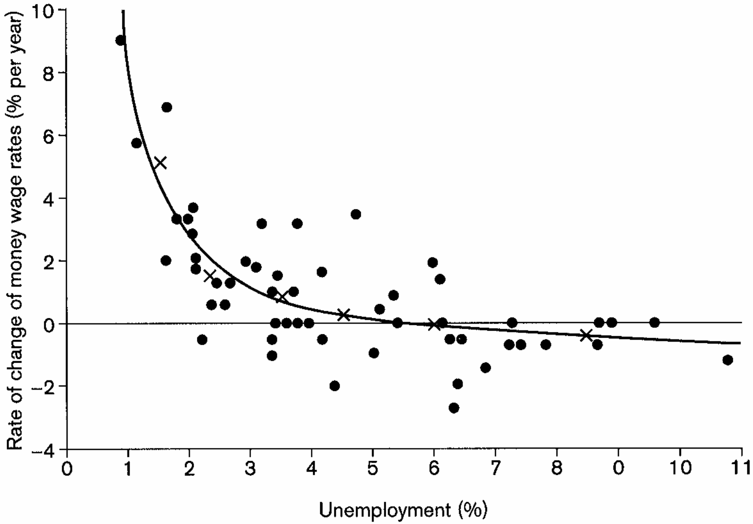
13. INFLATION, UNEMPLOYMENT AND AGGREGATE SUPPLY

■ **Inflation and unemployment are two of the most important macroeconomic problems**. Indeed, the **main goals of macroeconomic stabilization policy are to fight cyclical unemployment and to avoid high inflation**.

■ In this lecture we explore the **relationship between inflation and unemployment**. As we shall see, understanding the link between these two variables is **crucial for understanding how the supply side of the economy works** and **how the economy reacts to shocks**. In short, **studying the relationship between inflation and unemployment is fundamental for understanding business fluctuations**.

Background: a brief history of the Phillips curve

■ **For many years after the Second World War** most economists and policy makers **believed that there was an inescapable trade-off between inflation and unemployment**: if you **want less inflation, you have to live with permanently higher unemployment**, and vice versa. Figure 13.1 (a)(b), taken from a famous article published in 1958 by the New Zealand-born economist **A.W. Phillips**, suggest **why most observers came to believe in a permanent unemployment-inflation trade-off**.


Rate of change of money wage rates (% per year)
10
8
6
4
2
0
−2
−4
0
1
2
3
4
5
6
7
8
0
10
11
Unemployment (%)

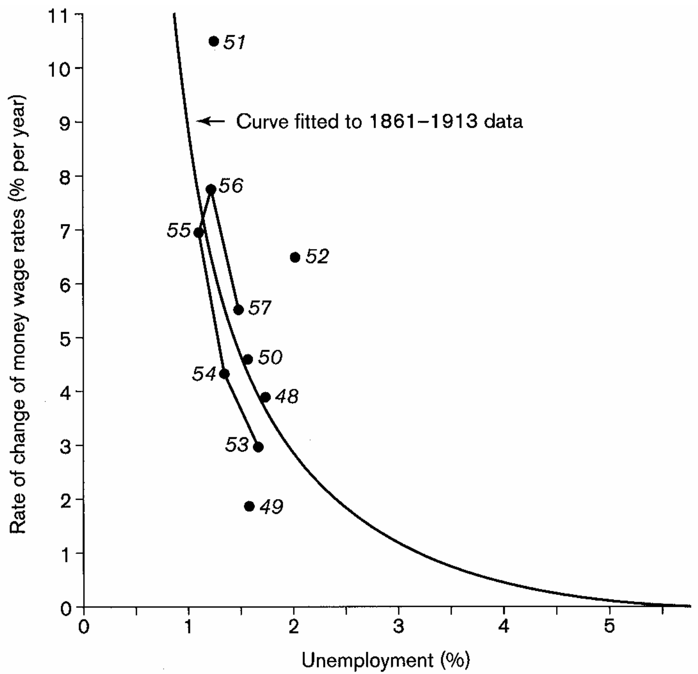

11
10
9
8
7
6
5
4
3
2
1
0
Rate of change of money wage rates (% per year)
51
Curve fitted to 1861–1913 data
56
55
52
57
50
54
48
53
49
0
1
2
3
4
5
Unemployment (%)

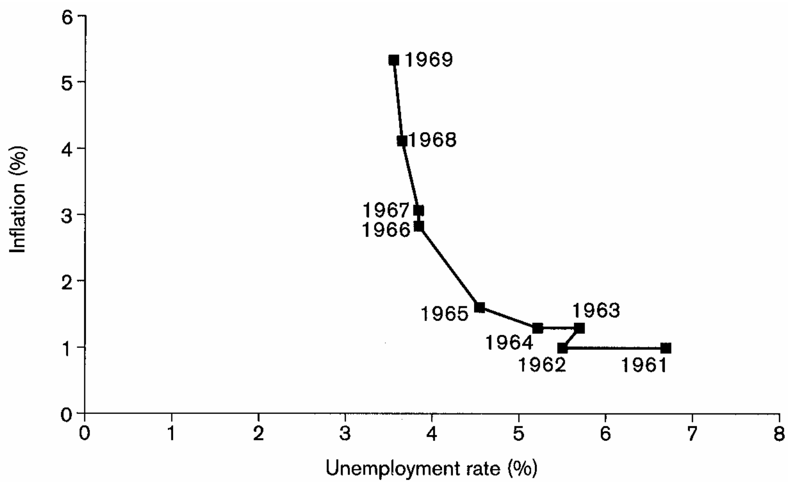
Figure 13.1: (a) The Phillips Curve in the United Kingdom, 1861-1913; (b) The Phillips Curve in the United Kingdom, 1948-1957

Source: A.W. Phillips, "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861 –1957", *Economica*, New Series, 25 (100), Blackwell Publishing, (Nov., 1958).

■ Figure 13.1 (a) reproduces the **curve which Phillips fitted to describe the relationship between unemployment and the rate of money wage inflation in the United Kingdom in the period 1861-1913**. We see that he found a **clear (although non-linear) negative correlation** between the two variables. Phillips then showed that the **curve fitted to the 1861-1913 data was able to explain the relationship between UK unemployment and wage inflation in the much later period 1948-1957**, shown in Figure 13.1 (b).

■ **Apparently Phillips had discovered a very stable and fundamental trade-off**. This trade-off was therefore quickly incorporated into macroeconomic models under the name of the **Phillips curve**.

■ As illustrated in Figure 13.2 (a) which is based on **US data on unemployment and the rate of consumer price inflation**, the **Phillips curve trade-off also seemed to exist throughout most of the 1960s**. However, **in the 1970s the relationship broke down** completely (see Figure 13.2 (b)).


6
5
4
3
2
1
0
Inflation (%)
1969
1968
1967
1966
1965
1964
1963
1962
1961
0
1
2
3
4
5
6
7
8
Unemployment rate (%)

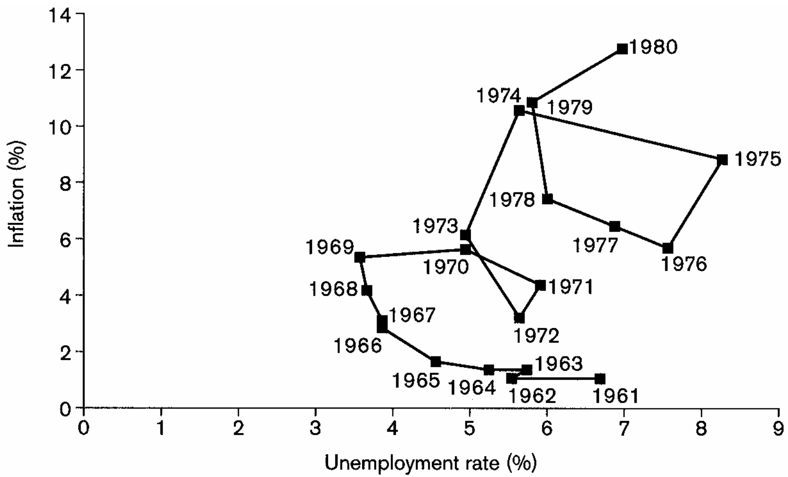


Figure 13.2: (a) The Phillips curve in the United States of the 1960s; (b) The breakdown of the simple Phillips curve in the United States

Source: R.B. Mitchell, International Historical Statistics, Macmillian, 1998; and Bureau of Labor Statistics.

■ Many times during the **1970s the US experienced a simultaneous rise in inflation and unemployment**, much to the perplexity and frustration of economic policy makers. The same thing happened in practically all OECD countries during that decade. What was going on?

■ In this lecture we develop a **theory of inflation and unemployment which offers an explanation for the apparently stable Phillips curve trade-off before the 1970s** as well as the **relationship between unemployment and inflation in the more recent decades**.

■ Our **theory of wage and price formation will be consistent with the theory of structural unemployment** presented earlier. As we shall see, this **framework can explain the short-run link between inflation and unemployment as well as the factors determining the long-run equilibrium rate of unemployment**, the "natural" rate. The relationship we shall arrive at is the so-called **expectations-augmented Phillips curve**,

$$\pi = \pi^e + \alpha(\bar{u} - u), \quad \alpha > 0, \qquad 13.1$$

where π is the **actual rate of inflation**, π^e is the **expected inflation rate**, u is the **actual rate of unemployment**, and $\bar{u}$ is the **natural unemployment rate**.

■ **Many roads lead to the expectations-augmented Phillips curve**. This lecture will take you down some of these roads. We offer a **theory of the expectations-augmented Phillips curve in line with the theory of trade union behaviour**. However, the same qualitative results may be obtained from the theory of efficiency wages.

■ The **model of inflation and unemployment** presented in the next section **assumes that nominal wages are rigid in the short run**. Later we show that the **expectations-augmented Phillips curve may also be derived from a model of a competitive labour market with fully flexible wages and prices**. By comparing these models, we are able to highlight how **nominal rigidities exacerbate the employment fluctuations which occur when economic agents underestimate or overestimate the rate of inflation**.

Nominal rigidities, expectational errors and employment fluctuations

■ **Inflation is a continuous rise in the general price level**. A **theory of inflation** therefore **requires a theory of price formation**. Since **prices depend on the cost of inputs**, and since **labour is the most important input**, our **theory of price formation will build on a theory of wage formation**.

■ The theory will allow for **imperfect competition in the markets for goods as well as labour**. Introducing imperfect competition in output markets **complicates the analysis**, but in return it **enables us to illustrate how structural changes in product markets affect inflation and the natural rate of unemployment**.

■ **In the lectures on the long run**, we **assumed that agents had correct expectations about the general level of wages and prices**, as must be the case in any long-run equilibrium. By contrast, **in the present short-run context we assume that people do not have perfect information about the current general price level**. As we shall see, this means that **employment and output may deviate from their long-run equilibrium levels**.

■ This section assumes that **wages are "sticky" in the short run, being set by trade unions**. We will therefore start with a description of trade union behaviour and wage formation.

The trade union's objective

■ We consider an **economy** which is divided into a **number of different sectors each producing a differentiated product**. Workers in each sector are **organized in a trade union** which **monopolizes the supply of labour to all firms in the sector**.

■ Because of its monopoly position, the **trade union in each sector may dictate the nominal wage rate to be paid by employers in that sector**, but **employers** have the "**right to manage**", that is, they can **freely choose the level of employment**. For simplicity, we assume that the **number of working hours for the individual worker is fixed**, so **total labour input is proportional to the number of workers employed**.

■ **Workers in sector *i* are educated and trained to work in that particular sector**, so they **cannot move to another sector** to look for a job. If a worker fails to find a job in his sector, he therefore becomes unemployed. His real income will then be equal to the real rate of **unemployment benefit *b***.

■ An **employed worker in sector *i* earns the real wage** $w_i \equiv W_i/P$, where W_i is the sectoral money wage and P is (an index of) the general price level, so his ***net* income gain from being employed is $w_i - b$**. The **trade union for sector *i* cares about this real income gain** for its employed members, but it **also cares about the total number of jobs** L_i secured for the membership. We formalize this by assuming that the **union sets the nominal wage rate** with the purpose of **maximizing a utility function Ω** of the form:

$$\Omega = (w_i - b)L_i^{\eta}, \quad \eta > 0 \qquad 13.2$$

■ The parameter ***η* reflects the weight which the union attaches to high employment relative to the goal of a high real wage** for employed union members. The more the union is concerned about employment relative to wages, the higher is the value of η. In the benchmark case **where $\eta = 1$, the union is simply interested in the aggregate net income gain obtained by employed members**.

■ When setting the wage rate, the union must account for the fact that a higher real wage will lower the employer's demand for labour. Our next step is to derive this constraint on the union's optimization problem.

Price setting and labour demand

■ The representative employer in sector *i* uses a **technology** described by the **production function**:

$$Y_i = BL_i^{1-\alpha}, \quad 0 < \alpha < 1 \qquad 13.3$$

where ***Y_i* is the volume of real output** produced and sold in sector *i*, and ***B* is a productivity parameter**. Since we are **concentrating on the short run where the capital stock is fixed**, we have **not included capital explicitly in the production function**. Earlier we worked with the **Cobb-Douglas** production function $Y = BK^{\alpha}L^{1\text{-}\alpha}$. Equation (13.3) is just a version of this production function where we have **fixed the capital stock *K* at unity**.

■ According to (13.3), the **marginal product of labour**, *MPL*, is:

$$MPL_i \equiv dY_i \big/ dL_i = (1-\alpha)BL_i^{-\alpha} \qquad 13.4$$

which is seen to **diminish as labour input increases**, due to the **fixity of the capital stock**.

■ The **employer** representing industry *i* **produces a differentiated product** and therefore has **some monopoly power**, so we assume that he faces a **downward-sloping demand curve** of the form:

$$Y_i = \left(\frac{P_i}{P}\right)^{-\sigma} \frac{Y}{n}, \quad \sigma > 1 \qquad 13.5$$

■ This demand curve has a **constant numerical price elasticity of demand** equal to $\sigma = -(dY_i/dP_i)(P_i/Y_i)$, where P_i is the price charged per unit of Y_i. The variable ***Y* is total GDP**, and n is the **number of different sectors in the economy**.

■ Aggregate output Y is a measure of the total size of the national market, and ***Y*/*n* is the market share captured by each industry if they all charge the same prices (so that $P_i = P$)**. (The demand curve (13.5) may be derived from the solution to the consumer's problem of utility maximization if utility functions are of the CES form. In that case the parameter σ is the representative consumer's elasticity of substitution between good i and any other good.)

■ The **total revenue of firm *i*** is $TR_i \equiv P_iY_i$, so according to (13.5) its **marginal revenue** (the increase in total revenue from selling an extra unit of output) will be:

$$MR_i \equiv \frac{dTR_i}{dY_i} = P_i + Y_i\left(\frac{dP_i}{dY_i}\right) = P_i\left(1 + \frac{dP_i}{dY_i}\frac{Y_i}{P_i}\right) = P_i\left(1 - \frac{1}{\sigma}\right) \qquad 13.6$$

■ From microeconomic theory we know that a **profit-maximizing firm will expand output to the point where marginal revenue equals marginal cost**, $MR_i = MC_i$. Because **labour is the only variable factor** of production, **marginal cost is equal to the price of an extra unit of labour** – the nominal wage rate, W_i – **divided by labour's marginal product**, MPL_i, since MPL_i measures the additional units of output produced by an extra unit of labour.

■ Thus $MC_i = W_i/MPL_i$. From (13.4) and (13.6), the necessary **condition for maximization of profits**, $MR_i = MC_i$, therefore **becomes**:

$$P_i\left(\frac{\sigma-1}{\sigma}\right)=\frac{W_i}{(1-\alpha)BL_i^{-\alpha}}$$

which is equivalent to:

$$P_i = m^p \cdot \overbrace{\left(\frac{W_i}{(1-\alpha)BL_i^{-\alpha}} \right)}^{MC_i}, \quad m^p \equiv \frac{\sigma}{\sigma - 1} > 1 \qquad 13.7$$

■ Equation (13.7) shows that the **profit-maximizing representative firm** in sector *i* will set its **price as a mark-up over its marginal cost**. Our previous **assumption $\sigma > 1$ guarantees that the mark-up factor m^p is positive and greater than one**.

■ The **price elasticity**, σ, is a **measure of the strength of product market competition**. The **higher the elasticity**, the greater is the fall in demand induced by a higher price (the **flatter is the demand curve**), and the **lower is the mark-up of price over marginal cost**. In the **limiting case where the price elasticity tends to infinity**, the price is driven down to the level of marginal cost ($\sigma \to \infty \Rightarrow m^p \to 1$), corresponding to **perfect competition**.

■ We can now **derive the labour demand curve of sector *i***, showing the **relationship between the real wage** W_i/P claimed by the union in sector i **and the level of employment** in that sector.

■ Dividing by P on both sides of (13.7) gives the **relative price, P_i/P, of sector *i*'s product**. **Inserting this P_i/P** into (13.5) then **gives production**, Y_i, in sector i. Finally, we can use (13.3) to **compute how much employment**, L_i, is needed to produce that level of output. Performing these operations, we end up with:

$$L_i = \left(\frac{Y}{nB}\right)^{\varepsilon/\sigma}\left(\frac{B(1-\alpha)}{m^p}\right)^{\varepsilon}\left(\frac{W_i}{P}\right)^{-\varepsilon}, \quad \varepsilon \equiv \frac{\sigma}{1+\alpha(\sigma-1)} > 0 \qquad 13.8$$

■ The **numerical real wage elasticity of labour demand** at the sectoral level (defined as $-dL_i/d(W_i/P))((W_i/P)/L_i))$ is **equal to the constant ε**. From the expression for ε you may verify that a **higher price elasticity of product demand** (tougher competition in product markets) **increases the wage elasticity of sectoral labour demand**.

■ This is intuitive: a **rise in the wage rate will drive up the output price by raising the firm's marginal cost**. The **higher the price elasticity of output demand**, the **greater is the fall in sales** and output, so the **greater is the resulting fall in labour demand**.

Wage setting

■ The **labour demand curve** (13.8) implies that **employment in sector *i* is a declining function**, $L_i(w_i)$, **of the real wage**, $w_i \equiv W_i/P$. The **union's utility function** (13.2) may therefore be written as:

$$\Omega(w_i) = (w_i - b)[L_i(w_i)]^\eta \qquad 13.9$$

■ **Suppose** for the moment that the **union has perfect information about the current price level** so that **it may perfectly control the real wage** $w_i \equiv W_i/P$ **via its control of the money wage** W_i. The **union will then choose** w_i, **so as to maximize** $\Omega(w_i)$.

■ The **necessary condition for a maximum**, $d\Omega(w_i)/dw_i = 0$, is $L_i^{\eta} + (w_i - b)\eta L_i^{\eta\text{-}1}(dL_i/dw_i) = 0$, which is **equivalent to**:

$$1+\frac{\eta(w_i-b)}{w_i}\left(\frac{dL_i}{dw_i}\frac{w_i}{L_i}\right)=0$$

■ **Using the fact** that $(dL_i/dw_i)(w_i/L_i) = -\varepsilon$, we may **rewrite this expression** as:

$$w_i = m^w \cdot b, \quad m^w \equiv \frac{\eta\varepsilon}{\eta\varepsilon - 1} \qquad 13.10$$

■ According to (13.10) the **union's target real wage is a mark-up over the opportunity cost of employment**. The **opportunity cost of employment is the rate of unemployment benefit** b, since this is the income a worker forgoes by being employed rather than unemployed. To secure that (13.10) actually implies a positive real wage, we **assume that $\eta\varepsilon$ > 1**. It then follows that the **wage mark-up factor, m^w, is greater than 1**.

■ Equation (13.10) implies that the **union's real wage claim will be lower the greater the weight it attaches to the goal of high employment**, i.e., the **higher the value of η**. It also follows from (13.10) that the **target real wage will be lower the higher the elasticity of labour demand**, ε. The reason is that a **higher labour demand elasticity increases the loss of jobs resulting from any given increase in the real wage**.

■ Finally, we see from (13.10) that a **higher rate of unemployment benefit drives up the target real wage** because **it reduces the income loss incurred by those union members who lose their jobs when the union charges a higher wage rate**.

■ We have so far **assumed** that the **union has perfect information about the current price level** and therefore perfectly **controls the real wage** W_i/P **through its control of the money wage rate**, W_i. However, **in practice, nominal wage rates are almost always preset for a certain period of time**, that is, **in the short run the nominal wage rate is rigid**.

■ Moreover, **at the start of the period when wages are set, trade union leaders cannot perfectly foresee the price level** which will prevail over the period during which the nominal wage rate will be fixed by the wage contract. A **trade union** setting the wage rate at the start of the current period must therefore **base its money wage claim on its expectation of the price level** which will prevail over the coming period.

■ Given that the **union strives to obtain the real wage** specified in (13.10), it will then set the money wage rate so as to achieve an **expected real wage equal to the target real wage** $m^w b$. (We **assume for simplicity that the union has a correct estimate of the level of b**. For example, we may assume that the nominal rate of unemployment benefit is automatically indexed to the current price level so as to protect its real value. The union will then be able to forecast the level of the real rate of unemployment benefit even if it cannot perfectly foresee the price level.) If the **expected price level for the current period is P^e**, the **nominal wage rate set by the union** at the start of the period will thus be:

$$W_i = P^e m^w b \qquad 13.11$$

■ Having **developed a theory of wage and price setting** as well as a **theory of labour demand**, we are now **ready to derive the link between inflation and unemployment**.

The expectations-augmented Phillips curve

■ Equation (13.11) implies that the **actual real wage may be written as** $W_i/P = (P^e/P)m^w b$. Inserting this expression into the labour demand curve (13.8) and rearranging, we obtain the **level of employment** in sector i:

$$L_i = \left(\frac{Y}{nB}\right)^{\varepsilon/\sigma}\left(\frac{B(1-\alpha)}{m^p m^w b}\frac{P}{P^e}\right)^{\varepsilon} \qquad 13.12$$

■ The **higher the actual price level relative to the expected price level**, P/P^e, that is, the **more the trade union underestimates the price level**, the **lower is its nominal wage claim**

relative to the actual price level, so the **lower is the real wage** and the **higher is the level of sectoral employment**, as we see from (13.12).

■ We will now show that a **similar qualitative relationship between employment and the ratio of actual to expected prices will prevail at the aggregate level**. In doing so we will assume that **all sectors in the economy are symmetric** so that output and employment in each sector are given by Eqs (13.3) and (13.12), respectively, where **all the parameters as well as the ratio P/P^e are the same across sectors**.

■ **Total employment** (L) will then be $L = nL_i$ and **total GDP** will be $Y = nY_i = nBL_i^{1-\alpha}$. Substituting the latter expression into (13.12) and computing $L = nL_i$ we get

$$L = nL_i = n \cdot \left(\frac{B(1-\alpha)}{m^p m^w b} \cdot \frac{P}{P^e} \right)^{1/\alpha} \qquad 13.13$$

where we have used the definition of ε given in (13.8) according to which $1 - \varepsilon(1 - \alpha)/\sigma = \alpha\varepsilon$.

■ Note that **since the real wage** $w \equiv W/P$ is the **same in all sectors** and equal to $(P^e/P)m^w b$, we may also write (13.13) as:

$$L = n\left(\frac{B(1-\alpha)}{m^p}\right)^{1/\alpha}\left(\frac{W}{P}\right)^{-1/\alpha} \qquad 13.14$$

■ This expression shows that **at the aggregate level the numerical real wage elasticity of labour demand is 1/*α***, whereas **at the level of the individual sector we found it to be equal to** $\varepsilon = \sigma/[1 + \alpha(\sigma - 1)]$.

■ **In a long-run equilibrium expectations must be fulfilled**. Inserting $P^e = P$ into (13.13), we therefore **obtain the long-run equilibrium level of aggregate employment**, $\bar{L}$, also called the **"natural" level of employment**:

$$\overline{L} = n\left(\frac{B(1-\alpha)}{m^p m^w b}\right)^{1/\alpha} \quad 13.15$$

■ Equation (13.15) gives the **level of employment which will prevail when price expectations are correct** so that **trade unions actually obtain their target real wage**. Dividing (13.13) by (13.15), we get a simple **relationship between the actual and the natural level of employment**:

$$\frac{L}{\overline{L}} = \left(\frac{P}{P^e}\right)^{1/\alpha} \quad 13.16$$

■ If the **aggregate labour force** is N and the **unemployment rate** is u, it follows by definition that $L \equiv (1 - u)N$. Similarly, the **"natural" unemployment rate**, $\overline{u}$, is defined by the relationship $\overline{L} \equiv (1-\overline{u})N$.

Substitution of these identities into (13.16) gives $(1-u)/(1-\overline{u}) = (P/P^e)^{1/\alpha}$. Taking natural logarithms on both sides and using the approximations $\ln(1 - u) \approx -u$ and $\ln(1-\overline{u}) \approx -\overline{u}$, we get:

$$p = p^e + \alpha(\overline{u} - u), \quad p \equiv \ln P, \quad p^e \equiv \ln P^e$$

■ Subtracting $p_{-1} \equiv \ln P_{-1}$ on both sides finally gives:

$$\pi = \pi^e + \alpha(\overline{u} - u), \quad \pi \equiv p - p_{-1}, \quad \pi^e \equiv p^e - p_{-1} \qquad 13.17$$

where the subscript "–1" indicates that the variable in question refers to the previous time period. Recalling that the change in the log of some variable roughly equals the relative change in that variable, it follows that **π is the actual rate of inflation** whereas **π^e is the expected rate of inflation**, assuming that **agents know the previous period's price level** p_{-1} **when they form their expectation about the current price level**.

■ Equation (13.17) is a **key macroeconomic relationship** called the **expectations-augmented Phillips curve**, and it provides the **link between inflation and unemployment** we have been looking for. The **theory of the expectations-augmented Phillips curve** was developed almost simultaneously by the US economists **Milton Friedman** and **Edmund Phelps** (see Milton Friedman, "The Role of Monetary Policy", *American Economic Review*, 58, 1968; Edmund S. Phelps, "Money-Wage Dynamics and Labor Market Equilibrium", *Journal of Political Economy*, 76, 1968).

■ The **curve shows** that **for any given expected rate of inflation**, a **lower level of unemployment is associated with a higher actual rate of inflation**, and vice versa. More precisely, we see from (13.17) that **unanticipated inflation** ($\pi > \pi^e$) **will drive unemployment below its natural rate**. The reason is that an **unexpected rise in the rate of inflation causes the real value of the pre-set money wage rate to fall below the target real wage of trade unions**, thereby **inducing firms to expand employment beyond the natural level**.

The simple versus the expectations-augmented Phillips curve

■ If we **set the expected inflation rate** in (13.17) equal **to 0**, we obtain a version of the **simple Phillips curve** presented in Section 1, **describing the unemployment-inflation trade-off discovered by Phillips**:

$$\pi = \alpha(\overline{u} - u) \qquad 13.18$$

■ We may now offer an **explanation why the simple unemployment-inflation trade-off estimated by Phillips broke down in the US** and elsewhere in the OECD from **around 1970**. Over the **long historical period** considered by Phillips – from around 1860 to the 1950s – there was **no systematic tendency for prices to rise for extended periods of time**, as you can see from Figure 13.3.

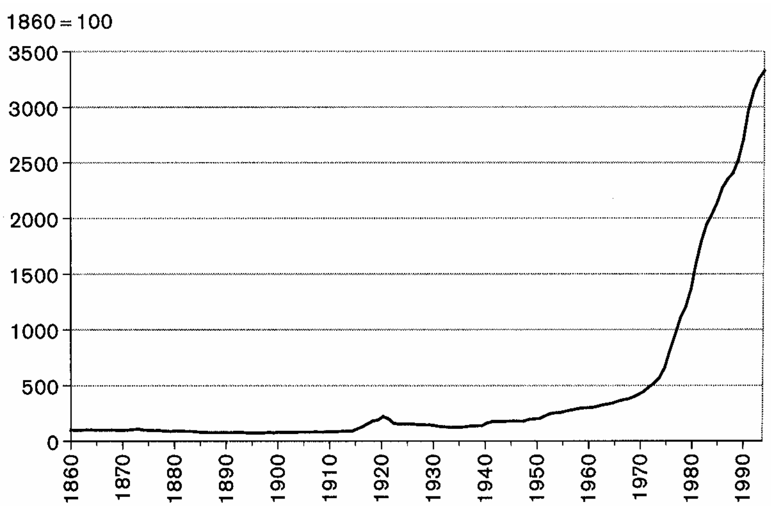


Figure 13.3: The consumer price index in the United Kingdom, 1860-1993

Source: B.R. Mitchell, *International Historical Statistics: Europe* 1750-1993, Macmillan Press, 1998.

■ Because of this **long experience of approximate price stability**, it was natural for economic **agents to expect prices to be roughly constant**. In such circumstances where π^e = 0, Eq. (13.17) does **indeed predict that a lower unemployment rate will always be associated with a higher inflation rate**, and vice versa.

■ However, **towards the end of the 1960s inflation had been systematically positive and gradually rising for several years**, so **people started to consider a positive inflation rate as a normal state of affairs**. As a consequence, the **expected inflation rate started to increase**.

■ According to (13.17) this **tended to drive up the actual rate of inflation associated with any given level of unemployment**, just as portrayed in Figure 13.2 (b) which showed that **many years during the 1970s were characterized by simultaneous increases in inflation and unemployment**.

■ There were also other reasons for these developments, such as dramatic **increases in the price of oil** due to turmoil in the Middle East, but **rising inflation expectations probably**

played an important role in the breakdown of the simple Phillips curve from the end of the 1960s.

■ The implication of all this is that the **simple negative Phillips curve relationship between inflation and unemployment is a short-run trade-off which will hold only as long as the expected rate of inflation stays constant**. For this reason the simple downward-sloping Phillips curve (defined for a given expected rate of inflation) may also be **called the short-run Phillips curve**. **Whenever the expected inflation rate π^e increases, the short-run Phillips curve will shift upwards**, as illustrated in Figure 13.4 which shows three different short-run Phillips curves, each corresponding to different levels of expected inflation.

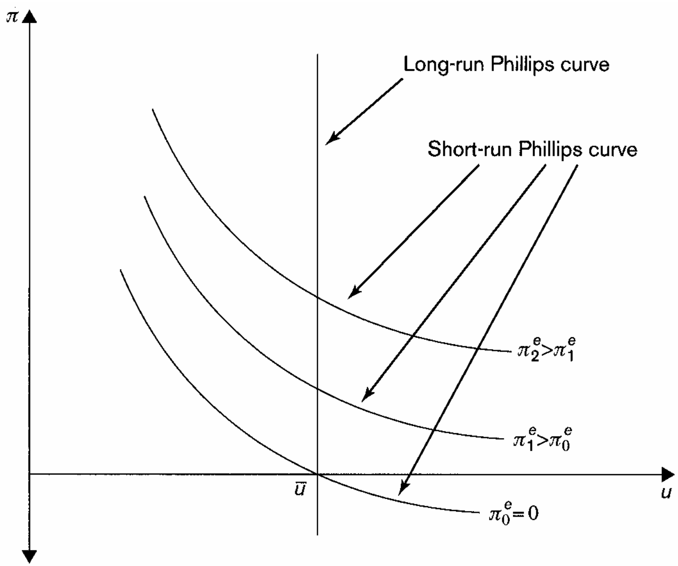


Figure 13.4: The expectations-augmented Phillips curve

■ **In a long-run equilibrium the expected inflation rate equals the actual inflation rate**, $\pi^e = \pi$. According to (13.17) this means that **only one unemployment rate** – the **natural rate** $\bar{u}$ – is **compatible with long-run equilibrium**. We may say that the long-run Phillips curve is vertical, passing through $u = \bar{u}$, as indicated in Figure 13.4. Hence there is no permanent trade-off between inflation and unemployment.

■ **Outside long-run equilibrium, the expected inflation rate differs from the actual inflation rate**. **If such expectational errors persist**, it is natural to assume that **economic agents will gradually revise their expectations** as they observe that their inflation forecasts turn out to be wrong. One **simple hypothesis** encountered in the previous lecture is that **people have static expectations**, expecting that this period's inflation rate will correspond to the rate of inflation observed during the previous period:

$$\pi^e = \pi_{-1} \qquad 13.19$$

■ This hypothesis means that **agents will change their inflation forecasts whenever they observe a change in last period's inflation rate**. Substitution of (13.19) into (13.17) gives:

$$\Delta\pi \equiv \pi - \pi_{-1} = \alpha(\bar{u} - u) \qquad 13.20$$

which shows that **inflation will accelerate when unemployment is below its natural rate**, and **decelerate when unemployment is above the natural level**. To prevent inflation from accelerating (or decelerating), **unemployment will thus have to be kept at its natural rate**. For this reason the **natural rate is sometimes called** the "**Non-Accelerating-Inflation-Rate-of-Unemployment**", or just the **NAIRU**, for short.

■ **Another important implication of the expectations-augmented Phillips curve** (13.17) is that there is **nominal inertia**: **if unemployment is at its natural rate, the inflation prevailing today will automatically continue tomorrow because it is built into expectations**. **To bring down inflation, it is necessary to push the actual unemployment rate above the NAIRU for a while**.

What determines the natural rate of unemployment?

■ It is obvious that the natural rate of unemployment plays an important role in our theory of inflation, given that inflation will tend to rise if unemployment is pushed below that level. But **what determines the natural rate?**

■ Our expression (13.15) for the natural level of employment provides the key to an answer. Recall that $\overline{L} = (1-\overline{u})N$. For simplicity, let us **set the number of workers in each sector equal to 1** so that the total labour force becomes $N = n$, implying $\overline{L} = (1-\overline{u})n$. Inserting (13.15) into this expression and rearranging, we get:

$$\overline{u} = 1 - \left(\frac{B(1-\alpha)}{m^p m^w b} \right)^{1/\alpha} \qquad 13.21$$

■ Equation (13.21) shows that the **natural unemployment rate depends on the level of the real unemployment benefit**, b, **among other things**.

■ It is reasonable to assume that the **government allows the rate of unemployment benefit to grow in line with real income per capita, at least over the longer run**. From the growth theory we know that the **long-run growth rate of per-capita income will equal the growth rate of total factor productivity** B. We will therefore **assume that the level of unemployment benefits is tied to the level of productivity** so that $b = cB$, where $c > 0$ is a parameter reflecting the **generosity of the system of unemployment compensation**.

■ Substituting cB for b in (13.21), we get the following expression for the natural rate of unemployment, where we assume that the combination of parameter values ensures a positive value of $\bar{u}$:

$$\bar{u} = 1 - \left(\frac{1-\alpha}{m^p m^w c} \right)^{1/\alpha} \qquad 13.22$$

■ According to (13.22) the **natural unemployment rate is higher the higher the mark-ups in wage and price setting**, and the **more generous the level of unemployment benefits** (the higher the value of c).

■ A **rise in m^p** $= \sigma/(\sigma - 1)$ **reflects a fall in the representative firm's price elasticity of demand** (σ) which means that **it takes a larger cut in the firm's relative price P_i/P to obtain a given increase in sales**. **To sell the extra output produced by an extra worker, the firm must therefore accept a larger price cut the lower the value of σ**. For any given wage level, the **profit-maximizing level of employment will thus be lower the lower the value of σ**. This is why the **natural unemployment rate will be higher the higher the mark-up factor m^p**.

■ A **fall in σ will also increase the wage mark-up**, since the **sectoral labour demand elasticity** $\varepsilon \equiv \sigma/[1 + \alpha(\sigma - 1)]$ is **increasing in σ**, and since $m^w = \eta\varepsilon/(\eta\varepsilon - 1)$ is decreasing in ε.

■ The **intuition for this rise in the wage mark-up** is that a **lower price elasticity of demand for the output of the representative firm reduces the drop in sales and employment occurring when a higher union wage claim drives up the firm's marginal cost and price**. Hence it becomes **less costly (in terms of jobs lost) for the union to push up the wage rate**, and this invites more aggressive wage claims.

■ The representative **firm's price elasticity of demand reflects the degree of competition in product markets**. The **greater the number of competing firms** in each market, and the **greater the substitutability of the products of different firms**, the tougher competition will be, and the **greater will be the price elasticity of demand faced by the individual firm** or industry.

■ Thus our analysis shows that a **lower degree of competition in product markets** (a lower σ) **will spill over to the labour market and raise the natural rate of unemployment**, partly because **it lowers labour demand**, and partly because **it induces more aggressive wage claims**. This is an interesting **example of how imperfections in some markets may exacerbate imperfections in other markets**.

■ It is worth noting **two more points** from (13.22). First, a **greater union concern about employment**, reflected in a higher value of the parameter η, will **reduce the natural rate of unemployment by lowering the wage mark-up** $m^w = \eta\varepsilon/(\eta\varepsilon - 1)$.

■ Second, the **level of productivity *B* does not affect the natural rate of unemployment**. This **prediction is in line with empirical observations**. As illustrated by Figure 6.1 in, the **unemployment rate tends to fluctuate around a constant level over the very long run despite the fact that productivity is steadily growing over time**. However, as we shall see later, **short-run fluctuations in productivity growth do affect the short-run unemployment-inflation trade-off**.

Nominal price rigidity

■ For simplicity, our **model of wage and price setting assumes that while nominal wages are rigid in the short run, output prices adjust immediately to changes in demand and marginal costs**.

■ This is a way of **capturing the stylized fact that nominal wages tend to be fixed for longer periods of time than most goods prices**. But in reality **many output prices are also held constant for considerable periods**.

■ We also saw that **small "menu costs" of price adjustment** – such as the costs of printing new price catalogues and communicating new prices to customers – **may make it suboptimal for firms to adjust prices too frequently**. When you interpret our theory of inflation and unemployment, you should therefore **keep in mind that a sluggish adjustment of inflation** – and hence a sluggish adjustment of unemployment to its natural level – **may not only be due to a slow adjustment of nominal wage rates**. It may **also reflect that it takes time for changes in expectations to feed into the actual price level because it is costly for firms to change prices too frequently**.

The expectations-augmented Phillips curve in a competitive labour market

■ The **theory of inflation and unemployment** presented above **included two elements which are typically used to explain how it is possible for economic activity to deviate from its long-run equilibrium** level: **expectational errors** (erroneous price expectations) and **nominal rigidity**. We allowed for **nominal rigidity** by assuming that **nominal wage rates are preset at the start of each period** and **do not adjust within the period even if labour demand changes**. In other words, **within each period the nominal wage rate is fixed**, although it **adjusts between periods as price expectations change**.

■ In this section we will try to **deepen your understanding of the importance of expectationals errors and nominal rigidity** for explaining fluctuations in employment. We will show that while **expectational errors are both necessary and sufficient to generate deviations of unemployment from its natural rate, nominal rigidity is not necessary but will amplify the fluctuations in employment caused by expectational errors**.

■ To demonstrate this, we will **analyse the response of employment to unanticipated inflation in a model with fully flexible nominal wages** and **compare this model with the one developed above where nominal wages are "sticky" in the short run**.

The link between inflation and employment in a competitive labour market: the worker-misperception model

■ To highlight the role of nominal rigidity, it is instructive to **consider the link between inflation and employment which would prevail if the labour market were competitive**, that is, if **nominal and real wages were fully flexible**, adjusting instantaneously **to balance labour supply and labour demand**.

■ In a competitive labour market there are **no trade unions**. Our **wage setting equation** (13.11) specifying union wage claims is therefore **replaced by a labour supply curve showing how workers adjust their labour supply in response to changes in the expected real wage**.

■ To facilitate comparison with the trade union model considered above, we **continue to assume that each employed worker works a fixed number of hours** which we may denote by H. **Changes in aggregate labour supply will then take the form of more workers entering the labour market or some workers exiting the market**.

■ Suppose that **worker *j* requires a minimum real wage w_j to be willing to sacrifice *H* hours of leisure** by taking a job. In that case he will **only enter the labour market if the expected real wage, W/P^e, is at least equal to w_j**.

■ Suppose further that **different workers have different valuations of leisure**, with some requiring only a **low real wage to be willing to accept a job**, while **others require a high real wage** to be willing to enter the labour market. If there is a **continuum of required minimum real wages**, the **number of workers entering the labour market**, L^s, will **rise continuously as the expected real wage increases**, implying an aggregate labour supply function of the form $L^s = f(W/P^e)$, $f' > 0$.

■ For simplicity, let us **assume that the distribution of the taste for leisure** across workers (the distribution of required real wages) is **such that the function $f(W/P^e)$ has a constant**

elasticity *φ* with respect to the expected real wage. We then get the **aggregate labour supply function**:

$$L^s = Z\left(\frac{W}{P^e}\right)^{\phi} = Z\left(w \cdot \frac{P}{P^e}\right)^{\phi}, \quad Z > 0 \qquad 13.23$$

where ***Z* is a constant reflecting the size of the population**, and where, you recall, that $w \equiv W/P$ is the actual real wage. Equation (13.23) makes the reasonable **assumption that the worker knows his nominal wage rate *W* when he accepts a job**, but he **does not have perfect information on the current price level when he makes his labour supply decision**, so he must **base his decision on his expectation of the current price level**.

■ **Aggregate labour demand** L^d is still given by Eq. (13.14) which may be written as:

$$L^d = Xw^{-1/\alpha}, \quad X \equiv n\left(\frac{B(1-\alpha)}{m^p}\right)^{1/\alpha} \qquad 13.24$$

■ In a **competitive labour market** the **real wage** ***w*** **will adjust to balance supply and demand**, $L^s = L^d$, implying:

$$w = \left(\frac{X}{Z}\right)^{1/(\phi+1/\alpha)}\left(\frac{P}{P^e}\right)^{-\phi/(\phi+1/\alpha)} \qquad 13.25$$

■ The **equilibrium real wage** found in Eq. (13.25) may be **inserted** into (13.24) to give the **level of employment in the competitive labour market**:

$$L = X^{\phi/(\phi+1/\alpha)}Z^{(1/\alpha)/(\phi+1/\alpha)}\left(\frac{P}{P^e}\right)^{(\phi/\alpha)/(\phi+1/\alpha)} \qquad 13.26$$

■ Figure 13.5 illustrates how the **equilibrium levels of *w* and *L*** are determined by the **intersection of the aggregate labour supply curve** (13.23) **and the aggregate labour demand curve** (13.24).

■ The **natural employment level** $\bar{L}$ is found at the **equilibrium point** $\bar{E}$ **where price expectations are correct** ($P^e = P$) so that the **labour supply curve** (13.23) **collapses to** $L^s = Zw^{\varepsilon^s}$.

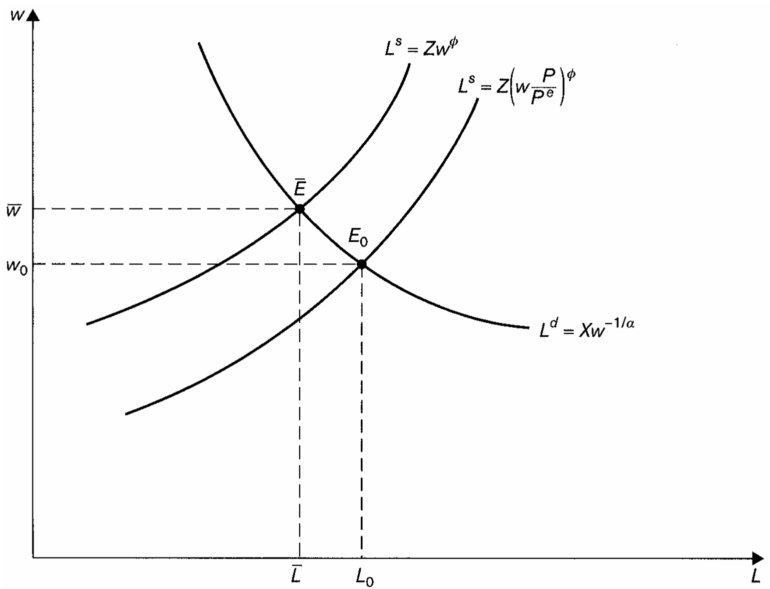


Figure 13.5: Labour market equilibrium in the worker-misperception model

■ In the **equilibrium** E_0 **employment is above the natural level because workers underestimate the price level** ($P > P^e$). Whenever there is a **change in the ratio of the actual to the expected price level**, P/P^e, the l**abour supply curve will shift**, generating new short-run equilibrium levels of the real wage and employment.

■ This model of the labour market is sometimes called "**the worker-misperception model**" because it postulates that **employment fluctuations are driven by workers' misperceptions of the price level**, that is, by fluctuations in P/P^e.

■ **Natural employment** may be found from (13.26) by setting $P^e = P$. We then get:

$$\bar{L} = X^{\phi/(\phi+1/\alpha)} Z^{(1/\alpha)/(\phi+1/\alpha)} \qquad 13.27$$

■ Dividing (13.26) by (13.27) gives:

$$\frac{L}{\overline{L}} = \left(\frac{P}{P^e}\right)^{(\phi/\alpha)/(\phi+1/\alpha)} \qquad 13.28$$

■ We see that (13.28) has **exactly the same form** as our earlier (13.16) which was **derived from the model with union wage setting**. The only difference is that the **coefficient 1/*α* has now been replaced by** $(\varphi/\alpha)/(\varphi + 1/\alpha)$.

■ By taking **logs on both sides** of (13.28) and using the a**pproximations** $\ln(1 - u) \approx -u$ and $\ln(1-\overline{u}) \approx -\overline{u}$, we can **still derive an expectations-augmented Phillips curve of the form** $\pi = \pi^e + \hat{\alpha}(\overline{u} - u)$, where $\hat{\alpha}$ is a constant.

■ This shows that the **expectations-augmented Phillips curve is quite a general relationship** which does **not assume a particular market structure**. But as we shall demonstrate below, it is quite **important for the quantitative relationship between employment and unanticipated inflation whether the labour market is competitive or not**.

The competitive versus the unionized labour market

■ To see **how unanticipated inflation affects employment in the competitive and in the unionized labour market**, we take natural **logs on both sides** of (13.28) and (13.16) and use the **definitions of the actual and the expected inflation rate**, $\pi \equiv \ln P - \ln P_{-1}$ and $\pi^e \equiv \ln P^e - \ln P_{-1}$. We then obtain the following results:

Competitive labour market:

$$\ln L - \ln \bar{L} = \left(\frac{1/\alpha}{1 + 1/\alpha\phi} \right)(\pi - \pi^e) \qquad 13.29$$

Unionized labour market:

$$\ln L - \ln \bar{L} = (1/\alpha)(\pi - \pi^e) \qquad 13.30$$

■ Since $(1/\alpha)/(1 + 1/\alpha\varphi) < 1/\alpha$, these equations show that **for any given amount of unanticipated inflation**, $\pi - \pi^e$, the **percentage deviation of employment from its natural level**, $\ln L - \ln \overline{L}$, **will be larger in the unionized than in the competitive labour market**.

■ This may be explained as follows. Suppose that, **due to some unanticipated positive shock to aggregate demand for goods, the actual price level rises unexpectedly**, driving π above π^e. This increase in the price level **will erode the real wage**, W/P, thereby **stimulating the demand for labour**.

■ **In the competitive labour market the increase in labour demand immediately drives up the flexible money wage**, generating an increase in the expected real wage, W/P^e, which **induces workers to supply more labour**. Because of the rise in W, the **fall in the actual real wage generated by the rise in *P* will be dampened**, which **in turn dampens the increase in labour demand** and employment.

■ However, in the **unionized labour market** the **nominal wage is fixed** at the start of the period, and consequently there is **no dampening effect on labour demand stemming from an increase in *W***.

■ Hence the **short-run increase in employment generated by any given amount of unanticipated inflation is greater in the unionized than in the competitive labour market**. To put it another way, the **short-run aggregate supply curve is flatter when nominal wages are rigid than when they are flexible**.

■ We may also say that **individual labour supply in the unionized labour market is infinitely elastic**. Because **there is involuntary unemployment**, **workers are willing to increase their labour supply in response to an increase in labour demand even if the expected real wage stays constant or falls** (as long as the expected real wage does not fall too much).

■ By contrast, in the **competitive labour market** there is **no involuntary unemployment, so labour supply will only increase if the expected real wage goes up**.

■ This **difference in the short-run flexibility of labour supply explains why employment fluctuates more strongly in the competitive than in the unionized labour market**. To convince yourself of this, note from (13.29) and (13.30) that **if individual labour supply in the competitive labour market were infinitely elastic** so that $\varphi \rightarrow \infty$, the **two equations would be equivalent**, implying the **same employment response to any given amount of unanticipated inflation**.

■ Equations (13.29) and (13.30) also demonstrate the **basic point that expectational errors** ($\pi \neq \pi^e$) **are both necessary and sufficient to cause deviations between the actual and the natural level of employment**.

■ In other words, it is **not really necessary to assume nominal rigidities in order to explain why employment sometimes deviates from its trend level**. However, our analysis shows that **once expectational errors occur, nominal rigidities will amplify the resulting fluctuations in employment**. In the **real world money wage rates are in fact typically fixed by wage contracts for a certain period** of time **even in non-unionized labour**

markets. It is therefore **realistic to assume some amount of short-run nominal wage rigidity**, so we will continue to work with our model with a pre-set nominal wage rate.

Supply shocks

■ Our **expectations-augmented Phillips curve** (13.20) postulates a **strict deterministic relation between the unemployment rate and the change in the rate of inflation**. In this section we shall see that the **link between these two variables is not really that tight**.

■ The reason is that the **labour market is frequently hit by shocks which generate "noise" in the relationship between unemployment and inflation**. These so-called **supply shocks** may **take the form of short-run fluctuations in our parameters m^p, m^w and B** around their long-run trend levels. Below we will extend our model of unemployment and inflation to account for supply shocks.

■ In Section 2 we **assumed that the rate of unemployment benefit is tied to the level of** *B,* since **productivity** determines long-run income per capita. In that case we should observe substantial **short-run fluctuations in unemployment benefits** as B oscillates around its long-run growth trend. However, **in practice benefits do not move up and down in this way**. It is reasonable to assume that **benefits are instead linked to the underlying trend level of productivity**, denoted by $\overline{B}$, which evolves gradually and smoothly over time. This is equivalent to assuming that **benefits are allowed to rise in line with the underlying trend growth in per-capita income**.

■ The **magnitude** $\boldsymbol{m^w b}$ in the denominator on the right-hand side of (13.13) is the **representative trade union's target real wage**. Given our new assumption that $b = c\overline{B}$, the **target real wage becomes** $m^w c\overline{B}$. Inserting this in (13.13), we find that the **actual level of employment** is given by:

$$L = n \cdot \left(\frac{B(1-\alpha)}{m^p m^w c\overline{B}} \cdot \frac{P}{P^e} \right)^{1/\alpha} \qquad 13.31$$

■ Our **next step** is to **redefine the natural level of employment**. Specifically, we now define **natural employment as the level of employment which will prevail when expectations are fulfilled and when productivity as well as the wage and price mark-ups are all at their "normal" long-run trend levels**.

■ Denoting the **normal mark-ups** by $\overline{m}^{p}$ and $\overline{m}^{w}$ and remembering that $b = c\overline{B}$, it follows that the **natural employment level** previously stated in (13.15) now **modifies to**:

$$\overline{L} = n \cdot \left(\frac{1-\alpha}{\overline{m}^{p} \cdot \overline{m}^{w} \cdot c} \right)^{1/\alpha} \qquad 13.32$$

■ Dividing (13.31) by (13.32) and using the facts that $L \equiv (1-u)N$ and $\overline{L} \equiv (1-\overline{u})N$, we get (for simplicity, we do not distinguish between the current labour force N and its trend level $\overline{N}$, since the cyclical fluctuations in the labour force tend to be quite modest):

$$\frac{1-u}{1-\bar{u}} = \left(\frac{B \cdot \bar{m}^p \cdot \bar{m}^w}{\bar{B} m^p m^w} \cdot \frac{P}{P^e} \right)^{1/\alpha} \qquad 13.33$$

■ Taking **logs on both sides** of (13.33) and using the **approximations** $\ln(1 - u) \approx -u$ and $\ln(1-\bar{u}) \approx -\bar{u}$ plus the definitions $\pi \equiv \ln P - \ln P_{-1}$ and $\pi^e \equiv \ln P^e - \ln P_{-1}$ we end up with:

$$\pi = \pi^e + \alpha(\bar{u} - u) + \tilde{s}, \quad \tilde{s} \equiv \ln\left(\frac{m^p}{\bar{m}^p}\right) + \ln\left(\frac{m^w}{\bar{m}^w}\right) - \ln\left(\frac{B}{\bar{B}}\right) \qquad 13.34$$

■ Equation (13.34) is an **expectations-augmented Phillips curve, extended to allow for supply shocks**. The specification of the **supply shock variable**, $\tilde{s}$, shows that **a positive shock to inflation occurs if the wage mark-up or the price mark-up rises above its normal level**, whereas a **negative shock to inflation occurs if productivity rises above its trend level**.

■ By construction, $\tilde{s}$ will fluctuate around a **mean value of 0**, since $\overline{m}^p$ and $\overline{m}^w$ are the average values of m^p and m^w, respectively, and since B is on average on its trend growth path $\overline{B}$.

■ We are now ready to **confront our theory of inflation and unemployment with some data**.

Testing the Phillips curve theory

Does the Phillips curve theory fit the data?

■ If we **insert our earlier assumption of static inflation expectations**, $\pi^e = \pi_{-1}$ into (13.34), we obtain an equation of the form

$$\Delta\pi = a_0 - a_1 u + \tilde{s}, \quad E[\tilde{s}] = 0 \qquad 13.35$$

where a_0 and a_1 are positive constants, and $E[\bullet]$ is the **expectations operator**.

■ Thus our theory implies that the **change in the rate of inflation should be negatively related to the rate of unemployment**. If we have data for inflation and unemployment, we can use **econometric techniques** (regression analysis) to estimate the magnitude of the parameters a_0 and a_1. In this way we can check **whether the estimated parameter values have the "correct" positive sign** expected from theory, and we can test **whether they are significantly different from zero in a statistical sense**.

■ Figure 13.6 shows observations of the **unemployment rate and the annual change in the rate of consumer price inflation in the US** in the period 1962-1995. The downward-sloping straight line in the figure is a regression line indicating the "average" relationship between unemployment and the change in inflation.

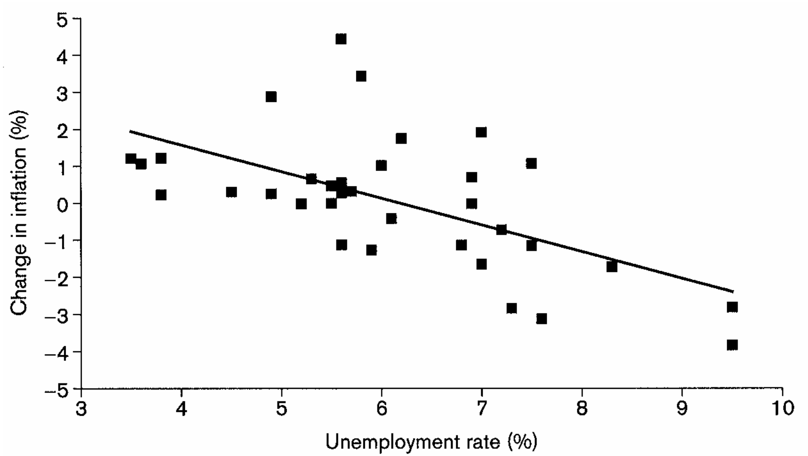


Figure 13.6: Relation between unemployment and the change in inflation in the United States, 1962-1995

Source: R.B. Mitchell, *International Historical Statistics*, Macmillan 1998; and Bureau of Labor Statistics.

■ The regression line has the following **quantitative properties**, where the figures in brackets indicate the standard errors of the estimated coefficients, and where R^2 is the coefficient of determination measuring the share of the variation in $\Delta\pi$ which is explained by our estimated regression line:

$$\Delta\pi = 4.467 - 0.723\,u \qquad 13.36$$
$$(se = 1.081)\ (se = 0.172)\ R^2 = 0.355$$

■ The **coefficients** in (13.36) do indeed **have the signs we would expect from theory**. They are also **significantly different from 0 in a statistical sense**. (As a rule of thumb, the estimated **coefficient should be numerically at least twice as big as its standard deviation** to be statistically significant.) Figure 13.6 shows a fairly clear **tendency for inflation to fall as unemployment goes up**.

■ Note that the estimated coefficients in (13.36) enable us to offer an **estimate of the natural rate of unemployment in the US**. According to (13.34) and (13.35) we have

$\Delta\pi = a(\bar{u} - u) = a_0 - a_1$ if we set $\tilde{s}$ equal to its mean value of 0. Since $\Delta\pi = 0$ when $\bar{u} - u$, it follows that $\bar{u} = a_0 / a_1$. Inserting the estimated parameter values from (13.36), we find that $\bar{u} = 4.467 / 0.723 \approx 6.2$. This implies that the **natural unemployment rate in the US averaged around 6.2 per cent** in the estimation period 1962-1995.

■ In summary, the **theory of the expectations-augmented Phillips curve seems roughly consistent with the US data**. At the same time we also see that the **observed change in inflation has often deviated quite a lot from the estimated regression line**. Indeed, the value of R^2 suggests that **variations in unemployment can only explain a little over one-third of the variation of inflation**. According to our theory, the **rest of the variation must be accounted for by the exogenous shocks** incorporated in our supply shock variable $\tilde{s}$.

■ Given the strong simplifying assumptions we have made, it is **not really surprising that our regression equation leaves a lot of the variation in inflation unexplained**. Our **assumption that inflation expectations are static is rather mechanical**.

■ For example, in periods where the **fiscal or monetary authorities announce a significant change in economic policies**, the private sector may have good reasons to believe that **tomorrow's inflation rate will not simply equal the current rate of inflation**. As another example, our **simple production function** (13.3) abstracts from the fact that **production requires inputs of raw materials** as well as labour input. Hence our Phillips curve does not capture changes in **inflation which are driven by changes in the international price of important raw materials** such as oil.

Productivity growth, the Phillips curve and the "New Economy"

■ Despite these weaknesses, the important message from Eq. (13.36) is that **there seems to be a systematic and statistically highly significant negative relationship between the level of unemployment and the change in the rate of inflation**.

■ However, **in the second half of the 1990s many observers began to question this relationship**. The reason was the **remarkable performance of the US economy during that period**. As you can see from Figure 13.7, having been located to the far northeast of the unemployment-inflation scatter diagram, **during the 1990s the short-run Phillips curve seemed to shift all the way back to the favourable position it had occupied in the 1960s**.

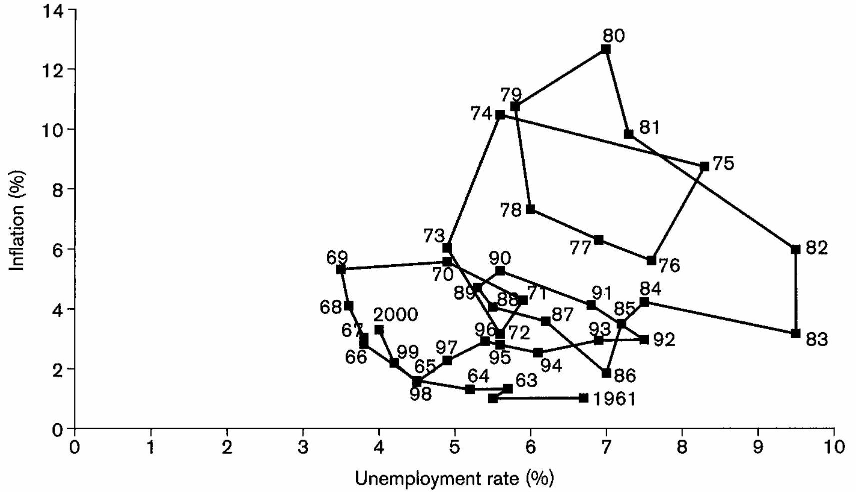


Figure 13.7: The shifting short-run Phillips curve in the United States

Source: R.B. Mitchell, *International Historical Statistics*, Macmillan, 1998; and Bureau of Labor Statistics.

■ Apparently this shift was **not a simple consequence of a fall in expected inflation** generated by the observed fall in actual inflation since the early 1980s. This point is illustrated in Figure 13.8.

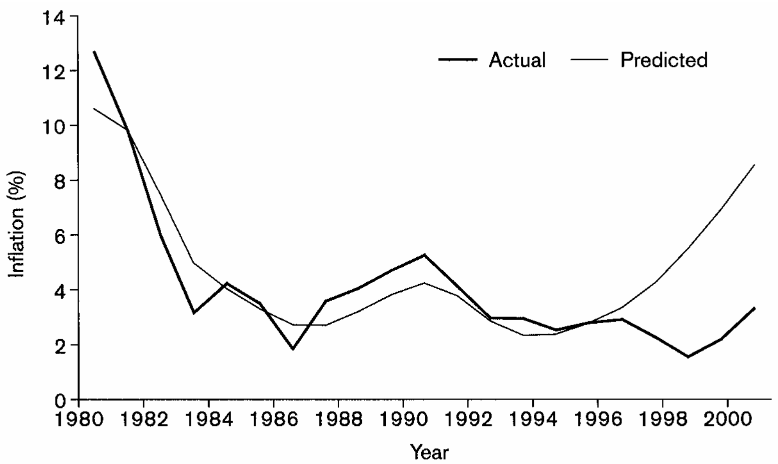


Figure 13.8: Actual and predicted inflation in the United States

Note: The predicted inflation rate was found from Eq. (13.39).
Source: R.B. Mitchell, *International Historical Statistics*, Macmillan, 1998; and Bureau of Labor Statistics.

■ The figure **compares the actual inflation rate with the rate of inflation predicted** from our Phillips curve, (13.36), which was estimated from data for 1962–1995. We see that **from 1996 and onwards, the rate of inflation predicted from the historical link between unemployment and inflation systematically overshoots the actual inflation rate**.

■ For example, based on the behaviour observed during the 1962–1995 period, one would have **expected to see a US inflation rate of 8.5 per cent in 2000, but the actual inflation rate remained subdued at a level of 3.3 per cent**, despite the low rate of unemployment. In other words, it seemed that a **structural shift took place in the US economy** around the mid 1990s, causing a breakdown of the expectations-augmented Phillips curve which had fitted the data reasonably well up until 1995.

■ At the same time as **unemployment fell without driving up the rate of inflation**, the **growth rate of US labour productivity started to pick up**. This is shown in Figure 13.9.

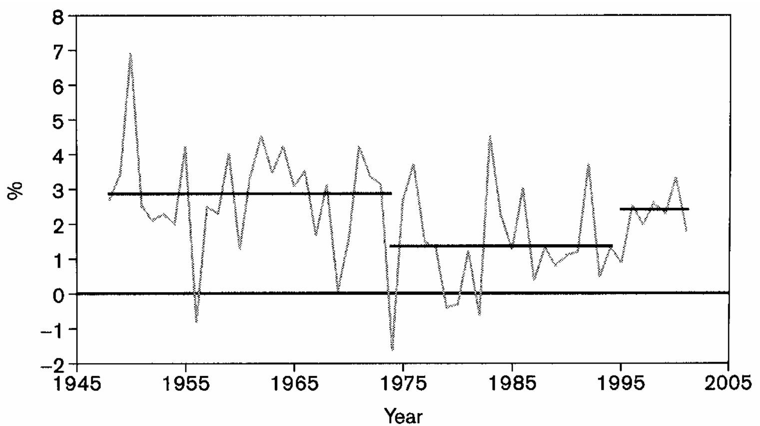


Figure 13.9: Annual growth rate of labour productivity in the United States

Note: Growth rate of output per hour in non-farm business sector. The horizontal lines are average growth rates over the subperiods indicated.
Source: Bureau of Labor Statistics.

■ As indicated by the horizontal lines, the **average growth rate of labour productivity during the period of the prolonged productivity slowdown from 1974 to 1995 was only 1.35 per cent** per year, whereas the average **productivity growth rate rose to 2.42 per cent** per year during 1996-2001.

■ Impressed by these developments, many commentators argued that a "**New Economy**" had arrived which **did not obey the "old rules of the game"**. Some participants in the economic policy debate even **claimed that it was time to scrap the established macro-economic theory** which apparently could no longer explain what was going on. These proponents of the "New Economy" paradigm **argued that it was now possible to maintain a much lower unemployment rate in the US without provoking high and accelerating inflation**.

■ However, with a slight **reinterpretation our theory of wage formation actually offers an explanation for these US developments**. Recall that the **"normal" productivity level** $\overline{B}$ **enters our supply shock variable**, $\tilde{s}$, because the **target real wage of workers** (which we may denote by w^*) is **tied to normal productivity**:

$$w^* = m^w c\overline{B} \qquad 13.37$$

■ We may **interpret the target real wage as a wage norm reflecting worker perceptions of what a "fair" or "normal" real wage ought to be**. Worker **aspirations regarding the growth rate of real wages are presumably influenced by the rate of real wage growth experienced in the past**, which is **determined by the historical growth in productivity**.

■ In (13.37) the growth over time in the **variable** $\overline{B}$ **captures the speed with which workers believe that their real wages "ought" to grow**. During a period like the late 1990s when productivity growth was accelerating after a long period of slow growth, the **growth in the target real wage (the growth in** $\overline{B}$ **) will probably lag behind the growth in actual productivity** B, since workers emerging from a long period of relatively low productivity growth are **still accustomed to a relatively low growth rate in their real earnings**.

■ **In a time of accelerating productivity growth, the magnitude** $\ln(B/\overline{B}) = \ln B - \ln \overline{B}$ **included in our supply shock variable** $\tilde{s}$ **will thus tend to be positive**. According to

(13.34) this will **reduce the rate of inflation associated with any given level of unemployment and expected inflation**, in line with US experience since 1995.

■ The idea that **accelerating productivity growth may explain the favourable shift in the US Philips curve has received empirical support** in a study by American economists Laurence **Ball** and Robert **Moffitt** (2001), "Productivity Growth and the Phillips Curve", National Bureau of Economic Research, NBER Working Paper 8421, August 2001. They show that a **Phillips curve which assumes that the real wage growth demanded by workers is a geometrically weighted average of realized past rates of real wage growth** (which depend on past productivity growth) **can fully account for the favourable US unemployment-inflation trade-off in the late 1990s**.

■ According to the theory of Ball and Moffitt, an **acceleration of productivity growth can temporarily improve the short-run unemployment-inflation trade-off**. However, the theory also implies that **once real wage expectations catch up with the higher rate of productivity growth, the rate of inflation will pick up again**, restoring the old relationship between inflation and unemployment.

The aggregate supply curve

■ Our **theory of aggregate demand implied a systematic link between the output gap** (the percentage deviation of output from trend) **and the rate of inflation**. We shall now show that our **theory of inflation and unemployment implies another systematic link between these two variables**.

■ Recall that **in a symmetric general equilibrium, total GDP is $Y = nY_i$, and total employment is $L = nL_i$**. From (13.3) we then have:

$$Y = nB\left(\frac{L}{n}\right)^{1-\alpha} = n^{\alpha}BL^{1-\alpha} \qquad 13.38$$

■ Taking **logs on both sides** of (13.38) and using $L \equiv (1-u)N$ plus $\ln(1-u) \approx -u$, we get:

$$y \equiv \ln y = \ln n^{\alpha} + \ln B + (1-\alpha)\ln[(1-u)N]$$
$$\approx \ln n^{\alpha} + \ln B + (1-\alpha)\ln N - (1-\alpha)u \Leftrightarrow \qquad 13.39$$
$$u = \ln N + \frac{\ln n^{\alpha} + \ln B - y}{1-\alpha}$$

■ Let us now **define** **"natural" output**, $\overline{Y}$, as the **volume of output produced when employment is at its natural level and productivity is at its trend level**:

$$\overline{Y} = n^{\alpha}\overline{B}\cdot\overline{L}^{1-\alpha} \qquad 13.40$$

■ In other words, natural output – sometimes also referred to as **potential output** – is the level of production prevailing **when the economy is on its long-run growth trend**. Defining $\overline{y} \equiv \ln\overline{Y}$ and using $\overline{L} \equiv (1-\overline{u})N$ plus $\ln(1-\overline{u}) \approx -\overline{u}$, we take logs in (13.40) and find an expression analogous to (13.39):

$$\bar{u} = \ln N + \frac{\ln n^{\alpha} + \ln \bar{B} - \bar{y}}{1-\alpha} \qquad 13.41$$

■ Substituting (13.39) and (13.41) into our expectations-augmented Phillips curve (13.17) and collecting terms, we end up with the economy's **short-run aggregate supply (SRAS) curve**:

$$\pi = \pi^{e} + \gamma(y - \bar{y}) + s,$$
$$\gamma \equiv \frac{\alpha}{1-\alpha} > 0, \quad s \equiv \ln\left(\frac{m^{p}}{\bar{m}^{p}}\right) + \ln\left(\frac{m^{w}}{\bar{m}^{w}}\right) - \frac{\ln(B/\bar{B})}{1-\alpha} \qquad 13.42$$

■ The magnitude $y - \bar{y}$ is the **percentage deviation of output from trend**, referred to as the **output gap**. From (13.42) we see that, *ceteris paribus*, the **rate of inflation varies positively with the output gap**.

■ The reason is that a **rise in output requires a rise in employment**, and because of **diminishing marginal productivity of labour**, **higher employment generates an increase in marginal cost** which is **translated into an increase in prices via the mark-up pricing** behaviour of firms. Equation (13.42) also implies that the **actual rate of inflation varies positively with the expected rate of inflation and with the supply shock variable**, s, capturing shocks to mark-ups and to productivity.

■ The **short-run aggregate supply curve** in (13.42) **summarizes the supply side** of the economy. **Because the expected inflation rate is here taken as given, the curve is a short-run relationship**. Over time, the **expected inflation rate will gradually adjust in reaction to previous inflation forecast errors**.

■ **When π^e changes**, it follows from (13.42) that the **short-run aggregate supply curve will shift** upwards or downwards. This is illustrated in Figure 13.10 which shows three different SRAS curves corresponding to three different levels of expected inflation rate.

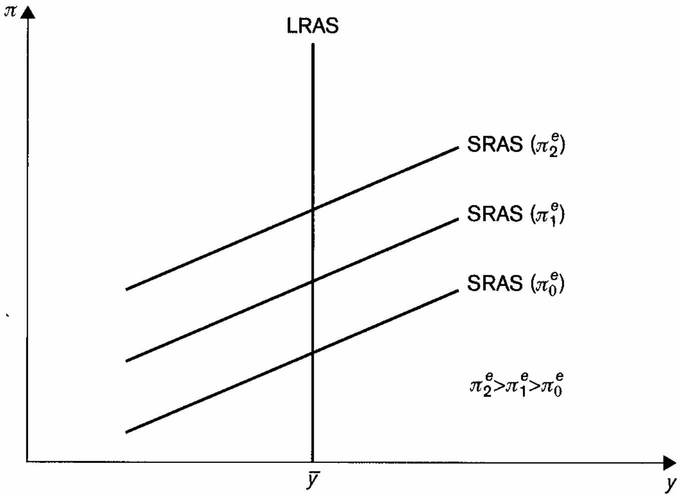


Figure 13.10: Aggregate supply in the short run (SRAS) and in the long run (LRAS)

■ In **long-run equilibrium, when expected inflation equals actual inflation** and there are **no shocks** (s = 0), we see from (13.42) that **output must be equal to its "natural" level**, $\bar{y}$. The **natural rate of output is independent of the rate of inflation**, since the natural unemployment rate $\bar{u}$ is independent of π. The **long-run aggregate supply (LRAS) curve** is therefore **vertical**, as shown in Figure 13.10.

■ Apart from depending on the expected rate of inflation, the **position of the short-run aggregate supply curve also depends on the supply shock variable**, s. From (13.42) we see that the **SRAS curve will shift upwards in the case of a positive shock to one of the mark-ups m^w or m^p, or in the case of a negative shock to productivity** ($B < \bar{B}$).

■ Note that **several types of supply shocks may be modelled as productivity shocks**. For example, a **loss of output due to industrial conflict may be interpreted as a temporary fall in labour productivity**. An unusually **bad harvest** due to bad weather conditions may likewise be seen as a temporary drop in productivity.

■ An **exogenous increase in the real price of imported raw materials such as oil will also work very much like a negative productivity shock**. If the price of oil increases relative to the general price level, an economy dependent on imported oil (like Lithuania) will have to reserve a greater fraction of domestic output for exports to maintain a given volume of oil imports. Thus, for given inputs of domestic labour and capital, a **lower amount of domestic output will be available for domestic consumption, just as if factor productivity had declined**. More generally, any exogenous **change in the economy's international terms of trade** (a shift in import prices relative to export prices) **may be modelled as a productivity shock** in our AS-AD model.

■ Over the last three decades, the real price of energy inputs has fluctuated considerably, as illustrated in Figure 13.11.

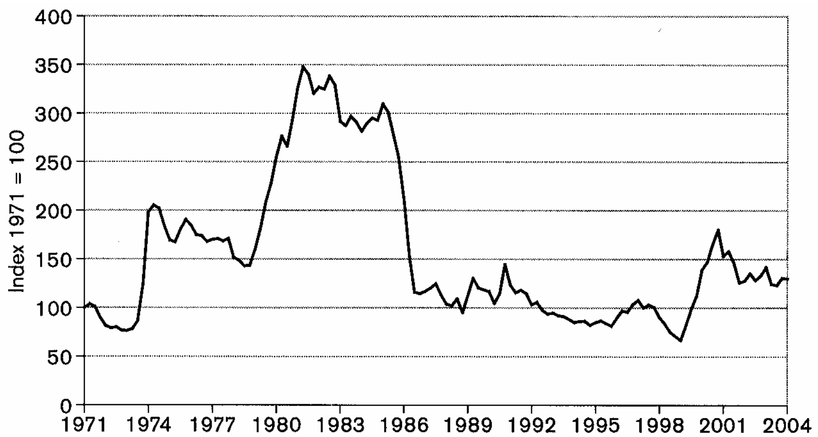


Figure 13.11: The real price of fuel imports in Denmark

Source: MONA database.

■ For example, following political upheaval in the Middle East, the **OPEC cartel** of oil-exporting countries was able to raise the real price of oil quite dramatically in **1973-74** and again in **1979-80**. Because most OECD economies were large net importers of oil at the time, these **oil price shocks worked like a significant negative productivity shock** for the OECD area. On the other hand, the collapse of oil prices from around 1985 tended to boost real incomes in the OECD, just like a positive productivity shock.

■ This completes our theory of the aggregate supply side. In the next lecture we shall see how aggregate supply interacts with aggregate demand to determine total GDP as well as the rate of inflation.

Summary

■ The link between inflation and unemployment determines how the supply side of the economy works. Some decades ago most economists and policy makers believed in the simple Phillips curve which postulates a permanent trade-off between inflation and unemployment: a permanent reduction in the rate of unemployment can be only achieved by accepting a permanent increase in the rate of inflation, and vice versa.

■ Empirically the simple Phillips curve broke down in the stagflation of the 1970s. This led to the theory of the expectations-augmented Phillips curve which says that the simple Phillips curve is just a short-run trade-off between inflation and unemployment, existing only as long as the expected rate of inflation is constant. When the expected inflation rate goes up, the actual inflation rate increases by a corresponding amount, other things equal.

■ The expectations-augmented Phillips curve implies the existence of a "natural" rate of unemployment, defined as the level of unemployment which will prevail in a long-run equilibrium where the expected inflation rate equals the actual inflation rate. Since any fully anticipated rate of inflation is compatible with long-run equilibrium, the long-run Phillips curve is vertical. When the actual inflation rate exceeds the expected inflation rate, the actual unemployment rate falls below the natural unemployment rate, and vice versa.

■ Several different theories of wage and price formation lead to the expectations-augmented Phillips curve. One such theory is the "sticky-wage model" in which nominal wage rates are pre-set at the start of each period. In the sticky wage model presented in this lecture, money wages are dictated by trade unions seeking to achieve a certain target real wage, given their expectations of the price level which will prevail over the next period. Given the wage rate set by unions, profit-maximizing monopolistically competitive firms set their prices as a mark-up over marginal costs and choose a level of employment which is declining in the actual real wage. According to this model, employment increases above its natural rate when the actual price level exceeds the expected price level, and vice versa. The model also implies that, in general, there is some amount of involuntary unemployment.

■ In the sticky-wage model the target real wage is a mark-up over the opportunity cost of employment which is given by the rate of unemployment benefit. The wage mark-up factor – and hence the target real wage – is higher the lower the wage elasticity of labour demand, and the lower the weight the union attaches to the goal of high employment relative to the goal of a high real wage. The mark-up of prices over marginal costs is higher the lower the price elasticity of demand for the output of the representative firm. The natural rate of unemployment is higher the higher the wage and price mark-ups and the more generous the level of unemployment benefits.

■ Another theory leading to the expectations-augmented Phillips curve is the "worker-misperception model" which assumes a competitive clearing labour market with fully flexible wages. Labour demand is a declining function of the actual real wage, while labour supply is an increasing function of the expected real wage, since workers are imperfectly informed about the current general price level. This model also implies that employment rises above the natural level when the actual price level exceeds the expected price level. However, for any given amount of unanticipated inflation, the increase in employment is smaller in the worker-misperception model than in the sticky wage model where nominal wage rates are fixed in the short run. Even in the absence of nominal rigidities, unanticipated inflation will thus generate deviations of employment from the natural rate, but nominal rigidities will amplify the fluctuations in employment.

■ According to the hypothesis of static expectations, the expected inflation rate for the current period equals the actual inflation rate observed during the previous period. Combined with the expectations-augmented Phillips curve, the assumption of static expectations implies that the rate of inflation will keep on accelerating (decelerating) when actual unemployment is below (above) the natural unemployment rate.

■ So-called supply shocks in the form of fluctuations in productivity and in the wage and price mark-ups create “noise” in the relationship between inflation and unemployment. An unfavourable supply shock implies an increase in the actual rate of inflation for any given levels of unemployment and expected inflation. In the presence of supply shocks the natural unemployment rate is defined as the rate of unemployment prevailing when inflation expectations are fulfilled and productivity as well as the wage and price mark-ups are at their trend levels.

■ An expectations-augmented Phillips curve with static inflation expectations is consistent with US data on inflation and unemployment in the period from the early 1960s to the mid 1990s. In the “New Economy” of the late 1990s inflation was surprisingly low, given the low rate of unemployment prevailing during that period. This experience may be seen as a result of a favourable supply shock arising from the fact that target real wages were lagging behind the accelerating rate of productivity growth.

■ The economy's short-run aggregate supply curve (the SRAS curve) implies a positive link between the output gap and the actual rate of inflation, given the expected rate of inflation. The SRAS curve may be derived from the expectations-augmented Phillips curve, using the production function which links the unemployment rate to the level of output. The SRAS curve shifts upwards when the expected inflation rate goes up, or when the economy is hit by an unfavourable supply shock. When there are no supply shocks and expected inflation equals actual inflation, the economy is on its long-run aggregate supply curve (the LRAS curve) which is vertical at the natural level of output corresponding to the natural rate of unemployment.