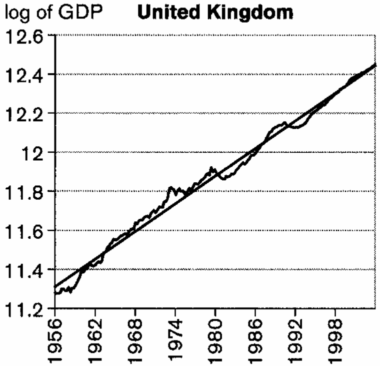
PART V. THE SHORT RUN: ECONOMIC FLUCTUATIONS, SHORT-RUN UNEMPLOYMENT AND STABILIZATION POLICY

9. THE ECONOMY IN THE SHORT RUN: SOME FACTS ABOUT BUSINESS CYCLES

■ Since the time of the Industrial Revolution the **Western world has experienced a tremendous growth** of total output. But history tells us that economic **growth has been far from steady**. In the **short and medium term the growth rate fluctuates considerably**, as you can see from Figure 9.1 which plots quarterly data for the logarithm of real GDP for a number of Western countries.


log of GDP
United Kingdom
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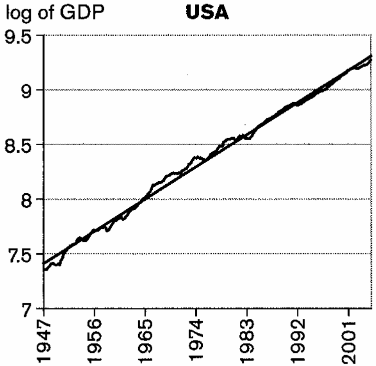
log of GDP
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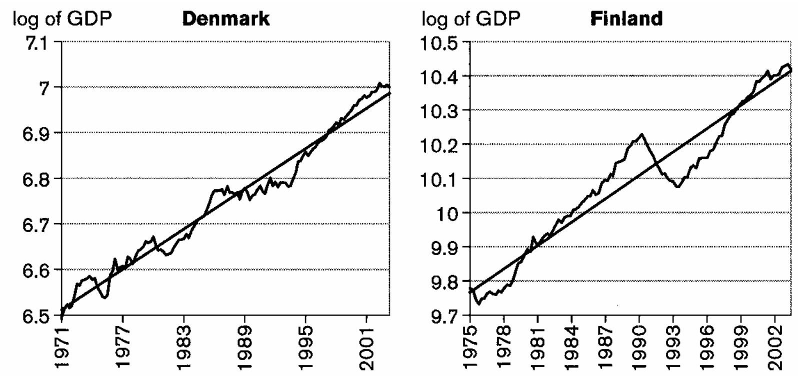


Figure 9.1: The evolution of real GDP in some Western countries

■ **If the growth rate of the economy were constant, the log of GDP would follow the straight lines** in Figure 9.1. The fact that the graphs for the **log of actual GDP are sometimes steeper and sometimes flatter than the straight lines** reflects that **periods of rapid growth tend to alternate with intervals of slow growth**.

■ Indeed, the **graph has frequently had a negative slope**, indicating that the **growth rate sometimes even becomes negative**. Note that the **data** underlying Figure 9.1 are **seasonally adjusted**, so the **fluctuations do not reflect the regular changes in business activity** occurring with the changing seasons of the year, for example, the seasonal swings in construction activity due to changing weather conditions. Thus there are **more fundamental forces causing an uneven pace of economic growth**.

■ We will now study these **short-term fluctuations in economic activity**, commonly known as **business cycles**. **How can we explain that the state of the economy repeatedly alternates between business cycle expansions characterized by rapid growth, and business cycle contractions or recessions characterized by declining economic activity?** To answer this question is one of the basic **challenges of macroeconomic theory**.

Why understanding business cycles is important

■ The **fact that economic growth is repeatedly interrupted by recessions** is a major source of **concern for economic policy makers** and the general public, since **recessions bring considerable economic hardship to workers who lose their jobs**, to **entrepreneurs and homeowners who go bankrupt**, and to ordinary **consumers who suffer capital losses on their assets**.

■ Even for those who are not directly affected by layoffs and bankruptcies, **recessions may cause a decline in well-being by generating fears of job losses and of future reductions in income and wealth**. Understanding business cycles is therefore not only of academic interest; it may also help the economist to offer advice to policy makers on the **possibility of reducing business fluctuations through macroeconomic stabilization policy**, that is, active monetary and fiscal policy.

■ At the very least an insight into the workings of the business cycle may enable the economist to suggest **how policy makers can avoid amplifying the business cycle through misguided macroeconomic policies**.

■ On **several occasions in history**, recessions have developed into severe **economic depressions paving the way for social and political disaster**. A glance at Figure 9.2 should convince you why it is important to understand the causes of depressions and the means to avoid them.

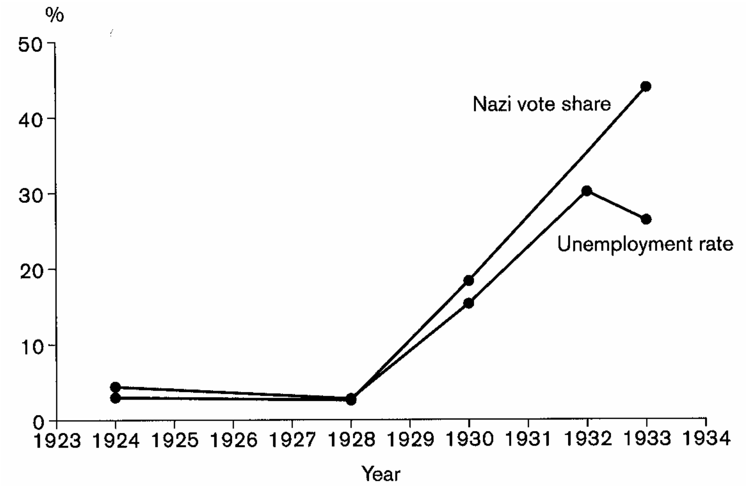


Figure 9.2: Unemployment and political extremism in Germany, 1924-1933

Note: Nazi vote share in 1932 is an average across two elections.

Sources: Unemployment rate from B.R. Mitchell, *International Historical Statistics*, Europe 1750-1988, Macmillan, New York, 1993. Nazi vote share from Richard F. Hamilton, *Who Voted for Hitler*?, Princeton University Press, 1982.

■ The figure shows a **striking correlation between the unemployment rate in interwar Germany** and the share of total **votes in Reichstag elections going to Adolf Hitler's Nazi Party**. In the 1928 election, when unemployment stood at the low level of 2.8 per cent, the Nazi Party captured only 2.6 per cent of the votes and were not considered a serious political force. But as the democratic system of the Weimar Republic proved unable to prevent the mass unemployment and human suffering caused by the Great Depression, a rapidly growing number of Germans became receptive to Hitler's radical critique of the parliamentary system. By 1933, with unemployment close to 30 per cent of the labour force, Hitler obtained a vote share of almost 44 per cent in the last free election before he established his Nazi dictatorship and **steered Germany towards the Second World War**. Although there were several other factors explaining Hitler's rise to power, there is no doubt that the economic depression made it easier for him to gather support.

■ The **Great Depression of the 1930s** was **exceptional in its severity and in its social and political consequences**. Nevertheless we have several recent examples of economic downturns which have caused social upheaval, including the **South-east Asian crisis of 1997-98**, and the **global economic crisis, caused by the subprime mess**.

■ **By studying business cycles** we will not only learn more about the workings of a market economy; **we will also improve our understanding of the general course of social and political events**.

■ The reason why it makes sense to theorize about business cycles is that, even though **no two business cycles are identical**, they **usually have some important features in common**. Nobel laureate **Robert Lucas** of the University of Chicago made this point in the following way:

> Though there is absolutely **no theoretical reason to anticipate it**, one is **led by the facts to conclude** that, **with respect to the qualitative behavior of comovements among series** (economic variables), **business cycles are all alike**. To theoretically inclined

economists, this conclusion should be attractive and challenging, for it suggests the **possibility of a unified explanation of business cycles**, grounded in the **general laws governing market economies**, rather than in **political or institutional characteristics specific to particular countries** or periods (Robert E. Lucas, Jr., "Understanding Business Cycles", in K. Brunner and A.H. Meltzer, eds., *Carnegie-Rochester Conference Series on Public Policy*, 5, Autumn 1977).

■ In the rest of this lecture we will **describe some of those co-movements** of economic variables which are characteristic of business cycles. Before we start theorizing about business cycles, we want to get some idea of the phenomenon which our theory is supposed to explain. We will **begin by restating a definition of business cycles** which has become familiar in the literature.

■ We will then move on to the question **how we can measure business cycles in quantitative terms**. That is, how can we **separate short-term business cycle fluctuations** in economic activity **from the long-term economic growth trend**? Following this, we will be ready to describe **in quantitative terms the co-movements** of important economic variables during a "typical" business cycle.

Defining business cycles

■ In a **famous book** which became a milestone in empirical business cycle research, the American economists Arthur **Burns** and Wesley **Mitchell** gave the following **classic definition of business cycles**:

> **Business cycles** are a type of **fluctuations found in the aggregate economic activity** of nations that **organize their work mainly in business enterprises**: a **cycle consists of expansions** occurring **at about the same time in many economic activities**, followed by similarly general **recessions, contractions, and revivals** which **merge into the expansion phase** of the next cycle; this **sequence of changes is recurrent but not periodic**; in **duration business cycles vary from more than one year to ten or twelve years**; they are **not divisible into shorter cycles** of similar character with amplitudes approximating

their own (Arthur F. Bums and Wesley C. Mitchell, *Measuring Business Cycles*, National Bureau of Economic Research (NBER), New York, 1946).

■ This **definition** of business cycles emphasizes **several points**.

- **Aggregate economic activity**: Business cycles are characterized by a **co-movement of a large number of economic activities and not just by movements in a single variable like real GDP**.
- **Organization in business enterprises**: Business cycles are a **phenomenon occurring in decentralized market economies**. Although they had several other economic problems, the **former socialist economies** of Eastern Europe **did not go through business cycles** of the type known in the Western world.
- **Expansions and contractions**: Business cycles are characterized by periods of expansion of economic activity followed by periods of contraction in which activity declines.
- **Duration of more than a year (persistence)**: A full business cycle lasts for more than a year. Fluctuations of shorter duration do not have the features characteristic of business cycles. This means that purely **seasonal variations** in activity within a year

are not business cycles. We may also say that **business cycle movements display persistence**: once an expansion gets going, it usually lasts for some time during which the **expansionary forces tend to be self-reinforcing**, and once a **contraction sets in**, it tends to **breed further contraction** for a while.

- **Recurrent but not periodic**: Although business **cycles repeat themselves**, they are **far from being strictly periodic**. The duration of cycles has varied from slightly more than a year to 10-12 years, and the severity of recessions has also varied considerably, with **recessions sometimes** (but not always) **turning into depressions**.

Dating business cycles

■ The contribution of **Burns** and **Mitchell** was to **document the movements over time of a large number of economic variables**. Through their work it **became possible to identify the turning points** in economic activity and hence to offer a **dating of business cycles**.

■ Since the movements of the different economic variables are not perfectly synchronized, it is a **matter of judgement** to identify the **point in time at which the business cycle reaches**

its peak and moves from expansion into contraction, and to determine when it reaches its **trough**, **moving from contraction (recession) to expansion**.

■ Building on the tradition established by Burns and Mitchell, the **US National Bureau of Economic Research** (NBER) has for many years had a **Business Cycle Dating Committee** consisting of **experts in empirical business cycle research**. The NBER committee defines a **recession** (contraction) as a **period of significant decline in total output, income, employment and trade**, usually lasting from six months to a year, and marked by **widespread contractions in many sectors of the economy**. On this basis the committee has arrived at a dating of US business cycles since 1854. This dating is reproduced in Table 9.1.

Table 9.1: US business cycle expansions and contractions

Business cycle reference dates			Duration in months			
Trough	Peak	Trough	1. Expansion	2. Contraction	Cycle[1]	1./2.
December 1854	June 1857	December 1858	30	18	48	1.67
December 1858	October 1860	June 1861	22	8	30	2.75
June 1861	April 1865	December 1867	46	32	78	1.44
December 1867	June 1869	December 1870	18	18	36	1.00
December 1870	October 1873	March 1879	34	65	99	0.52
March 1879	March 1882	May 1885	36	38	74	0.95
May 1885	March 1887	April 1888	22	13	35	1.69
April 1888	July 1890	May 1891	27	10	37	2.70
May 1891	January 1893	June 1894	20	17	37	1.18
June 1894	December 1895	June 1897	18	18	36	1.00
June 1897	June 1899	December 1900	24	18	42	1.33
December 1900	September 1902	August 1904	21	23	44	0.91
August 1904	May 1907	June 1908	33	13	46	2.54
June 1908	January 1910	January 1912	19	24	43	0.79
January 1912	January 1913	December 1914	12	23	35	0.52
December 1914	August 1918	March 1919	44	7	51	6.29
March 1919	January 1920	July 1921	10	18	28	0.56

July 1921	May 1923	July 1924	22	14	36	1.57
July 1924	October 1926	November 1927	27	13	40	2.08
November 1927	August 1929	March 1933	21	43	64	0.49
March 1933	May 1937	June 1938	50	13	63	3.85
June 1938	February 1945	October 1945	80	8	88	10.0
October 1945	November 1948	October 1949	37	11	48	3.36
October 1949	July 1953	May 1954	45	10	55	4.50
May 1954	August 1957	April 1958	39	8	47	4.88
April 1958	April 1960	February 1961	24	10	34	2.40
February 1961	December 1969	November 1970	106	11	117	9.64
November 1970	November 1973	March 1975	36	16	52	2.25
March 1975	January 1980	July 1980	58	6	64	9.67
July 1980	July 1981	November 1982	12	16	28	0.75
November 1982	July 1990	March 1991	92	8	100	11.5
March 1991	March 2001	November 2001	120	8	128	15.0
Average for pre-First World War period (15 cycles)[2]			25	23	48	1.10
Average for interwar period (5 cycles)[3]			26	20	46	1.30
Average for post-Second World War period (10 cycles)[4]			57	10	67	5.50

■ The **length of the business cycle** is **measured from trough to trough**, and the last column of the table measures the **duration of the expansion phase relative to the duration of the contraction phase**. Table 9.1 illustrates the point stressed by Burns and Mitchell: business **cycles are far from regular and periodic**.

■ The duration of the cycle varies greatly, and though the **expansion phase usually lasts longer than the contraction phase** – reflecting the **economy's long-term potential for growth** – there are also examples of cycles where the contraction has lasted longer than the previous expansion. At the bottom of the **Great Depression** in March 1933, the US economy had been **contracting for 43 months**. During this economic nightmare, **real GDP fell by almost 30 per cent**, and **unemployment rose to 25 per cent**. Notice, however, that the **contraction of the 1870s lasted considerably longer than the Great Depression**, although economic historians tell us that the decline in activity was less catastrophic.

■ The dates in Table 9.1 indicate that **business cycle expansions** have tended to last **longer** and that **contractions** have on average been **shorter after the Second World War** than before that time. Until recently, the expansion from February 1961 to December 1969 was the longest economic boom in US history. That record was beaten by the **ten-year long expansion starting in March 1991**. Although the subsequent recession lasted only eight months, the latest cycle was the longest business cycle on record in the US.

■ The **long US boom of the 1990s inspired many commentators** to speculate about the **arrival of a "New Economy"** in which the **expansionary forces stemming from innovations in information technology** were so strong that **serious recessions would be a thing of the past**, at least in the US.

■ Interestingly, the long **boom of the 1960s gave rise to a similar unfounded optimism**. In 1967, several leading US economists gathered for a conference asking: **"Is the Business Cycle Obsolete?"** (The conference participants tended to answer the question in the affirmative. The conference papers were published in Martin Bronfenbrenner (ed.), *Is the Business Cycle Obsolete*? Wiley, New York, 1969). But the **recession** in the US and in many other countries at the beginning of this decade (after the crash of **dot.com bubble**) and in **2008-2009** shows that the **business cycle is still with us**.

■ Let us therefore move from the dating of business cycles to the **problem of quantitative measurement of business fluctuations**.

Measuring business cycles

■ **Most economic time series fluctuate around a growing time trend**. The growth **trend reflects the forces described in the theory of economic growth**, while the **task of business cycle theory is to explain the fluctuations around that trend**. For example, if Y_t is real GDP in period t, it is useful to **think of Y_t as the product of a growth component Y_t^g** indicating the trend value which Y_t would assume if the economy were always on its long-term growth path, and a **cyclical component Y_t^c** which fluctuates around a **long-run mean value of 1**:

$$Y_t = Y_t^g \cdot Y_t^c \tag{9.1}$$

■ Our **assumption on the mean value of Y_t^c implies that $Y_t = Y_t^g$ on average**. Equation (9.1) also implies that **as long as the amplitude of the fluctuations in the cyclical component** Y_t^c **remains constant**, the **absolute amplitude of the business cycle fluctuations in real GDP will rise in proportion to the trend level of output** so that the **percentage deviations of actual output from trend output over the business cycle will tend to stay constant over time**.

■ It will be **convenient to work with the natural logarithms** of the various variables rather than with the variables themselves, because **changes in the log of some variable X approximate percentage changes in X**. Taking logs on both sides of equation (9.1) and defining $y_t \equiv \ln Y_t$, $g_t \equiv \ln Y_t^g$, and $c_t \equiv \ln Y_t^c$, we get:

$$y_t = g_t + c_t \tag{9.2}$$

■ In this section we will discuss **how we can estimate the trend component** g_t **and the cyclical component** c_t separately, given that we **only have observations of y_t.** Let us start by going back to Figure 9.1. The **straight lines in that figure are regression lines with a slope equal to the average growth rate over the period of observation**.

■ Technically, the **intercept and the slope of the regression line are chosen so as to minimize the sum of the squared deviations between the observed values of the log of GDP and the points on the line**.

■ It might be **tempting to let the straight regression line represent the trend value of output** and to **measure the cyclical component of GDP as the deviation from that hypothetical steady growth path**. But a moment's reflection should convince you that this is **not a satisfactory procedure**.

■ Recall that **along the straight regression line the economy's real growth rate is constant**. If we take the regression line to represent the trend growth path, we are therefore **postulating that the economy would always be in a steady state equilibrium with a constant growth rate if it were not disturbed by business fluctuations**.

■ However, the **theory of economic growth gives no reason to believe that the economy is always in a steady state**. Conventional growth theory tells us that the **economy's growth rate will decline over time if it starts out with a capital-labour ratio below the steady-state level**, and vice versa.

■ Moreover, the modern **theory of endogenous growth suggests that the rate of technical progress may vary with the endogenous innovation activity of firms**. Indeed, **even if major technological innovations are exogenous** to the economic system, they are **unlikely to arrive at an equal pace** over time, and this is **sufficient reason to discard the assumption of a constant long-term growth rate**.

■ An inspection of Figure 9.1 also suggests that the **longer-term movement of the economy does not follow a straight line**, even if we abstract from the short-term ups and downs of the graphs for real GDP.

■ Hence we need a **more sophisticated method for separating the growth trend from the cyclical component** of a variable like GDP. Since we do not perfectly understand how the economy works, we **cannot claim that there is a single objectively correct way of separating** c_t from g_t. Still, our reasoning above suggests that we **need a method which allows for variation over time in the underlying growth trend**, but which nevertheless ensures that the short-term fluctuations are categorized as temporary cyclical deviations from trend.

■ One such method which has become widely used is the so-called **Hodrick-Prescott filter**, named after American economists Robert **Hodrick** and Edward **Prescott** who popularized its use (Robert J. Hodrick and Edward C. Prescott, "Post-war U.S. Business Cycles: An Empirical Investigation", *Journal of Money, Credit, and Banking*, 29, 1997, originally published as a working paper in 1980). Under this method of **"filtering"** (that is, **detrending**) an economic time series like $(y_t)_{t=1}^{T}$ for the **log of GDP**, the **growth component** g_t **is determined by minimizing the magnitude**:

$$HP = \sum_{t=1}^{T} \overbrace{(y_t - g_t)}^{c_t}{}^2 + \lambda \sum_{t=2}^{T-1} \left[\overbrace{(g_{t+1} - g_t) - (g_t - g_{t-1})}^{\text{change in trend growth rate from period t to t + 1}} \right]^2 \qquad 9.3$$

with respect to all of the g_t, where observations are available for the time periods $t = 1,..., T$, and where **λ is a parameter which is chosen by the observer**. Note that **since y_t is measured in logarithms**, the magnitudes **$g_{t+1} - g_t$ and $g_t - g_{t-1}$ are approximately the percentage growth rates of the trend value of real GDP** in periods $t + 1$ and t, respectively.

■ The **term in the square bracket** in (9.3) thus **measures the change in the estimated trend growth rate from one period to the next**. Note also that, **by definition**, the term $y_t - g_t$ in (9.3) **measures the cyclical component c_t of log(GDP)** in period t.

■ **Minimizing** the expression in (9.3) therefore **forces us to compromise between two objectives**. On the one hand, **we want to choose the g_t's so as to minimize changes in the estimated trend growth rate over time, since this will minimize the expression in the**

second term in (9.3). On the other hand, **we want to bring g_t as close as possible to (the log of) actual output y_t so as to minimize the first sum** in (9.3). The **relative weight placed on each of these conflicting objectives depends on our choice of λ**.

■ Consider first the **extreme case where we set $\lambda = 0$**. In this special case **we will minimize *HP* by simply choosing $g_t = y_t$** for all $t = 1,..., T$, since ***HP* will then attain its lowest possible value of zero**. But this amounts to **postulating that all observed fluctuations in y_t reflect changes in the underlying growth trend**. This clearly does not make sense, unless we want to **deny the existence of business fluctuations**.

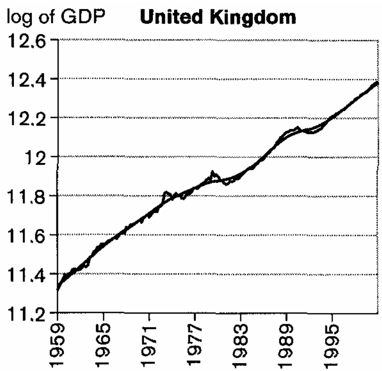
■ Consider next the **opposite extreme where we let λ tend to infinity**. In that case the **first sum in (9.3) does not carry any weight**, and **HP will then attain its lowest possible value of zero if we choose the g_t's to ensure that the estimated trend growth rate is constant throughout the period of observation**, that is $g_{t+1} - g_t = g_t - g_{t-1}$ for all $t = 2,3,..., T - 1$. This **would give us the straight lines** in Figure 9.1, but we have already seen that it is **unreasonable to assume that the trend growth rate is a constant**.

■ Clearly, then, $\boldsymbol{\lambda}$ **should be positive but finite**. The **greater the value of** $\boldsymbol{\lambda}$, the **more we will try to avoid variation over time in the estimated trend growth rate**, that is, the smoother will be our estimated growth trend (the **closer it will be to a straight line**).

■ On the other hand, the **smaller the value of** $\boldsymbol{\lambda}$, the **smaller will be the deviation between our estimated** $\boldsymbol{g_t}$ **and the actual value of output** $\boldsymbol{y_t}$, that is, the **greater is that part of the movement in actual output which we ascribe to changes in the underlying growth trend**.

■ **Among business cycle researchers using quarterly data, it is customary to set** $\boldsymbol{\lambda = 1600}$**.** This is basically a **convention**, based on a consensus that this value of λ produces a fitted growth trend that a "reasonable" student of business cycles would draw through a time plot of quarterly data for (the log of) real GDP.

Figure 9.3 shows the fitted growth trend for the countries included in Figure 9.1 when the trend is estimated via the HP filter using $\lambda = 1600$. We see that the **HP filter does indeed seem to capture the gradual changes in the growth trend** which are apparent to the naked eye.


log of GDP
United Kingdom
12.6
12.4
12.2
12
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1959
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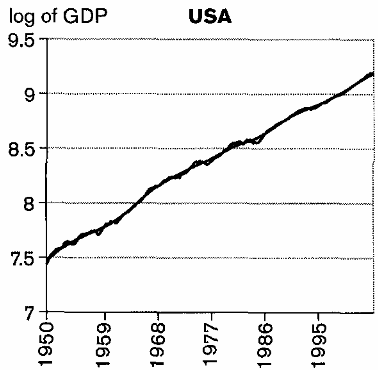
log of GDP
USA
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8
7.5
7
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1968
1977
1986
1995

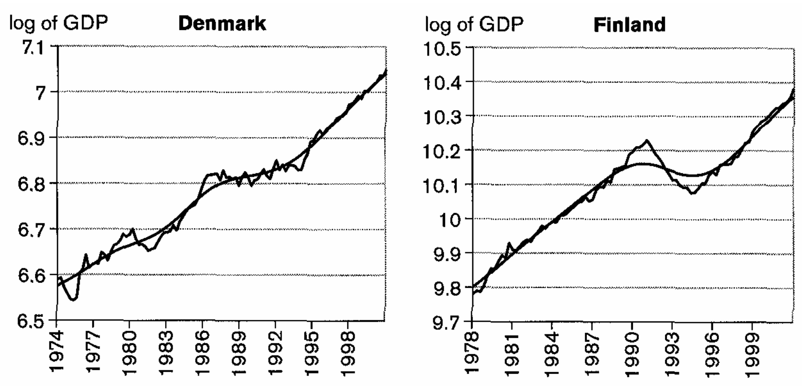
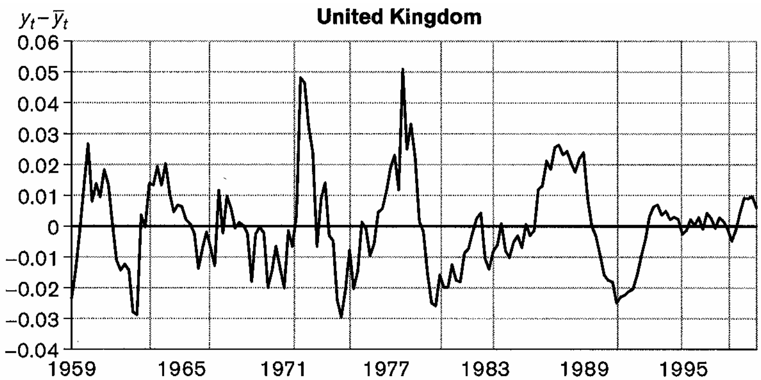
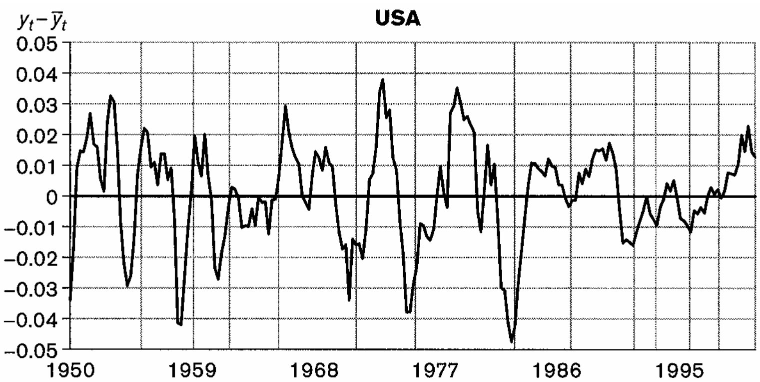


Figure 9.3: Real GDP and its underlying trend

Note: Quarterly data. The growth trend has been estimated by using the Hodrick-Prescott filter with $\lambda = 1600$.

■ Once we have fitted a growth trend using the HP filter, we immediately obtain an **estimate of the cyclical component of the (log of) quarterly real GDP** by rearranging equation (9.2) to get $c_t = y_t - g_t$. In Figure 9.4 we have plotted the **resulting estimates of business cycles**, that is, the values of all the c_t's for our group of countries.




USA
$y_t - \bar{y}_t$
0.05
0.04
0.03
0.02
0.01
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−0.01
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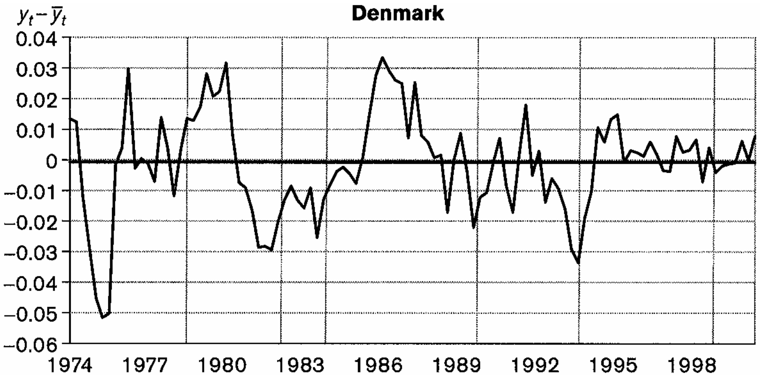
1995



Denmark
$y_t - \bar{y}_t$
0.04
0.03
0.02
0.01
0
−0.01
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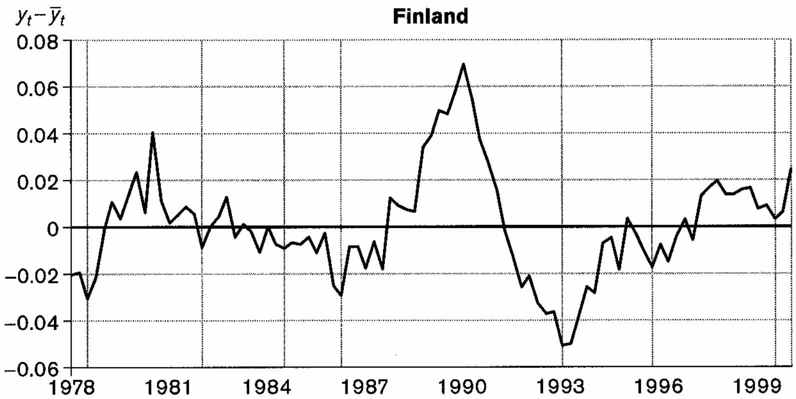
$y_t - \bar{y}_t$
Finland
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1978
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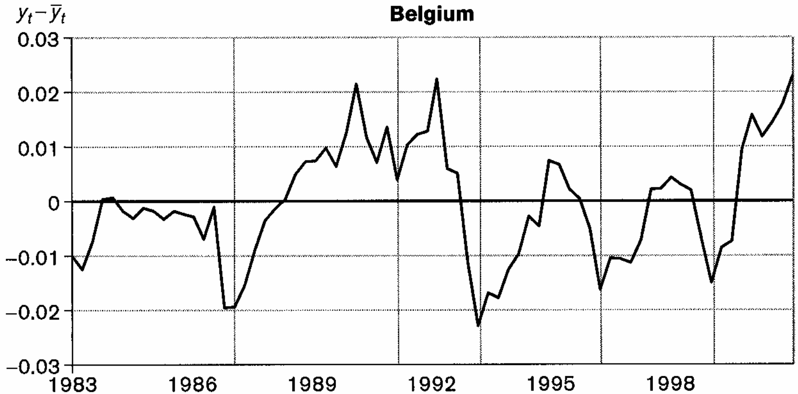
$y_t - \bar{y}_t$
Belgium
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1983
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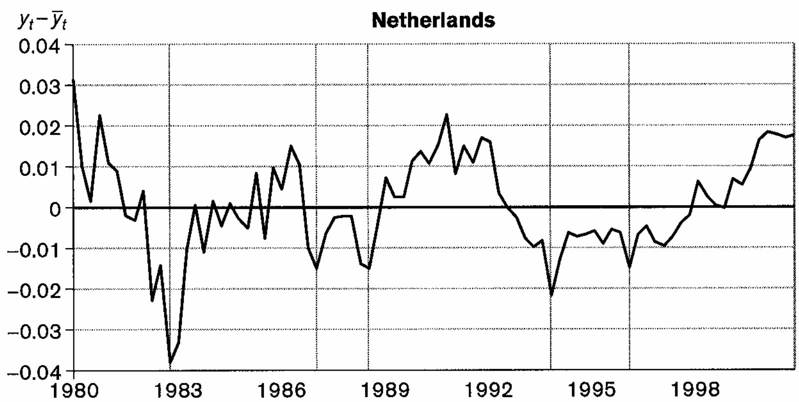


Figure 9.4: Cycles in real GDP in the United Kingdom, United States, Denmark, Finland, Belgium, and the Netherlands

■ The graphs confirm what we have already emphasized: **periods of expansion and periods of contraction tend to alternate, but the business cycles are far from periodic and**

regular, and even within each longer cycle there are **erratic quarterly fluctuations in activity**.

■ It is tempting to offer a dating of recent business cycles based on Figure 9.4, for although business cycles involve the co-movement of many economic variables (as we shall see), **GDP** is, after all, the **most common single indicator of aggregate economic activity**. We have inserted **vertical lines** in Figure 9.4 **to indicate business cycles measured from trough to trough**. The **identification of business cycle troughs and peaks** is based on the following **simple rules of thumb**:

1. A **trough must be followed by a peak**, and a peak must be followed by a trough.
2. The **expansion phase** as well as the **contraction phase** must **last for a minimum of two quarters**.
3. A **business cycle must span a minimum of five quarters**.

■ If the first criterion is not met, it does not make sense to speak of a “cycle”. The second criterion implies that **we require a minimum degree of persistence** in the movement of economic activity before we can speak of a systematic tendency for activity to expand or contract. The last criterion reflects the **convention that fluctuations spanning only a year or less do not count as business cycles**.

■ We see from Figure 9.4 that **all the countries** for which data are available **experienced a serious contraction in the mid-1970s**. All countries also fell into **recession in the early 1980s and in the early 1990s**.

What happens during business cycles?

■ The **HP filter is a useful method of separating the growth trend from the cyclical component** of an economic time series. In this section we will study the **statistical properties of the estimated cyclical components** of a number of time series for our group of countries. By doing so we will get more information on **what happens during business cycles**.

■ Our study is based on **seasonally adjusted quarterly data** going back as far as such data are available for our six countries. The data sets include the series for real GDP which we have already considered. The **components of national income and product are measured in fixed prices**, and all **variables have been detrended** by means of the HP filter, using the λ-value of 1600 which is customary for business cycle analysis of quarterly data.

■ **Variables displaying a growing time trend have been transformed into natural logarithms before detrending**. Researchers have found that the **HP filter tends to give imprecise estimates of the trend at the end-points of the time series**. For this reason our statistical analysis **excludes the first and the last 12 estimated cyclical components of each quarterly time series**, in line with **common practice**.

Volatility

■ The first question we will ask is: what is the **magnitude of the variability** in different economic variables during a "typical" business cycle? We may quantify this variability by calculating the **standard deviations of the estimated cyclical components** of the various time series. The **empirical standard deviation** s_x of a series of observations of variable x_t over the time interval $t = 1,\ldots,T$ is defined as:

$$s_x = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(x_t - \bar{x})^2}\ ,\ \bar{x} \equiv \frac{1}{T}\sum_{t=1}^{T} x_t \qquad 9.4$$

where $\bar{x}$ is the empirical mean value of the x_t's. The empirical **standard deviation measures the "average" deviation of x_t from its mean** over the period of observation. It is thus a natural indicator of the **degree of volatility** of the economic variable x_t.

■ In the middle columns of Table 9.2 we use the **absolute standard deviation as a measure of the volatility** of the cyclical components of some important macroeconomic variables. Recall that **when variables are measured in logarithms**, the **absolute standard deviation** of some variable $x \equiv \ln X$ **roughly indicates the average percentage deviation of X from its mean**.

■ For example, the first figure in the middle column for the United Kingdom indicates that, **on average over the UK business cycle, the cyclical component of real quarterly GDP deviates about 1.5 per cent from its mean value**.

Table 9.2: Macroeconomic volatility in some countries

United Kingdom	Average share in GDP (%)	Absolute standard deviation (%)	Relative standard deviation[1]
GDP	100	1.51	1.00
Private consumption	61	1.68	1.11
Domestic investment[2]	15	6.34	4.21
Public consumption	23	1.30	0.86
Exports	18	2.98	1.98
Imports	18	3.78	2.51
Employment		1.15	0.76

[1] Standard deviation relative to standard deviation of GDP.
[2] Includes both private and public investment.
Note: Based on quarterly data from 1956Q1 to 2003Q4. 24 end-point observations excluded.

United States	Average share in GDP (%)	Absolute standard deviation (%)	Relative standard deviation[1]
GDP	100	1.66	1.00
Private consumption	64	1.33	0.80
Private investment	16	7.61	4.58
Public consumption	16	3.40	2.04
Public investment	4	6.02	3.62
Exports	7	5.43	3.26
Imports	8	5.15	3.10
Employment		1.41	0.85

[1] Standard deviation relative to standard deviation of GDP.

Note: Based on quarterly data from 1947Q1 to 2003Q4. 24 end-point observations excluded.

Denmark	Average share in GDP (%)	Absolute standard deviation (%)	Relative standard deviation[1]
GDP	100	1.67	1.00
Private consumption	51	2.21	1.32
Private investment	18	9.76	5.84
Public consumption	26	1.19	0.71
Public investment	2	7.91	4.73
Exports	31	2.65	1.58
Imports	28	4.53	2.71
Employment		0.85	0.51

[1] *Standard deviation relative to standard deviation of GDP.*

Note: Based on quarterly data from 1971Q1 to 2003Q2. 24 end-point observations excluded.

Finland	Average share in GDP (%)	Absolute standard deviation (%)	Relative standard deviation[1]
GDP	100	2.29	1.00
Private consumption	52	2.11	0.92
Private fixed investment	20	8.49	3.71
Public consumption	23	1.38	0.60
Public fixed investment	3	5.72	2.50
Exports	27	4.46	1.95
Imports	25	5.97	2.61
Employment		2.00	0.87

[1] Standard deviation relative to standard deviation of GDP.
Note: Based on quarterly data from 1975Q1 to 2003Q1. 24 end-point observations excluded.

■ In the last columns in Table 9.2 we have measured the **standard deviations of the various variables relative to the standard deviation of GDP**. A **figure in excess of (smaller than) 1 means that the variable considered tends to be more (less) volatile than GDP**.

■ One striking feature of Table 9.2 is that **investment is between three and eight times as volatile as GDP**. The volumes of **exports and imports also fluctuate a lot more than GDP**, indicating that the foreign trade sector is relatively unstable. On the other hand, **employment fluctuates considerably less than GDP**. Private **consumption is sometimes more and sometimes less volatile than GDP**.

■ The main messages from Table 9.2 may be summarized as **three stylized facts** regarding business cycles.

Stylized business cycle fact 1. Investment is many times more volatile over the business cycle than GDP. It is the **most unstable component** of aggregate demand.

Stylized business cycle fact 2. Foreign trade volumes are typically **two to three times as volatile as GDP**.

Stylized business cycle fact 3. Employment and unemployment are considerably less volatile over the business cycle **than GDP**.

Correlation, leads and lags

■ Table 9.2 tells us how much different variables fluctuate relative to the fluctuations in GDP. But we are also interested in studying whether and **to what extent the cyclical component**, x_t, **of some economic variable moves in the same direction as or opposite to the cyclical component of real GDP**, c_t. For this purpose we introduce the **empirical covariance** between x_t and c_t, defined as:

$$s_{xc} = \frac{1}{T-1}\sum_{t=1}^{T}(x_t - \bar{x})(c_t - \bar{c})\,,\ \bar{c} \equiv \frac{1}{T}\sum_{t=1}^{T} c_t \qquad 9.5$$

where $\bar{c}$ is the mean value of the c_t's. The **covariance measures the degree to which *x* and *c* move together**, but its magnitude will **depend on our choice of the units** in which we measure x and c.

■ To obtain an **indicator which is independent of the choice of units**, it is preferable to **normalize the observations** of $x_t - \overline{x}$ and $c_t - \overline{c}$ **by the respective standard deviations** s_x and s_c and to study the **covariation of the normalized deviations**, $(x_t - \overline{x})/s_x$ and $(c_t - \overline{c})/s_c$. Following this procedure, we obtain the **coefficient of correlation** between x and c, which is defined as:

$$\rho(x_t, c_t) = \frac{s_{xc}}{s_x s_c} = \frac{\sum_{t=1}^{T}(x_t - \overline{x})(c_t - \overline{c})}{\sqrt{\sum_{t=1}^{T}(x_t - \overline{x})^2} \cdot \sqrt{\sum_{t=1}^{T}(c_t - \overline{c})^2}} \qquad 9.6$$

■ The **coefficient of correlation will always assume a value somewhere in the interval from –1 to +1**. If $\rho(x_t, c_t)$ is equal to **1** we say that x_t and c_t are **perfectly positively**

correlated, and if $\rho(x_t, c_t)$ equals **–1** we say that the two variables are **perfectly negatively correlated**. In both cases there is a strict linear relationship between the two variables.

■ If $\rho(x_t, c_t)$ is positive but less than 1, x and c will tend to move in the same direction, with the co-movement being more systematic the smaller the deviation of $\rho(x_t, c_t)$ from 1. On the other hand, a negative value of $\rho(x_t, c_t)$ indicates that the two variables tend to move in opposite directions. Clearly, if $\rho(x_t, c_t)$ is (close to) **0**, there is **no systematic relationship** between x and c.

■ In the present context where c_t **represents the cyclical component of real GDP**, we say that ***x*** **varies procyclically** when $\rho(x_t, c_t)$ is **substantially greater than 0**, since the positive correlation indicates that ***x*** **tends to rise and fall with GDP**. By analogy, if $\rho(x_t, c_t)$ is negative, we say that x moves in a countercyclical fashion because x tends to move in the opposite direction of GDP.

■ The **co-movements of the different economic variables are not always synchronized** over the business cycle: some **variables may reach their turning point before others do**.

To investigate whether a variable x moves out of sync with real GDP, we may measure the coefficient of **correlation $\rho(x_{t-n}, c_t)$** between c_t and the value of x observed n periods earlier (x_{t-n}), and the **correlation coefficient $\rho(x_{t+n}, c_t)$** between c_t and the value of x observed n periods later (x_{t+n}).

■ **If $\rho(x_{t-n}, c_t)$ is significantly different from 0 and numerically greater than $\rho(x_t, c_t)$**, we say that **x_t is a** leading indicator, because a change in x observed n periods earlier tends to be associated with a change in GDP in the current period. In other words, movements in x tend to lead movements in aggregate output, so a **turnaround in x indicates a later turnaround in c**.

■ Similarly, we say that **x is a** lagging variable **if $\rho(x_{t+n}, c_t)$ is significantly different from 0 and numerically greater than $\rho(x_t, c_t)$**, since this is an indication that **x tends to reach its peaks and troughs later than c**.

■

Table 9.3 shows coefficients of correlation between the logs of various variables and the log of GDP, including leads and lags.

Table 9.3: Macroeconomic correlations, leads and lags in some countries

United Kingdom	Coefficient of correlation between GDP and X_t Quarterly leads and lags				
	−2	−1	0	1	2
X_t (real variables)					
GDP	0.61	0.78	1.00	0.78	0.61
Private consumption	0.55	0.66	0.76	0.60	0.51
Gross domestic investment	0.46	0.64	0.78	0.66	0.49
Public consumption	−0.23	−0.19	−0.16	−0.22	−0.14
Exports	0.14	0.27	0.45	0.33	0.34
Imports	0.41	0.61	0.69	0.61	0.54
Employment	0.32	0.50	0.66	0.74	0.77
Real wage	−0.06	0.01	0.11	0.07	0.07
Labour productivity	0.51	0.52	0.60	0.25	0.00
X_t (Nominal variables)					
Inflation rate (CPI)	−0.03	0.02	0.27	0.27	0.38
Short-term nominal interest rate	−0.30	−0.12	0.05	0.27	0.38
Long-term nominal interest rate	−0.33	−0.16	−0.03	0.11	0.24

Note: Based on quarterly data from 1956Q1 to 2003Q4. 24 end-point observations excluded.

United States	Coefficient of correlation between GDP and X_t Quarterly leads and lags				
	−2	−1	0	1	2
X_t (real variables)					
GDP	0.59	0.84	1.00	0.84	0.59
Private consumption	0.65	0.78	0.79	0.59	0.35
Private investment	0.57	0.75	0.84	0.65	0.39
Public consumption	−0.09	−0.01	0.12	0.21	0.27
Public investment	0.02	0.12	0.23	0.25	0.26
Exports	−0.07	0.15	0.36	0.45	0.45
Imports	0.46	0.62	0.68	0.60	0.38
Employment	0.26	0.57	0.81	0.89	0.82
Real wage	0.20	0.23	0.21	0.16	0.09
Labour productivity	0.56	0.56	0.51	0.17	−0.14
X_t (Nominal variables)					
Inflation rate (CPI)	0.16	0.29	0.39	0.39	0.35
Short-term nominal interest rate	−0.13	0.14	0.35	0.44	0.45
Long-term nominal interest rate	−0.29	−0.10	0.05	0.11	0.12

Note: Based on quarterly data from 1947Q1 to 2003Q4. 24 end-point observations excluded.

Denmark	Coefficient of correlation between GDP and X_t Quarterly leads and lags				
	−2	−1	0	1	2
X_t (real variables)					
GDP	0.51	0.73	1.00	0.73	0.51
Private consumption	0.59	0.74	0.75	0.46	0.30
Private investment	0.45	0.64	0.84	0.70	0.44
Public consumption	−0.01	0.10	0.21	0.25	0.24
Public investment	0.24	0.33	0.38	0.40	0.39
Exports	−0.13	−0.12	0.07	−0.06	−0.02
Imports	0.51	0.66	0.72	0.51	0.26
Employment	0.35	0.55	0.69	0.72	0.65
Real wage	−0.22	−0.18	−0.04	0.10	0.21
Labour productivity	0.06	0.13	0.47	0.12	−0.07
X_t (Nominal variables)					
Inflation rate (consumption deflator)	−0.17	−0.01	0.12	0.08	−0.02
Short-term nominal interest rate	−0.37	−0.26	−0.07	0.11	0.28
Long-term nominal interest rate	−0.45	−0.36	−0.22	−0.16	−0.16

Note: Based on quarterly data from 1971Q1 to 2003Q2. 24 end-point observations excluded.

Finland	**Coefficient of correlation between GDP and X_t** Quarterly leads and lags				
	−2	**−1**	**0**	**1**	**2**
***X_t* (real variables)**					
GDP	0.77	0.86	1.00	0.86	0.77
Private consumption	0.73	0.81	0.86	0.84	0.78
Private gross fixed investment	0.60	0.72	0.88	0.83	0.82
Public consumption	0.07	0.22	0.36	0.49	0.62
Public gross fixed investment	0.06	0.17	0.24	0.25	0.27
Exports	0.38	0.30	0.29	0.13	−0.03
Imports	0.62	0.66	0.73	0.64	0.51
Employment	0.43	0.60	0.75	0.85	0.90
Real wage	−0.19	−0.12	−0.09	0.04	0.10
Labour productivity	0.34	0.29	0.29	0.13	0.04
***X_t* (Nominal variables)**					
Inflation rate (Cost-of-Living Index)	0.28	0.33	0.36	0.32	0.27
Short-term nominal interest rate	−0.26	−0.09	0.09	0.20	0.30
Long-term nominal interest rate	−0.18	−0.02	0.11	0.20	0.27

Note: Based on quarterly data from 1974Q1 to 2003Q1. 24 end-point observations excluded.

Belgium	**Coefficient of correlation between GDP and X_t** Quarterly leads and lags				
	−2	**−1**	**0**	**1**	**2**
***X_t* (real variables)**					
GDP	0.61	0.81	1.00	0.81	0.61
Private consumption	0.33	0.52	0.68	0.69	0.61
Private investment	0.24	0.42	0.54	0.42	0.41
Public consumption	−0.05	0.02	−0.01	−0.06	−0.04
Public fixed investment	0.07	0.01	−0.08	−0.20	−0.30
Exports	0.53	0.60	0.67	0.65	0.47
Imports	0.46	0.60	0.69	0.66	0.54
Unemployment	−0.37	−0.52	−0.65	−0.71	−0.73
Real wage	−0.22	−0.36	−0.46	−0.48	−0.43
***X_t* (Nominal variables)**					
Inflation rate (CPI)	0.22	0.15	0.21	0.16	0.23
Short-term nominal interest rate	0.10	0.26	0.45	0.56	0.57
Long-term nominal interest rate	0.32	0.48	0.61	0.60	0.51

Note: Based on quarterly data from 1980Q1 to 2003Q4. 24 end-point observations excluded.

Netherlands	Coefficient of correlation between GDP and X_t Quarterly leads and lags				
	−2	**−1**	**0**	**1**	**2**
X_t (real variables)					
GDP	0.57	0.71	1.00	0.71	0.57
Private consumption	0.62	0.66	0.75	0.67	0.58
Domestic investment	0.49	0.50	0.73	0.55	0.37
Public consumption	−0.18	−0.14	−0.05	0.02	−0.02
Exports	0.42	0.58	0.55	0.43	0.35
Imports	0.59	0.61	0.59	0.55	0.39
Unemployment	−0.42	−0.53	−0.65	−0.72	−0.74
Real wage	−0.09	−0.15	−0.21	−0.25	−0.18
X_t (Nominal variables)					
Inflation rate (CPI)	0.13	0.26	0.32	0.24	0.15
Short-term nominal interest rate	0.20	0.37	0.59	0.66	0.70
Long-term nominal interest rate	0.10	0.27	0.44	0.45	0.45

Note: Based on quarterly data from 1977Q1 to 2003Q4. 24 end-point observations excluded.

■ The **middle columns headed “0”** show the **contemporaneous correlation coefficients**, $\rho(x_t, c_t)$, where x_t is the relevant variable indicated in the left part of the table. The **first two columns** for each country show correlations between current GDP (c_t) and $\boldsymbol{x_{t-2}}$ and $\boldsymbol{x_{t-1}}$ respectively, whereas the **last two columns** show correlations between y_t and $\boldsymbol{x_{t+1}}$ and $\boldsymbol{x_{t+2}}$, respectively. Recall that the **length of a time period is one quarter**. From the second row for the **United Kingdom** we therefore infer that the **coefficient of correlation between current GDP and private consumption two quarters earlier is 0.55**, whereas the correlation between current GDP and private consumption one quarter later is 0.60.

■

Table 9.3 shows that whereas **public consumption seems to be more or less uncorrelated with GDP**, **private consumption, private investment and imports are all procyclical**, displaying a **clear positive correlation with aggregate output**. In particular, we see that **private consumption and investment are strongly correlated with contemporaneous GDP**.

■ Not surprisingly, we see that **employment varies procyclically**, since an **increase in output requires an increase in labour input**. The mirror image is that **unemployment is countercyclical**, as shown by the data for Belgium and the Netherlands. We also see that **employment and unemployment are lagging variables**, since they are more strongly correlated with the GDP of the previous quarter than with contemporaneous GDP.

■ While **employment displays a strong positive correlation with output**, the **correlation between real wages and real GDP is seen to be much weaker** and less systematic. **Average labour productivity (output per working hour) tends to be positively correlated with contemporaneous GDP**, suggesting either that **workers tend to work harder when the demand for output is high**, or that **productivity shocks are of some importance for the fluctuations in GDP**.

■ This may help to explain **why employment is a lagging variable**: **if labour productivity rises as soon as output goes up, there is less need for firms to add to their stock of employees** right from the start of a business cycle upswing.

■ While employment is clearly a lagging variable, there are **only a few examples of leading variables** in Table 9.3. In **Finland and the Netherlands**, the volume of **exports seems to be a leading indicator**, having a stronger positive correlation with GDP in the subsequent quarter(s) than with contemporaneous GDP. However, this pattern is not found in the other countries considered, so **in general business fluctuations do not seem to be initiated by changes in export demand**.

■ All the **variables discussed so far have been defined in real terms**. The **bottom rows** in

Table 9.3 show the **correlation between real output and some important nominal variables**. In almost all countries the rate of **inflation tends to be positively correlated with GDP**, although the **correlation is not particularly strong**. As our theoretical analysis in later lectures will make clear, a **positive correlation between output and inflation indicates that business cycles are driven mainly by shocks to aggregate demand**. We also see that in all countries the **short-term nominal interest rate tends to go up in the two quarters following a rise in GDP**, reflecting that **central banks typically tighten monetary policy in reaction to higher economic activity**.

■ Let us sum up the main lessons from Table 9.3.

Stylized business cycle fact 4. Private **consumption, investment and imports are strongly positively correlated with GDP**.

Stylized business cycle fact 5. **Employment** (unemployment) **is procyclical** (countercyclical) and **more strongly correlated with GDP than real wages and labour productivity**. Labour **productivity tends to be procyclical**, whereas real wages tend to be very weakly correlated with GDP.

Stylized business cycle fact 6. In most countries **inflation** tends to be **positively correlated** with GDP, although the correlation is not very strong.

Stylized business cycle fact 7. **Employment is a lagging variable**; short-term nominal **interest rates** also tend to be **lagging** variables.

Persistence

■ Another **interesting property** of an economic variable is its **degree of persistence**. As you recall, one characteristic of business cycles is that, **once the economy moves into an expansion or a contraction, it tends to stay there for a while**.

■ **Persistence** in some variable x **means** that the observed value of x in period t, $\boldsymbol{x_t}$, **is not independent of the value,** $\boldsymbol{x_{t-n}}$, of x in some previous period $t - n$, where $n \geq 1$. In other words, **if** $\boldsymbol{x}$ **assumed a high (low) value in previous period** $t - n$, there is a **greater chance that it will also assume a high (low) value in the current period** t.

■ We can **measure such persistence** in a time series $(x_t)_{t=1}^{T}$ by **calculating the coefficient of correlation between** $\boldsymbol{x_t}$ **and its own lagged value** $\boldsymbol{x_{t-n}}$, for $n = 1, 2, \ldots$ This particular correlation coefficient $\rho(x_t, x_{t-n})$ is called the **coefficient of autocorrelation**. **If** $\boldsymbol{\rho(x_t, x_{t-n})}$ **is significantly above zero for several positive values of** $\boldsymbol{n}$**, there is a high degree of persistence**: once x has been pushed above or below its mean value, it tends to continue to be above or below its mean for a long time.

■ Table 9.4 measures the persistence of business fluctuations by the coefficients of autocorrelation.

Table 9.4: Macroeconomic persistence in some countries

United Kingdom	Coefficient of autocorrelation 1-quarter lag	2-quarter lag	3-quarter lag	4-quarter lag
Real variables				
GDP	0.78	0.61	0.45	0.26
Private consumption	0.78	0.64	0.50	0.31
Gross domestic investment	0.70	0.49	0.30	0.13
Public consumption	0.59	0.45	0.39	0.20
Exports	0.40	0.29	0.06	−0.11
Imports	0.68	0.43	0.22	0.00
Employment	0.94	0.81	0.64	0.47
Real wage	0.74	0.51	0.26	0.07
Labour productivity	0.73	0.53	0.37	0.19
Nominal variables				
Inflation rate (CPI)	0.44	0.26	0.01	−0.07
Short-term nominal interest rate	0.79	0.59	0.38	0.20
Long-term nominal interest rate	0.78	0.49	0.29	0.11

Note: Based on quarterly data from 1956Q1 to 2003Q4. 24 end-point observations excluded.

United States	Coefficient of autocorrelation 1-quarter lag	2-quarter lag	3-quarter lag	4-quarter lag
Real variables				
GDP	0.84	0.59	0.33	0.10
Private consumption	0.80	0.63	0.39	0.15
Private investment	0.79	0.55	0.28	0.04
Public consumption	0.88	0.73	0.53	0.30
Public investment	0.80	0.61	0.40	0.26
Exports	0.70	0.54	0.30	0.05
Imports	0.71	0.45	0.27	0.07
Employment	0.91	0.70	0.44	0.19
Real wage	0.81	0.61	0.42	0.21
Labour productivity	0.71	0.45	0.19	–0.01
Nominal variables				
Inflation rate (CPI)	0.49	0.27	0.33	0.11
Short-term nominal interest rate	0.80	0.53	0.39	0.22
Long-term nominal interest rate	0.80	0.53	0.29	0.04

Note: Based on quarterly data from 1947Q1 to 2003Q4. 24 end-point observations excluded.

Denmark	Coefficient of autocorrelation 1-quarter lag	2-quarter lag	3-quarter lag	4-quarter lag
Real variables				
GDP	0.73	0.51	0.27	0.11
Private consumption	0.61	0.47	0.31	0.14
Private investment	0.65	0.45	0.23	0.06
Public consumption	0.76	0.56	0.38	0.22
Public investment	0.68	0.55	0.38	0.32
Exports	0.45	0.46	0.18	−0.02
Imports	0.70	0.35	−0.01	−0.28
Employment	0.86	0.71	0.55	0.41
Real wage	0.66	0.50	0.36	0.22
Labour productivity	0.23	0.05	−0.05	−0.02
Nominal variables				
Inflation rate (consumption deflator)	−0.02	−0.10	−0.15	−0.15
Short-term nominal interest rate	0.53	0.26	0.05	−0.25
Long-term nominal interest rate	0.79	0.53	0.25	0.01

Note: Based on quarterly data from 1971Q1 to 2003Q2. 24 end-point observations excluded.

Finland	Coefficient of autocorrelation 1-quarter lag	2-quarter lag	3-quarter lag	4-quarter lag
Real variables				
GDP	0.86	0.77	0.67	0.52
Private consumption	0.90	0.79	0.67	0.55
Private gross fixed investment	0.82	0.75	0.65	0.53
Public consumption	0.88	0.76	0.62	0.49
Public gross fixed investment	0.65	0.27	0.08	0.07
Exports	0.37	0.30	0.18	−0.06
Imports	0.52	0.49	0.34	0.08
Employment	0.95	0.86	0.74	0.58
Real wage	0.35	0.31	0.13	0.12
Labour productivity	0.06	0.01	0.03	0.09
Nominal variables				
Inflation rate (Cost-of-Living Index)	0.26	−0.17	0.08	0.52
Short-term nominal interest rate	0.72	0.47	0.36	0.26
Long-term nominal interest rate	0.82	0.49	0.18	−0.04

Note: Based on quarterly data from 1975Q1 to 2003Q1. 24 end-point observations excluded.

Belgium	Coefficient of autocorrelation 1-quarter lag	2-quarter lag	3-quarter lag	4-quarter lag
Real variables				
GDP	0.81	0.61	0.37	0.12
Private consumption	0.85	0.66	0.44	0.23
Private investment	0.35	0.34	0.21	−0.05
Public consumption	0.74	0.41	0.17	−0.07
Public fixed investment	0.92	0.73	0.46	0.20
Exports	0.73	0.55	0.36	0.13
Imports	0.60	0.49	0.37	0.19
Unemployment	0.94	0.82	0.65	0.46
Real wage	0.90	0.71	0.45	0.17
Nominal variables				
Inflation rate (CPI)	0.27	0.11	0.31	0.02
Short-term nominal interest rate	0.76	0.49	0.34	0.29
Long-term nominal interest rate	0.86	0.65	0.43	0.21

Note: Based on quarterly data from 1980Q1 to 2003Q4. 24 end-point observations excluded.

Netherlands	Coefficient of autocorrelation 1-quarter lag	2-quarter lag	3-quarter lag	4-quarter lag
Real variables				
GDP	0.71	0.57	0.47	0.32
Private consumption	0.81	0.71	0.58	0.37
Domestic investment	0.53	0.43	0.12	0.04
Public consumption	0.61	0.46	0.30	0.23
Public fixed investment	0.29	−0.13	0.07	0.15
Exports	0.62	0.50	0.20	0.01
Imports	0.75	0.55	0.34	0.13
Unemployment	0.96	0.88	0.74	0.56
Real wage	0.89	0.69	0.44	0.17
Nominal variables				
Inflation rate (CPI)	0.28	0.23	0.17	0.02
Short-term nominal interest rate	0.86	0.63	0.44	0.28
Long-term nominal interest rate	0.85	0.63	0.44	0.22

Note: Based on quarterly data from 1977Q1 to 2003Q4. 24 end-point observations excluded.

■ The **first figure in the first column for the UK (0.78)** means that **if real GDP goes up by one percentage point in the current quarter**, then on average **0.78 percentage points of that increase will remain in the next quarter** if the economy is not exposed to new shocks.

■ We see from Table 9.4 that there is **considerable persistence in the movements of GDP and of private consumption**, but the **most persistent variables are employment and unemployment**. The high persistence of employment may reflect that **firms are reluctant to hire and fire workers because hiring and firing is costly**. To sum up, we have:

Stylized business cycle fact 8. There is considerable **persistence in GDP** and about the same degree of persistence in **private consumption**.

Stylized business cycle fact 8. **Employment and unemployment** are even **more persistent** than GDP.

Measuring and decomposing the output gap: the production function approach

■ The **percentage difference between real GDP and its trend value** is usually termed the **output gap**. Economic policy makers and business cycle researchers take great interest in this variable, since a **significant positive output gap means that the economy is in a boom**, whereas a substantial **negative output gap indicates that the economy is in recession**, or at least that resources are being underutilized.

■ As we have seen, the **output gap may be measured by detrending the time series for the log of real GDP** by means of the HP filter. However, there is **another and more elaborate way of estimating the output gap** which allows an **interesting decomposition of the gap**. We shall now sketch this method which makes use of the concept of the **aggregate production function** known from the theory of economic growth.

■ Specifically, suppose that real GDP is given by the following **Cobb-Douglas** production function:

$$Y_t = B_t K_t^{\alpha} L_t^{1-\alpha}\text{, } 0 < \alpha < 1 \qquad 9.7$$

where K_t is the aggregate **capital stock**, L_t is the aggregate number of **hours worked**, and B_t is the "**total factor productivity**" measuring the combined productivity of capital and labour. By definition, total working hours are given as:

$$L_t = (1 - u_t)N_t H_t \qquad 9.8$$

where u_t is the **unemployment rate**, N_t is the **total labour force**, and H_t is the **average number of working hours per person** employed. Hence we can specify GDP as:

$$Y_t = B_t K_t^{\alpha}[(1-u_t)N_t H_t]^{1-\alpha} \qquad 9.9$$

■ Suppose now that Y_t, B_t, u_t, N_t and H_t **all tend to fluctuate around some long-run trend levels** denoted by $\overline{Y}_t$, $\overline{B}_t$, $\overline{u}_t$ and $\overline{N}_t$, respectively. By analogy to (9.9), we may then write **trend output** (also referred to as **potential output**) as:

$$\overline{Y}_t = \overline{B}_t K_t^{\alpha}[(1-\overline{u}_t)\overline{N}_t\overline{H}_t]^{1-\alpha} \qquad 9.10$$

■ Note that this specification does not distinguish between the actual capital stock and its trend level, since we **assume for simplicity that the capital stock is always fully utilized**.

■ The **output gap may be approximated by** $y_t - \overline{y}_t$, where $y_t \equiv \ln Y_t$ and $\overline{y}_t \equiv \ln \overline{Y}_t$. Taking **logs on both sides** of (9.9) and (9.10), **subtracting the resulting expressions from one another**, and **using the approximation** $\ln(1-u) \approx -u$, we get:

$$y_t - \overline{y} \approx \ln B_t - \ln \overline{B}_t + (1-\alpha)[(\ln N_t - \ln \overline{N}_t) + (\ln H_t - \ln \overline{H}_t) - (u_t - \overline{u}_t)] \qquad 9.11$$

■ Thus the **output gap may be found as the cyclical component of total factor productivity**, $\ln B_t - \ln \overline{B}_t$, **plus 1 – *α* times the cyclical component of total labour input** (the term within the square brackets). The **latter may in turn be decomposed into the cyclical component of the labour force**, $\ln N_t - \ln \overline{N}_t$, the cyclical component of **average working hours**, $\ln H_t - \ln \overline{H}_t$, and the amount of **cyclical unemployment**, $u_t - \overline{u}_t$.

■ Equation (9.11) may be used to estimate the output gap provided one has access to **data on real GDP, the labour force, average working hours, unemployment, and the total capital stock**. The cyclical components of labour supply and unemployment may be estimated by **detrending the time series** for $\ln N_t$, $\ln H_t$ and u_t by means of the HP filter.

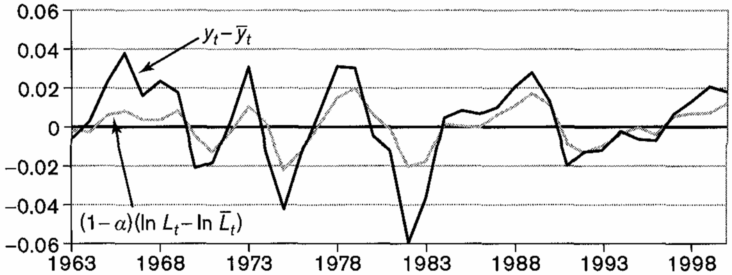
■ To estimate the **cyclical component of (the log of) total factor productivity**, one may proceed as follows. First, take logs on both sides of (9.7) and rearrange to find:

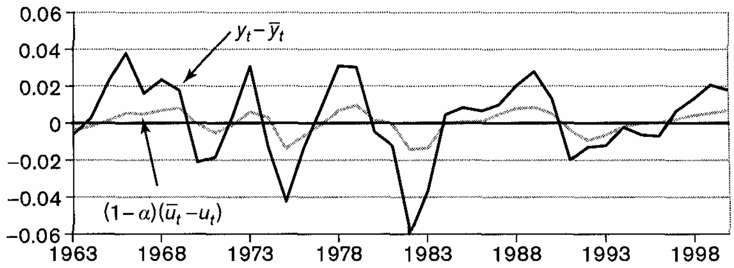
$$\ln B_t = \ln Y_t - \alpha \ln K_t - (1 - \alpha)\ln K_t \qquad 9.12$$

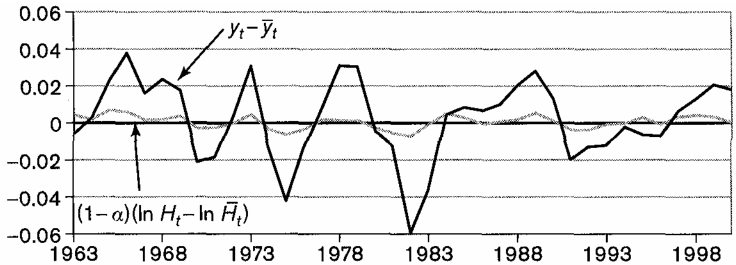
where L_t may be calculated from (9.8) (or where data on L_t may be directly available). From the theory and empirics of economic growth we know that the magnitude **1 – *α* should correspond roughly to the labour income share in total GDP which is close to 2/3** in most countries. Hence we may set $\alpha = 1/3$. Plugging the data for Y_t, K_t and L_t into equation (9.12), then, gives an **estimate of total factor productivity**. This **way of estimating total factor productivity** is closely **related to the method of "growth accounting"** used to identify the sources of economic growth.

■ In a second step, one may detrend the estimated time series for $\ln B_t$ through HP filtering to obtain an estimate of the cyclical component of total factor productivity. The **estimates for** $\ln B_t - \ln \overline{B}_t$, $\ln N_t - \ln \overline{N}_t$, $\ln H_t - \ln \overline{H}_t$ and $u_t - \overline{u}_t$ may finally be i**nserted into (9.11)** along with $\alpha = 1/3$ to give an **estimated time series for the output gap**.

■ Figure 9.5 shows an estimate and **decomposition of the output gap in the United States**, based on the method just described and **using annual data**. The value of the parameter ***λ* in the HP filter has been set to 100**, which is **common practice in business cycle analysis of annual data**. Since the **HP filter gives imprecise estimates of the trend at the end points**, we have **excluded the first and the last three estimates of the cyclical components at the end points** of each time series.




0.06
0.04
0.02
0
−0.02
−0.04
−0.06
$y_t - \bar{y}_t$
$(1-\alpha)(\bar{u}_t - u_t)$
1963
1968
1973
1978
1983
1988
1993
1998


0.06
0.04
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−0.02
−0.04
−0.06
$y_t - \bar{y}_t$
$(1-\alpha)(\ln H_t - \ln \bar{H}_t)$
1963
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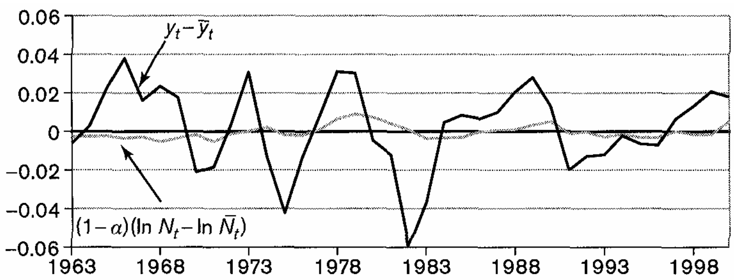

Figure 9.5: The US output gap and its components estimated by the production function method

Source: OECD. Economic Outlook Database.

■ The **upper part** of Figure 9.5 shows the part of the **fluctuations in the output gap that can be traced to cyclical fluctuations in total labour input**. It follows from (9.11) that the **vertical distance between the curve for the output gap and the curve** $(1-\alpha)(\ln L_t - \ln \bar{L}_t)$ **measures the contribution of cyclical fluctuations in total factor productivity to the total gap**.

■ Note that **if there are variations in the degree of utilization of the capital stock**, this will tend to **generate cyclical fluctuations in our measure of total factor productivity** (TFP). Similarly, **if work intensity varies over the business cycle**, say, because people tend to **work harder when there is more work** to do, this **will also be captured in the cyclical component of TFP**. Hence the fluctuations in $\ln B_t - \ln \overline{B}_t$ **do not only reflect instability in the rate of technical progress**; they also capture variations in the intensity with which factors of production are utilized.

■ We see from the top diagram in Figure 9.5 that a **large part of variation in the output gap stems from the cyclical variation in total labour input**. At the same time the **cyclical component of TFP accounts for a large fraction of the output gap at business cycle peaks and troughs, presumably reflecting that work intensity and capacity utilization are unusually low in recessions and unusually high in boom periods.**

■ The **other diagrams** in Figure 9.5 show the **separate contributions of the cyclical swings in unemployment, average working hours and the labour force** to the swings in the output gap. **Changes in cyclical unemployment account for the greatest part of the variation in labour input**, but **average working hours also tend to fluctuate in a procyclical manner**, suggesting that **employees tend to work longer hours when there is more work** to be done.

■ The **labour force does not seem to respond very much to the business cycle**, although there is a tendency for the workforce to vary in a slightly procyclical manner (while lagging a bit behind the output gap) from the early 1970s and onwards. We may sum up this analysis of the output gap as follows:

Stylized business cycle fact 10. Total factor productivity, **TFP, varies procyclically and the cyclical component of TFP accounts for a large fraction of the total output gap** at business cycle peaks and troughs.

Stylized business cycle fact 11. Most of the cyclical variation in total labour input stems from fluctuations in cyclical unemployment, but average working **hours**, and to some extent the total **labour force**, also **vary procyclically**.

■ It is of interest to **compare the estimate of the output gap based on the production function** method to the estimate obtained by simply **HP filtering** the time series for the log of GDP. This comparison is made in Figure 9.6.

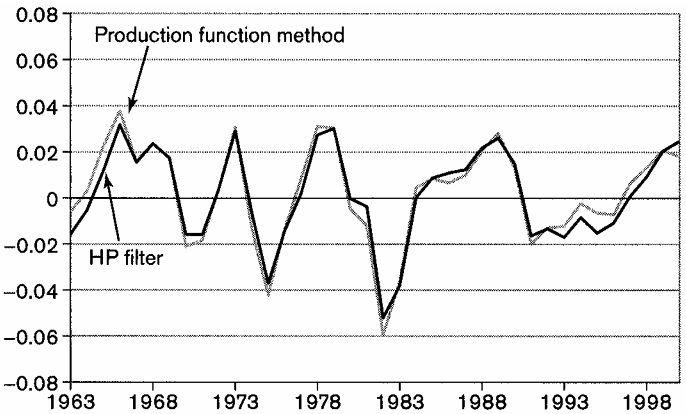

Figure 9.6: Alternative measures of the US output gap: the simple HP filter versus the production function method

Source: OECD, Economic Outlook Database.

■ It is reassuring to see that the **output gaps found from the two alternative methods are quite close** to each other. Hence **HP filtering** of the real GDP series may be a **quick and easy way of obtaining a first estimate of the output gap**, but if one wants to identify the various **contributions to the gap**, one will have to use some version of the **production function method**, as international organizations like the OECD, the IMF and the European Commission actually do.

HP filtering: a final word of caution

■ Even more sophisticated versions of the **production function method typically rely on the use of the HP filter**, say, for the purpose of **estimating the trend in TFP**. Although convenient, the method of **HP filtering is not unproblematic**. We have already mentioned that the **HP trend tends to be imprecisely estimated at the end points of the time series**.

■ Hence the serious **researcher should disregard some end-point observations**, as we have done above. However, this is **unfortunate since one is often particularly interested in estimating the output gap for the most recent periods** in order to **evaluate the need for active macro-economic policy** to smooth the business cycle.

■ Another problem is that **there is no objectively correct value of the parameter λ** which determines the estimated HP trend. In Figure 9.7 we have shown two different estimates of the US output gap, using the HP filter with λ = 100 and with λ = 1000, respectively. We see that the difference between the two measures is non-negligible in the 1960s and early 1970s, so the basic arbitrariness in the choice of λ adds another element of uncertainty to measures of cyclical fluctuations based on the HP filter.

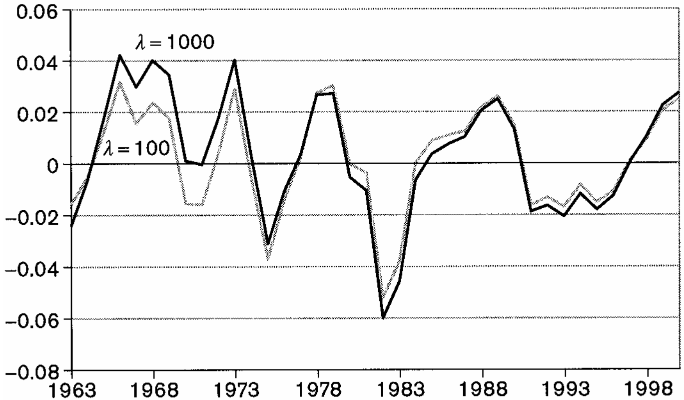

Figure 9.7: The US output gap estimated by the HP filter: the importance of the choice of λ

■ A further problem is that the **HP filter cannot capture structural breaks in the trends** of economic time series. For example, if a labour market reform leads to a significant one-time shift in the level of the natural unemployment rate, this **change in structural unemployment**

will only be slowly and gradually picked up by the estimated HP trend in unemployment.

■ Thus there is **considerable uncertainty about the "true" output gap**, reflecting our **imperfect knowledge of the way the economy works**. The uncertainty regarding the size (and sometimes even the sign) of the output gap creates **difficulties when policy makers try to reduce the short-run fluctuations** in output and employment through active fiscal and monetary policy.

A look ahead

■ We have now described some facts about business cycles. In the following lectures our main goal will be to **construct an economic model which may explain short-run fluctuations in aggregate output, employment and inflation**. Specifically, we will gradually build up a **model**, which may be summarized in the manner depicted in Figure 9.8, where **real output and the rate of inflation are determined by the intersection of an upward-sloping aggregate supply curve and a downward-sloping aggregate demand**

curve. We will then use this model to study **how the economy reacts over time to various shocks** to the aggregate supply curve and the aggregate demand curve.

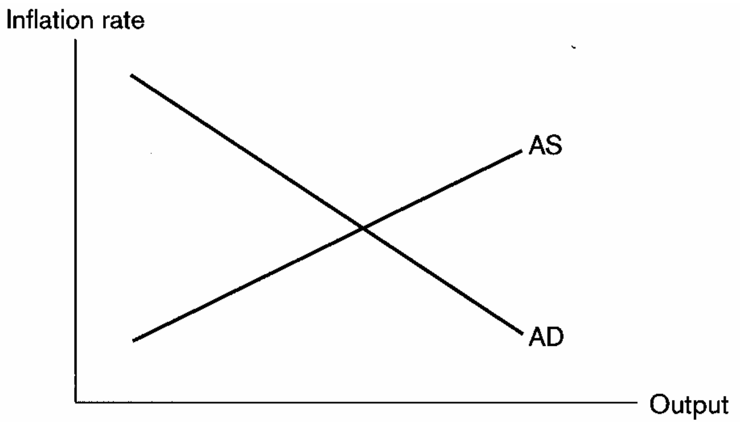

Figure 9.8: Aggregate supply and aggregate demand

■ Our goal is to construct a **model in which the effects of aggregate demand and supply shocks tend to persist** over time through so-called **propagation mechanisms** arising from the links between central macroeconomic variables.

■ In this view of the world business **cycles are initiated by random shocks to the economy** such as an unanticipated change in the **oil price** or a change in **business confidence** due, say, to unexpected **political events**. However, the **cumulative and systematic character of business fluctuations** documented in this lecture will be **explained endogenously by the properties of our macroeconomic model**.

■ One cannot promise to explain all the features of business cycles – **economists are still far from having a perfect understanding of this complex phenomenon** – but our model economy will at least have the **property that random shocks tend to generate irregular cycles displaying a certain persistence**.

■ As indicated in Figure 9.8, the aggregate demand curve and the aggregate supply curve are the central building blocks of our model. **To construct the aggregate demand curve we**

must build a theory of private investment and private consumption. This is our agenda for the next two lectures. Then we combine the insights from these lectures with a study of **monetary policy** to derive the aggregate demand curve.

■ After that we will analyse the **relation between inflation and unemployment as a basis for constructing the aggregate supply curve**. This will enables us to set up our basic **AS-AD model** which will be used **to reproduce some of the stylized facts** about business cycles.

Summary

■ Business cycles are periods of expansion of aggregate economic activity followed by periods of contraction in which activity declines. These fluctuations are recurrent but not periodic; in duration business cycles have varied from a little more than a year to 10-12 years. The severity of recessions has also varied considerably, with recessions sometimes turning into depressions where output and employment fall dramatically.

■ The expansion phase of the business cycle usually lasts considerably longer than the contraction phase, reflecting the economy's capacity for long-term growth. In the period since the Second World War business cycle expansions have tended to last longer, and recessions have tended to be shorter and milder than was the case before the war. For the post-Second World War period the average duration of the US business cycle expansions has been 57 months, while recessions have on average lasted 10 months. By contrast, the average recession lasted about 22 months before the war.

■ The business cycle fluctuation in a macroeconomic time series may be measured as the deviation of the actual time series from its long-term trend. The trend may be estimated by means of the HP filter which allows for smooth changes in the underlying (growth) trend in a series.

■ The volatility of the cyclical component in a macroeconomic time series may be measured by its standard deviation. By this measure, investment is a lot more volatile over the business cycle than GDP, whereas employment is considerably less volatile.

■ The co-movements in different economic variables over the business cycle may be measured by their coefficients of correlation with GDP. Private investment, consumption and imports all have a strong positive correlation with GDP. Employment also displays a clear positive correlation with GDP, but it is a lagging variable, being more strongly correlated with the GDP of the two previous quarters than with current GDP. Labour productivity tends to vary positively with GDP, and so does inflation in most countries, although the latter correlation is not very strong. The nominal short-term interest rate tends to go up in the two quarters following a rise in GDP, reflecting a tightening of monetary policy.

■ The degree of persistence in a macroeconomic variable may be measured by its coefficients of correlation with its own lagged values, the so-called coefficients of autocorrelation. There is considerable persistence in GDP and private consumption, and even more persistence in employment. This means that once these variables start to move in one direction, they will continue to move in the same direction for a while, unless they are disturbed by new significant shocks.

■ The output gap is the percentage difference between actual GDP and trend GDP. The output gap may be estimated by means of the production function method which allows a decomposition of the gap into contributions from cyclical variations in unemployment, average working hours, the total labour force, and total factor productivity (TFP). Such a decomposition shows that fluctuations in TFP – capturing cyclical swings in work intensity and capacity utilization as well as an uneven pace of technical progress – account for a relatively large share of the fluctuations in output at business cycle peaks and troughs. The largest part of the cyclical variation in labour input comes from fluctuations in cyclical unemployment, but average working hours (and to a minor extent the labour force) also tend to vary positively with the output gap, reflecting that labour supply tends to increase when there is more work to do.

■ The method of detrending an economic time series by means of the HP filter should be used with care, because (i) the HP filter gives imprecise estimates of the trend at the end-points of the time series; (ii) the filter relies on an arbitrary choice of the λ-parameter which determines the smoothness of the estimated trend, and (iii) the HP filter cannot capture structural breaks in the data series. For these and other reasons there is considerable uncertainty associated with the measurement of business cycles.