1 Introduction

Underlying the existence of macroeconomics as a separate field of study are the phenomena of economywide movements in output, unemployment, and inflation. Although developed economies are characterized by growth, this growth is far from steady. Expansions and recessions alternate over time, associated with movements in unemployment. Occasionally, recessions turn into depressions, such as the U.S. depression from 1873 to 1878, the Great Depression of the 1930s, and the long period of high unemployment in Europe in the 1980s. Periods of price deflation, such as the prolonged price level decline in the last two decades of the nineteenth century, the recession of 1920–21, and the Great Depression, appear to be something of the past: most economies now alternate between periods of low and high, sometimes very high, inflation. It is the main purpose of macroeconomics, and of this book, to characterize and explain these movements of output, unemployment, and prices.

In this chapter we introduce the major issues of macroeconomics by characterizing the basic facts that call for explanation. We then provide a preview of the book, and end by stating some of our goals and choices in writing it.

1.1 Macroeconomic Facts

Growth, Employment, and Productivity

The dominant macroeconomic fact in developed economies in the last two centuries is that of output growth.[1] Figure 1.1 shows the behavior of U.S. real GNP from 1874 to 1986.[2] Using Maddison's first estimate of U.S. real GNP, U.S. growth averaged 3.7% per year for the period 1820 to 1986. The average rate of growth has been 3.4% since 1874, 3.0% since 1919, and 3.2% since 1950. Equivalently, real GNP is about 37 times larger than it was

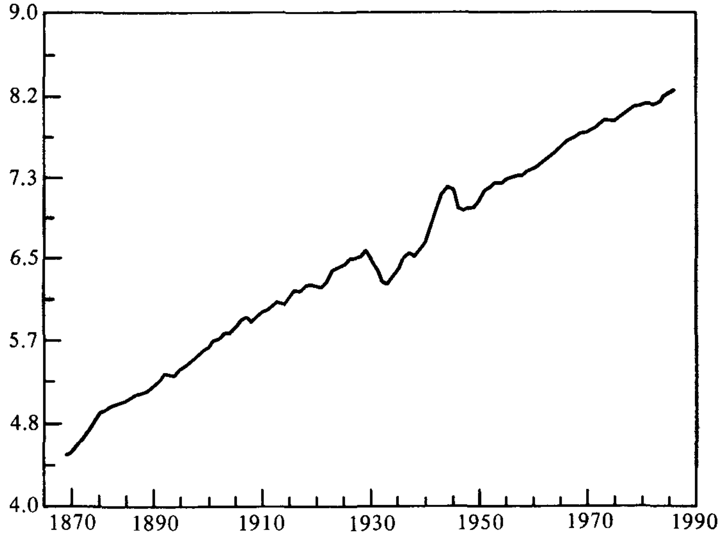

Figure 1.1
Logarithm of real GNP (1982 dollars). Sources for GNP: 1874–89, Romer (1986b, table 3); 1890–1908, Romer (1986b, table 5); 1909–28, Romer (1987, table 5); 1929–47, Commerce Dept. (1986, table 1.4); 1948–86, Economic Report of the President (1987).

in 1874, 7 times larger than in 1919, and 3 times larger than in 1950. Extrapolating backward leads to the well-known conclusion that economic growth at these rates cannot have been taking place for more than a few centuries.

What are the sources of this growth? Here are the stylized facts as laid out by Solow in 1970. First, output growth reflects growth in both the labor force and labor productivity: total labor hours have increased 1.4% per year and output per hour by 2.0% per year since 1874. Thus output growth has come more from increasing labor productivity than from increases in the labor force; this is shown in figure 1.2 which gives total man-hours and output per man-hour for the private domestic sector (i.e., excluding the government) since 1874.[3] Growth in output per man-hour, labor productivity, has been 2.1% since 1919 and 2.1% since 1950; output per man-hour is now nine times higher than it was in 1874, and double its 1950 level.[4]

Where does this growth in living standards, reflected in output per man-hour, come from? How much of it is due to increases in capital and applied knowledge, and to increased specialization? Solow (1957) suggested

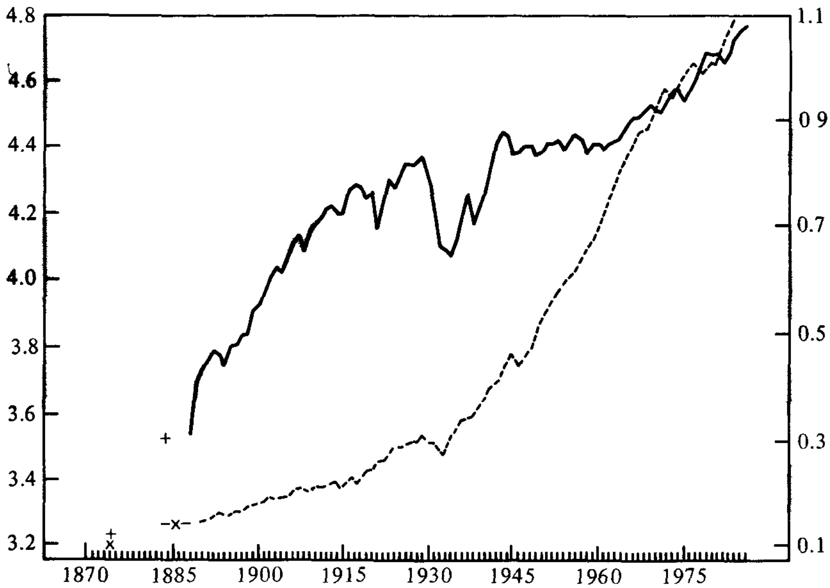

Figure 1.2
Logarithm of man-hours (solid line, left-hand scale) and output per man-hour (dashed line, right-hand scale, 1977 ≡ 1.0). Crosses indicate annual data not available. Sources for GPDP: *1870–1928*, Commerce Dept. *(1973*, LTEG, series A13); *1929–47*, Commerce Dept. (1973, LTEG, series A14); 1948–86, Commerce Dept. (1987, table 1). For man-hours: 1870–1947, Commerce Dept. (LTEG, series A59); 1948–86, Commerce Dept. (1987, table 1).

a simple decomposition that, though not theory-free, provides a useful description of the data. Under the assumptions of constant returns to scale and competitive markets, the rate of growth of output can be written as

$$g_y = ag_n + (1 - a)g_k + q,$$

where g_y, g_n, and g_k are the growth rates of output, labor, and capital, respectively, and a is the share of labor in output; q then measures that part of growth that cannot, under the maintained assumptions, be explained by either growth of labor or growth of capital.[5] This term has been dubbed *multifactor productivity growth*, or less formally, the Solow residual.

The data suggest that the Solow residual plays an important role in growth. We can rewrite the above equation as

$$(g_y - g_n) = \left(\frac{1-a}{a}\right)(g_k - g_y) + \left(\frac{1}{a}\right)q.$$

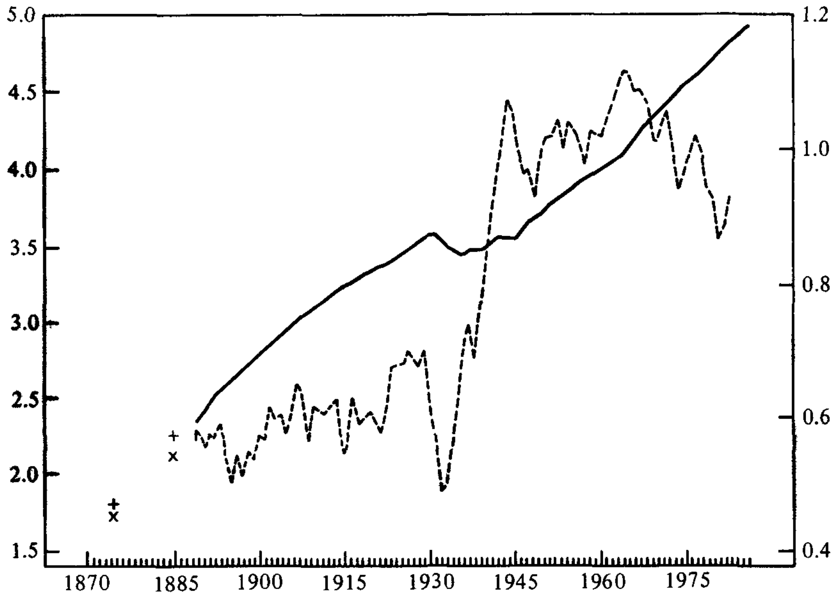

Figure 1.3
Logarithm of capital services (solid line, left-hand scale) and output per unit of capital (dashed line, right-hand scale, 1977 ≡ 1.0). Crosses indicate annual data not available. Sources for GPDP: see figure 1.2. For capital: 1870–1947, Commerce Dept. (1973, series A59); 1948–86, Commerce Dept. (1987, table 1).

The rate of growth of output per man-hour depends positively on the rate of growth of the capital–output ratio and on the Solow residual. There can be labor productivity growth, even if q is equal to zero, as long as the capital–output ratio increases. Existing measures of capital suggest, however, that capital has grown at a rate roughly similar to that of output, so that $g_k - g_y$ has been close to zero. This can be seen in figure 1.3, which shows the evolution of capital as well as the output–capital ratio for the private domestic sector since 1874.[6] The average rate of growth of capital has been 2.8% since 1874, 2.1% since 1919, and 3.4% since 1950.

The relative constancy of the output–capital ratio implies a positive Solow residual, equal roughly to the labor share times the rate of growth of labor productivity. Multifactor productivity, for the private domestic sector, is plotted in figure 1.4. Its rate of change averages 1.9% since 1874, 2.0% since 1919, and 1.7% since 1950, accounting for approximately half of the growth in the private economy over the whole period. Despite the detailed

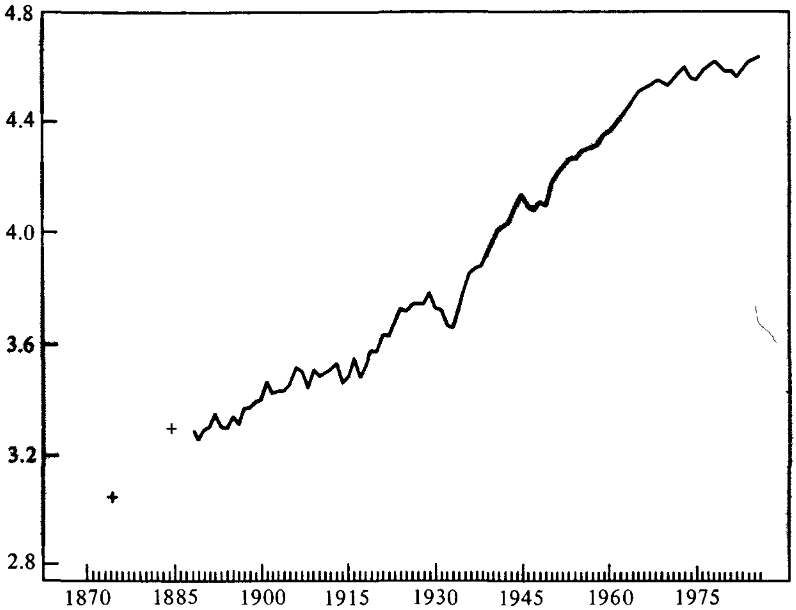

Figure 1.4
Logarithm of multifactor productivity. Crosses indicate annual data not available. Sources for GPDP: see figure 1.2. For total input: 1870–1947, Commerce Dept. (1973, series A59); 1948–86, Commerce Dept. (1987, table 1).

work of Denison and others, we have only a limited understanding of where this residual comes from, and of why it is higher in some countries than in others, or higher during some periods than during others. In seeking to explain the interactions among output, employment, and capital accumulation, we shall for the most part take as given the long-term movements in multifactor productivity.

Both the figures and the data we have presented emphasize the most important fact of modern economic history: persistent long-term growth. But, as the large fluctuations in figures 1.1 to 1.4 make clear, this growth is far from steady. We turn now to the fluctuations.

The Stochastic Behavior of Output and Unemployment

Figure 1.1 shows substantial fluctuations in GNP growth over time. Associated with these movements in output are movements in unemployment, which are plotted for the period since 1890 in figure 1.5. There is little

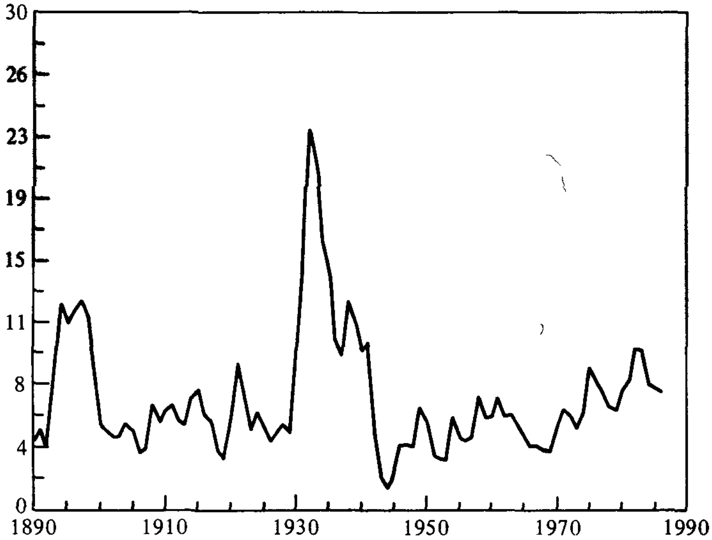

Figure 1.5
Unemployment rate. Sources: 1890–1930, Romer (1986a, table 9); 1931–40, Darby (1976, p. 8); 1940–86, Economic Report of the President (1987).

question that these movements are associated with fluctuations in welfare: periods of boom, expansion, and declining unemployment are widely perceived as happy times in which governments win reelection; periods of recession and depression are often times of crisis and despair.

Explaining booms and recessions will be the object of several chapters of this book, but at this stage we limit ourselves to describing them.[7] Although it is of interest to look at actual movements in output and to see whether fluctuations can be related to specific events or policies, our goal is to describe the general characteristics of fluctuations rather than to study specific episodes. We want to know, for example, how long typical recessions or expansions last, whether fluctuations in output are largely transitory or largely permanent. To do so, we must look at the series for output and other variables as time series with well-defined characteristics and thus use time series methods to uncover those characteristics.

Macroeconomists are, and should be, schizophrenic about the use of time series methods. On the one hand, there is no hope of discovering empirical regularities unless variables follow stable stochastic processes over time. On the other, it is clear that there are episodes, such as depressions or hyperinflations, during which some variables behave abnormally and where a straightforward use of time series methods would be inappropriate. (Even if there existed a stable Kondratieff process that generated depressions on average every 50 years, this would not help us much given the average length of our macroeconomic time series.) The intellectually uncomfortable attitude of most macroeconomists has been to study these episodes separately, and to use time series methods for times when the assumption that variables follow some stable process is not obviously unacceptable. This is what we do below by focusing on the U.S. postwar period, thus ignoring the Great Depression.

The first systematic time series study of business cycles was that of Burns and Mitchell (1946). Their approach was to treat each cycle as a separate episode, terminating and starting at a trough and going from trough to peak through an expansion, and from peak to trough through a contraction. The typical business cycle was then characterized by the mean lengths of expansions and contractions, the amplitude of fluctuations, and the behavior of economic variables relative to the business cycle chronology. This business cycle chronology was used creatively by researchers in the NBER tradition, for instance, by Friedman and Schwartz (1963) in their monumental *Monetary History*.

Most macroeconometricians, however, have abandoned the Burns-Mitchell methodology. This is because the approach is partly judgmental and the statistics it generates do not have well-defined statistical properties. Much of the recent work has proceeded, instead, under the assumption that variables follow linear stochastic processes with constant coefficients. As we shall see later in the book, this has had the advantage of allowing for a better integration of macroeconomic theory and econometrics. In return for this integration and for well-understood statistical properties, some of the richness of the Burns-Mitchell analysis, such as its focus on asymmetries between recessions and expansions or its notion of business cycle time (as opposed to calendar time) may well have been lost.[8] For the postwar United States, however, the assumption that major economic variables follow linear (or loglinear) stochastic processes does not appear too strongly at variance with the data.

Trends versus Cycles, Permanent and Transitory Shocks

The main problem macroeconomists have struggled with in characterizing output fluctuations has been that of separating trend from cycle. This decomposition can be seen as a purely statistical issue devoid of economic significance.[9] Most economists, however, believe that, behind short-run fluctuations, the economy evolves along an underlying growth path, which can be thought of as the trend. The issue is then how to characterize that trend.

A useful way of approaching the issue is to think of the economy as being affected by two types of shocks. Some shocks have permanent effects on output—we shall call them permanent shocks. Prime candidates are improvements in productivity or increases in the labor force. Some shocks have transitory effects, effects on output that disappear over time; they may include bad crops, temporary increases in government spending, changes in the money. We may then think of the trend as that part of output that is due to permanent shocks; by construction, this series is nonstationary. That part of output that comes from transitory shocks can be thought of as the cycle; by construction, that series is stationary.

We now present three decompositions. The first, and traditional approach, assumes that the trend component of output is smooth so that most of the short-run fluctuations in output come from transitory shocks. This decomposition has recently been challenged on the grounds that the assumption of a smooth trend is not justified. We thus present a second decomposition that assumes, instead, that all fluctuations are due to permanent shocks, that actual output and trend output are the same. We then discuss those results and present a third decomposition, which we find more reasonable, that uses information from both output and unemployment movements.

The Traditional Decomposition

The traditional business cycle approach characterizes the economy as growing along a smooth trend path from which it is disturbed by cyclical fluctuations.

Several methods have been used to define the trend, the simplest being an exponential growth path that best fits the historical data. But there appear to be long-run changes in productivity growth that are badly captured by such a trend. Okun (1962) developed an alternative approach to capture such changes. He defined the trend, or "potential output," as that level of output that would prevail if the unemployment rate was equal to 4% instead of its actual value. To derive the relation between actual output and unemployment required to get from actual to potential output, he examined alternative methods. One consisted of regressing first differences of output on first differences of unemployment. Okun found that a 1% decrease in the unemployment rate was associated with a 3% increase in output. This ratio of 3 to 1 has become known as Okun's law.

Many decompositions of output between trend and cycle have followed the spirit of Okun's computation. Some construct the trend by fitting a piecewise linear trend through the logarithm of GNP in years with similar levels of unemployment. Some use a smoothed version of the potential output series constructed using Okun's law. Those decompositions all lead to an estimated trend growth rate that is lower in the 1970s and the 1980s than in earlier decades.[10]

We now give the results of such a decomposition, using data on U.S. quarterly GNP, measured at an annual rate, for the period 1947-I to 1987-II. Based on the results described above, we allow trend growth to differ pre- and post-1973. Thus we first regress the logarithm of GNP on a piecewise linear trend; we then fit an ARMA process to the deviations of the logarithm of GNP from the estimated trend, the cyclical component. Estimated trend growth is 3.4% for 1947-I to 1973-I and 2.3% from 1973-I to 1987-II. The behavior of the cyclical component is well captured by an ARMA(2, 2) process:

$$y = 1.31y(-1) - 0.42y(-2) + e - 0.06e(-1) + 0.25e(-2), \qquad (1)$$
$$\sigma_e = 1\%.$$

The term e, which we will refer to as the shock, is, by construction, that part of the deviation of current GNP from trend that cannot be predicted from past GNP. It is therefore serially uncorrelated. The standard deviation of the quarterly movements in GNP that cannot be predicted from past values is equal to 1% of GNP, which is large.

A useful way of seeing what equation (1) implies is to look at the moving average representation of the process, or equivalently to trace out the dynamic effects of a shock e on GNP over time. This is done in figure 1.6. The graph of the dynamic effects of a shock in e on output is hump shaped, increasing initially and eventually fading out. A shock has an effect on GNP that increases for three quarters and then decreases slowly over time. After 10 quarters, the effect is still 40% of the initial impact; after 20 quarters, all but 3% of the effect has disappeared.[11] The view that reversible cyclical fluctuations account for most of the short-term movements of real GNP and unemployment has been dominant for most of the last half century.

An Alternative Decomposition

The traditional approach proceeds on the assumption that the part of output that is due to permanent shocks is smooth. But this assumption has recently been challenged, most forcefully by Prescott (1986). There is no reason to

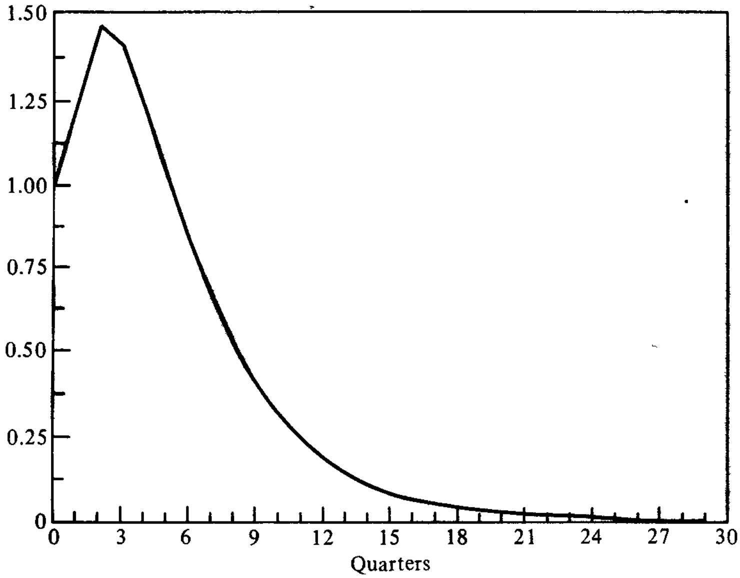

Figure 1.6
Dynamic response of GNP to a shock under the assumption of trend stationarity

believe, the argument goes, that productivity shocks, for example, lead to smooth growth in output; the process for productivity growth itself may not be smooth and may lead to fluctuations in output as well as in employment.

An extreme view along these lines is that all fluctuations are the results of the dynamic effects of permanent shocks, that actual and trend outputs are the same. Therefore, removing a deterministic or even a smooth trend from output makes no economic sense, and the output process must be thought of (and estimated as) a nonstationary process in which all shocks have permanent effects.[12]

Campbell and Mankiw (1987a), building on work by Nelson and Plosser (1982), have shown that the behavior of the logarithm of quarterly real GNP is well captured, for the postwar United States, by an ARIMA(1, 1, 2), which implies that the growth rate of output itself follows an ARMA(1, 2) process. Let Δy denote $y - y(-1)$, the change in the logarithm of real GNP and thus the growth rate. (Note that the growth rate is per quarter.) The ARIMA process, estimated over the same period as equation (1) is

$$\Delta y = c + 0.2\Delta y(-1) + e + 0.08e(-1) + 0.24e(-2), \qquad \sigma_e \doteq 1\%, \quad (2)$$

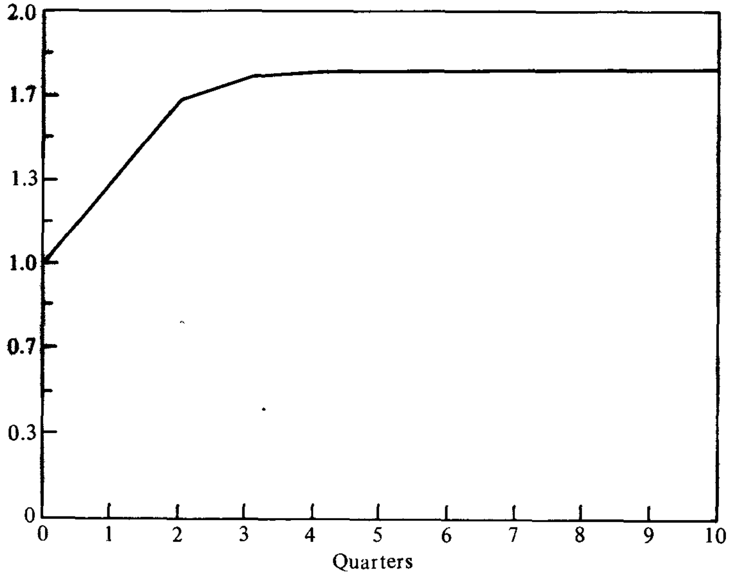

Figure 1.7
Dynamic response of GNP to a shock under the assumption of difference stationarity

where *c*, the drift term, is a positive constant, reflecting the fact that output growth is on average positive. Note that the standard error in equation (2) is roughly the same as that in (1).

The dynamic effect of a shock on output, an increase in *e*, is in this case presented in figure 1.7. By construction, shocks have permanent effects. This does not, however, a priori rule out dynamic effects that are larger in the short run than in the long run. But what emerges is a dynamic response of shocks that steadily increases through time: the effect on GNP of a shock of 1 in the first quarter builds up to reach 1.7 after four quarters, and remains equal to 1.7 permanently thereafter.

This approach leads to a very different description of movements in GNP. Movements in GNP result from the accumulation of shocks, each of which is on average positive (when the drift term is taken into account) and has large permanent effects on output. Slowdowns in growth result from small or even negative shocks, expansions from large positive ones. There is no sense in which recessions or expansions are temporary, no sense in which there are cyclical fluctuations.

Interpreting the Time Series Representations

Under the traditional decomposition, transitory shocks account for nearly all fluctuations in output. Under the alternative decomposition, permanent shocks account instead for all movements in output. What are we to conclude?

The first step may be to test which decomposition fits the data better. This has been done by Campbell and Mankiw (1987a), who have compared equation (2) to a deterministic-trend-plus-stationary-ARMA representation. They found that the data were unable to give a clear answer, that both representations gave approximately the same fit. But the problem is actually more serious than that. Equation (2) tells us that output is well represented by a nonstationary process; there are infinitely many ways of decomposing a nonstationary process as the sum of a nonstationary process (the trend) and a stationary process (the cycle). In particular, we can always decompose the series for output into a trend that is arbitrarily smooth and a stationary series.[13]

Where does this leave us? There is clearly no hope of making further progress by looking only at the behavior of output. But progress can be made by looking at other variables in addition to output and by assuming that different shocks affect them differently.[14] We now present one such decomposition that uses information from both unemployment and output.

The Stochastic Process of Output and Unemployment

Our approach is related to Okun's method of obtaining a time series for potential output. But rather than attempting to disentangle trend and cycle, we use the joint behavior of GNP and unemployment to try to disentangle the effects of permanent and transitory shocks.[15] We assume the presence of two types of shocks in the economy. The first type, transitory shocks, has no long-run effect on either output or the unemployment rate. The second type, permanent shocks, has a long-run effect on output but no long-run effect on the unemployment rate. This set of assumptions clearly implies that because neither type of shocks has a long-run effect on the unemployment rate, the unemployment rate is stationary, an assumption that appears consistent with the postwar evidence.[16] Under these assumptions, one can recover the time series for each type of shock and thus obtain the components of output and unemployment movements that are a result of permanent and transitory shocks, respectively.[17]

Figure 1.8 gives the two output series that would have obtained had there been no transitory or no permanent shocks. The top graph can be thought

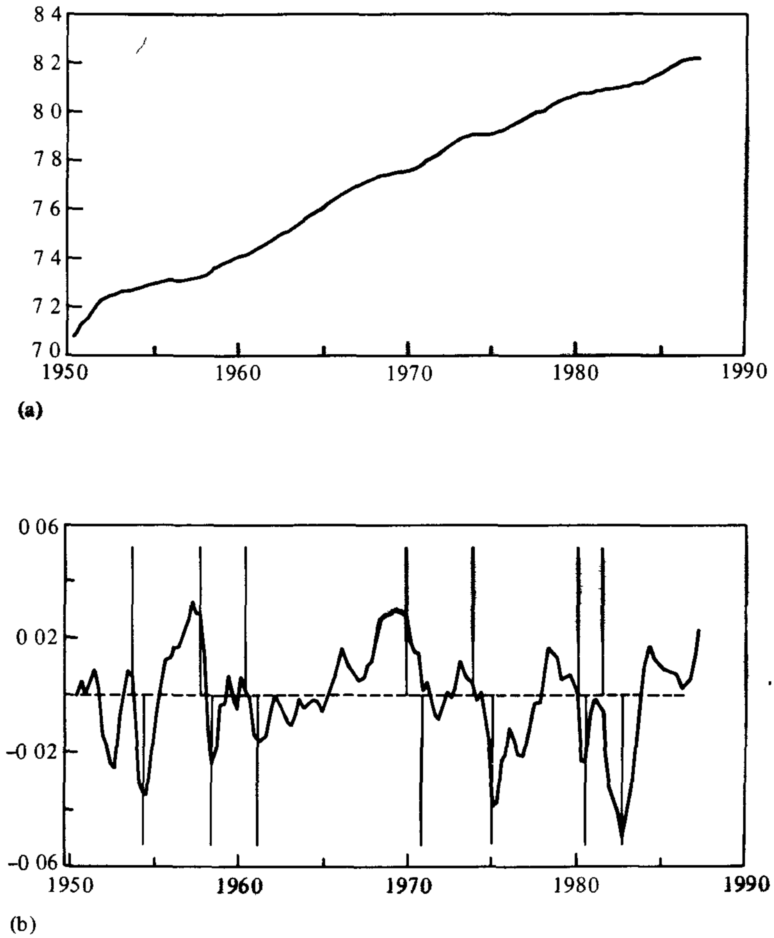

Figure 1.8
Output fluctuations (a) due to permanent shocks, (b) due to transitory shocks

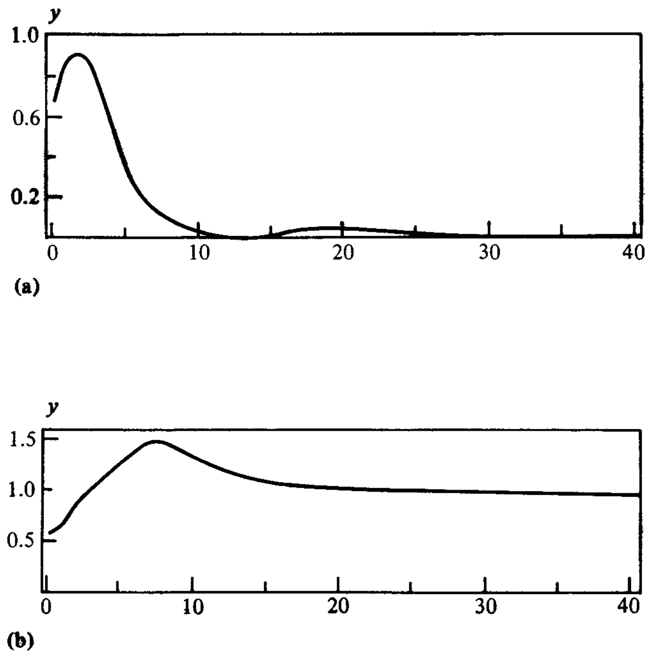

Figure 1.9
Moving average responses of output: (a) to transitory shocks; (b) to permanent shocks

of as the trend component, the bottom graph as the cyclical component of output. The moving average responses of output to each type of shock are presented in figure 1.9.

The picture that emerges from these figures is that of an economy in which both types of shocks play an important role. Transitory shocks matter and have a hump-shaped effect on output before their effects die out. But the path of output would be far from smooth even in the absence of those transitory shocks. What emerges is a more complex image of fluctuations than is implied by either of the two earlier decompositions, with temporary shocks moving output around a stochastic trend that itself contributes significantly to movements in real GNP.

We return in subsequent chapters to this characterization of the business cycle. Because the leading candidate as a cause of permanent shocks to the economy is changes in technical knowledge, we see the movements in output due to permanent shocks as evidence of the importance of movements in aggregate supply; because aggregate demand shocks (e.g., those caused by changes in the money stock in the face of imperfectly adjusting wages and prices) have largely transitory effects on output, we see the presence of temporary shocks as consistent with theories that emphasize the role of aggregate demand in the business cycle. The issue of the relative importance of aggregate demand and supply shocks in economic fluctuations is one of the recurrent themes of the book.

Comovements of GNP and Other Variables

The stylized facts of macroeconomic behavior extend beyond those of long-term growth and the dynamics of output and unemployment to the comovements of output and other variables. Both to set out the facts that need explanation, and to help discriminate among theories, we describe these comovements here.

Because researchers differ in the questions they want to answer and in the implicit theories that guide them through the data, there is a plethora of reported statistics on covariations in macroeconomic variables. We will draw on these results and compute our own set of statistics. These are correlations, at various leads and lags, of innovations obtained from estimation of univariate ARIMA processes for each series.[18] They have a simple interpretation. For example, a high positive contemporaneous correlation between innovations in consumption and innovations in GNP indicates that unexpected movements in GNP—that is, movements that cannot be predicted from past values of GNP—are usually associated with unexpected movements in consumption of the same sign.

Comovements in GNP and Its Components

Table 1.1 gives estimated ARIMA processes for the logarithms of GNP, consumption, fixed investment, and government spending and for the level of inventory investment.[19] It also reports the correlations between the innovations in GNP and the innovations in each component at lags -3 to $+3$.

Table 1.1 confirms that all components of spending move with output.[20] The contemporaneous correlation between innovations in GNP and each component is large and significant; correlations between innovations in GNP and innovations in each component one period later and one period earlier are smaller but also significant (except in one case). Correlations at other leads and lags are usually insignificant.

From the information in the table one can also compute the coefficient from a regression of the innovation in each component on the contem-

Table 1.1
Comovements in GNP and its components: correlations between innovations[a]

	Innovations in GNP at time:[b]						
Innovations at time 0 in:	−3	−2	−1	0	+1	+2	+3
Consumption[c]	−0.09	0.00	0.14	0.48	0.16	0.00	0.02
Fixed investment[d]	−0.01	0.03	0.10	0.52	0.16	0.01	−0.12
Government spending[e]	−0.01	0.13	0.15	0.23	−0.06	0.06	−0.01
Inventory investment[f]	0.00	0.07	0.21	0.57	−0.15	−0.03	0.06

a. Residuals from ARIMA processes for GNP and its components. Quarterly data, at annual rates, billions of 1982 dollars, from 1947-IV to 1987-II.
b. $\Delta y = 0.6 \times 10^{-2} + 0.24\Delta y(-1) + e + 0.08e(-1) + 0.24e(-2)$, $s = 0.10 \times 10^{-1}$; where y is the logarithm of GNP and s is the estimated standard error of the innovation.
c. $\Delta c = 0.8 \times 10^{-2} + e + 0.02e(-1) + 0.24e(-2)$, $s = 0.8 \times 10^{-2}$, where c is the logarithm of personal consumption expenditures.
d. $\Delta i_{\text{fix}} = 0.6 \times 10^{-2} + 0.31\Delta i_{\text{fix}}(-1) + e + 0.22e(-1)$, $s = 0.25 \times 10^{-1}$, where i_{fix} is the logarithm of fixed investment.
e. $\Delta g = 0.3 \times 10^{-2} + 0.57\Delta g(-1) + e + 0.01e(-1) + 0.11e(-2)$, $s = 0.18 \times 10^{-1}$, where g is the logarithm of government purchases of goods and services.
f. $\Delta i_{\text{inv}} = 0.28 - 0.14\Delta i_{\text{inv}}(-1) + e - 0.23e(-4)$, $s = 15.7$, where i_{inv} is the level of inventory investment, with heteroscedasticity correction (divided by the estimated time trend of absolute value of first difference).

poraneous innovation in GNP.[21] Though one must be careful not to interpret such a regression as causal, the regression coefficient, which has the dimension of an elasticity, gives an idea of how much a particular component moves with GNP. The elasticity of consumption to GNP, so defined, is equal to 35%, and thus is much smaller than 1. The elasticity of fixed investment to GNP is equal to 1.2. Because inventory investment is in levels, it would make no sense to report the regression coefficient in that case. However, movements in inventory investment can be very large compared to those in GNP. In particular, recessions are usually accompanied by inventory disinvestment. In those periods after 1948 when GNP declines relative to a deterministic trend, the average share of the fall attributable to a decline in inventory investment is about 50%.[22]

The strong covariation of GNP and both consumption and investment is one of the best established facts characterizing economic fluctuations. It is this set of facts that led early on to the development of the multiplier-accelerator model of fluctuations. The positive covariation of inventory investment and GNP has proved harder—although, as we shall see, not impossible—to reconcile with demand-driven models of fluctuations: one would expect transitory increases in sales to come partly out of inventories and partly out of production, generating a negative correlation between inventory investment and sales.

Comovements in GNP and Relative Prices

Table 1.2 characterizes the comovements between output and relative prices. The first two are indexes of real wages in terms of consumption ("consumption wages" for short): hourly earnings in manufacturing and in the private sector, both deflated by the CPI. The third is a "product wage," with hourly earnings in manufacturing deflated by the price index relevant for firms, the PPI. The next two are the relative prices of crude fuels and of nonfuel-nonfood materials, deflated by the CPI. The sixth is an intertemporal price, the nominal interest rate, measured as the yield on three-month treasury bills. The last is a real interest rate, r, constructed as the yield on three-month treasury bills minus the one-period-ahead forecast of CPI inflation, itself obtained from ARMA estimation of the inflation process.

The table presents estimated ARIMA processes for the logarithms of the three real wages and the logarithms of the two relative prices. Because it is not clear whether the process for the nominal interest rate is stationary, we give the results of estimation of both ARMA and ARIMA processes for the nominal interest rate. The real rate is clearly stationary and is thus estimated by an ARMA model. We then report the correlations at lags $+3$ to -3 between the various innovations and innovations in the logarithm of GNP.

There is very little correlation at any lead or lag betwen economywide real wages and output, but there is a significant positive contemporaneous correlation between manufacturing wages and output. The correlation is stronger for the consumption wage than for the product wage. These two findings are representative of the results of the large amount of research on the cyclical behavior of consumption or product wages since Keynes' *General Theory*. The *General Theory* assumption that firms are always on the demand curve for labor implies, together with the assumption of decreasing returns to labor, a negative correlation between real wages and output or employment. It was soon found, in particular by Dunlop (1938), that real wages are, if anything, procyclical rather than countercyclical, and this led Keynes (1939) to doubt his own characterization of the transmission mechanism of demand shocks to output. This initial finding has been largely confirmed by subsequent research, at least for the United States, at the aggregate level (Sargent 1978; Kennan 1988), at the industry level (Bernanke and Powell 1986), and at the individual level, using panel data (Bils 1985).

Table 1.2
Comovements in GNP and relative prices: correlations between innovations[a]

	Innovations in GNP at time:						
Innovations at time 0 in:	−3	−2	−1	0	+1	+2	+3
Real consumption wage w[b]	−0.03	−0.02	−0.13	0.19	0.06	0.02	−0.03
Real consumption wage in manufacturing w_m[c]	0.06	0.09	−0.09	0.41	0.05	0.00	0.00
Real product wage in manufacturing w_{mp}[d]	0.12	−0.01	−0.09	0.26	0.11	−0.03	0.06
Relative price of crude fuel p_f[e]	−0.08	−0.02	−0.18	−0.04	−0.04	−0.13	−0.06
Relative price of nonfuel-nonfood materials p_{nf}[f]	−0.16	0.08	0.12	0.22	0.13	−0.02	−0.10
Nominal interest rate i							
Level[g]	0.00	0.15	0.13	0.14	−0.01	−0.30	−0.14
First differences[h]	0.00	0.17	0.17	0.18	0.02	−0.26	−0.12
Real interest rate r[i]	−0.03	−0.15	−0.10	0.04	0.11	−0.11	−0.01

a. Residuals from ARIMA processes as estimated for relative prices. Quarterly data, 1948-IV to 1987-II. See table 1.1 for estimated GNP process.
b. $\Delta w = 0.10 \times 10^{-2} + 0.66\Delta w(-1) + e - 0.19e(-1) + 0.27e(-3)$, $s = 0.48 \times 10^{-2}$, where w is the logarithm of average hourly earnings in the private sector corrected for overtime and interindustry shifts divided by the CPI.
c. $\Delta w_m = 0.10 \times 10^{-2} + 0.60\Delta w_m(-1) + e - 0.35e(-1)$, $s = 0.75 \times 10^{-2}$, where w_m is the logarithm of average hourly earnings in manufacturing, corrected for overtime and interindustry shifts, and divided by the CPI.
d. $\Delta w_{mp} = 0.20 \times 10^{-2} + 0.52\Delta w_{mp}(-1) + e - 0.26e(-1)$, $s = 0.98 \times 10^{-2}$, where W_{mp} is the logarithm of average hourly earnings in manufacturing corrected for overtime and interindustry shifts, divided by the producer price index (PPI) for finished goods in manufacturing.
e. $\Delta p_f = 0.57 \times 10^{-2} + 0.04\Delta p_f(-1) + e + 0.18e(-1) + 0.31e(-4)$, $s = 0.26 \times 10^{-1}$, where p_f is the logarithm of the producer price index for crude fuels divided by the CPI.
f. $\Delta p_{nf} = -0.13 \times 10^{-2} + 0.33\Delta p_{nf}(-1) + e + 0.25e(-1)$, $s = 0.31 \times 10^{-1}$, where p_{nf} is the logarithm of the producer price index for nonfuel-nonfood crude materials divided by the CPI.
g. $i = 0.30 + 0.67i(-1) + 0.03i(-2) + 0.24i(-3) + e + 0.63e(-1)$, $s = 0.75$, where i is the average yield on three-month Treasury bills.
h. $\Delta i = 0.04 - 0.22\Delta i(-1) - 0.26\Delta i(-2) + 0.09\Delta i(-3) + e + 0.57e(-1)$, $s = 0.74$.
i. $r = 0.61 - 0.17r(-1) + 0.36r(-2) + 0.44r(-3) + e + 0.63e(-1)$, $s = 2.06$, where r is the average yield on three-month Treasury bills minus the one period ahead forecast of CPI inflation based on an ARMA(1, 2) process.

The correlation between changes in real wages and changes in output or employment is usually slightly positive but often statistically insignificant.

There is a small but consistently negative correlation in table 1.2 between the price of crude fuel and GNP. This is consistent with the finding by Hamilton (1983) that there have been sharp rises in the price of crude oil before every post-World War II recession in the United States except in 1960. It is clear, in particular, that in both 1974 and 1980, major increases in oil prices were associated with sharp recessions in output. By contrast, nonfood-nonfuel prices are procyclical: cross correlations with GNP are small but mostly positive.

The behavior of both the nominal and the real interest rates is worth noting.[23] Nominal interest rate innovations are positively correlated with current and lagged GNP innovations but negatively correlated with GNP two to five quarters later (the table reports results only up to three quarters ahead). Under the assumption that money shocks are a major source of fluctuations, this set of correlations implies that if nominal interest rates play a major role in the transmission mechanism of money shocks to output, they do so with a lag of two or more quarters.[24] Due to the difficulties involved in constructing an expected inflation series, one must interpret the real interest rate results with caution; in any case they do not suggest any strong relation between real rates and GNP innovations.

Comovements of GNP and Nominal Variables

In table 1.3 we present the correlations between innovations in GNP and the innovations in price inflation measured by the rate of change of the CPI, wage inflation measured by the rate of change of the manufacturing wage, and money growth defined as the rate of growth of M1. Here again it is not clear whether price and wage inflation are themselves stationary (nominal wage and price levels surely are not). Thus correlations are reported using innovations from both ARMA and ARIMA estimations.

There is, perhaps surprisingly, little contemporaneous correlation between innovations in GNP and innovations in inflation. The only (marginally) significant correlation is between GNP innovations and inflation one quarter later. The contemporaneous correlation between innovations in wage inflation and GNP is, however, positive and significant: it is this correlation that underlies the Phillips curve, which plays a central role in theories of the business cycle that allow aggregate demand disturbances to affect output.

Money growth exhibits less serial correlation than either wage or price inflation. Innovations in money growth are positively contemporaneously correlated with innovations in GNP. That correlation—as well as the wealth

Table 1.3
Comovements in GNP and nominal variables: correlations between innovations from ARIMA processes[a]

	Innovations in GNP at time:						
Innovations at time 0 in:	−3	−2	−1	0	+1	+2	+3
Price inflation							
π Level[b]	0.05	0.02	0.19	−0.06	−0.03	−0.09	−0.06
First differences[c]	0.07	0.04	0.23	0.00	0.02	0.03	0.03
Wage inflation							
w Level[d]	0.05	0.12	−0.06	0.38	−0.04	−0.13	−0.07
First differences[e]	0.09	0.19	−0.03	0.39	−0.03	−0.13	−0.10
Money growth m_1[d]	0.14	0.02	−0.09	0.26	0.14	0.11	−0.12

a. All variables at annual rates. See table 1.1 for estimated GNP process.
b. $\pi = 0.10 \times 10^{-2} + 0.89\pi(-1) + e - 0.06e(-1) - 0.26e(-2)$, $s = 0.5 \times 10^{-2}$, where π is the rate of change of the CPI.
c. $\Delta\pi = -0.7 \times 10^{-4} + e - 0.06e(-1) - 0.31e(-2) + 0.37e(-3)$, $s = 0.5 \times 10^{-2}$.
d. $w = 0.27 \times 10^{-2} + 0.8w(-1) + e - 0.44e(-1) + 0.03e(-2)$, $s = 0.5 \times 10^{-2}$, where w is the rate of change of the manufacturing wage.
e. $\Delta w = -0.10 \times 10^{-3} + e - 0.62e(-1) - 0.13e(-2)$, $s = 0.5 \times 10^{-2}$.
f. $m = 0.47 \times 10^{-2} + 0.55m(-1) + e - 0.11e(-1)$, $s = 0.75 \times 10^{-2}$, where m is the rate of growth of nominal M1.

of qualitative and other quantitative evidence to the same effect accumulated in particular by Friedman and Schwartz (1963)—has led to wide acceptance of the view that movements in money can have large effects on output. The recent evidence from the disinflations of the 1980s, both in the United States and abroad, has also convinced many that sharp contractions in money lead to sharp contractions in output.[25] The positive correlation between money growth and output innovations must, however, be juxtaposed with the positive contemporaneous correlation between short nominal rates and innovations in GNP presented above. If money is the major source of fluctuations in GNP, then its contemporaneous effect on GNP cannot be explained through interest rates.[26]

This concludes our first pass at the facts. The reader should remember the major correlations and conclude that no simple monocausal theory can easily explain them. Equilibrium theories based on supply shocks have to confront the weak correlations between real wages and GNP, as well as the positive relation between nominal variables and activity. Theories in which the cycle is driven by demand shocks have to give convincing explanations for the behavior of real wages. Theories that emphasize money shocks have to confront the correlations among interest rates, money, and output.

1.2 An Overview of the Book

Our theoretical starting points are the two basic real models that provide the frameworks for most optimizing models in macroeconomics: the Ramsey model in chapter 2 and the overlapping generations model in chapter 3.

In chapter 2 we analyze an economy where there is no uncertainty, people are infinitely lived, firms maximize their value, all markets are competitive and clear instantaneously, and there is no money. This perfectly operating economy provides a benchmark with which to compare other economies whose behavior is based on alternative assumptions.

We start the chapter by studying the optimal allocation of resources, the optimal consumption and investment decisions that would be chosen by a central planner maximizing the utility of the representative individual in the model (a problem first analyzed by Ramsey 1928). We then show the equivalence of this central planning allocation to that implied by a competitive economy in which individuals make optimal consumption and investment decisions based on the sequences of current and anticipated market-clearing wage and interest rates. This equivalence is hardly surprising, given our assumptions, but it turns out nevertheless to be very useful: it is often much simpler to solve the central planning problem directly rather than to solve for the equilibrium of the decentralized economy.

The Ramsey model is more than a benchmark. We show its usefulness by characterizing the equilibrium of a small open economy that has access to international capital markets in which it can borrow and lend at the world interest rate; we proceed to describe the optimal dynamic responses of saving, investment, and the current account to adverse supply shocks.

In chapter 3 we focus again on the dynamics of saving, investment, and capital accumulation, this time taking into account the fact that people are less than infinitely lived and that they may not care about what happens after they die. We develop two models. The first is a discrete time model, the overlapping generations model of Diamond (1965), in which people live for two periods, and the second a continuous time model, developed by Blanchard (1985), in which people face a constant probability of death.

We study the issue of dynamic efficiency, whether it is possible for such an economy to accumulate too much capital. We then turn to how government policies, including deficit-financed fiscal policy and the introduction of social security, affect capital accumulation and welfare. We examine the issue of the elasticity of saving with respect to the interest rate. In addition we discuss a question raised by Barro (1974), whether the fact that parents care for their children makes the economy behave like the infinite horizon Ramsey economy described in chapter 2.

Money is introduced in chapter 4. We consider a variety of approaches but spend a good part of the chapter developing a model, due to David Romer (1986), that extends to general equilibrium the Baumol-Tobin approach to the demand for cash balances. In that economy people have to use money to buy goods and thus have to keep money in addition to interest-paying bonds; we trace the flow of transactions through the economy and characterize the equilibrium and the effects of money and inflation on the real equilibrium. We then study, in a simpler version of the Romer model and in an earlier model developed by Sidrauski (1967), the dynamic effects of changes in money growth on real variables when all markets are competitive and prices perfectly flexible. We conclude that the real effects of changes in money growth are unlikely to be large if prices are perfectly flexible.

Issues of nonuniqueness are swept under the rug at various points in the first three chapters, either by assumption or by relegating them to discrete notes at the end of each chapter. Chapter 5 returns to the nonuniqueness issue. One type of nonuniqueness that arises in dynamic models with rational expectations is associated with bubbles, cases in which variables differ from their fundamental values. Well-known examples include bubbles on asset prices such as stocks, whereby the price is high because it is expected to increase further, and indeed does increase, validating initial expectations. We discuss, in a partial equilibrium framework, the circumstances under which such bubbles can arise and the form they may take. Then, following work by Tirole (1985) and Weil (1987), we discuss when and how general equilibrium considerations allow us to rule out such bubbles; the conditions turn out to be closely related to the conditions for dynamic efficiency discussed in chapter 3.

We then examine other issues that arise from nonlinearities. Among these the most interesting is that of deterministic cycles, explored by Grandmont (1985). We present this possibility and explain why we do not think that it provides convincing foundations for a theory of macroeconomic fluctuations.

Moving to fluctuations, we introduce stochastic shocks and uncertainty in the economy in chapter 6. Following the early lead of Slutsky (1937) and Frisch (1933), fluctuations are analyzed in terms of impulses (or shocks) and propagation mechanisms. Throughout the rest of the book we allow for uncorrelated (and unexplained) shocks to tastes, technology, nominal money, government behavior, and the like, and trace out their dynamic effects on the main macroeconomic variables. The ultimate goal is to find a plausible set of shocks and propagation mechanisms that can explain actual fluctuations.

In chapter 6 we examine, within a partial equilibrium context, consumption, investment, and production-inventory decisions. Our intention in each case is to show the effects of uncertainty on behavior and the dynamic effects of different types of shocks.

In chapter 7 we examine the dynamic effects of shocks in the general equilibrium real models developed in chapters 2 and 3. In doing so, we are studying real equilibrium business cycle models, which have been advocated in particular by Prescott (1986). We consider Diamond- and Ramsey-like models with technological shocks and study the behavior of output, consumption, fixed investment, and inventory investment. We show that such models can easily explain the joint behavior of output and its components as dynamic responses to plausible processes for productivity. However, the approach runs into severe difficulties in explaining the behavior of employment, even when the models are extended to allow for decentralized labor markets and search. These difficulties stem largely, and not surprisingly, from the inability to explain the joint behavior of output, employment, and real wages characterized earlier in this chapter.

At the end of chapter 7 we extend the equilibrium business cycle approach to models with money in which imperfect information about nominal magnitudes provides a potential channel for aggregate demand shocks to affect output, along the lines of Lucas (1973). We conclude that such an extension does not provide a convincing explanation of the effects of demand shocks on output.

In chapter 8 we explore the Keynesian approach, based on the view that suppliers are slow to adjust prices and wages and that supply accommodates long-lasting movements in aggregate demand.[27] In the 1970s the disequilibrium approach was to study the implications of slowly adjusting prices and wages, taking such slow adjustment as both given and unexplained. This strategy has run out of steam, making it clear that to make progress, the behavior of prices and quantities must be simultaneously explained.

The chapter starts by exploring the old notion that coordination problems are in large part responsible for economic fluctuations. Constructing a general equilibrium model of monopolistic competition, we show that the social return to price adjustment exceeds the private return and that small costs of price adjustment can therefore lead to large fluctuations of output, an argument first formalized by Akerlof and Yellen (1985) and Mankiw (1985). We then show that the larger the proportion of price-setters who do not adjust, the smaller is the private cost of not adjusting for those remaining; we also explore the possibility of multiple equilibria.

We then extend the analysis to a dynamic economy in which price-setters change prices infrequently. We study the choice of price rules and the macroeconomic implications of such rules. Three well-known models along those lines are the models developed by Fischer (1977), Taylor (1979), and Caplin and Spulber (1987); we show how and when they can generate persistent effects of aggregate demand on output and how results can be quite different under alternative price rules.

Although this approach must be part of any model that explains effects of aggregate demand on output, we conclude, however, that it cannot by itself explain such effects. Put simply, if fluctuations are associated with unemployment and if the unemployed are worse off than those with jobs, small costs of decreasing nominal wages do not provide a convincing explanation of why the unemployed do not bid down nominal wages.

This leads us, in chapter 9, to examine the potential role of further imperfections in goods, labor, and credit markets. Throughout, the focus is on macroeconomic implications, in particular, on why unemployment may not lead to a decrease in wages given prices and why in goods markets firms may prefer to satisfy demand at a constant markup of prices over wages, even in the presence of increasing marginal cost. In each case we draw the main implications from the imperfection and show its aggregate implications within a macroeconomic model, with or without nominal rigidities.

In examining labor markets, we explore three separate directions of research. The first is whether the presence of contracts modifies the behavior of real wages and employment, in particular, whether the provision of insurance under imperfect information may lead to real wage rigidity and larger employment fluctuations. The second is whether the ability of some workers to organize formally (in unions) or informally can also lead to more real wage rigidity and larger or more persistent employment fluctuations. The third covers efficiency wage theories, which have in common the implication that the productivity of labor depends on the wage or the relative wage paid by the firm. We conclude that both the second and third avenues hold promise for explaining real wage rigidity in the face of movements in unemployment.

We then turn to goods markets. There we explore theories based on imperfect competition, which have in common that firms are sometimes willing to supply higher output at approximately constant markups. We also explore the possibility that if marginal costs decrease with the level of activity, the economy may have multiple equilibria; we analyze two models along these lines, one based on trading externalities, the other based on increasing returns to scale. Finally, we turn to credit markets. If, as is obviously often the case, loans are risky and the characteristics of borrowers are not known, credit markets may be characterized by moral hazard and adverse selection. Changes in credit conditions may take place without changes in interest rates; we show how, in the presence of nominal rigidities or in some cases even in the absence of such rigidities, monetary policy can affect activity but have little effect on interest rates.

Although chapter 9 takes us to the frontiers of current research, it does not leave us with a single unified framework in which we an analyze all questions in macroeconomics. Thus for the time being, and probably forever, we have to rely on a variety of models to analyze current issues and current policies. Chapter 10 presents such a battery of models and shows how each can be used to shed light on current events.

Some of the models are or can be derived from first principles. Among these is the model of asset pricing developed by Lucas (1978), which can be used, for example, to analyze why stocks pay on average more than bonds or how the term structure of interest rates should behave under different sources of shocks. But most of the models are not derived from first principles. These include (1) the money demand model of Cagan (1956), which, supplemented by a government budget constraint, allows a simple analysis of the interaction between fiscal policy and inflation, (2) the IS-LM model, which can be used to analyze the effects of current as well as anticipated policies in the presence of price rigidities, (3) the Mundell-Fleming-Dornbusch model, which can be used to look at the same issues in an open economy, and (4) the aggregate supply–aggregate demand model, along the lines of Taylor (1979) and Layard and Nickell (1986). Whether the shortcuts that underlie these models are acceptable or misleading is for current and future research to decide. They have all repeatedly proved useful in allowing macroeconomists to think about complex events in an organized way.

Our approach to the analysis of policy in chapter 11 is similarly pragmatic. We cannot wait for "the true model" to give policy advice. Similarly, we cannot recommend that, because of our ignorance, policy be inactive: Is it inactive fiscal policy to raise tax rates in recessions so as to balance the budget or to leave tax rates unchanged and run countercyclical deficits? Using the models developed earlier in the book, we consider in turn issues of monetary and fiscal policy, and then the more general issue of dynamic inconsistency which was first raised by Kydland and Prescott (1977).

Our discussion of monetary policy takes place mostly within sticky price models in which money can have strong effects on output. Taking this as a given, we analyze first the consequences for the inflation rate and the price level of alternative operating rules for monetary policy, such as fixed money growth or a fixed nominal interest rate. We examine particularly the question of whether accommodating policies may render the price level or inflation rate indeterminate and what that might mean. We then turn to issues associated with the active use of policy, in the absence of either complete current information or exact knowledge of the structure of the economy, to ask whether the best practicable policy is one of keeping the growth rate of money constant.

Fiscal policy, such as changes in the level of taxes, is likely to have real effects even in equilibrium models. Because the fiscal policy questions in sticky price models are not very different from the monetary policy issues, we study fiscal policy mainly in equilibrium models. We focus, in particular, on the issue of whether the government should try to balance the budget or run, instead, countercyclical deficits when it has only distortionary taxes at its disposal.

Finally, we turn to issues of dynamic consistency. If private actions depend on expectations of future policies, the government typically has an incentive to announce policies but, when the time comes, to follow others. We present the structure of the argument and then analyze the role of reputation and other devices in alleviating the problem. We conclude by assessing the empirical relevance and policy implications of the dynamic consistency issue.

1.3 Prelude

We end this introductory chapter with a description of our goals in writing this book and our approach to macroeconomics, and of the prerequisites for assimilating its contents.

On Contents

As should be clear from the guided tour, we have not written a treatise nor presented a unified view of the field. That was possible when Patinkin wrote *Money, Interest and Prices,* which integrated the Keynesian revolution into macroeconomics while pointing to future developments. But the field is now too large and too fragmented. The Keynesian framework embodied in the "neoclassical synthesis," which dominated the field until the mid-

1970s, is in theoretical crisis, searching for microfoundations; no new theory has emerged to dominate the field, and the time is one of explorations in several directions with the unity of the field apparent mainly in the set of questions being studied.

That macroeconomics is in crisis should not be taken to mean that the field is starting from scratch. Indeed, we hope to show that there is much known and even much agreed on. We do believe that there now exists a useful macroeconomics. At the same time neither the microfoundations nor the evidence is strong enough for any reasonable researcher to feel at ease. The questions that macroeconomics tries to answer are inherently difficult ones; the fact that modern approaches can be defined as the study of dynamic general equilibrium under uncertainty, with incomplete (and possibly imperfect) markets gives a flavor of that difficulty. We believe that macroeconomics is at one of its most creative and productive stages, and we try to reflect that sense of excitement.

That we present alternative theories as honestly as we can does not imply that we are theoretical wimps. We believe that most (not all) current theories do capture important aspects of reality; we do not believe in monocausal or monodistortion accounts of fluctuations. We believe that eclecticism in the pursuit of truth is no crime; we are sure, however, that our preferences, which are obviously reflected in our own research, will be clear to the careful reader.

On Our Approach

One of our main choices has been to start from a neoclassical benchmark, with optimizing individuals and competitive markets. As our guided tour indicates, this is not because we believe that such a benchmark describes reality or can account for fluctuations. We are sure that incomplete markets and imperfect competition are needed to account for the main characteristics of actual fluctuations. We also believe that such nonneoclassical constructs as bounded rationality (in the discussion of the existence of bubbles) or interdependent utility functions (in some versions of efficiency wage theories) may be needed to understand important aspects of financial and labor markets. We believe, however, that looking at their effects as arising from deviations from a well-understood benchmark is the best research strategy.[28] *Alternative strategies that have started squarely from a different* benchmark have for the most part proved unsuccessful.

If and when one specific deviation from the benchmark model appears to be an essential ingredient of any macroeconomic theory, an alternative model may arise as a benchmark for macroeconomics.[29] If, for example, imperfect competition and increasing returns turn out to be essential, much of what is in chapters 2 and 3, such as the process of capital accumulation and growth or the form of the golden rule, will need to be reconsidered.[30] We are not there yet.

Our neoclassical bent does not extend to thinking that the only valid macroeconomic models are those explicitly based on maximization. The models presented in chapter 10 make this point. We are aware of the danger of shortcuts, which can prove in the end to have been highly misleading: the crisis of Keynesian economics comes precisely from having used such shortcuts for too long. However, we believe that waiting for a model based on first principles before being willing to analyze current events and give policy advice is a harmful utopia that leaves the real world to the charlatans rather than to those who recognize the uncertainties of our current knowledge. Thus we see no alternative to using shortcuts, at least for the time being and probably forever.

For lack of space and because this would require more knowledge of econometrics than we want to assume, we do not present much formal empirical work. Such work, and the integration of theory and empirical work, is nonetheless essential to macroeconomics, defined as the field that analyzes and tries to understand economywide movements in output, employment, and prices. *The integration of empirical and theoretical work on fluctuations, through the common use of the impulse-propagation mechanism framework and its associated time series implications, is certainly one of the most important achievements of postwar macroeconomics.*

Finally, and despite first impressions to the contrary, we have for lack of space left out topics that we would have liked to cover. We will mention three.

The first, which we touched on earlier in this chapter, is that of productivity growth and productivity movements. Although most of the increase in our standard of living comes from productivity growth, we are remarkably ignorant about its determinants, about why it differs across time and across countries. Recent real business cycle models rely on productivity shocks to generate dynamics, but we have little direct evidence on such shocks and how they propagate. Recent work on increasing returns has looked at such issues in a novel way and would be included in a longer book.

The second is that of asset pricing. Many theoretical developments have taken place—such as the development of the consumption asset-pricing model—that have clarified the link between macroeconomics and finance.

Given our primary focus on macroeconomic fluctuations, we have for the most part omitted them, except for a brief presentation in chapter 10.[31]

The third is open economy macroeconomics. It is common to note that all major economies, including the United States, are now open to trade in both goods and assets markets. Although we present some open economy models and issues, in chapter 2 and again in chapter 10, we have made no attempt to give a complete review of the issues within an open economy.[32]

On the Prerequisites

This book has evolved from lectures to graduate students specializing in macroeconomics at both Harvard and MIT. This roughly defines the level of the book. It requires some maturity in macroeconomics so that, for example, a thorough understanding of the issues at the level of the Dornbusch and Fischer textbook (1987) is a strict minimum. Several chapters can be used in a first-year graduate course, but we do not think that the book should be used as a textbook in such courses. We would and do build a first-year course differently, going earlier to the models of chapter 10 to provide motivation for what macroeconomics is in the end about. We think of the book as a textbook for students specializing in the field and as a reference book for researchers.

We have tried throughout to deemphasize techniques in favor of intuition. Nevertheless, most of the arguments are formal, and the book assumes a number of specific prerequisites.[33] Knowledge of calculus and some basic knowledge of calculus of variations are essential. Basic knowledge of statistics (distributions, conditional distributions, commonly used distributions, Bayes' rule) is required. Basic knowledge of time series, essentially ARIMA models, is useful. Other techniques are introduced when needed; we present them briefly, together with references to more thorough treatments.

Notes

1. Maddison (1982) reviews the historical record, for some countries since 1700, for most of the members of the OECD.

2. We limit ourselves to the United States, but the features we emphasize are common to developed economies. The earliest starting year for consistent data for both GNP and the various measures of inputs is 1874 (actually the average of the decade 1869–1878).

3. Annual data for the series presented in figures 1.2 to 1.4 are available only from 1889. Estimates are available for 1874 and 1884.

4. Although labor productivity growth appears roughly constant over the specified periods, there are of course substantial variations over shorter periods. For instance, output per hour grew 2.7% per year from 1950 to 1973 and only 0.9% per year from 1973 to 1986.

5. If one believes, however, that part of growth comes from the exploitation of returns to scale and that markets may not be competitive, the Solow residual is no longer the correct measure of that part of growth that does not come from growth of inputs. Denison (1974) in his calculations of the sources of growth assumed that the production function exhibited scale economies of 10%; that is, an increase in all inputs by 100% would increase output by 110%. Denison recognized that there was no firm statistical basis for this estimate, but he did review earlier studies of the issue. For two recent approaches, see Hall (1986) and Romer (1987).

6. Note, however, the large increase in the output-capital ratio during 1933 to 1945. Part of the increase appears to come from undermeasurement of investment during the war (Gordon 1969). Part of the increase appears genuine, however, suggesting a step change in the output-capital ratio pre-1930 and post-1945.

7. Nevertheless, what follows touches on many conceptual and technical issues, to which we will return more formally and more precisely later. All that is needed to follow the basic argument is some knowledge of time series, in particular of ARMA and ARIMA processes. A good introduction, sufficient for those purposes, is given in Pindyck and Rubinfeld (1981).

8. Recent work has returned to exploring those aspects. See, for example, Neftci (1984) and DeLong and Summers (1986) on asymmetries, and Stock (1987) on time deformation.

9. This is, for example, the approach taken by Prescott (1986).

10. See, for example, Perloff and Wachter (1979) and Gordon (1984).

11. The discussion in the text proceeds as if there was only one type of shock affecting output. This is surely not the case. There are likely to be many types of shocks, each of them with a different dynamic effect on GNP. We can think of the moving average representation given in figure 1.6 as being roughly a weighted average of the dynamic responses of GNP to each of those shocks, with the weights being proportional to the relative importance of the shocks. See Granger and Morris (1976) for a more formal discussion of the relation between univariate and multivariate moving average representations.

12. By nonstationary processes we mean processes with a unit root. These processes are such that shocks have a permanent but bounded effect on output.

13. By arbitrarily smooth we mean a process such that the variance of the shock is arbitrarily small. We know of no simple reference for this result. Although a proof would take us too far afield, the intuition behind the result is a simple one for readers

with some background in time series: though the nonstationary component has to account for all fluctuations in output at zero frequency, we can attribute all fluctuations in output at positive frequencies to the stationary component. In this way we can make the nonstationary component, the trend, arbitrarily smooth.

14. The NBER itself bases the dating of cycles on the behavior of many series—in contradiction to the widely held view that a recession is defined by two consecutive quarters of decline in real GNP.

15. The methodology follows Blanchard and Quah (1987). Other related decompositions of the behavior of output have been given by Evans (1987) and Campbell and Mankiw (1987b).

16. The evidence is less clear-cut than this sentence may suggest. Over the postwar period, unemployment has trended upward slowly. So we cannot think of the unemployment rate as stationary around a constant mean. If we look at longer time periods and at evidence from other countries, the unemployment rate seems sometimes to remain very high or very low for long periods of time. This is suggestive of some form of nonstationarity. We return to this issue later in the book.

17. Explaining how this is done would take us too far afield. See Blanchard and Quah (1987).

18. These correlations are not very sensitive to whether an ARIMA process is fitted to the original series or whether an ARMA process is fitted to deviations from a smooth trend, for example, an exponential trend. There is a close relation between the correlations presented here and the results of Granger-Sims causality tests, popularized by Sims (1972) and often used to describe the joint behavior of time series: a variable x will Granger-cause variable y if the set of correlations between current innovations in y and lagged innovations in x is significant.

19. We cannot take the logarithm of inventory investment because the series is sometimes negative. The innovations for inventory investment are from a process estimated in levels, with a heteroscedasticity correction.

20. Since output is the sum of its components, it should come as no surprise that the average contemporaneous correlation is positive in table 1.1.

21. The regression coefficient is equal to the correlation coefficient multiplied by the ratio of the standard deviation of the innovation in the specific component to the standard deviation of the innovation in GNP.

22. The data are presented in Dornbusch and Fischer (1987). The percentage is even higher (68%) if one calculates inventory disinvestment as a percentage of the peak to trough decline in GNP (Blinder and Holtz-Eakin 1986).

23. The process for the nominal interest rate exhibits substantial subsample instability. In particular, it appears to be sharply different in the 1980s. Thus the estimated process is at best an average process.

24. The joint behavior of nominal interest rates, nominal money, and output has been examined within the framework of vector autoregressions by Sims (1980) and Litterman and Weiss (1985). Both studies find that given nominal money, there is a positive correlation between innovations in interest rates and future innovations in GNP. What theories this finding rules out is still unclear, however.

25. The quantitative evidence on the role of money growth in the 1980s U.S. disinflation is, however, less than conclusive. Although the 1982 recession was preceded by a period of very low money growth, money grew faster on average in the eighties than earlier. The major sign of monetary tightness preceding the recession was very high nominal interest rates. Thus one must argue that these episodes were associated with shifts in money demand. Although such arguments are reasonable, they cannot be supported by looking only at money growth-output correlations.

26. There is a limit to what can be learned from simple bivariate correlations. If, for example, the economy is well described by the Keynesian model, and if fiscal and monetary shocks are roughly of equal importance in affecting output, the correlation between innovations in interest rates and output may well be close to zero. This zero correlation does not imply that money does not affect output, only that there are two types of shocks in that economy, with opposite effects on interest rates.

27. Although we call the approach Keynesian, it long predates Keynes. Monetarists have emphasized the slow adjustment of wages and prices to monetary shocks.

28. The same point is made by Solow in his American Economic Association presidential address (1980).

29. Stiglitz and Weiss (1987) argue for a new benchmark model based on imperfect information about buyers' and sellers' characteristics.

30. See, for example, Romer (1987) for how increasing returns and monopolistic competition may modify the "neoclassical" theory of growth.

31. Sargent (1987) has an extensive discussion of asset pricing.

32. This is done masterfully in Dornbusch (1988).

33. It is traditional at this stage to claim that nothing more is needed than high school algebra, but that would not be right.

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