Volume Title: Business Cycles: Theory, History, Indicators, and Forecasting

Volume Author/Editor: Victor Zarnowitz

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-97890-7

Volume URL: http://www.nber.org/books/zarn92-1

Conference Date: n/a

Publication Date: January 1992

Chapter Title: How Trends and Fluctuations Are Observed, Modeled, and Simulated: An Introduction

Chapter Author: Victor Zarnowitz

Chapter URL: http://www.nber.org/chapters/c10377

Chapter pages in book: (p. 181 - 202)

II History and Measurement

6 How Trends and Fluctuations Are Observed, Modeled, and Simulated: An Introduction

Part I of this book included many excursions into the history of business cycles, but its focus was on theories and their assessment in light of "stylized facts" broadly defined. Part II concentrates on problems of history and measurement: How are long-term trends and short-term fluctuations of the economy related in the available records? What lessons can be learned about the regularity or irregularity of business cycles? Can macroeconometric models simulate cyclical behavior of major economic variables, and if so, how and how well? These questions are addressed in chapters 7, 8, and 9. What follows is a guide to this set of topics, again with some extensions.

6.1 Trend-Cycle Decompositions

A frequently used univariate approach to modeling growth and fluctuations in rising macroeconomic series is to adjust each for seasonal variations, if relevant, and then represent the nonseasonal series as a sum of a deterministic trend and the residual "cyclical" component. For example, the postwar real GNP would be treated as consisting of an exponential trend and stochastic deviations arising from cumulation of random shocks.[1] But it is very unlikely that a given type of a deterministic trend would persist and prove projectable over long stretches of historical time, that is, across periods of great technical and structural changes, wars, booms and depressions, inflation and deflation.

1. Let Q = log real GNP; $L^nQ_t = Q_{t-n}$, where L is the lag (backshift) operator; $AL = 1 - \Theta_1 L - Q_2L^2 - . . . - Q_kL^k$; and ε_t is white noise. Then

(1) $$Q_t = a + bt + A(L)\varepsilon_t,$$

where the trend $(a + bt)$ is purely deterministic and the shocks affect only the cyclical component. The effects of each shock would persist but decline and die out after k periods (the polynomial $A(L)$ must satisfy the stationarity and invertibility conditions).

This is a strong argument against the applicability of this trend-stationary (TS) representation.

In contrast, consider the autoregressive integrated moving-average (ARIMA) modeling, in which the time series are reduced to stationarity by differencing and then their autoregressive and moving-average components are analyzed (Box and Jenkins 1976). Here a purely stochastic difference-stationary (DS) process is obtained in the presence of an autoregressive (AR) unit root.[2] In this case, the shocks affect the *change* in the series in the short run or transitorily but the *level* of the series in the long run or permanently. There is evidence that real GNP and other important economic aggregates resemble DS processes much more than TS processes (Nelson and Plosser 1982). This was interpreted as lending support to the real business cycle (RBC) theory on the ground that only real, not monetary, shocks can have permanent effects. But economic activity is most likely affected by more than one type of disturbance, and some shocks may have long effects, others short effects.[3]

The empirical estimates of the DS process are unsatisfactory in that they confuse the trend and cyclical movements in series such as real GNP. The "trends" include not only the secular growth but also most of what is generally viewed as the "cycle," including major declines. Series that look like DS could alternatively originate in TS processes with AR roots close to but distinct from 1.0, and no finite-sample tests can conclusively distinguish between DS and TS series in such cases. Hence the RBC hypothesis cannot be validated statistically along these lines (McCallum 1986).

Much more satisfactory trend and cycle estimates have been obtained recently by using unobserved components (UC) models, in which the trend is a random walk with drift and the cycle consists of deviations from trend that represent a covariance stationary process (Watson 1986).[4] The UC model for

2. This model replaces $(a + bt)$ in equation (1) with a constant and adds to it a stationary and invertible ARMA term. A simple example is

$$(1 - L)Q_t = \Delta Q_t = b + (1 - \Theta L)\varepsilon_t, \tag{2}$$

which is *DS* for $|\Theta| < 1$. (For $\Theta = 1$, however, the process is TS; in the case of $b = 0$, Q_t would just equal ε_t.)

3. A frequent assumption in modern macroeconomics is that demand disturbances have transitory effects that dominate business cycles, whereas supply disturbances have cumulative effects that dominate the long trends. For estimated decompositions of output and unemployment based on this premise, see Blanchard and Quah 1989.

4. For example, let T and C denote the trend and cyclical components of output Q, and let e^T and e^C be white-noise shocks to T and C. Then the model consists of

$$Q_t = T_t + C_t; \tag{3a}$$

$$T_t = a + T_{t-1} + e_t^T; \tag{3b}$$

and

$$C_t = \Theta(L)e_t^C. \tag{3c}$$

In the version used for estimation, e_t^T and e_{t-k}^C are uncorrelated for all k. A more general but also more difficult to implement version would allow for some correlation between T_t and C_t.

real GNP produced a cyclical component with one-to-one correspondence with the NBER chronology for 1951–83 (Watson 1986, p. 64). Harvey (1985), too, presents a general argument and supporting evidence in favor of "structural" UC modeling.

What emerges from these and other recent studies (Beveridge and Nelson 1981; Stulz and Wasserfallen 1985; Campbell and Mankiw 1987a, 1987b; Clark 1987) is that changes in macroeconomic activity measured by real GNP, employment, and industrial production have exhibited a high degree of persistence, not prompt reversals to deterministic time trends, in the United States and other developed economies. The cyclical component was relatively strong before World War II and after 1970, and was weak in the early postwar period of mild fluctuations, when stochastic trend models performed very well (but, it is important to note, this is limited evidence coming from annual estimates only).

I interpret these results to mean that trends and cycles interact and cannot be clearly separated. This agrees with the view that "the business-cycle theorist . . . cannot imitate the business-cycle statistician in merely eliminating secular trends" (Mitchell 1927, p. 233; see also Burns and Mitchell 1946, p. 270). The interdependence of growth and fluctuations (discussed from the historical point of view in chapter 7) is consistent with a number of theories, endogenous and exogenous, and does not necessarily preclude an active role for money and credit or favor supply over demand factors in the origination of business cycles.

6.2 An Illustration: Trends and Cycles in Real GNP

Even though the trend-cycle decompositions thus appear to be basically problematic, working with detrended series is considered necessary for some analytical purposes. This includes in particular the study of "growth cycles," that is, sequences of significant retardations and accelerations, or phases of below-average and above-average growth rates in indicators of aggregate economic activity. In the initial stages of the development of growth cycle measures and chronologies, long-term moving averages were experimentally used as estimates of flexible but rising trends, with a fixed span of 75 months being favored (Mintz 1969, 1972). Later, improved results were found to be provided by the phase-average trend technique (Boschan and Ebanks 1978; Klein and Moore 1985, ch. 2). Another alternative is the Whittaker-Henderson type of trend curve used as a low-frequency filter in Hodrick and Prescott 1980. Detrending in this form has been applied in several RBC studies, despite the claim of the underlying theory to explain growth along with cycles (for a criticism along these lines, see King and Rebelo 1989).

Figure 6.1 compares three different trend estimates for quarterly data on GNP in constant dollars, 1948–90, plotted separately but to the same logarithmic scales. The trends are shown as solid curves; the underlying RGNP data as dotted curves. The first trend is log-linear, that is, a straight line sloping

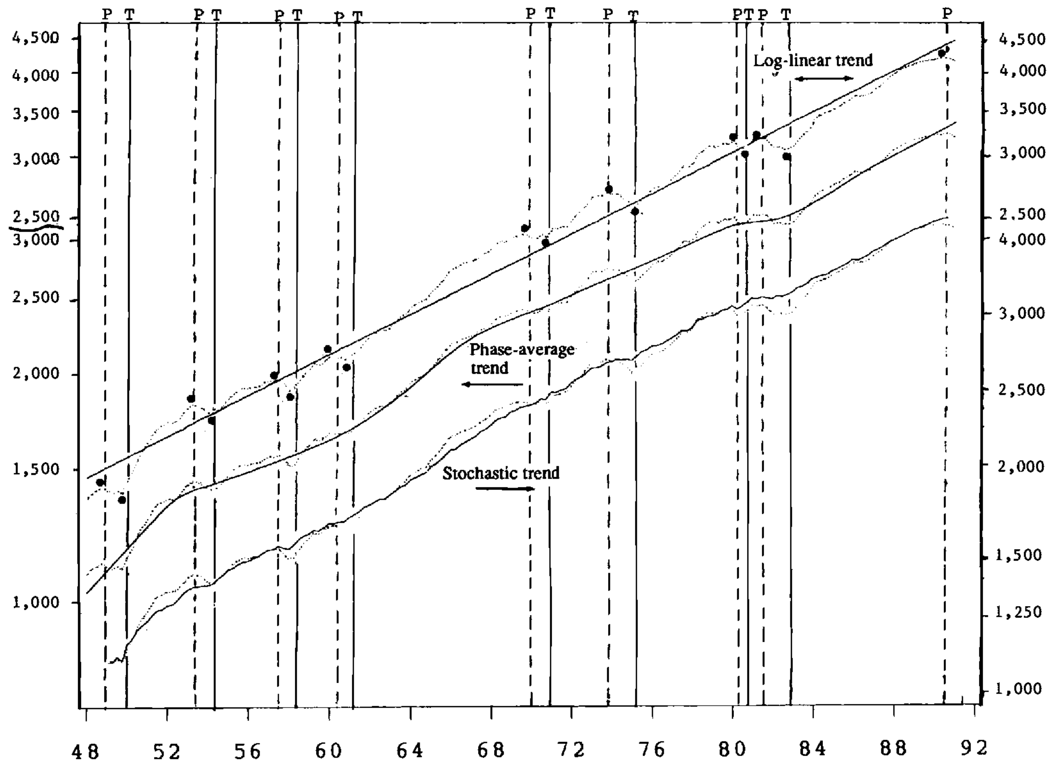

Fig. 6.1 Seasonally adjusted levels of real GNP: Specific cycles and two trend estimates, 1948–91

Note: Broken vertical lines represent business cycle peaks (P); solid vertical lines represent business cycle troughs (T). Dotted curves represent RGNP; solid curves represent trends in RGNP. Dots identify peaks and troughs of specific cycles in RGNP (shown for the top curve only).

upward at a constant rate of growth equal to 0.84% per quarter (or 3.42% per year). The second trend is nonlinear, based on the phase-average method of combining moving averages and interpolations between mean values of the series in its successive business cycle phases. The third trend, introduced and discussed in Watson 1986, is stochastic and based on an unobserved components representation of the process describing the RGNP data. Here log RGNP is treated as a sum of the trend, modeled as a random walk with drift, and a residual, modeled as a covariance stationary process and labeled the cyclical component. In the general case, the two components are partially correlated.[5]

The deterministic log-linear trend is, of course, free of any cyclical or other short-term movements. The phase-average trend is clearly much more flexible and fits the same data much more clearly; it too is designed so as not to contain any cyclical elements. In contrast, the stochastic trend flattens in several recessions (1953–54, 1973–75, 1981–82) and even declines in some (1957–58, 1960).

The specific-cycle peaks and troughs in the level of real GNP are identified by filled dots in figure 6.1. There is a one-to-one correspondence between the cyclical declines in the total output of the economy so measured and the business contractions as dated by NBER, which are represented by the grid of the vertical broken lines (peaks, P) and solid lines (troughs, T). But on a few occasions timing discrepancies can be observed, where the center month of the real GNP turning quarter precedes the monthly NBER reference date. The latter, it should be recalled, is based on the consensus of roughly coincident indicators, monthly and quarterly, including measures of real income, sales, production, and employment. The figure also shows that the recognized chronology of U.S. business cycles does not validate the popular rule of thumb according to which two consecutive quarterly declines in real GNP denote a recession. For example, according to the current data, no decline of two or more quarters occurred in either of the two recession years, 1960 and 1980.

Figure 6.2 shows deviations from each of the three trends, again plotted separately but to the same arithmetic scales, with each trend level equated to 100. The deviations of the data from the log-linear trend are very large much of the time, especially downward in the late 1940s and on and off in the last decade, upward in the middle 1960s and early 1970s. It is evident that the assumption of log-linearity produces a poor trend estimate. The economy grew much faster in 1948–52 (one recession) than in 1953–60 (three recessions), and again much faster in the 1960s (one long expansion) than in the 1970s and early 1980s (four recessions). The phase-average trend takes these variations into account, and the deviations from it are relatively small. The stochastic trend includes many small random movements, so here the deviations are remarkably smooth. They appear to be much more "cyclical" and

5. I am very much indebted to Mark Watson for letting me have his data and programs for both this univariate trend and also an interesting multivariate trend estimate from King, Plosser, Stock, and Watson 1991. (The latter is annual and not used here.)

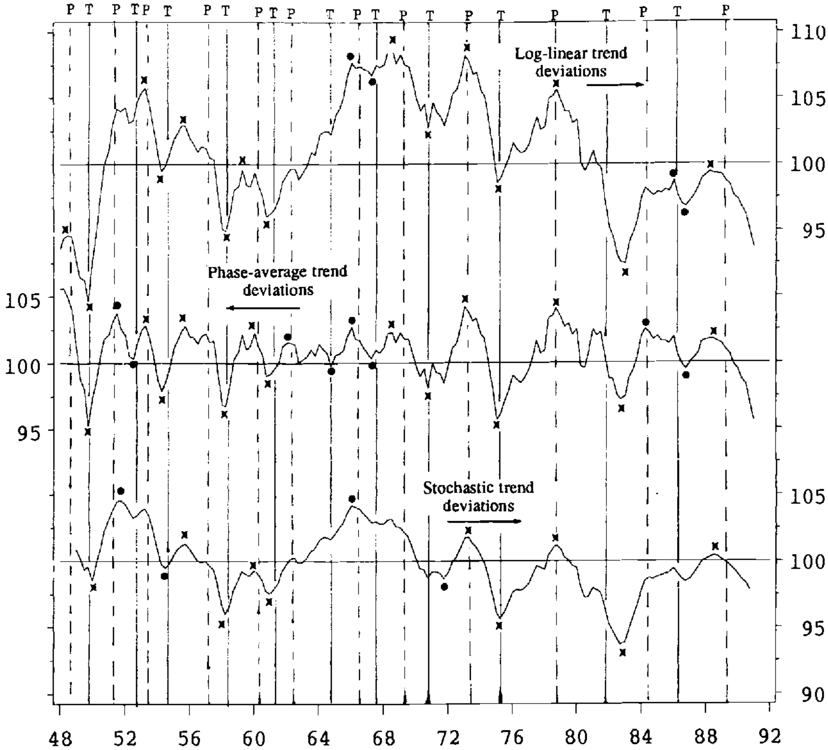

Fig. 6.2 Real GNP: Deviations from log-linear trend (A) and from phase-average trend (B), 1948–85
Note: Trend level = 100. Broken vertical lines represent growth cycle peaks (P); solid vertical lines represent growth cycle troughs (T). Dots identify peaks and troughs of specific cycles; crosses identify those turning points that match growth cycle peaks or troughs.

less "irregular" than the deviations from the phase-average trend and, though smaller, show more similarity to the deviations from the log-linear trend.

The deviations from trend follow a pattern of growth cycles represented in figure 6.2 by a grid of vertical broken and solid lines, which are respectively peaks and troughs separating phases of above-normal and below-normal growth. A comparison of figures 6.1 and 6.2 confirms that five of nine post-war business cycle peaks (in 1957, 1969, 1973, 1980, and 1990) were preceded by growth retardations that lasted from 6 to 17 months. On four occasions, in 1951–52, 1962–64, 1966–67, and 1984–86, the nation's output decelerated markedly without becoming negative. These are slowdowns that did not turn into recessions; that is, they belong to those growth cycles that did not become growth cycles.

The series of deviations from both the log-linear trend and the stochastic trend show three large waves each, with troughs in the recession years 1949, 1957, 1975, and 1982. The deviations from the better fitting phase-average trend do not have this configuration.

6.3 How Growth and Fluctuations Interact

The reference cycle analysis of Burns and Mitchell (1946) describes the movements of each time series of interest during each business cycle covered. The average standing of the series in each of nine successive stages of a cycle (the initial trough, three successive thirds of the expansion, the peak, three successive thirds of the contraction, and the terminal trough) is expressed as a percentage of the average level of the series during the entire cycle. That average level is always equated to 100, so the method eliminates the intercycle trend but retains the intracycle trend. The historical studies of the National Bureau analyzed such reference cycle patterns for hundreds of time series in efforts to identify the prevailing behavior of the variables covered and any systematic changes in it. This helped to build up our knowledge of the stylized facts, some of which are summarized in chapter 2, section 2.2, and elsewhere in part I of this book. The patterns for upward-trending series, which include most of the data on incomes, output, and employment, show strong effects of secular growth: terminal troughs tend to be higher than the initial troughs, and the peak and average levels as a rule increase from one cycle to the next. The few exceptions have occurred in connection with the most severe contractions and the shortest and mildest expansions.

Since business expansions and contractions vary in length across the different cycles, so will the stages into which they are divided. In effect, then, the NBER analysis proceeds in two units of measurement: business cycle time and calendar time. The latter is more familiar and probably preferable for many purposes, including studies of contemporary developments and forecasting (the calendar-time lengths of the current phase and cycle are unknown). But many historical regularities may be better articulated in business cycle time, for example, leads and lags may vary less across cycles when expressed in stages and their fractions rather than months. More generally, business cycle time may be more closely related to "psychological time" (Allais 1966, 1972). If events are perceived to move more slowly in long than in short cycle phases, then expectations may cover longer chronological time spans in the former and adjustments may be slower (Friedman and Schwartz 1982, p. 358).

This argument would apply best to a world in which qualitatively much the same train of events would occur in each business cycle, only stretched out in long phases and compressed in short ones. This is probably often a fair approximation to reality but far from being a firm rule. Occasionally an expansion is aborted: short *and* slow, with little net growth; or a contraction is aggravated: long *and* fast, that is, a severe depression. A long expansion may also be vigorous much of the time, though seldom continuously so.

Some RBC models explicitly predict a trade-off between growth and stability: when people opt for higher expected returns and accept higher risks, the result will be faster but also more volatile growth in profits, income, and output (see Black 1987, p. 76). But analogies between individuals and societies can be misleading, and rules of personal finance need not apply to processes of aggregate economic activity. Historical data indicate that in periods when the annual growth rates in U.S. output were on average high (low), their standard deviations were low (high). Thus in 1903–13, 1923–29, and 1948–69 (37-year, nine peak-to-peak cycles) mean growth per annum was 3.7%, with a standard deviation of 3.7; in 1913–23, 1929–48, and 1969–81 (41-year, nine peak-to-peak cycles) mean growth p.a. was 2.6%, with a standard deviation of 7.2.[6] In short, relatively *high* growth was apparently associated with relatively *low* instability.

The relationship between long-term growth and cyclical variability is apt to vary depending on their sources. No correspondence exists, for example, between the average growth rates and the relative duration of contractions. The latter was historically lower on average in periods of long inflationary trends than in periods of long deflationary trends (Zarnowitz and Moore 1986, pp. 525–31), but real growth was often weak in times of high inflation, as in 1913–23 and 1969–81.

6.4 Some International Comparisons

The evidence for the United States and other countries in the postwar period is consistent with the hypothesis that business cycles are less frequent and milder when and where long-term real growth is higher. First, growth was generally lower and cyclical instability greater in the second than in the first half of the postwar era. Second, economies that grew fast (notably Japan and West Germany) had milder fluctuations than economies that grew more slowly (notably the United States and United Kingdom).

In the 1950s and 1960s, France, Italy, West Germany, Japan, and a number of smaller countries enjoyed extraordinarily high rates of economic growth. World War II devastated the physical capital and wealth of these nations and their initial postwar activity levels were very low, but their human capital was much better preserved and hence their productive potential was high. Monetary and fiscal reforms restored sound currencies and free markets, and political reforms restored democratic values and institutions. The transitions from closed, regimented, and inept systems to open, free, and efficient ones were relatively smooth. Foreign aid helped in this historically unique process, and foreign trade helped even more.

During this period, real growth in continental Europe and the Far East was

6. See chapter 7, table 7.1 and text, and Zarnowitz and Moore 1986, table 9.11 and text, pp. 551–53, for detail.

interrupted infrequently and mostly by slowdowns rather than absolute declines in overall economic activity. Thus, the benefits of high growth were augmented by those of high cyclical stability.

Figure 6.3 presents the evidence, based on composite indexes of coincident indicators for eight countries. These indexes combine monthly and quarterly measures of total output, industrial production, employment, real sales, and inverted unemployment, and have trends equal to those of the corresponding series for real GNP or GDP. The data are collected and processed by the Center for International Business Cycle Research (CIBCR) at Columbia University Business School.

The black dots mark peaks and troughs of specific cycles in the indexes. The so-identified declines last several (as a rule, 6 or more) months and have amplitudes of several or more percentage points (as a rule, at least 1%). They presumably reflect business contractions.[7] The unfilled dots mark shorter and/or smaller declines that do not qualify as recessions but may be associated with significant retardations in general economic activity. However, substantial business slowdowns can occur without any noticeable decreases in the levels of the coincident indexes, particularly in places and times of very high overall growth (e.g., West Germany, 1956–57, and Japan, 1957 and 1964).

The charts show some important similarities between the country indexes, notably the concentration of long expansions in the 1960s and 1980s, of mild recessions or slowdowns in the middle or later 1960s, and of more severe contractions in the mid-1970s and early 1980s. But there are also pronounced differences, which are clearly related in the main to longer growth trends. The central point here is that high growth helps to reduce the frequency and depth of business contractions.

Thus, according to these data (which for some countries begin only in the mid-1950s), France had its first postwar recession in 1958–59, Italy in 1963–65, West Germany in 1966–67, and Japan in 1973–75. Meanwhile, Canada, United Kingdom, United States, and Australia, all countries that suffered much smaller direct wartime damages, had less need of domestic reconstruction, lower growth rates, and earlier and more frequent recessions (fig. 6.3).

Economic growth slowed considerably everywhere during the 1970s and 1980s, and simultaneously business contractions became both more common and more severe. They spread worldwide in 1974–75, after the first oil price shock, and in 1980–82, after new OPEC cartel price hikes and strong counterinflationary policy moves in the United States. In 1990–91, recessions spread mainly in the English-speaking countries, following new tight-money actions, the conflict over Kuwait, and the war with Iraq.

The economies of the United States and United Kingdom had relatively low

7. There is no NBER-type international reference chronology of business cycle peaks and troughs for the post–World War II period.

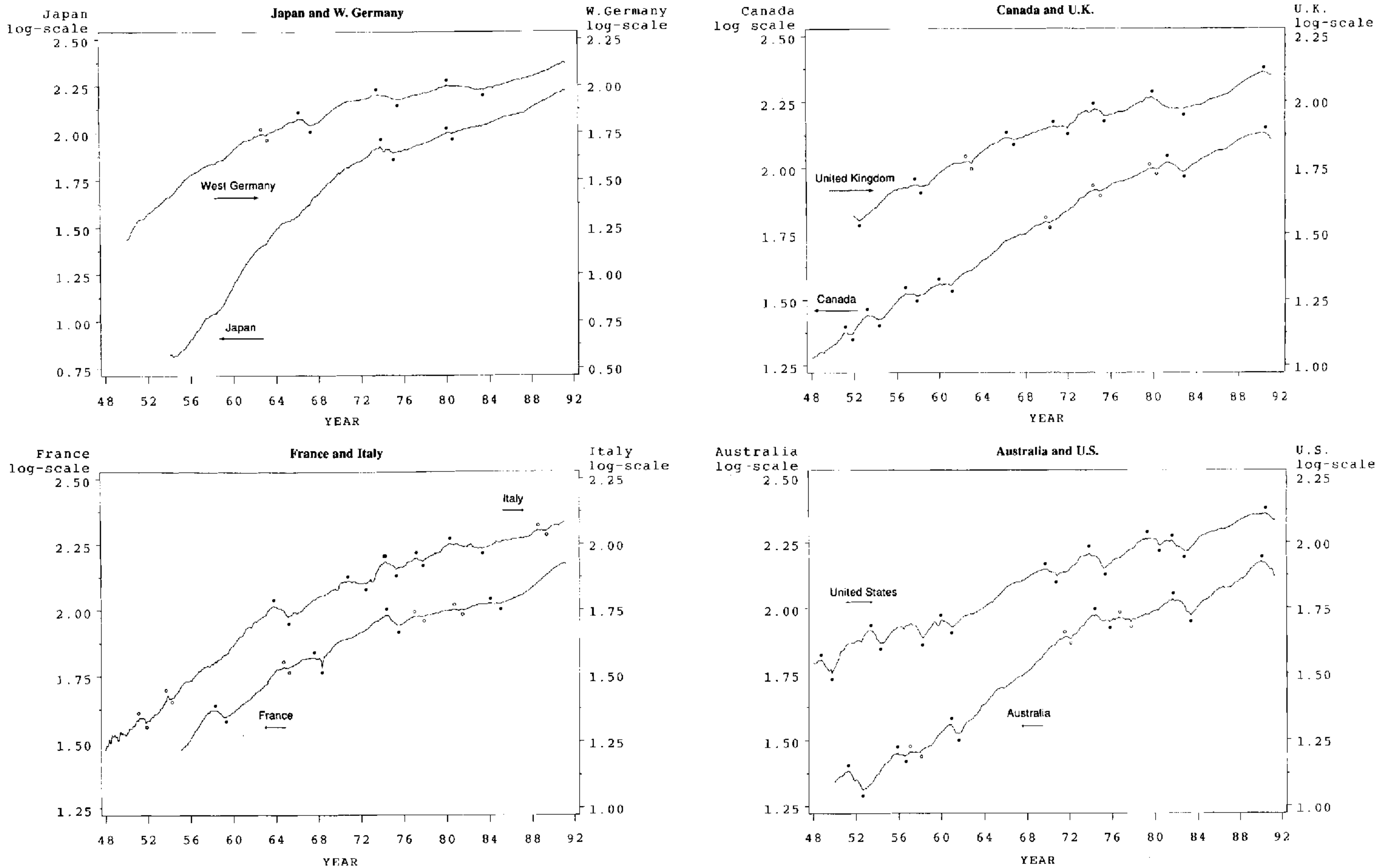

Fig. 6.3 Trend-adjusted indexes of coincident indicators

rates of real growth and most cyclical variability. In sharp contrast, West Germany and, particularly, Japan had both the highest growth rates and least cyclicality. Indeed, one can say that in Japan business cycles as we know them were essentially absent. Although Japan's growth was much slower after the mid-1970s than before, it still continued to be remarkably steady. The index for France shows frequent but short and shallow declines, except in 1958–59 and 1974–75 (its sharp decline in the spring of 1968 reflects largely the concurrent political unrest).

In 1955–90, the longest common period covered, the number of complete peak-to-peak cycles in the indexes were as follows: United States, six; United Kingdom and Italy, five each; France and Australia, four each; Canada and West Germany, three each; Japan, two. In all, the postwar business cycles were shorter and more numerous in the United States than in any of the other countries. An inspection of the charts suggests that this was mainly due to the shorter durations of U.S. expansions. More generally, expansions differed much more than contractions across the countries, in both length and amplitude.

It is widely recognized that higher rates of saving-cum-investment in real terms favor higher rates of growth. The most successful economies are those that achieve the highest average long-term rates of investment in productive capital, human and physical. Even though investment as measured in national income accounts (i.e., investment in the physical capital of the business sector) has been much more cyclical than consumption, it is not necessarily true that a larger share of this or a more comprehensive investment aggregate will increase the fluctuations of the economy, along with its growth. Investment can be both high and stable, provided it is a part of, and a response to, growth in aggregate demand that is sufficient to keep the economy near full employment.[8]

6.5 Are There Periodicities in Cyclical Behavior?

There is little evidence of regularity in the durations of business expansions and contractions inferred from the NBER studies of historical annals and data for the United States, Britain, France, and Germany. These numbers vary greatly without suggesting any particular pattern. But they synthesize measures for a wide range of conditions: major and minor cycles in times of peace and war, different monetary regimes, and long inflationary and deflationary trends. Some fluctuations are well documented in the data; others, mainly for the more distant past, are not. So the apparent lack of periodicity could be an artifact due to the aggregation over the different categories of observed cycles.

Moreover, it is possible for unobserved cycles of different durations to co-

8. Investment, broadly interpreted, is in the end only justified by growth in the demand for the product of the new capital. Equally true, growth itself depends positively on prior rates of investment that enhances productivity and improves competitiveness. See Zarnowitz 1991.

exist: there could be several of them, concurrent and interacting, each with its own characteristic frequency. The observed movements would then be composites of short and small subcycles, business cycles of larger and intermediate dimensions, and possibly "long waves" measured in decades rather than years. To isolate the multiple periodicities hidden in the data, careful distinctions and decomposition methods need to be applied.

However, this hypothesis is not supported by the data in any clear and consistent way (chapter 8). Excluding the wartime episodes (which consist of expansions of above-average length followed by contractions of below-average length) reduces the variance of durations of cyclical phases but not by much. The few cycles with deep depressions typically followed by long and large but not always vigorous expansions were certainly very different from all others. Of course, a separate treatment of such outliers would produce smaller variances for each of the resulting groups. But most of the NBER-designated business cycles do not lend themselves to a clear-cut classification into major and minor cycles. The longer cycles are not simply combinations of the short ones, nor do the large and small fluctuations occur in any particular sequence over time. Durations and amplitudes of cyclical movements are likely to be correlated positively but not strongly. Convincing evidence of the existence of long waves in economic growth is essentially lacking (Kondratieff 1926 [1935]; Burns and Mitchell 1946, pp. 431–40; Garvy 1943; chapter 8, sec. 8.2.2, this volume). This is so not just because it is very difficult to elicit the necessary information from time series that cover at most the two and a half cycles dated by Kondratieff between 1790 and 1920 (most cover only one or one and a half cycles). Support for the long-wave hypothesis comes mainly from series on wholesale prices; it is very fragmentary and weak for indicators of real economic activity.

The historical sequence of inflationary trends (1789–1814, 1843–64, 1896–1920) alternating with deflationary trends (1814–43, 1864–96, 1920–32) reflects mainly the parallel long movements in the growth of money and credit as related to gold discoveries, wars, and monetary regimes and policies. Expansions tended to be longer relative to contractions in the periods of rising trends in prices than they were in periods of falling trends, but there is no correlation between the long-term rates of growth and inflation, and none is expected on theoretical grounds.

Some elements of limited and temporary periodicities emerge between the 1870s and 1930s, when major cycles are defined as being marked off by troughs in severe contractions for both the United States and Britain. But no deep depressions occurred after World War II, and the long-wave theory predicted a deflationary downswing at least since the later 1960s or early 1970s, but none has materialized so far.

There are good reasons why no close and persistent periodicities exist in the recurrent macroeconomic fluctuations. If they did, the turning points of business cycles would presumably be easy to predict, but they are certainly not. Downturns in particular are poorly forecast (as demonstrated in part III below). If they could be correctly anticipated with sufficient lead times, successful actions might be undertaken to prevent or at least reduce socially costly declines in total output and employment.

6.6 Does Detrending Reveal Regularities?

Chronologies of growth cycles, based on the consensus of fluctuations in trend-adjusted series on aggregate output, employment, and other measures of real economic activity, were first developed by Mintz (1969, 1972, 1974) at the National Bureau. They were soon improved and extended to more countries by Moore and his associates at the CIBCR, where the international indicators used in this analysis are kept up to date (Klein and Moore 1985; Moore and Moore 1985). The basic methodology of identifying and dating cyclical movements remains the same as in the traditional NBER analysis, with the important difference that here it is applied to detrended series. However, as already noted, trend and cycles influence each other in such ways that it is impossible to separate the two without error, and the danger to guard against is that the procedure may hide or distort more than it reveals.

Some major results of comparing business cycles and growth cycles are clear and simple, however. Some slowdowns that interrupt long business cycle expansions are sufficiently long and diffuse to give rise to additional cyclical declines in the detrended aggregates when compared with the original ones. Also, most postwar recessions were preceded by marked retardations. Hence, growth cycles are on the whole shorter, more frequent, and more nearly symmetrical than business cycles; they are less differentiated by duration but still quite variable. There is considerable correspondence between the dates of postwar growth cycles in the principal industrialized economies of North America, Europe, and the Far East (see chapter 7, sec. 7.4; chapter 8, sec. 8.2.4; also Moore and Zarnowitz 1986, sec. 8).

As shown in section 6.4, slowdowns rather than recessions interrupted the sharp growth trends during the early part of the postwar era in continental Europe and Japan. Recessions reappeared there only in the mid-1960s or later as the rebuilding was completed and the growth rates came down to their normal levels. Meanwhile the more slowly growing economies of the United States, Canada, and the United Kingdom continued to experience recurrent recessions, though they were generally mild. Detrending reduces all these episodes to comparable growth cycles, but the international differences between the trends are important and should not be obscured, and the same applies to the differences between cyclical slowdowns and contractions.

In short, growth cycles recur with greater frequency than business cycles and are a feature of even those economies that expand at high rates and rarely contract. They seem to be more alike—that is, more regular—than business cycles. This is presumably because of the elimination of trends that vary over time and across the different variables and countries. Even so, growth cycles exhibit much variability in durations and amplitudes. When figure 7.1 in chapter 7 is updated, the following numbers are obtained, which indicate that slowdowns without recession prevailed in Japan, West Germany, and Canada, while slowdowns with recession prevailed in the United States, United Kingdom, and (slightly) France.[9]

	U.S.	Canada	U.K.	Germany	France	Japan
Slowdown, no recession	4	7	3	5	3	6
Slowdown and recession	7	5	5	3	4	2
Total	11	12	8	8	7	8

One reason why our knowledge of how trends and cycles interact is meager is that much empirical work in macrodynamics uses methods that apply to stationary series obtained by trend adjustment or differencing. Spectral analysis reveals periodicities at cyclical and shorter frequencies in all types of U.S. fixed investment (log differences) and inventory investment (levels) in both the interwar and the postwar periods. This does not support well the old idea that fixed investment is the source of major cycles, and inventory investment of minor cycles. Rather, the results suggest the limitations of the method but also, again, the likely diversity of cyclical experience (chapter 8, figs. 8.1–8.4).

6.7 Implications of Nonlinear Models

The fact that business cycles show no regularity in the durations of their phases constitutes a strong argument against those models which, on the contrary, imply periodic fluctuations. A simple and strict example is provided by the deterministic theory limited to a high accelerator-multiplier combination and a constant rate of autonomous real investment. With constant parameters, this nonlinear or piecewise-linear model (the accelerator is suspended in the downswing) will generate a periodic limit cycle. But it is in principle easy to enlarge such a model and produce more diversity, for example, by allowing for monetary influences and/or fluctuations in autonomous investment (Hicks 1950).

Other diverse examples of repetitive behavior include nonlinear models of income-investment or profit-investment dynamics in a stationary economy (Kaldor 1940; Kalecki 1971); a limit cycle in the labor market (Rose 1967); and the "predator-prey" model of interacting fluctuations in employment, wages, capital accumulation, and profits around an equilibrium path of growth (Goodwin 1967; Samuelson 1971). These models, too, are essentially illus-

9. This count does not include the 1990–91 recessions in the United States, Canada, and the United Kingdom.

trative of certain particular ideas or mechanisms, and they remain fragmentary and untested, though much explored mathematically. But extensions to include relationships with nominal and policy variables and stochastic elements are likely to receive future attention, along with efforts at empirical implementation (from calibration to econometric tests). Nonlinear models are attractive because they can generate undamped cyclical solutions, asymmetries, discontinuities, and irreversibilities. In fact, as discussed in chapter 8, section 8.3, this area of study has recently been very active. In addition to many papers elaborating on the earlier ideas, monographs surveying the old and new theories and techniques have appeared (Gabisch and Lorenz 1987; Ferri and Greenberg 1989).

Some of the above models are locally (piecewise) linear, and their overall nonlinearity arises because of constraints (ceilings, floors, or both) or regime switches at which changes in parameters or initial conditions are activated. Others are explicitly nonlinear throughout and use mathematical tools of classical nonlinear analysis. Both approaches produced endogenous models of periodic cycles. The ability to generate business cycles without having to rely on the deus ex machina of outside shocks was long viewed as a major advantage by many theorists, whereas the need to move away from models of periodic replication was not sufficiently appreciated. And it seemed that the only alternative to the elegant self-contained dynamics would indeed be the introduction of some unexplained disturbances, time variation or shifts of some parameters, and the like.

New analytical possibilities opened up with the discovery (in meteorology: Lorenz 1963) of "deterministic chaos," that is, for certain nonlinear difference equations changes in parameters can result in erratic, nonperiodic fluctuations that need not converge to a cycle of any order. Phases of sharp oscillations can follow upon or alternate irregularly with phases of relatively smooth growth in ways that are completely unpredictable. Thus a model without any random shocks is capable of generating behavior that "looks" stochastic. A small cause (difference or error in initial conditions) may be associated eventually with very large effects. In macroeconomic dynamics, examples of the emergence of chaotic fluctuations are provided in the context of the Goodwin model (Pohjola 1981), the classical and neoclassical growth models (Day 1982, 1983), and Keynesian models (Day and Shafer 1985).

The prospect of new lessons from new analytical approaches is generally exciting, but as stated by Samuelson (1990, p. 57), "It will take very large samples of time-series data to enable the scientist to refute the hypothesis of chaos or to provisionally accept it. History—relevant history—is what we economists are short on." The studies here considered are breaking new ground, and it is impossible to predict where they will lead (the same applies to the related exercises in "catastrophe theory" (see chapter 2, sec. 2.3.4). Still, it is important to note the problems that are already apparent. The available, dimensionally restricted illustrations of chaotic trajectories due to nonlinear feedbacks show hypothetical time series dominated by sharp sawtoothed movements. Few economic time series look like that, and hardly any comprehensive aggregates or indexes do. Business cycles are nonperiodic but they consist of fluctuations that are far more persistent and smooth. Economic rationalizations for the shapes of the functions underlying the models of chaotic behavior seem to be lacking. It is safe to conclude that the new paradigm and techniques will influence economic theorizing about business cycles and growth but represent no immediate threat to the prevailing type of stochastic modeling and econometric work.

6.8 Types of Theory and the Regularity of Business Cycles

One can conceive of fluctuations caused by regularly recurring outside events; such fluctuations would belong in the deterministic-exogenous class. In such "forced oscillations" the driving factor is itself cyclical and the system responds passively. But it is hard to think of any external force that could possibly dominate economic life to the point of being responsible for business cycles. Seasonal movements come to mind but they depend not only on the more or less regular changes in weather but also on custom, economic decisions, and random influences. Natural causes were invoked early to explain business cycles but it soon became clear that such theories fail: whatever drives the general expansions and contractions is almost certainly man-made in the socioeconomic sense. This practically rules out theories that are both deterministic and exogenous.

A counterargument might point to the possibility of government actions designed to win elections that would somehow cause business cycles without being themselves significantly affected by the recent or current changes in the economy. But this is hardly a serious possibility, because policymakers both react to the observed and expected changes and try to influence future macroeconomic conditions, whereas private individuals and organizations respond to the past and anticipated government operations. Unanticipated policy actions themselves act as shocks to the public, although a good deal of what is going on in the private economy is undoubtedly surprising to the government as well. Models of "political business cycles" are useful to the extent that they absorb these endogenous and stochastic elements.

The deterministic-endogenous class of theories is well represented. In the early and mathematically well-articulated models of this type, nonlinearities are required to keep the trajectories from exploding, because the moving equilibrium or "steady state" is here intrinsically unstable; also, as already noted, the cycles produced by these models are periodic-regular. These are not attractive features. The new chaos models are free of them but they are as yet short on economic motivation and long on output that, though not explosive, shows excessive volatility.

Stochastic theories can be either exogenous or endogenous. The latter include the models with multiple rational expectations equilibria, in which random events trigger generalized changes in expectations that become self-fulfilling. The "sunspot" events need not effect any changes in economic fundamentals. These theories increasingly center on financial market imperfections and crises and use techniques of nonlinear dynamics (see collections of essays in Barnett, Geweke, and Shell 1989; and Semmler 1989).

Stochastic and exogenous theories are currently the best known and most dominant in the literature. In this case, the equilibrium is intrinsically stable, and continuing outside shocks are needed to produce recurrent fluctuations. The prototype for linear business cycle models of this type is Frisch 1933, a pre-Keynesian dynamic model of cyclical motion (not growth). Frisch's idea that random "impulses" keep fluctuations alive even though the undisturbed economy (his "propagation mechanism") is highly dampened established a tradition for many subsequent theoretical and almost all active macroeconometric models.[10]

The magnitude of the white-noise shocks impinging on the so-represented economy is the main determinant of the amplitude of the resulting fluctuations, whereas the length of the latter and the tendency toward dampening depend primarily on the parameters of the propagation mechanism (Frisch 1933, p. 171). Other things equal, the less dampened the system, the more distinct will be the periodicity of the generated cycles. This is the case of "free oscillations," which arise in a system that responds cyclically to impulses that are themselves noncyclical.

The original stochastic-exogenous cycle analysis worked with white-noise shocks only. Serially correlated disturbances would result in smoother and more markedly periodic movements. Sufficiently large sporadic or clustered shocks could affect the timing of turning points and the duration of a business cycle.

It is instructive to think of the pure types of theory but they are not all mutually preclusive, and it stands to reason that the business cycles of the real world include elements of these theories in various combinations. For the central phenomenon to exist, a set of relationships possessing considerable regularity is necessary; but for the manifestations in time of this phenomenon to be variable, the balance of forces acting on and within the system must be changing. The more endogenously business cycles can be explained, the better in principle; but some parts of the big picture must be left exogenous if the

10. In the Frisch model, output of capital goods is a distributed-lag function of orders that depend on the change in consumption, which is inversely related to a weighted total output of both consumption and capital goods. Thus technology, the acceleration principle, and an equation based on the notion that consumption yields to cash pressure as money supply lags behind money demand are all linked to production and income. Recent simulations confirm that random shocks can produce considerable fluctuations in this model but not excessive periodicity for parameter values that Frisch favored, that is, for a relatively high degree of dampening. See Thalberg 1990, where it is shown that adding a multiplier relation improves the results of the model qualitatively while introducing a potential for instability.

explanation is to be economic and comprehensible. Some influences that are identifiably important are external to the economy, and some of these may be essentially random. Linear approximations will do well locally in many cases but not globally everywhere. The general fluctuations may be "free" but some particular relations within the economy probably reflect "forced" cyclical movements.

6.9 Simulations with Macroeconometric Models

The 1955 Klein-Goldberger model of the U.S. economy estimated on annual data for 1929–52 was intensively studied by Adelman and Adelman (1959), who found it to be essentially noncyclical in the absence of shocks. Stochastic simulations with random shocks to extrapolated values of the exogenous variables also did not generate significant fluctuations, but simulations with random shocks to the fitted equations of the model did. Adelman and Adelman compared the time paths of the latter with the NBER reference cycle patterns for the variables in question and found considerable similarities. They concluded that these results are consistent with the concept of an economy that is a dynamically stable system that propagates outside disturbances into business cycles (the Wicksell-Slutsky-Frisch hypothesis). Despite caveats by the authors about limitations of the model and method used, their findings have at times been taken as a *proof* that the origin of business cycles is truly stochastic.

However, detailed tests of an array of much more elaborate quarterly macroeconomic models reject the classical version of the Frisch theory, namely, that purely random shocks are necessary and sufficient to cause cyclical fluctuations in the estimated systems. A comprehensive study of three large-scale models (Wharton, Commerce Department, and FRB-MIT-Penn) found that they were all noncyclical in deterministic forms and also did not reproduce continuous cyclical developments when subjected to random disturbances (Zarnowitz, Boschan, and Moore 1972). In chapter 9, which is a brief summary of that study, some similar results for a fourth model (Brookings) are also included. When correlated shocks were used, smoother and more distinct fluctuations resulted, but even these were much weaker than those observed in the historical series used in the estimation of the models. Consistent evidence comes from several other contributions to the NBER conference that produced these simulation studies (Hickman 1972).

It is possible that a combination of random shocks to both the exogenous and the behavioral variables would perform better than either kind of shock alone and, also, that mixing correlated and uncorrelated disturbances would help (Adelman 1972, p. 535). Wars, strikes, technological innovations, government policy, and political developments, etc., are potential sources of temporal persistence in exogenous factors; they will inevitably impart some serial correlation to some of the shocks to the model equations as well. But the situation is unfortunately blurred by the very real possibility that the results of the simulations reflect in significant measure misspecification errors in the models. For example, the inadequate cyclicality of the long stochastically simulated trajectories could be partly due to insufficient nonlinear elements in the models.

The Hickman (1972) volume was followed by comparative studies of econometric model performance that were concerned more with forecasting accuracy and multiplier analysis but added some evidence on the cyclical problem under examination here (Klein and Burmeister 1976). The Michigan quarterly model is described as one that "will not produce a sustained cyclical path in non-stochastic simulations with 'smooth' exogenous variables" (Hymans and Shapiro 1976, p. 268). The mechanism of response to outside shocks is highly dampened, and dynamic simulations show generally smaller amplitudes than the corresponding actual series. The authors argue that this is as it should be, to the extent that recessions, booms, high inflation, etc., represent unique or abberrant behavior patterns.

Similarly, in the Data Resources, Inc. (DRI), model relatively smooth paths characterize simulations that removed many exogenous and random influences by holding constant the growth rates of fiscal variables, nonborrowed reserves, etc. (Eckstein, Green, and Sinai 1976). It is asserted that "the model's endogenous structure *should* display the strongly damped oscillatory character that the economy seems to possess" (p. 212; emphasis added). But "noise" defined narrowly to include only the (presumably random) equation errors accounted for very little (only 7.4%) of the total "cyclicality" (an index of relative deviations from trend) in the more recent version of the DRI model (Eckstein and Sinai 1986, pp. 70–73, 81). This may be largely attributable to the use of many special, or dummy, variables in the very large and difficult-to-evaluate DRI model. Be that as it may, the macroeconometric evidence lends more support to the hypothesis of the importance of exogenous variables than to the hypothesis of pure random shocks.

6.10 A Note on the Recent History of These Models

The late 1960s and early 1970s represent the heyday of the application of comprehensive econometric models to macroeconomic analysis and forecasting. Since then, the econometricians and their models came to be criticized for not dealing well with the short-term effects and future implications of commodity and oil price shocks (which were, understandably, unanticipated). More important, they were seen as unprepared for the concurrence of rising inflation and severe recessions that materialized in 1972–80. This failure has been widely shared in the profession and attributed to Keynesian theory and policy generally, but the ambitiously large and complex models presented a particularly visible target for criticism. Moreover, with the advent of the rational expectations hypothesis, the models came under attack on the ground that changes in policy regimes alter private expectations and behavior so as to invalidate certain key equations in the models that are wrongly treated as fixed (Lucas 1976).

These developments led to a sharp decline in the interest of academic economists in the existing and commercially active macroeconometric models. The influential Lucas critique met with the valid counterclaim that shifts in policy rules are very rare and normal policy actions have no disruptive effects on important macrorelationships (Sims 1982). Whether and how rational expectations apply is itself a matter of dispute (see chapter 2). Some of the defense of the models by their builders (Eckstein 1981) finds support in the data and some of the criticism does not. But the large-scale models no longer inspire the confidence and hopes they once did, their limitations are widely recognized, and even many friendly critics view them as overdeveloped and underexplained.

It is also true, however, that the models continue to be used with commercial success for practical purposes of forecasting and consulting. As such they are being almost continuously reexamined and repaired, but little is known about precisely how and with what effects. The estrangement between the academic economists and the practitioners in the econometric bureaus persists. This can hardly be a healthy state of affairs, since it is likely that the two sides have much to learn from each other.

Alternative simulations and forecasts with different macroeconometric models are useful devices in the search for good questions and answers on what is expected and unexpected and what is self-produced and externally caused in the economy's motion. Yet, to my knowledge, little work of the type discussed here and in chapter 9 has been done more recently. No major new models have been developed, and the documentation on the revisions of the commercial models is not publicly available. The lessons from the reported simulations and tests are worthwhile and need to be extended.