations in employment from its target than on deviations in inflation, and vice versa. A more inflation-averse central bank is characterized by a higher β.[7]

With $\beta = 1$, the central bank is equally concerned about inflation and output deviations from its targets. The loss function is simple to draw: each indifference curve is a circle with (y_e, π^T) at its centre (see Fig. 3.5a). The loss declines as the circle gets smaller. When $\pi_t = \pi^T$ and $y_t = y_e$, the circle shrinks to a single point (called the 'bliss point') and the loss is at a minimum, which is zero. With $\beta = 1$, the central bank is indifferent between inflation 1% above (or below) π^T and output 1% below (or above) y_e. They are on the same loss circle.

If $\beta > 1$, the central bank is called inflation-averse: it is indifferent between (say) inflation 1% above (or below) π^T and output 2% above (or below) y_e. They are on the same loss curve. This makes the indifference curves ellipsoid as in Fig. 3.5b. They are flat because the central bank is willing to trade off a small fall in inflation for a large rise in unemployment above equilibrium. A central bank with less aversion to inflation ($\beta < 1$) will have ellipsoid indifference curves with a vertical rather than a horizontal orientation (Fig. 3.5c). In that case, the indifference curves are steep, reflecting that the central bank is only willing to trade off a given fall in inflation for a smaller fall in output than in the other two cases. If the central bank cares only about inflation then the loss ellipses become one dimensional along the line at $\pi_t = \pi^T$.

The value of β does not reflect whether the central bank focuses on achieving an inflation target or an output target. Rather, a central bank with lower β is willing to trade off a longer period during which inflation is away from target to reduce the impact on unemployment of the adjustment path back to equilibrium than would a more inflation-averse central bank with a higher β. Central bank preferences are discussed in more detail in Chapter 13.

[7] The central bank's preferences can be presented in this simple way if we assume that the central bank's discount rate is infinite. This means that it only considers one period at a time when making its decision.

The Phillips curve constraint

As discussed in Chapter 2, output affects inflation via the (adaptive expectations) Phillips curve:

$$\begin{aligned} \pi_t &= \pi_t^E + \alpha(y_t - y_e) \qquad (3.1) \\ &= \pi_{t-1} + \alpha(y_t - y_e), \qquad \text{(Phillips curve, } PC) \end{aligned}$$

where $\pi_t^E = \pi_{t-1}$.

The Phillips curve is a constraint for the central bank because it shows all the output and inflation combinations from which the central bank can choose for a given level of expected inflation. In other words, in any period, the central bank can only choose to locate the economy at a point on the Phillips curve it faces. In the Phillips curve used in this chapter, expected inflation is simply lagged inflation—other methods of forming inflation expectations will be discussed in Chapter 4.

This is shown in Fig. 3.6, where the upward sloping lines are the Phillips curves we worked with in Chapter 2. In the diagram, it is assumed that $\alpha = 1$, so that each Phillips curve has a slope of 45°. Each Phillips curve is labelled by a given level of expected inflation, which in the adaptive expectations Phillips curve is equal to lagged inflation. Assume that $\pi_t^E = \pi_{t-1} = \pi^T = 2$ (remember that this *PC* must go through point *A* at which $y = y_e$ and $\pi = 2$). The central bank is in the happy position of being able to choose bliss point *A* or (π^T, y_e) at which its loss is zero.

What happens if there has been a shock to inflation and it is not equal to the inflation target? Suppose, for example, that lagged inflation was 4%. The central bank is faced with the constraint of the Phillips curve shown by $PC(\pi_t^E = 4)$ and can only choose among points along it. The bliss point is no longer obtainable. The central bank faces a trade-off: if it wants a level of output of y_e next period, then it has to accept an inflation rate above its target, i.e. $\pi_t = 4 \neq \pi^T$ (i.e. point *B*). On the other hand, if it wishes to hit the inflation target next period, it must accept a much lower level of output next period (point *C*). Point *B* corresponds to a fully accommodating monetary policy in which the objective is purely to hit the output target ($\beta = 0$), and point *C* corresponds to a completely non-accommodating policy, in which the objective is purely to hit the inflation target.

It is clear from Fig. 3.6 that given its preferences, if the central bank is faced by $PC(\pi_t^E = 4)$, then it can do better (achieve a loss circle closer to *A*) than either point *B* or point *C*. It minimizes its loss function by choosing point *D*, where the $PC(\pi_t^E = 4)$ line is tangential to

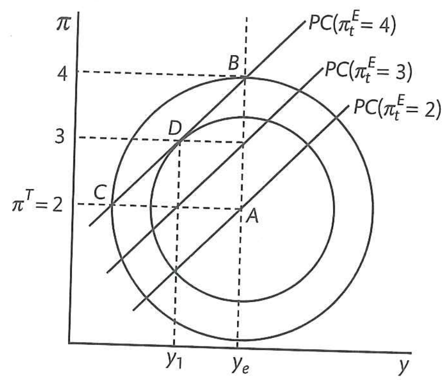


Figure 3.6 Loss circles and Phillips curves.

the indifference curve of the loss function closest to the bliss point. Thus if is it on $PC(\pi_t^E = 4)$ it will choose an output level y_1 which will in turn imply an inflation rate of 3% and a Phillips curve the following period of $PC(\pi_t^E = 3)$.

Deriving the monetary rule (*MR*) curve graphically

The *MR* curve shows the central bank's preferred output-inflation combination for any Phillips curve it faces. It can be derived graphically by finding the points of tangency between the Phillips curves and the loss circles. As shown in Fig. 3.7a, points *A*, *B* and *C* all minimize the loss function of the central bank for their given Phillips curve. For example, take point *B*, which is on $PC(\pi_t^E = 3)$. If the central bank were to choose any other point on that Phillips curve, then the economy would be on a loss circle further from the bliss point and hence at a lower level of utility.

If we join up the points of tangency as shown in Fig. 3.7b, this gives us the *MR* curve. This shows the output and inflation combination that the central bank will choose to minimize its loss function for any given Phillips curve it is faced with.

In the Appendix, we derive the monetary rule using the equations for the central bank's loss function and the Phillips curve. The equation for the *MR* curve shown in Fig. 3.7 is:

$$(y_t - y_e) = -\alpha\beta(\pi_t - \pi^T). \qquad \text{(Monetary rule, } MR\text{)}$$

The *MR* tells the central bank what output gap it should choose when it observes that inflation is away from its target. The monetary policy rules used by central banks are often described as Taylor Rules. The difference between the *MR* and a Taylor Rule is that the latter is expressed in terms of the interest rate the central bank should choose to implement its chosen output gap. Taylor Rules used by central banks are discussed in Chapter 13. To find out the interest rate the central bank should choose once it has decided on its preferred output gap using the *MR*, for example, to achieve point *C* at an output level of y_1 in Fig. 3.7, we need to introduce the *IS* curve. In addition to the Phillips curve (*PC*) and the monetary rule (*MR*), the *IS* is the third equation in the 3-equation model.

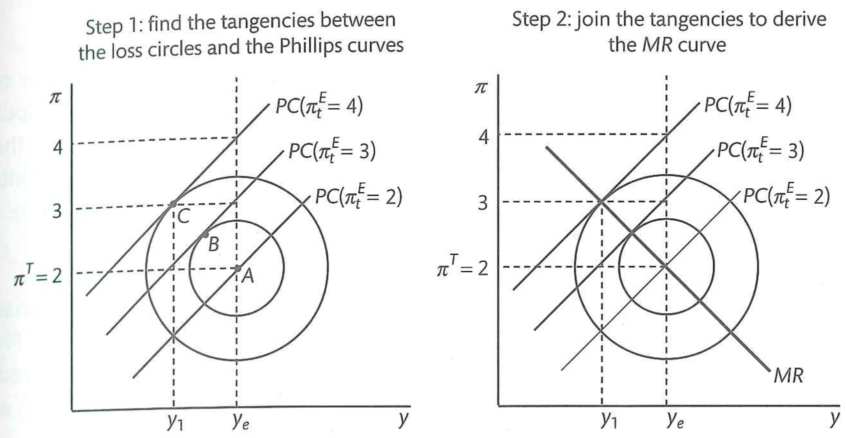


Figure 3.7 Deriving the *MR* curve.

Implementing central bank policy—the *IS* curve

In the previous subsection, we set out the process by which the central bank pins down its preferred output gap in response to an economic shock. The instrument the central bank uses to implement its policy is the real interest rate, *r*. The fact that the central bank must adjust the *nominal* interest rate that it sets in order to achieve a particular *real* interest rate on the *IS* curve is called the Taylor Principle.

The real interest rate is chosen to secure the appropriate level of aggregate demand and hence output. The central bank chooses the best point along the Phillips curve that it faces and in order to deliver the right level of aggregate demand, it must set the interest rate at the level shown by the *IS* curve. The *IS* curve shows the effect of changes in the interest rate on aggregate demand and was introduced in the following form in Chapter 1:

$$\begin{aligned} y &= k(c_0 + a_0 + G) - ka_1 r && (3.2) \\ &= A - ar, && (IS\text{ curve}) \end{aligned}$$

where $A \equiv k(c_0 + a_0 + G)$, $a \equiv ka_1$ and *k* is the multiplier. The term *A* includes the multiplier and the demand shift variables such as government spending and both the autonomous and forward-looking components of consumption and investment.

In the 3-equation model, we will use a 'dynamic' *IS* curve to represent the demand side, which captures the fact that aggregate demand responds negatively to the real interest rate (*r*) with a one period lag. This is in line with the Bank of England's estimates that the impact of interest rates on output takes up to (a maximum of) one year.[8]

The dynamic *IS* curve is defined as follows,

$$y_t = A_t - ar_{t-1}. \qquad \text{(dynamic } IS\text{ curve)}$$

[8] Compare the *How Monetary Policy Works* section of the Bank of England's website.

3.2.2 Using the 3-equation model

This section shows how the 3-equation model can be used to explain the response of the central bank to a shock. The economy is initially at the central bank's 'bliss point'—output is at equilibrium and inflation is at target. This is the medium-run equilibrium, y_e, where the *WS* and *PS* curves intersect and there is therefore no pressure on inflation to change. The interest rate that is associated with equilibrium is known as the *stabilizing rate of interest*, or r_S.

Inflation shock

An inflation shock is the simplest to analyse and serves to highlight the dynamic behaviour of the model. The term inflation shock is used to refer to an exogenous shift in the Phillips curve. This could be caused, for example, by a natural disaster such as a drought that reduces agricultural output and raises food prices, or by a temporary burst of union militancy, which pushes up wages.

In the 3-equation model framework, the central bank follows two main steps to stabilize the economy after an inflation shock:

1. The inflation shock shifts the Phillips curve upwards. The central bank must choose the position on the new Phillips curve that minimizes their loss function. This will be where the *MR* curve intersects the new Phillips curve. As inflation is above target, the central bank will have to reduce output below equilibrium to squeeze inflation out of the system.

2. The central bank uses the *IS* curve to find the increase in the real interest rate required to get the economy back onto the *MR* curve. The higher interest rate dampens output and inflation starts to fall. The central bank then gradually reduces the interest rate until output rises back to equilibrium and inflation falls back at target.

Figure 3.8 provides a summary of the dynamic adjustment of the economy to an inflation shock (start at the top and follow round). Figure 3.9a shows the typical fashion in which shocks can be modelled graphically in the 3-equation model, with the *IS* diagram at the top and the *PC* – *MR* diagram directly below it. This allows the position of the economy to be shown simultaneously on both diagrams. As shown in Fig. 3.9a, the adjustment of the economy to the inflation shock is as follows:

Period 0 The economy starts at *A*, where the central bank's utility is highest. The economy is then hit by an inflation shock which shifts the *PC* to *PC*(inflation shock) in the lower panel and the economy moves from *A* to *B*. Point *B* is not on the central bank's *MR* curve. The central bank forecasts the *PC* in the next period. In this case, the *PC* will stay in its post shock position, as output has not deviated from equilibrium as a result of the shock. We denote next period's *PC* as $PC(\pi_1^E = \pi_0)$. Faced with this *PC*, the central bank would like to locate at point *C*, back on the *MR* curve. They therefore set the interest rate at r_0. The interest rate can only affect economic output with a one period lag, however, so the economy ends period 0 with inflation at π_0, output at y_e and the interest rate at r_0.

Period 1 The new interest rate has had time to reduce aggregate demand by dampening investment. The economy moves to point *C*, with output below equilibrium at y_1 and inflation at π_1. The central bank forecasts the *PC* in the next period. The Phillips curve shifts when inflation expectations are updated: hence the *PC* will change in the next period, moving to $PC(\pi_2^E = \pi_1)$. Faced with this *PC*, the central bank would like to locate at point *D*, back on their *MR* curve. They therefore reduce the interest rate to r_1. The interest rate can only affect economic output with a one period lag, however, so the economy ends period 1 with inflation at π_1, output at y_1 and the interest rate at r_1.

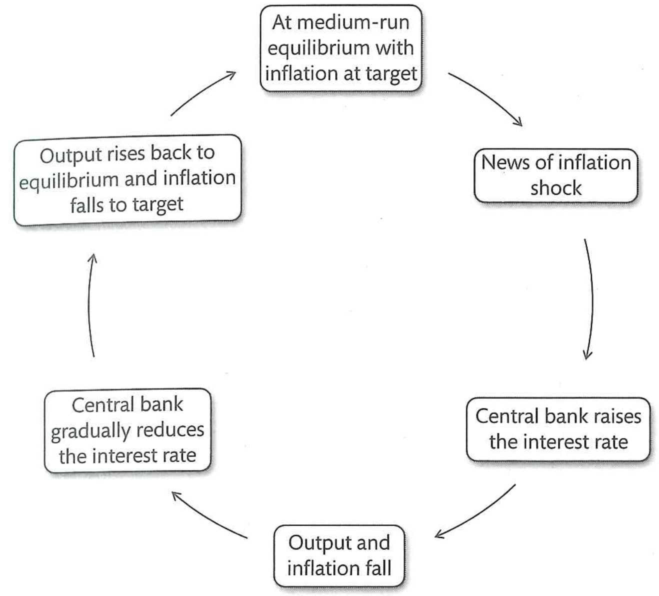


Figure 3.8 Dynamic adjustment to an inflation shock.

Period 2 onwards In period 2, the economy moves to point *D*, as the lower interest rate stimulates demand. This increases output to y_2 and inflation falls to π_2. The same process now repeats itself until the economy is back at equilibrium at *Z*. This involves the central bank forecasting next period's *PC* and setting the interest rate in the current period to ensure they stay on the *MR* curve in the following period. The adjustment from *D* to *Z* will take a number of periods. The economy will move gradually down the *MR* curve, as the central bank slowly adjusts the interest rate down from r_1 to r_S. This causes output to rise slowly from y_2 to y_e and inflation to fall slowly from π_2 to π^T. The economic adjustment to the inflation shock ends when the economy is back at point *Z*, with output at y_e, inflation at π^T and the interest rate at r_S.

Figure 3.9b shows the path of the key macroeconomic variables over time following the inflation shock. These types of graphs are called *impulse response functions* and are useful for visualizing the adjustment path of the economy following an economic shock. In this case, we can see that inflation has risen after the shock and is then slowly brought back to target. The interest rate follows a similar path, rising as soon as the shock takes place and then slowly being reduced to target. The path of output is slightly different, in that it does not change until one period after the shock. This is because the higher interest rate takes one period to affect output, as shown by the *IS* relation underlying the model, $y_t = A - ar_{t-1}$.

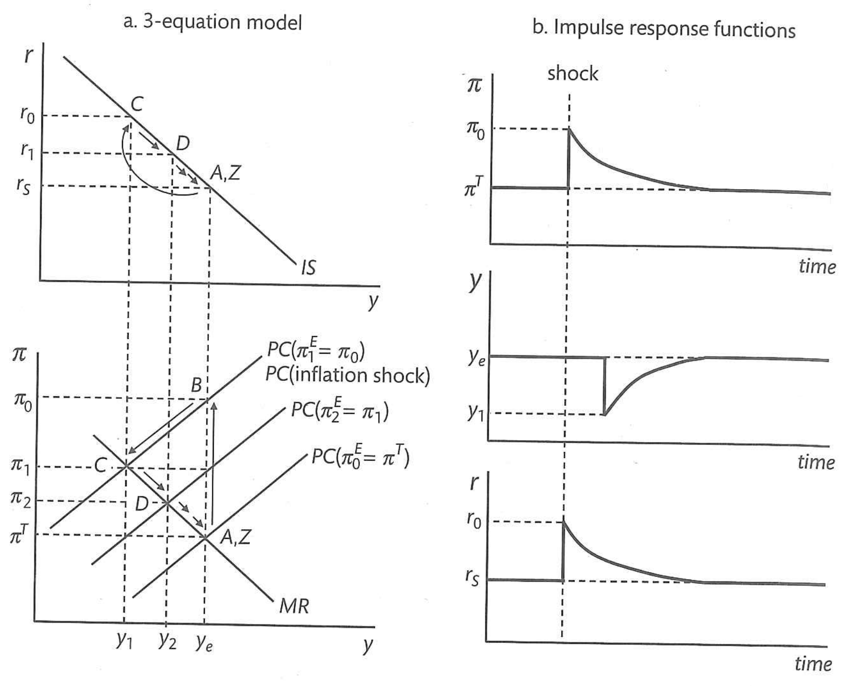


Figure 3.9 Inflation shock and the monetary rule.

The 3-equation model can be used to analyse a wide range of situations faced by the central bank. In Section 3.3, it is used to analyse demand and supply shocks and to examine the special case of a deflation trap.

3.3 Applications

In this section, we show more examples of the 3-equation model at work, focusing on demand- and supply-side shocks. We highlight the integral role played by central bank forecasting in identifying the best response interest rate to ensure medium-run economic stability. We go on to analyse the special case of a deflation trap, where a sizeable negative demand shock pushes the economy into a vicious cycle of falling inflation and output. We provide some escape routes from a deflation trap, whilst noting their potential pitfalls. We end this section by looking at a supply shock, which is a shift in either the wage- or price-setting curve. In this case, the central bank acts to stabilize the economy at the new equilibrium level of output fixed by the new intersecton of the *WS* and *PS* curves.

3.3.1 A temporary demand shock

We assume that the economy starts off in equilibrium with output at the equilibrium and inflation at the target rate of π^T (see Fig. 3.10). The economy is then disturbed by a temporary positive aggregate demand shock. By a temporary aggregate demand shock, we mean that the shock shifts the *IS* curve to *IS′*, but it only remains at *IS′* for one period. The economy is

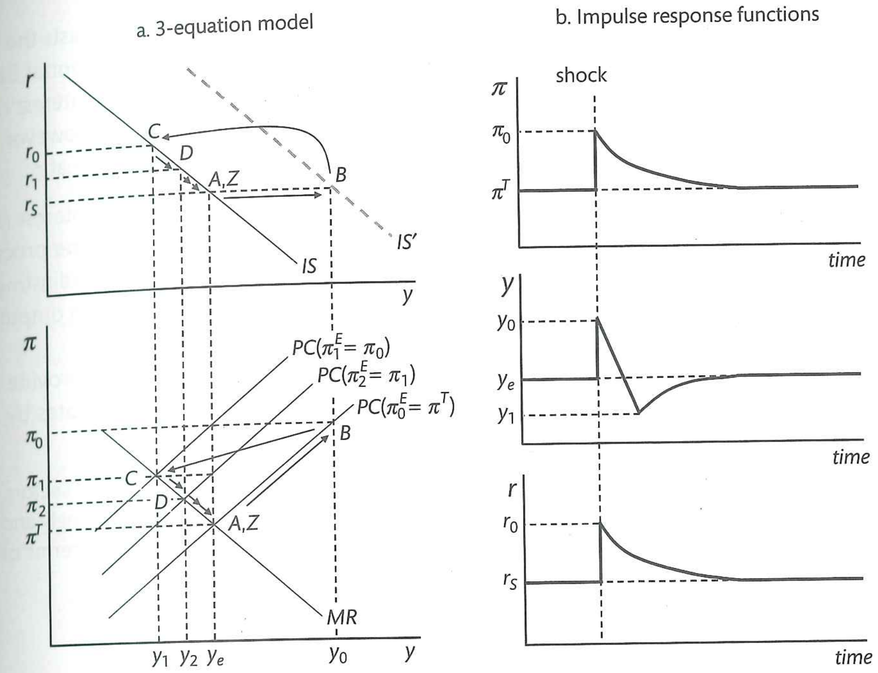


Figure 3.10 Adjustment of the economy to a temporary positive aggregate demand shock.

shifted from *A* to *B* in Fig. 3.10 as a result of the aggregate demand shock. This rise in output builds a rise in inflation above target into the system. Because of inflation inertia, this can only be eliminated by pushing output below and (unemployment above) the equilibrium. The central bank therefore raises the interest rate in response to the aggregate demand shock because it can work out the consequences for inflation. It must raise the interest rate in order to depress interest-sensitive demand and reduce output. The central bank is forward looking and takes all available information into account.

The adjustment to the shock is shown in Fig. 3.10.

Period 0 The economy starts at *A*—the central bank's bliss point. Following the demand shock, the economy moves from *A* to *B*. The shock has increased both output ($y_0 > y_e$) and inflation ($\pi_0 > \pi^T$). Point *B* is not on the central bank's *MR* curve. The central bank forecasts the *PC* in the next period. The Phillips curve shifts when inflation expectations are updated: hence the *PC* will change in the next period, moving to $PC(\pi_1^E = \pi_0)$. Faced with this *PC*, the central bank would like to locate at point *C*, back on their *MR* curve. They therefore set the interest rate at r_0.The central bank expects the demand shock to be temporary, so that the *IS* curve will shift back in the next period. This is the reason they use the original *IS* curve to set the interest rate. The interest rate can only affect economic output with a one period lag, however, so the economy ends period 0 with inflation at π_0, output at y_0 and the interest rate at r_0.

Period 1 The new interest rate has had time to affect aggregate demand. The higher rate of interest dampens investment. This reduces output and the economy moves to point *C*, with output below equilibrium at y_1 and inflation at π_1. The central bank forecasts the *PC* in the next period: the *PC* will move to $PC(\pi_2^E = \pi_1)$. Faced with this *PC*, the central bank would like to locate at point *D*, on their *MR* curve. They therefore reduce the interest rate to r_1. The interest rate can only affect economic output with a one period lag, however, so the economy ends period 1 with inflation at π_1, output at y_1 and the interest rate at r_1.

Period 2 onwards In period 2, the economy moves to point *D*, as the lower interest rate stimulates demand. This increases output to y_2 and inflation falls to π_2. The same process now repeats itself until the economy is back at equilibrium at *Z*. The economic adjustment to the temporary demand shock ends when the economy is back at point *Z*, with output at y_e, inflation at π^T and the interest rate at r_S.

We can use a Reserve Bank of Australia press release from March 2005 to provide an example of a case where an inflation-targeting central bank increased interest rates by 25 basis points to 5.5% in response to rising demand pressures:[9]

> In Australia, there are high levels of confidence in both the business and household sectors, credit growth is providing ample support for spending, employment is growing strongly and national income and spending will continue to be boosted this year by the rising terms of trade.

3.3.2 **Forecasting and lags**

The example of the central bank's reaction to a demand shock can be used to highlight the role played by forecasting and lags in the effect of monetary policy on aggregate demand and output. In the previous subsection, we discussed the adjustment of the economy to a temporary positive demand shock (Fig. 3.10). We now use Fig. 3.11 to compare this to the case of a permanent demand shock. It is left as an exercise for the reader to set out the detailed period by period adjustment for the permanent case.

The examples highlight two important points about the central bank's reaction to an aggregate demand shock:

1. The central bank has to forecast both the *PC* and *IS* curves. The forecasting of the *IS* curve means predicting the length of the shock—is it temporary or permanent?
2. The reason that the central bank must forecast the *IS* is that the persistence of the shock affects the central bank's preferred reaction. In Fig. 3.11, where the shock is permanent, the *IS* curve remains at *IS′*. The initial increase in the interest rate (i.e. from r_S to r_0) is much greater in the case of a permanent shock. In addition, a permanent shock leads to a higher stabilizing rate of interest in the new equilibrium—r_S'. This is because the higher autonomous aggregate demand (for example, due to improved consumer confidence) needs to be offset by lower interest-sensitive aggregate demand (i.e. investment) if output is to return to its equilibrium level y_e.

What happens if the central bank is uncertain about whether the shock is temporary or permanent? In this case, the central bank would be likely to set an interest rate somewhere in

[9] Excerpt taken from: Mr Ian Macfarlane, 2nd March 2005, *Statement by the Governor, Mr Ian Macfarlane: Monetary Policy.*

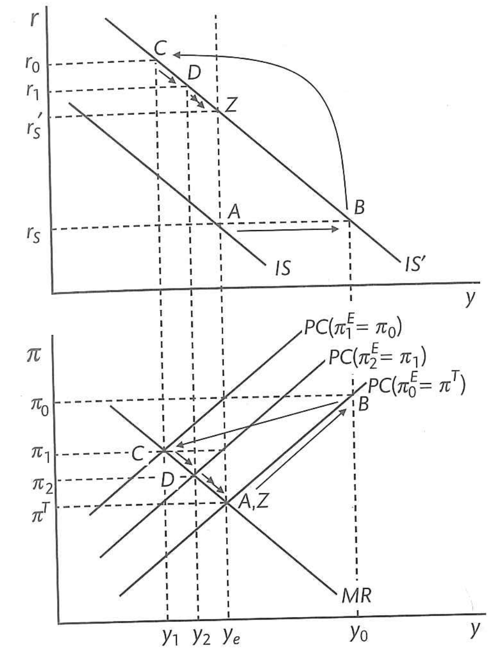


Figure 3.11 Adjustment of the economy to a permanent positive aggregate demand shock.

between the interest rates it would set in the cases presented in Figs. 3.10 and 3.11. In reality, central banks are unlikely to be able to tell (in the period of the shock) whether shocks will be temporary or permanent, so use their best judgement to respond to shocks and often have to adjust interest rates as new information arrives.

In the benchmark 3-equation model, the interest rate affects output with a one period lag: $y_t = A - ar_{t-1}$. However, it is interesting to see what happens if the central bank could affect output immediately, i.e. if $y_t = A - ar_t$. In this case, as soon as the *IS* shock is diagnosed, the central bank would raise the interest rate to r_S'. The economy then goes directly from *A* to *Z* in the *IS* diagram (in Fig. 3.11) and it remains at *A* in the *PC–MR* diagram, i.e. points *A* and *Z* coincide. Since the aggregate demand shock is fully and immediately offset by the change in the interest rate, there is no chance for inflation to rise.

This underlines the crucial role of lags and hence of forecasting for the central bank: the more timely and accurate are forecasts of shifts in aggregate demand (and of other kinds of shock), the greater is the chance that the central bank can offset them and limit their impact on inflation. Once inflation has been affected, the presence of inflation inertia means that the central bank must change the interest rate and get the economy onto the *MR* curve in order to steer it back to the inflation target.

The Bank of England's first strategic priority for 2012/13 was to 'keep inflation on track to meet the Government's 2% target'. One of the key actions the Bank committed to take to achieve this objective was to 'exploit the new suite of models in forecasting and analysis'.[10]

[10] These excerpts are taken from *The Bank's Strategy* section of the Bank of England's website.

This shows the focus and resources modern central banks apply to forecasting and modelling to make better informed monetary policy decisions.

3.3.3 The deflation trap

Problems arise for using monetary policy along the lines of the 3-equation model when the real rate of interest needed to stabilize demand cannot be achieved because the nominal interest rate cannot be reduced further.

The zero lower bound on nominal interest rates

In Chapter 1, we set out the Fisher equation, which shows the relationship between the real and nominal interest rates and the expected rate of inflation:

$$i = r + \pi^E. \qquad \text{(Fisher equation)}$$

When responding to an economic shock, the central bank adjusts the nominal interest rate (i), in order to affect the real interest rate (r) which in turn affects aggregate demand through the *IS* relation. To do this, it must take into account expected inflation as shown by the Fisher equation. In this regard, we can model the central bank as setting the real interest rate.

We saw in Fig. 3.1, that the central bank will respond to falling inflation by reducing the interest rate to stimulate aggregate demand. There is, however, a limit to the extent to which the central bank can reduce the nominal interest rate. The lowest nominal interest rate the central bank can set is zero (see the box below). From the Fisher equation, we can see that if the real interest rate that is needed to achieve the central bank's chosen output gap on the *MR* curve is, for example, 0.75%, and expected inflation is -1%, then a nominal interest rate of -0.25% would be required. With a *zero lower bound (or ZLB)* on the nominal interest rate, the minimum real interest rate that can be achieved is set by:

$$\min r \geq -\pi^E. \qquad (3.3)$$

This means that in our example, the minimum real interest rate achievable is 1%, which is not low enough get the economy on to the *MR* and on the path back to equilibrium. This condition is shown in Fig. 3.12 where the stabilizing real interest rate is below the minimum feasible rate of 1%. Given the depressed state of aggregate demand depicted by the position of the *IS* curve, if inflation has fallen to -1%, then it will be impossible to achieve the equilibrium level of output using conventional monetary policy. The economy is stuck at point *A* on the *IS* curve.

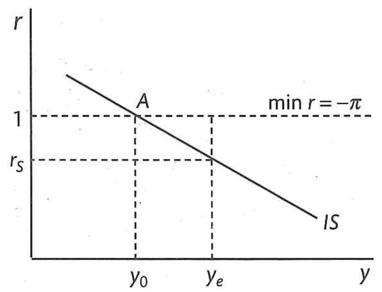


Figure 3.12 The zero lower bound on the nominal interest rate.

Box 3.1 Why can't nominal interest rates fall below zero?

There is no technical reason why nominal interest rates cannot be negative. The central bank could, for example, set the interest rate at -5%. In this environment, an individual who put $100 in the bank at the start of the year could withdraw $95 at the end of the year. This is not beneficial for savers, but this could be the interest rate required to get the economy onto the *MR* curve and back to equilibrium. It would certainly be expected to stimulate borrowing, by making the cost of obtaining credit cheaper.

There is, however, a major practical implication to negative interest rates; the presence of currency. When nominal interest rates are negative, there is nothing to stop people simply holding their savings in cash, which has a nominal interest rate of zero.

The existence of high denomination notes, such as the $100 bill and the €500 note, reduces the cost associated with carrying large sums of money in cash. If only very small denomination notes were left in circulation then this cost of carrying cash might become so large that accepting negative interest rates would be preferable. However, monetary authorities have shown no intention of moving towards this system so currency still acts as the limiting factor on setting nominal interest rates.[a]

[a] For a more thorough discussion on negative interest rates see Willem Buiter's Maverecon blog column for the Financial Times entitled 'Negative interest rates: when are they coming to a central bank near you?' (May, 2009).

The deflation trap and the 3-equation model

We can use the 3-equation model to provide a period by period explanation of how a negative aggregate demand shock can lead to the economy becoming stuck in a deflation trap, where output and inflation are falling without limit. We assume that the economy starts off with output at equilibrium and inflation at the target rate of π^T as shown in Fig. 3.13. The economic adjustment to the shock is as follows:

Period 0 The economy starts at *A*—the central bank's bliss point. The economy is hit by a large permanent negative aggregate demand shock which shifts the *IS* curve to *IS′* and the economy moves from *A* to *B*. The shock has reduced both output ($y_0 < y_e$) and inflation ($\pi_0 < \pi^T$). In fact, inflation has become negative—i.e. there is deflation. Point *B* is not on the central bank's *MR* curve. The central bank forecasts the *PC* in the next period. Inflation is currently below equilibrium at π_0, which means the *PC* will shift in the next period, moving to $PC(\pi_1^E = \pi_0)$. Faced with this *PC*, the central bank would like to locate at point *C′*, back on their *MR* curve. This would require setting an interest rate of r_0'. However, this is below the minimum real interest rate the central bank can achieve (by setting nominal interest rates to zero). The lowest interest rate they can achieve is $r_0 = -\pi_0$. The central bank expects the demand shock to be permanent, so that the *IS* curve will stay at *IS′* in the next period. This is the reason they use the new *IS* curve to set the interest rate. The interest rate can only

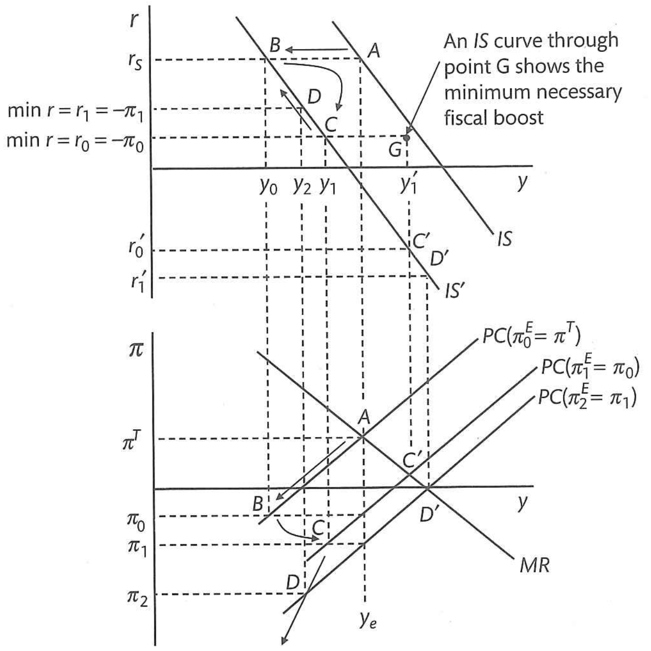


Figure 3.13 How a large negative permanent aggregate demand shock can lead to the economy entering a deflation trap.

affect economic output with a one period lag, however, so the economy ends period 0 with inflation at π_0, output at y_0 and the interest rate at r_0.

Period 1 The new interest rate has had time to affect aggregate demand. The lower rate of interest boosts investment. This increases output and the economy moves to point *C*, with output still below equilibrium at y_1. This level of output is far below the the central bank's best response level of y_1', which causes inflation to fall further to π_1. The central bank forecasts the *PC* in the next period. The *PC* will move to $PC(\pi_2^E = \pi_1)$. Faced with this *PC*, the central bank would like to locate at point *D'*, back on their *MR* curve. This would require setting an interest rate of r_1'. However, this is below the minimum real interest rate the central bank can achieve (by setting nominal interest rates to zero). The lowest interest rate they can achieve is $r_1 = -\pi_1$. The interest rate can only affect economic output with a one period lag, however, so the economy ends period 1 with inflation at π_1, output at y_1 and the interest rate at r_1.

Period 2 onwards In period 2, the economy moves to point *D*, as the higher interest rate dampens demand. This reduces output to y_2 and inflation falls further to π_2. The economy has entered a deflation trap—both output and inflation are falling every period and conventional monetary policy is powerless to stop them. In each future period, inflation becomes more negative, which increases the minimum real interest rate the central bank can achieve. The higher interest rate dampens demand, which further reduces inflation. In other words, the economy is caught in a vicious cycle. The arrows on Fig. 3.13 show that the economy will not revert to medium-run equilibrium in this case, but rather it will diverge, with ever-falling inflation and output.

The downward spiral of the economy in a deflation trap explains why policy makers are so keen to avoid this situation. We have shown in Fig. 3.13 that conventional monetary policy (e.g. adjusting interest rates) is insufficient to escape a deflation trap. There are, however, two policies which could be initiated to pull the economy out of this downward spiral:

1. The *IS* curve could be shifted to the right (to go through point *G*) in the period after the initial demand shock. This would allow the central bank to achieve their desired output level of y_1' by setting the minimum achievable interest rate of r_0. This positive demand shock could take place via a spontaneous recovery of autonomous investment or a recovery of autonomous consumption. Alternatively, the government can step in and implement the desired output gap shown by the *MR* curve by using fiscal policy. In this case, the *MR* becomes a more general policy rule and would be labelled *PR*, for policy rule.

2. The creation of more positive inflation expectations. If expected inflation becomes less negative, the min *r* line shifts down and the *PC* curve shifts up. This may allow the central bank to use the interest rate based monetary rule in the usual way to move the economy to the south-east along the *IS* curve.

However, the idea of escaping from the deflation trap by creating positive inflation expectations may not work in practice. The way to create expectations of inflation in the future is to create expectations of future higher aggregate demand: if the authorities do not take measures to create the demand, there is no reason to think that people will expect higher inflation.

Another potential option for central banks stuck at the zero lower bound is to introduce unconventional monetary policies, such as quantitative easing. We leave a discussion of this policy option until Chapter 7, however, as it is easier to explain once we have introduced the banking system into the model.

3.3.4 **A supply shock**

At the end of Chapter 2, we looked at the implications for inflation of a positive aggregate supply shock. This was modelled as a downward shift of the *WS* curve, which could be the result of a number of factors, such as a decrease in union bargaining power or a reduction in unemployment benefits. The initial effect of this supply shock is a downward shift of the Phillips curve. We will now go on to explain how the central bank stabilizes the economy in the event of a supply shock and the characteristics of the new medium-run equilibrium (see Fig. 3.14).

The stabilizing interest rate is lower (at r_S') in the new medium-run equilibrium. Since equilibrium output is higher as a consequence of the supply-side shift, a lower real interest rate is required to provide the appropriate level of aggregate demand. This example highlights that supply shocks differ from inflation and demand shocks in two key ways:

1. Firstly, a supply shock changes the equilibrium level of output (i.e. y_e' in Fig. 3.14).
2. Secondly, a supply shock shifts the *MR* schedule so that it goes through the point where inflation is at target and output at the new equilibrium (i.e. *MR'* in Fig. 3.14)

The period by period adjustment of the economy to a positive supply shock and the central bank's intervention is illustrated in Fig. 3.14 and described below.

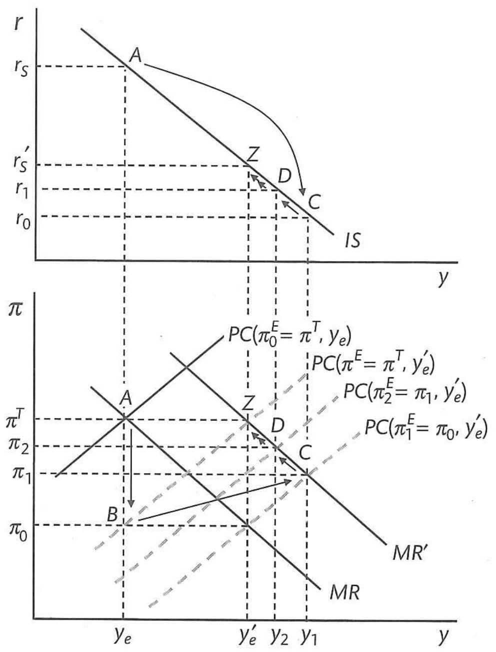


Figure 3.14 The adjustment of the economy to a positive permanent aggregate supply shock.

Period 0 The economy starts at *A*—the central bank's bliss point. The economy is hit by a permanent positive aggregate supply shock. This fundamentally changes the equilibrium level of output in the economy, increasing it from y_e to y_e'. At *A*, the economy is now below equilibrium output and there is pressure on inflation to fall (as $WS < PS$, see Chapter 2). The Phillips curve shifts down from $PC(\pi_0^E = \pi^T, y_e)$ to $PC(\pi_0^E = \pi^T, y_e')$, reflecting the change in the equilibrium level of output. The economy moves from *A* to *B*, where output is still at its original level, but inflation has fallen to π_0.

The central bank predicts that the shock is a permanent supply shock, so they shift the *MR* curve outwards to ensure their bliss point is now where output is equal to y_e' and inflation is equal to π^T. Point *B* is not on the central bank's new *MR* curve, *MR'*. The central bank forecasts the *PC* in the next period. Output is currently below the new equilibrium level of y_e', which means the *PC* will shift in the next period, moving to $PC(\pi_1^E = \pi_0, y_e')$. Faced with this *PC*, the central bank would like to locate at point *C*, on their new *MR* curve, *MR'*. They therefore set the interest rate at r_0. The interest rate can only affect economic output with a one period lag, however, so the economy ends period 0 at with inflation at π_0, output at y_e and interest rates at r_0.

Period 1 The new interest rate has had time to affect aggregate demand. The lower rate of interest boosts investment. This increases output and the economy moves to point *C*, with output above the new equilibrium at y_1 and inflation at π_1. The central bank forecasts the *PC* in the following period. Output is still away from the new equilibrium, so the *PC* will change again in the next period, moving to $PC(\pi_2^E = \pi_1, y_e')$. Faced with this *PC*, the central bank would like to locate at point *D*, on the *MR'* curve. They therefore increase the interest

rate to r_1. The interest rate can only affect economic output with a one period lag, however, so the economy ends period 1 with inflation at π_1, output at y_1 and interest rates at r_1.

Period 2 onwards In period 2, the economy moves to point *D*, as the higher interest rate dampens demand. This reduces output to y_2 and inflation rises to π_2. The same process now repeats itself in the usual way until the economy is back at equilibrium at *Z*. Adjustment to the supply shock ends when the economy is back at point *Z*, with output at y_e', inflation at π^T and the interest rate at r_S'.[11]

A positive supply shock can be the result of a shift in the *WS* or *PS* curves. We have shown the example of a downward shift in the *WS* curve above, but equally a positive supply shock could reflect an upward shift of the *PS* curve, due to increased product market competition or productivity gains. This latter case applies to the United States in the late 1990s, where the ICT revolution spurred productivity increases. The Federal Reserve correctly identified this as a positive supply shock and took into account its role in moderating inflation:[12]

> Responding to the availability of new technologies at increasingly attractive prices, firms have been investing heavily in new capital equipment; this investment has boosted productivity and living standards while holding down the rise in costs and prices.

3.4 Conclusions

This chapter has provided the final building block for the 3-equation model of the macroeconomy by setting out the monetary rule, or *MR* curve, which shows the central bank's chosen combination of output gap and inflation rate relative to target for any given Phillips curve they face. The equations of the 3-equation model are:

1. *IS* curve: $y_t = A - ar_{t-1}$.
2. *PC* curve: $\pi_t = \pi_{t-1} + \alpha(y_t - y_e)$.
3. *MR* curve: $(y_t - y_e) = -\alpha\beta(\pi_t - \pi^T)$.

The policy maker is modelled as an inflation-targeting central bank not because this is necessarily the best policy-making arrangement, but because it most closely resembles how modern stabilization policy is undertaken. We noted the economic and political reasons that have been used to explain why, in the more than two decades running up to the global financial crisis, stabilization policy was put in the hands of the monetary policy maker.

In Chapter 1, we introduced the *IS* curve to model the demand side of the economy. In Chapter 2, we introduced the Phillips curve (*PC*) to model the supply side of the economy.

[11] Note that, the Phillips curve in the new equilibrium is denoted by $PC(\pi^E = \pi^T, y_e')$. This does not include a time subscript because the Phillips curve is in this position in two periods—in period 0 straight after the supply shock and then in the period when the economy completes its adjustment to the new equilibrium at point *Z*.

[12] Excerpt taken from: The Federal Reserve Board, July 22nd, 1999, *Monetary Policy Report submitted to the Congress.*

In this chapter, we have introduced the *MR* curve to model the policy maker. These are the three components of the 3-equation model. The modelling section of this chapter set out the 3-equation model in full; the Appendix shows the mathematical derivation. Putting them together provides a framework in which to answer a variety of questions about the macro-economy and stabilization policy in particular:

1. Why target low and stable inflation? Central banks target low and stable inflation to minimize the negative effects of inflation on the economy—such as price distortions, shoe leather costs, menu costs—and to avoid high and rising (or volatile) inflation. Does that mean it is optimal to target 0% inflation? No, because central banks also want to guard against the threat of deflation (i.e. falling prices). Deflation is particularly problematic for the economy due to the possibility of entering a deflation trap. In light of this, the majority of developed economy modern central banks have chosen to target 2% inflation.

2. How do modern central banks go about achieving their inflation target? How do they react to economic shocks? The central bank's best response position—their 'bliss point'—is to be in medium-run equilibrium, with inflation equal to target (π^T) and output equal to equilibrium (y_e). The *monetary rule* (or *MR*) curve of a central bank shows the output and inflation combinations that minimize their *loss function* (i.e. maximize their utility) for any given Phillips curve they face. In response to an economic shock, the central bank finds the relevant Phillips curve and uses the *MR* curve to find their preferred output gap. The real interest rate (r) is the policy lever they use to achieve their desired output gap. It affects aggregate demand via the *IS* relation. The central bank then continues to adjust the interest rate to guide the economy to the new medium-run equilibrium. The use of the interest rate to implement monetary policy is sometimes called a Taylor rule based monetary policy. Demand shocks will cause the economy to diverge from its initial equilibrium level of output for a number of periods, whereas permanent supply shocks will cause the economy to move to a new equilibrium level of output.

3. What role do lags and forecasting play in monetary policy? The model reflects the real-world phenomenon that it takes time for the real interest rate to affect aggregate demand. This means that forecasting plays a large role in the central bank's setting of interest rates. For a shock in period zero, the central bank has to forecast where the Phillips curve will be next period and then set the appropriate interest rate (using the *MR* curve) to minimize their loss function. The Phillips curve also contains a backward-looking component, which means that if inflation is above target, a period of output below equilibrium (i.e. high unemployment) is required to reduce inflation back to target (and vice versa).

An important component of the core 3-equation model is the equilibrium rate of unemployment: it is possible to go straight from here to the analysis of the supply side institutions and policies that determine unemployment in Chapter 15. In this part of the book, we go on to consider a number of extensions to the model. In Chapter 4, we look in more depth at the way in which expectations about the future are formed. The role played by the banking system and how this can lead to instability and financial crises is integrated in the model in Chapters 5 and 6. The 3-equation model is extended to the open economy in Chapter 9.

3.5 Appendix

3.5.1 The 3-equation model in more detail

In the chapter, graphical analysis was used to provide a simple and intuitive explanation of the 3-equation model. In this section, we set out more carefully how the model works, focusing on the mathematical derivation of the *MR* curve. We start by deriving a more general form of the central bank's monetary rule. In setting out the equations that form the basis of the 3-equation model, we need to make explicit the timing structure. By choosing the interest rate in period zero, the central bank affects output and inflation in period 1. We assume it is only concerned with what happens in period 1. This is the reason that its loss function is defined in terms of y_1 and π_1. If we let β and α take any positive values, the central bank chooses y to minimize

$$L = (y_1 - y_e)^2 + \beta(\pi_1 - \pi^T)^2, \qquad \text{(central bank loss function)}$$

subject to

$$\pi_1 = \pi_0 + \alpha(y_1 - y_e). \qquad \text{(Phillips curve)}$$

By substituting the equation for the Phillips curve into the central bank loss function we can rewrite the loss function as:

$$L = (y_1 - y_e)^2 + \beta((\pi_0 + \alpha(y_1 - y_e)) - \pi^T)^2.$$

If we now differentiate this with respect to y_1 (since this is the variable the central bank can control via its choice of the interest rate), we have:

$$\frac{\partial L}{\partial y_1} = (y_1 - y_e) + \alpha\beta(\pi_0 + \alpha(y_1 - y_e) - \pi^T) = 0. \qquad (3.4)$$

Rearranging the Phillips curve to find π_0 and substituting this back into equation 3.4 gives:

$$(y_1 - y_e) = -\alpha\beta(\pi_1 - \pi^T). \qquad \text{(monetary rule, } MR\text{)}$$

The *monetary rule* shows the central bank's best response to a shock; it is the relationship between the inflation rate chosen indirectly and the level of output chosen directly by the central bank to maximize its utility (minimize its loss) given its preferences and the constraints it faces. The monetary rule is an inverse relation between π and y with a negative slope, which shows that the central bank must reduce aggregate demand and output, y, below y_e so as to reduce π below π^T.

In the general form of the *MR* curve shown above, it can be seen directly that the larger is α (i.e. the more responsive are wages to employment) or the larger is β (i.e. the more inflation averse is the central bank), the flatter will be the slope of the monetary rule.

In the first case this is because any reduction in aggregate demand achieves a bigger cut in inflation, i.e. whatever its preferences, the central bank gets a 'bigger bang (i.e. fall in inflation) for its buck (i.e. fall in aggregate demand)'.

In the second case, this is because, whatever the labour market it faces, a more inflation-averse central bank will wish to reduce inflation by more than a less 'hard-nosed' one.

Box 3.2 Summary of the 3-equation model

In formally deriving the *MR* curve, we now have all the components to set out the central bank's decision-making process:

1. The central bank minimizes its loss function, which expresses its objective of keeping inflation close to target, π^T

$$L = (y_t - y_e)^2 + \beta(\pi_t - \pi^T)^2, \qquad \text{central bank loss function}$$

2. subject to the constraint from the supply side, which is the Phillips curve (*PC*).

$$\pi_t = \pi_{t-1} + \alpha(y_t - y_e). \qquad \text{Phillips curve, } PC$$

3. This produces the monetary rule function (*MR*), which fixes the best response output gap $(y_t - y_e)$,

$$(y_t - y_e) = -\alpha\beta(\pi_t - \pi^T). \qquad \text{monetary rule, } MR$$

4. which is implemented through the central bank's choice of r using the dynamic *IS* equation, incorporating the lag from the interest rate to output

$$y_t = A - ar_{t-1}. \qquad \text{dynamic } IS \text{ curve}$$

Figure 3.15 shows the 3-equation model when the economy is in medium-run equilibrium—i.e. output is at equilibrium and inflation is constant at target. In the *PC* – *MR* diagram, the economy is at the central bank's 'bliss point'—the levels of output and inflation that minimize the loss function (i.e. y_e and π^T). In the *IS* diagram, we can use the *IS* curve to read off the interest rate the central bank must set to keep inflation constant and output at y_e. This is the *stabilizing rate of interest*, r_S.

In the case when output is at equilibrium (i.e. y_e) and the interest rate is at its stabilizing level (i.e. r_S), we can rewrite the dynamic *IS* curve as:

$$y_e = A - ar_S. \qquad (IS \text{ curve, in medium-run equilibrium})$$

We can use the two versions of the *IS* equation to find a relationship between deviations of output from equilibrium and the interest rate from its stabilizing level. We do this by subtracting one from the other, such that:

$$y_t - y_e = -a(r_{t-1} - r_S). \qquad (IS \text{ equation, in deviations})$$

In period zero, this becomes,

$$y_1 - y_e = -a(r_0 - r_S), \qquad (IS \text{ equation, in deviations, in period zero})$$

which takes into account the fact that interest rate changes in period zero do not affect output until period one (i.e. the lag structure of the model). It can be useful to think of the *IS* equation in deviations form in the 3-equation model and particularly for deriving interest rate rules, which will be discussed in detail in Chapter 13.

Figure 3.15 can also give us an insight into how varying the underlying targets or parameters will affect the 3-equation model. There are six key parameters that affect the

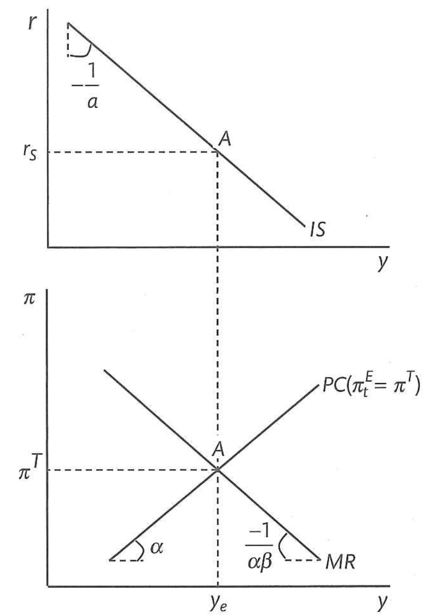


Figure 3.15 The 3-equation model in medium-run equilibrium.

underlying curves in the 3-equation model and the central bank's best response to economic shocks:[13]

1. the central bank's inflation target, π^T: this affects the position of the *MR* line;
2. the central bank's preferences, β: this determines the shape of the loss ellipses and affects the slope of the *MR* line;
3. the slope of the Phillips curve, α: this also affects the slope of the *MR* line;
4. the interest sensitivity of aggregate demand, a: this determines the slope of the *IS* curve;
5. the equilibrium level of output, y_e: this determines the level of output at which there is no pressure on inflation to change and affects the position of the *MR* line;
6. the stabilizing interest rate, r_S: the central bank adjusts the interest rate relative to r_S so it must always analyse whether this has shifted, e.g. as a result of a shift in the *IS* or due to a change in the equilibrium level of output, y_e.

3.6 Questions

3.6.1 Checklist questions

1. Why is monetary policy chosen over fiscal policy as the preferred tool for stabilization policy? What does the government gain from controlling monetary policy? Why would they choose to delegate responsibility for monetary policy to an independent central bank?

[13] The Macroeconomic Simulator available from the Carlin and Soskice website can be used to test the effects of varying key parameters on the adjustment path of the economy following an economic shock. See Questions 3 and 4 in Section 3.6.2.

2. 'If the economy has high but stable inflation, the government has much to lose and little to gain by reducing inflation to a low rate.' Explain and assess this statement.
3. What are the advantages and disadvantages of a target inflation rate of 4% as compared with one of 0% per annum?
4. Explain what is meant by the central bank's loss function. How are the central bank's preferences reflected in the loss function? Draw the loss 'circles' for the cases where
   (a) $\beta = 1$;
   (b) $\beta < 1$;
   (c) $\beta > 1$.

   In which of the three cases will the central bank reduce inflation back to target quickest after an inflation shock? Is there any downside to adopting this policy stance?
5. Assume that $\alpha = \beta = 1$, derive the *MR* curve graphically using the tangencies between the loss circles and the Phillips curves. With reference to the diagrams, explain the effect of the following (in each case, assume all other parameters are held constant):
   (a) An increase in the slope of the Phillips curve, α
   (b) An increase in central bank's inflation aversion, β.
6. Following an inflation shock, explain why unemployment goes up before the economy returns to medium-run equilibrium.
7. Draw the 3-equation model and give a detailed period by period description of the adjustment process for the case where the economy is hit by a permanent negative aggregate demand shock.
8. With reference to the scenario in Question 7, explain the behaviour of the central bank and the economy in a situation where there is no lag in the *IS* curve.
9. Draw the impulse response functions for output, inflation and the real interest rate after a permanent positive aggregate demand shock and a permanent positive supply shock. [Hint: the 3-equation model diagrams for these two cases are shown in Figs. 3.11 and 3.14 respectively.]
10. Use the 3-equation model diagrams to show how the economy can fall into a deflation trap. Explain, with reference to the diagram, how the central bank/government can intervene to escape the trap. Show the relevant *IS* curve and re-label the *MR* as the *PR* to indicate that fiscal policy is being used. Are there any reasons why these policies might not work?

3.6.2 Problems and questions for discussion

1. Pick one developed economy and one emerging or developing economy. Use the latest version of the IMF World Economic Outlook Database to download inflation data for each of the countries from 1980 to the latest available data. Plot the data in a graph. Answer the following:
   (a) Describe the evolution of inflation in each country.
   (b) Do the countries have independent central banks?
   (c) If the country does have an independent central bank, did inflation fall when the central bank gained independence? Propose some reasons why.
   (d) If the country does not have an independent central bank, have they managed to find other mechanisms to establish a low inflation monetary policy regime? Propose some reasons why.

2. Select two out of the following central banks: Bank of England, Reserve Bank of New Zealand, Bank of Canada, and the Swedish Riksbank. Each of these central banks has adopted explicit 'inflation targeting'. For each of your chosen banks, answer the following questions:
   (a) What is their target level of inflation and how do they justify choosing that level?
   (b) What actions did it take following the collapse of Lehman Brothers in September 2008 and how did it explain these actions?
   (c) Did they hit the zero lower bound on nominal interest rates during the global financial crisis? If so, how could they adjust their inflation target to reduce the likelihood of this happening again in the future? Check for evidence of a public debate about this issue.
3. This question uses the Macroeconomic Simulator available from the Carlin and Soskice website http://www.oup.com/uk/orc/carlin_soskice to model a negative temporary aggregate demand shock. Start by opening the simulator and choosing the closed economy version. Then reset all shocks by clicking the appropriate button on the left hand side of the main page. Use the simulator and the content of this chapter to work through the following:
   (a) Apply a temporary 5% negative demand shock. Save your data.
   (b) Use the impulse response functions from the simulator to help explain the path of the economy following the shock.
   (c) Draw the $IS - PC - MR$ diagrams for this scenario.
   (d) Adjust the central bank preferences (i.e. β) to 0.5 and save your data. Now, adjust the central bank preferences to 1.5 and save your data again.
   (e) How has varying β affected the impulse response functions? Relate this to the effect that changing β has on the *MR* curve.
4. This question uses the Macroeconomic Simulator available from the Carlin and Soskice website http://www.oup.com/uk/orc/carlin_soskice to show how the economy can get stuck in a deflation trap and what it can do to escape it. Start by opening the simulator and choosing the closed economy version. Then reset all shocks by clicking the appropriate button on the left hand side of the main page. Use the simulator and the content of this chapter to work through the following:
   (a) Apply a temporary 8% negative demand shock. Save your data.
   (b) Use the impulse response functions to help explain the path of the economy following the shock.
   (c) Apply a temporary increase in public expenditure of 7% alongside the original demand shock. Save your data.
   (d) Comment on the changes to the impulse response functions. [Hint: it might be necessary to view the second case in isolation to accurately view the movements in the impulse response functions]
   (e) Has fiscal policy been effective at stabilizing the economy? If so, explain why using the 3-equation model framework.