Chapter 1

BUSINESS CYCLE FLUCTUATIONS IN US MACROECONOMIC TIME SERIES

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Abstract

This chapter examines the empirical relationship in the postwar United States between the aggregate business cycle and various aspects of the macroeconomy, such as production, interest rates, prices, productivity, sectoral employment, investment, income, and consumption. This is done by examining the strength of the relationship between the aggregate cycle and the cyclical components of individual time series, whether individual series lead or lag the cycle, and whether individual series are useful in predicting aggregate fluctuations. The chapter also reviews some additional empirical regularities in the US economy, including the Phillips curve and some long-run relationships, in particular long run money demand, long run properties of interest rates and the yield curve, and the long run properties of the shares in output of consumption, investment and government spending.

Keywords

economic fluctuations, Phillips curve, long run macroeconomic relations

JEL classification: E30

1. Introduction

This chapter summarizes some important regularities in macroeconomic time series data for the United States since World War II. Our primary focus is the business cycle. In their classic study, Burns and Mitchell (1946) offer the following definition of the business cycle:

> A cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own.
>
> *Burns and Mitchell, 1946, p. 3.*

Figure 1.1 plots the natural logarithm of an index of industrial production for the United States from 1919 to 1996. (Data sources are listed in the Appendix.) Over these 78 years, this index has increased more than fifteen-fold, corresponding to an increase in its logarithm by more than 2.7 units. This reflects the tremendous growth of the US labor force and of the productivity of American workers over the twentieth century.

Also evident in Figure 1.1 are the prolonged periods of increases and declines that constitute American business cycles. These fluctuations coincide with some of the signal events of the US economy over this century: the Great Depression of the 1930s; the subsequent recovery and growth during World War II; the sustained boom of the 1960s, associated in part with spending on the war in Vietnam; the recession of 1973–1975, associated with the first OPEC price increases; the disinflationary twin recessions of the early 1980s; the recession of 1990, associated with the invasion of Kuwait by Iraq; and the long expansions of the 1980s and the 1990s.

To bring these cyclical fluctuations into sharper focus, Figure 1.2 plots an estimate

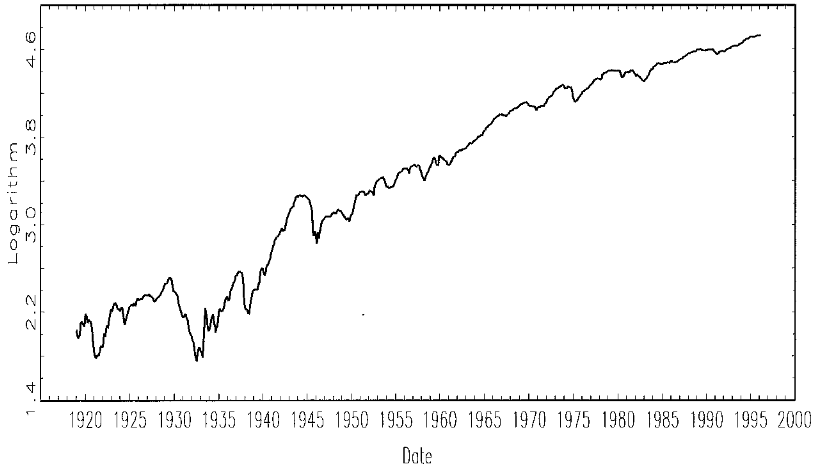

Fig. 1.1. Industrial production index (logarithm of levels).

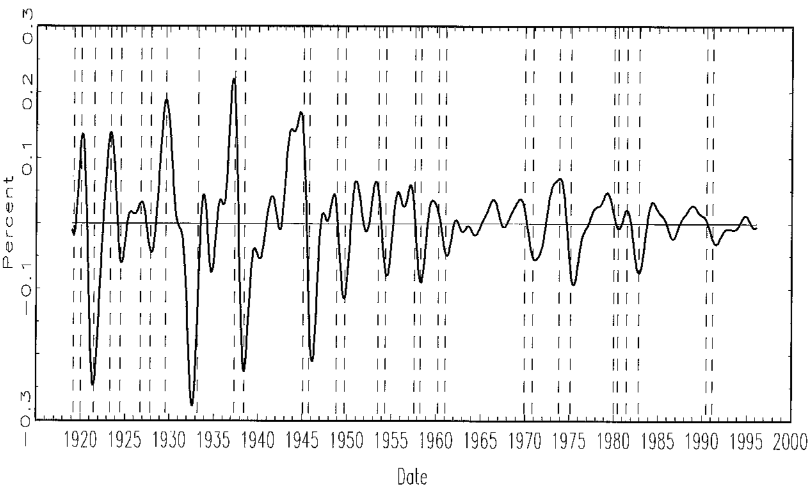

Fig. 1.2. Business cycle component of industrial production index.

of the cyclical component of industrial production. (This estimate was obtained by passing the series through a bandpass filter that isolates fluctuations at business cycle periodicities, six quarters to eight years; this filter is described in the next section.) The vertical lines in Figure 1.2 indicate cyclical peaks and troughs, where the dates have been determined by business cycle analysts at the National Bureau of Economic Research (NBER). A chronology of NBER-dated cyclical turning points from 1854 to the present is given in Table 1 (the method by which these dates were obtained is discussed in the next section). Evidently, the business cycle is an enduring feature of the US economy.

In the next two sections, we examine the business cycle properties of 71 quarterly US economic time series. Although business cycles have long been present in the US, this chapter focuses on the postwar period for two reasons. First, the American economy is vastly different now than it was many years ago: new production and financial technologies, institutions like the Federal Reserve System, the rise of the service and financial sectors, and the decline of agriculture and manufacturing are but a few of the significant changes that make the modern business cycle different from its historical counterpart. Second, the early data have significant deficiencies and in general are not comparable to the more recent data. For example, one might be tempted to conclude from Figure 1.2 that business cycles have been less severe and less frequent in the postwar period than in the prewar period. However, the quality of the data is not consistent over the 78-year sample period, which makes such comparisons problematic. Indeed, Romer (1989) has argued that, after accounting for such measurement problems, cyclical fluctuations since World War II have been of the same magnitude as they were before World War I. Although this position is controversial [see Balke and Gordon (1989), Diebold and Rudebusch (1992) and Watson (1994a)], there is general agreement that

Table 1
NBER business cycle reference dates

Trough		Peak	
December	1854	June	1857
December	1858	October	1860
June	1861	April	1865
December	1867	June	1869
December	1870	October	1873
March	1879	March	1882
May	1885	March	1887
April	1888	July	1890
May	1891	January	1893
June	1894	December	1895
June	1897	June	1899
December	1900	September	1902
August	1904	May	1907
June	1908	January	1910
January	1912	January	1913
December	1914	August	1918
March	1919	January	1920
July	1921	May	1923
July	1924	October	1926
November	1927	August	1929
March	1933	May	1937
June	1938	February	1945
October	1945	November	1948
October	1949	July	1953
May	1954	August	1957
April	1958	April	1960
February	1961	December	1969
November	1970	November	1973
March	1975	January	1980
July	1980	July	1981
November	1982	July	1990
March	1991		

[a] Source: National Bureau of Economic Research.

comparisons of business cycles from different historical periods is hampered by the severe limitations of the early data. For these reasons, this chapter focuses on the postwar period for which a broad set of consistently defined data series are available, and which is in any event the relevant period for the study of the modern business cycle.

There are other important features of the postwar data that are not strictly related to the business cycle but which merit special emphasis. In the final section of this chapter, we therefore turn to an examination of selected additional regularities in postwar economic time series that are not strictly linked to the business cycle. These include the Phillips curve (the relationship between the rate of price inflation and the unemployment rate) and some macroeconomic relations that hold over the long run, specifically long-run money demand, yield curve spreads, and the consumption–income and consumption–investment ratios. These relations have proven remarkably stable over the past four decades, and they provide important benchmarks both for assessing theoretical macroeconomic models and for guiding macroeconomic policy.

2. Empirical methods of business cycle analysis

2.1. Classical business cycle analysis and the determination of turning points

There is a long intellectual history of the empirical analysis of business cycles. The classical techniques of business cycle analysis were developed by researchers at the National Bureau of Economic Research [Mitchell (1927), Mitchell and Burns (1938), Burns and Mitchell (1946)]. Given the definition quoted in the introduction, the two main empirical questions are how to identify historical business cycles and how to quantify the comovement of a specific time series with the aggregate business cycle.

The business cycle turning points identified retrospectively and on an ongoing basis by the NBER, which are listed in Table 1, constitute a broadly accepted business cycle chronology. NBER researchers determined these dates using a two-step process. First, cyclical peaks and troughs (respectively, local maxima and minima) were determined for individual series. Although these turning points are determined judgementally, the process is well approximated by a computer algorithm developed by Bry and Boschan (1971). Second, common turning points were determined by comparing these series-specific turning points. If, in the judgment of the analysts, the cyclical movements associated with these common turning points are sufficiently persistent and widespread across sectors, then an aggregate business cycle is identified and its peaks and troughs are dated. Currently, the NBER Business Cycle Dating Committee uses data on output, income, employment, and trade, both at the sectoral and aggregate levels, to guide their judgments in identifying and dating business cycles as they occur [NBER (1992)]. These dates typically are announced with a lag to ensure that the data on which they are based are as accurate as possible. Burns, Mitchell and their associates also developed procedures for comparing cycles in individual series to the aggregate business cycle. These procedures include measuring leads and lags of specific series at cyclical turning points and computing cross-correlations on a redefined time scale that corresponds to phases of the aggregate business cycle.

The classical business cycle discussed so far refers to absolute declines in output and other measures. An alternative is to examine cyclical fluctuations in economic time series that are deviations from their long-run trends. The resulting cyclical fluctuations are referred to as growth cycles [see for example Zarnowitz (1992), ch. 7]. Whereas classical cycles tend to have recessions that are considerably shorter than expansions because of underlying trend growth, growth recessions and expansions have approximately the same duration. The study of growth cycles has advantages and disadvantages relative to classical cycles. On the one hand, separation of the trend and cyclical component is inconsistent with some modern macroeconomic models, in which productivity shocks (for example) determine both long-run economic growth and the fluctuations around that growth trend. From this perspective, the trend-cycle dichotomy is only justified if the factors determining long-run growth and those determining cyclical fluctuations are largely distinct. On the other hand, growth cycle chronologies are by construction less sensitive to the underlying trend growth rate in the economy, and in fact some economies which have had very high growth rates, such as postwar Japan, exhibit growth cycles but have few absolute declines and thus have few classical business cycles. Finally, the methods of classical business cycle analysis have been criticized for lacking a statistical foundation (for example Koopmans (1947)]. Although there have been some modern treatments of these nonlinear filters (for example Stock (1987)], linear filtering theory is better understood [1]. Modern studies of business cycle properties therefore have used linear filters to distinguish between the trend and cyclical components of economic time series [2]. Although we note these ambiguities, in the rest of this chapter we follow the recent literature and focus on growth recessions and expansions [3].

[1] A linear filter is a set of weights $\{a_i,\ i=0, \pm 1,\ \pm 2,\ \ldots\}$ that are applied to a time series y_t; the filtered version of the time series is $\sum_{i=-\infty}^{\infty} a_i y_{t-i}$. If the filtered series has the form $\sum_{i=0}^{\infty} a_i y_{t-i}$ (that is, $a_i=0,\ i<0$), the filter is said to be one-sided, otherwise the filter is two-sided. In a nonlinear filter, the filtered version of the time series is a nonlinear function of $\{y_t,\ t=0,\ \pm 1,\ \pm 2,\ \ldots\}$.

[2] See Hodrick and Prescott (1981), Harvey and Jaeger (1993), Stock and Watson (1990), Backus and Kehoe (1992), King and Rebelo (1993), Kydland and Prescott (1990), Englund, Persson and Svensson (1992), Hassler, Lundvik, Persson and Söderlind (1992), and Baxter and King (1994) for more discussion and examples of linear filtering methods applied to the business cycle.

[3] This discussion treats the NBER chronology as a concise way to summarize some of the most significant events in the macroeconomy. A different use of the chronology is as a benchmark against which to judge macroeconomic models. In an early application of Monte Carlo methods to econometrics, Adelman and Adelman (1959) simulated the Klein–Goldberger model and found that it produced expansions and contractions with durations that closely matched those in the US economy. King and Plosser (1994) and Hess and Iwata (1997) carried out similar exercises. Pagan (1997) has shown, however, that a wide range of simple time series models satisfy this test, which indicates that it is not a particularly powerful way to discriminate among macroeconomic models. Of course, using the NBER dating methodology to describe data differs from using it to test models, and the low power of the test of the Adelmans simply implies that this methodology is better suited to the former task than the latter.

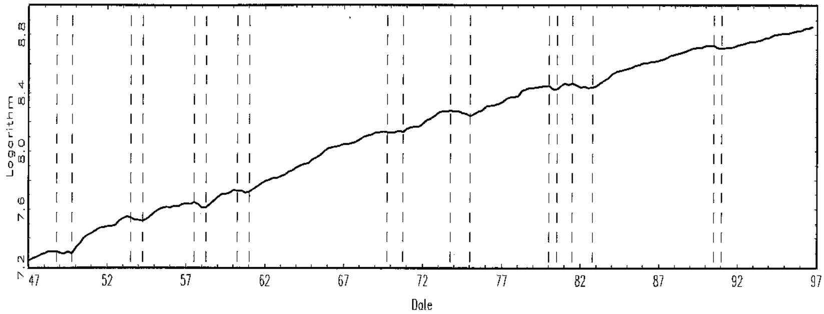

Fig. 2.1. Level of GDP.

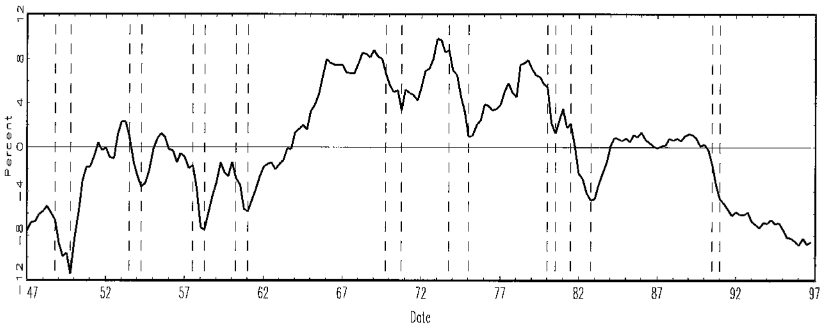

Fig. 2.2. Linearly detrended GDP.

2.2. Isolating the cyclical component by linear filtering

Quarterly data on the logarithm of real US GDP from 1947 to 1996 are plotted in Figure 2.1. As in the longer index of industrial production shown in Figure 1.1, cyclical fluctuations are evident in these postwar data. Without further refinement, however, it is difficult to separate the cyclical fluctuations from the long-run growth component. Moreover, there are some fluctuations in the series that occur over periods shorter than a business cycle, arising from temporary factors such as unusually harsh weather, strikes and measurement error. It is therefore desirable to have a method to isolate only those business cycle fluctuations of immediate interest.

If the long-run growth component in log real GDP is posited to be a linear time trend, then a natural way to eliminate this trend component is to regress the logarithm of GDP against time and to plot its residual. This "linearly detrended" time series, scaled to be in percentage points, is plotted in Figure 2.2. Clearly the cyclical fluctuations of output are more pronounced in this detrended plot. However, these detrended data still contain fluctuations of a short duration that are arguably not related to business cycles. Furthermore, this procedure is statistically valid only if the long-run growth component is a linear time trend, that is, if GDP is trend stationary (stationary around a linear

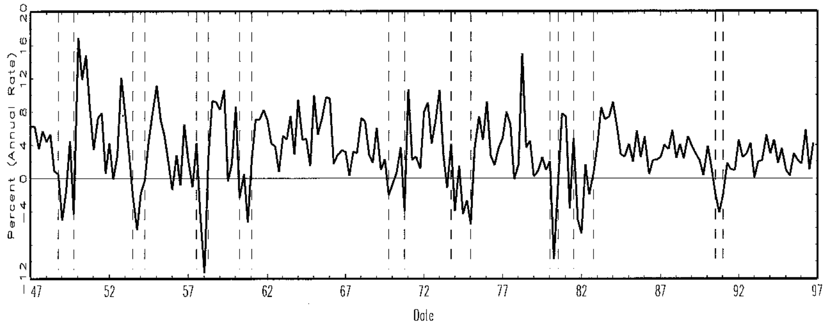

Fig. 2.3. Growth rate of GDP.

time trend). This latter assumption is, however, questionable. Starting with Nelson and Plosser (1982), a large literature has developed around the question of whether GDP is trend stationary or difference stationary (stationary in first differences), that is, whether GDP contains a unit autoregressive root. Three recent contributions are Rudebusch (1993), Diebold and Senhadji (1996), and Nelson and Murray (1997). Nelson and Plosser (1982) concluded that real GDP is best modeled as difference stationary, and much of the later literature supports this view with the caveat that it is impossible to distinguish large stationary autoregressive roots from unit autoregressive roots, and that there might be nonlinear trends; see Stock (1994). Still, with a near-unit root and a possibly nonlinear trend, linear detrending will lead to finding spurious cycles.

If log real GDP is difference stationary, then one way to eliminate its trend is to first difference the series which, when the series is in logarithms, transforms the series into quarterly rates of growth. This first-differenced series, scaled to be in the units of quarterly percentage growth at an annual rate, is plotted in Figure 2.3. This series has no visible trend, and the recessions appear as sustained periods of negative growth. However, first-differencing evidently exacerbates the difficulties presented by short-run noise, which obscures the cyclical fluctuations of primary interest.

These considerations have spurred time series econometricians to find methods that better isolate the cyclical component of economic time series. Doing so, however, requires being mathematically precise about what constitutes a cyclical component. Here, we adopt the perspective in Baxter and King (1994), which draws on the theory of spectral analysis of time series data. The height of the spectrum at a certain frequency corresponds to fluctuations of the periodicity that corresponds (inversely) to that frequency. Thus the cyclical component can be thought of as those movements in the series associated with periodicities within a certain range of business cycle durations. Here, we define this range of business cycle periodicities to be between six quarters and eight years[4]. Accordingly, the ideal linear filter would preserve

[4] The NBER chronology in Table 1 lists 30 complete cycles since 1858. The shortest full cycle (peak to peak) was 6 quarters, and the longest 39 quarters; 90% of these cycles are no longer than 32 quarters.

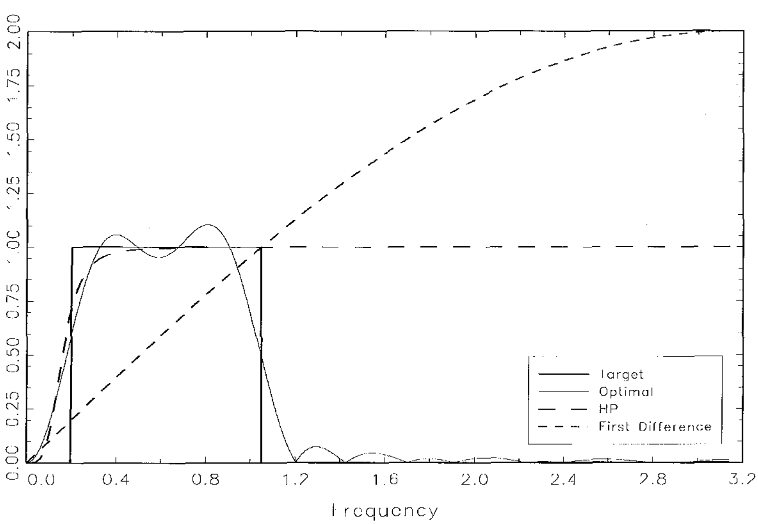

Fig. 2.4. Filter gains.

these fluctuations but would eliminate all other fluctuations, both the high frequency fluctuations (periods less than six quarters) associated for example with measurement error and the low frequency fluctuations (periods exceeding eight years) associated with trend growth. In other words, the gain of the ideal linear filter is unity for business cycle frequencies and zero elsewhere[5]. This ideal filter cannot be implemented in finite data sets because it requires an infinite number of past and future values of the series; however, a feasible (finite-order) filter can be used to approximate this ideal filter.

Gains of this ideal filter and several candidate feasible filters are plotted in Figure 2.4. The first-differencing filter eliminates the trend component, but it exacerbates the effect of high frequency noise, a drawback that is evident in Figure 2.3. Another filter that is widely used is the Hodrick–Prescott filter [Hodrick and Prescott (1981)]. This filter improves upon the first-differencing filter: it attenuates less of the cyclical component and it does not amplify the high frequency noise. However, it still passes much of the high frequency noise outside the business cycle frequency band. The filter adopted in this study is Baxter and King's bandpass filter, which is designed to mitigate these problems [Baxter and King (1994)]. This feasible bandpass filter is based on a twelve-quarter centered moving average, where the weights are chosen to minimize the squared difference between the optimal and approximately optimal filters,

[5] The spectral density of a time series x_t at frequency ω is $s_x(\omega)=(2\pi)^{-1}\sum_{j=-\infty}^{\infty}\gamma_x(j)\exp(-i\omega j)$, where $\gamma_x(j)=\mathrm{cov}(x_t,x_{t-j})$. The gain of a linear filter $a(L)$ is $|A(\omega)|$, where $A(\omega)=\sum_{j=-\infty}^{\infty}a_j\exp(i\omega j)$. The spectrum of a linearly filtered series, $y_t=a(L)x_t$, with L the lag operator, is $s_y(\omega)=|A(\omega)|^2\,s_x(\omega)$. See Hamilton (1994) for an introduction to the spectral analysis of economic time series.

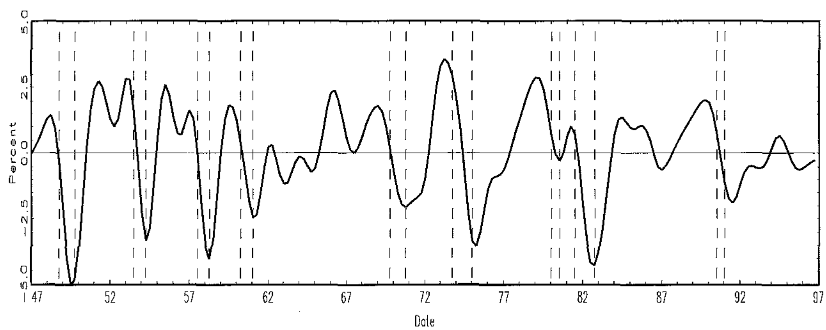

Fig. 2.5. Bandpass-filtered GDP (business cycle).

subject to the constraint that the filter has zero gain at frequency zero[6]. Because this is a finite approximation, its gain is only approximately flat within the business cycle band and is nonzero for some frequencies outside this band.

The cyclical component of real GDP, estimated using this bandpass filter, is plotted in Figure 2.5. This series differs from linearly detrended GDP, plotted in Figure 2.2, in two respects. First, its fluctuations are more closely centered around zero. This reflects the more flexible detrending method implicit in the bandpass filter. Second, the high frequency variations in detrended GDP have been eliminated. The main cyclical events of the postwar period are readily apparent in the bandpass filtered data. The largest recessions occurred in 1973–1975 and the early 1980s. The recessions of 1969–1970 and 1990–1991 each have shorter durations and smaller amplitudes.

Other cyclical fluctuations are also apparent, for example the slowdowns in 1967 and 1986, although these are not classical recessions as identified by the NBER. During 1986, output increased more slowly than average, and the bandpass filtered data, viewed as deviations from a local trend, are negative during 1986. This corresponds to a growth recession even though there was not the absolute decline that characterizes an NBER-dated recession. This distinction between growth recessions and absolute declines in economic activity leads to slight differences in official NBER peaks and local maxima in the bandpass filtered data. Notice from Figure 2.1 that output slowed markedly before the absolute turndowns that characterized the 1970, 1974, 1980 and 1990 recessions. Peaks in the bandpass filter series correspond to the beginning of these slowdowns, while NBER peaks correspond to downturns in the level of GDP.

The bandpass filtering approach permits a decomposition of the series into trend, cycle and irregular components, respectively corresponding to the low, business cycle, and high frequency parts of the spectrum. The trend and irregular components are

[6] To obtain filtered values at the beginning and end of the sample, the series are augmented by twelve out-of-sample projected values at both ends of the sample, where the projections were made using forecasts and backcasts from univariate fourth-order autoregressive models.

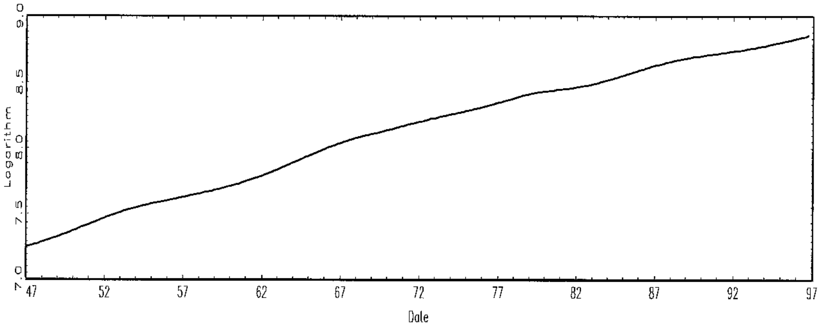

Fig. 2.6. Bandpass-filtered GDP (trend).

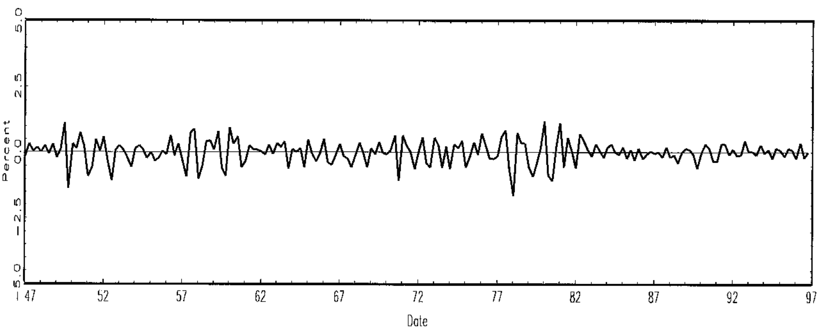

Fig. 2.7. Bandpass-filtered GDP (irregular).

plotted in Figures 2.6 and 2.7; the series in Figures 2.5–2.7 sum to log real GDP. Close inspection of Figure 2.6 reveals a slowdown in trend growth over this period, an issue of great importance that has been the focus of considerable research but which is beyond the scope of this chapter.

3. Cyclical behavior of selected economic time series

3.1. The data and summary statistics

The 71 economic time series examined in this chapter are taken from eight broad categories: sectoral employment; the National Income and Product Accounts (NIPA); aggregate employment, productivity and capacity utilization; prices and wages; asset prices; monetary aggregates; miscellaneous leading indicators; and international output. Most of the series were transformed before further analysis. Quantity measures (the NIPA variables, the monetary aggregates, the level of employment, employee hours, and production) are studied after taking their logarithms. Prices and wages are transformed by taking logarithms and/or quarterly difference of logarithms (scaled to be percentage changes at an annual rate). Interest rates, spreads, capacity utilization, and the unemployment rate are used without further transformation.

The graphical presentations in this section cover the period 1947:I–1996:IV. The early years of this period were dominated by some special features such as the peacetime conversion following World War II and the Korean war and the associated price controls. Our statistical analysis therefore is restricted to the period 1953:I–1996:IV.

Three sets of empirical evidence are presented for each of the three series. This evidence examines comovements between each series and real GDP. Although the business cycle technically is defined by comovements across many sectors and series, fluctuations in aggregate output are at the core of the business cycle so the cyclical component of real GDP is a useful proxy for the overall business cycle and is thus a useful benchmark for comparisons across series.

First, the cyclical component of each series (obtained using the bandpass filter) is plotted, along with the cyclical component of output, for the period 1947–1996. For series in logarithms, the business cycle components have been multiplied by 100, so that they can be interpreted as percent deviation from long run trend. No further transformations have been applied to series already expressed in percentage points (inflation rates, interest rates, etc.). These plots appear in Figures 3.1–3.70. Note that the vertical scales of the plots differ. The thick line in each figure is the cyclical component of the series described in the figure caption, and the thin line is the cyclical component of real GDP. Relative amplitudes can be seen by comparing the series to aggregate output.

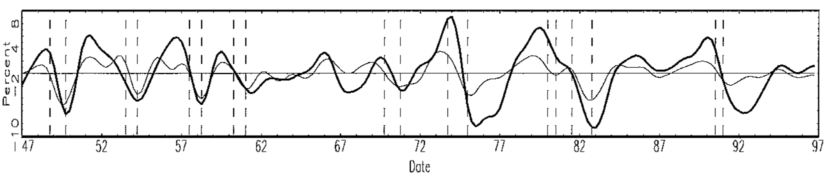

Fig. 3.1. Contract and construction employment.

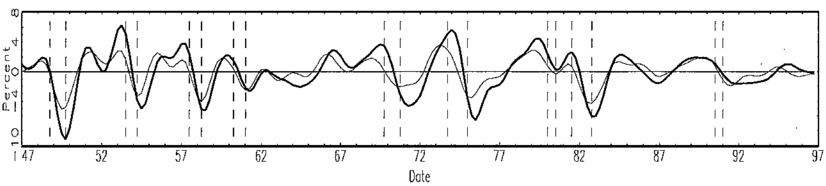

Fig. 3.2. Manufacturing employment.

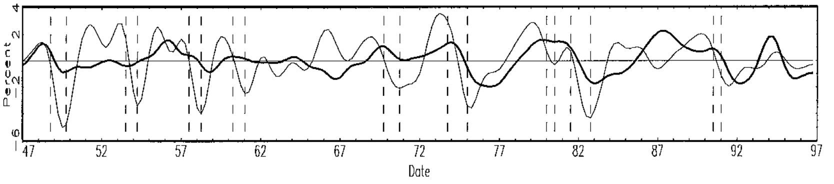

Fig. 3.3. Finance, insurance and real estate employment.

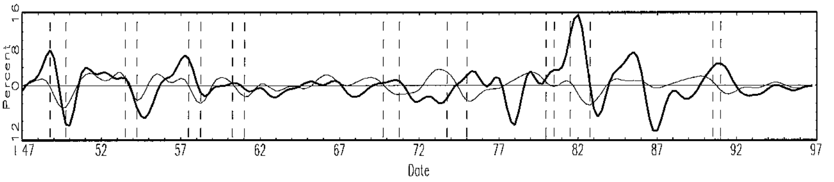

Fig. 3.4. Mining employment.

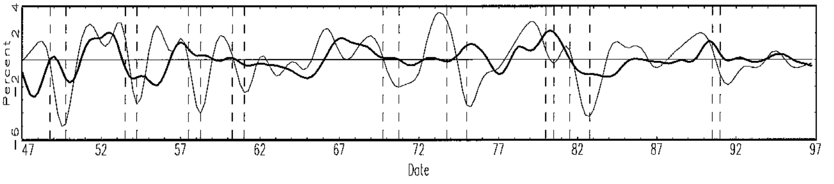

Fig. 3.5. Government employment.

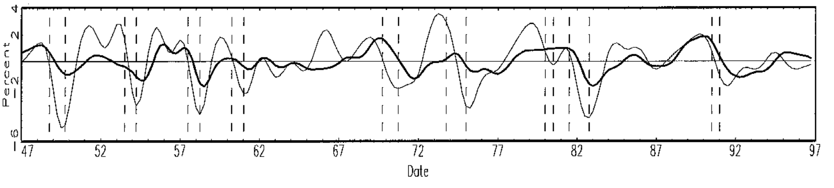

Fig. 3.6. Service employment.

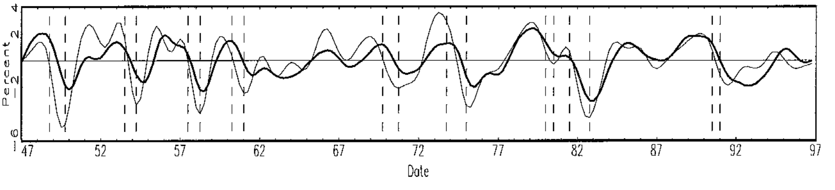

Fig. 3.7. Wholesale and retail trade employment.

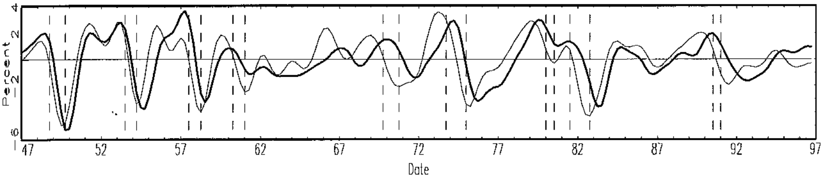

Fig. 3.8. Transportation and public utility employment.

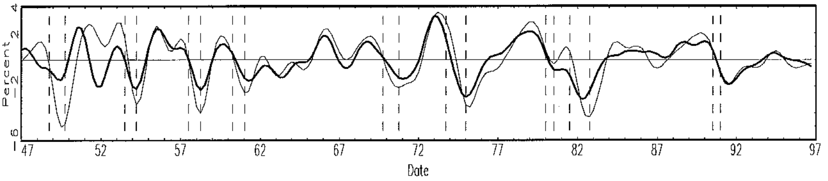

Fig. 3.9. Consumption (total).

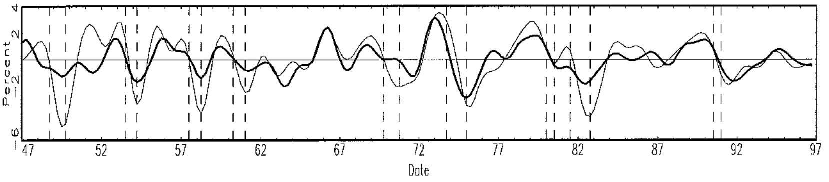

Fig. 3.10. Consumption (nondurables).

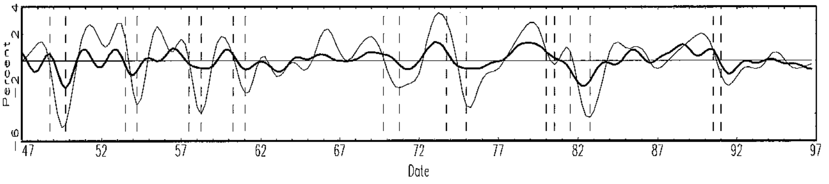

Fig. 3.11. Consumption (services).

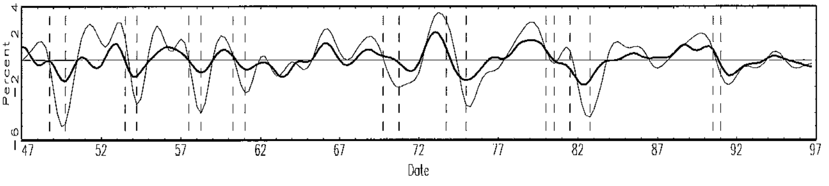

Fig. 3.12. Consumption (nondurables + services).

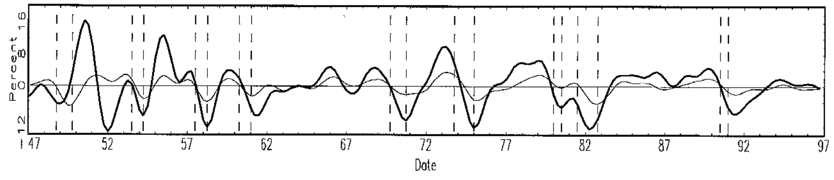

Fig. 3.13. Consumption (durables).

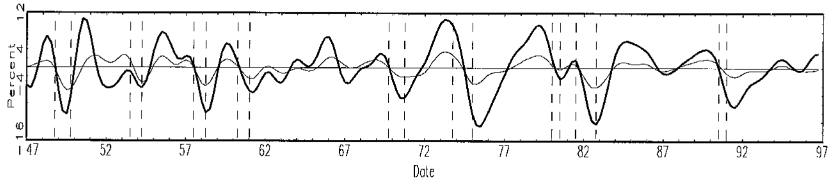

Fig. 3.14. Investment (total fixed).

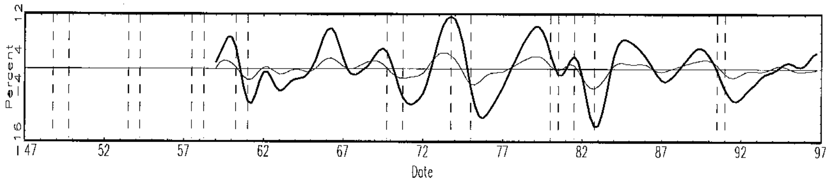

Fig. 3.15. Investment (equipment).

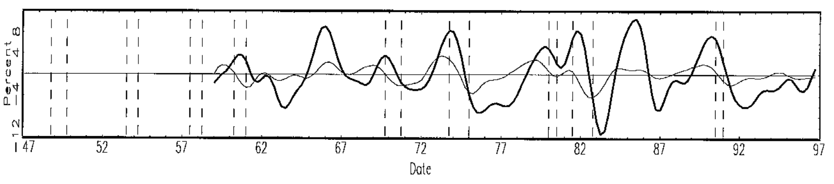

Fig. 3.16. Investment (nonresidential structures).

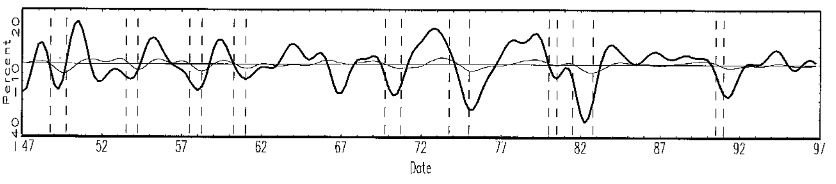

Fig. 3.17. Investment (residential structures).

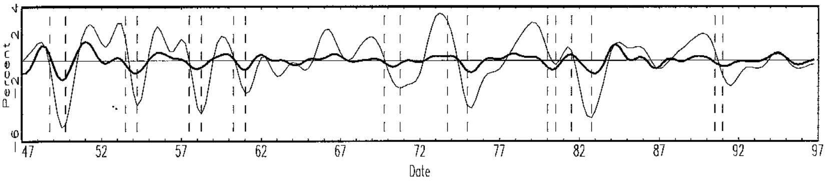

Fig. 3.18. Change in business inventories (relative to trend GDP).

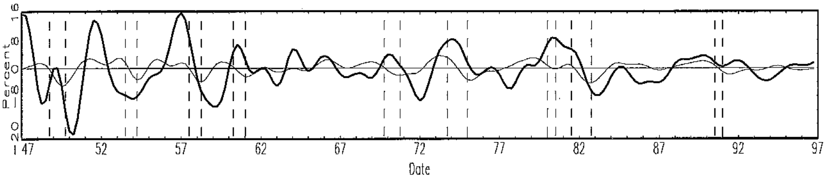

Fig. 3.19. Exports.

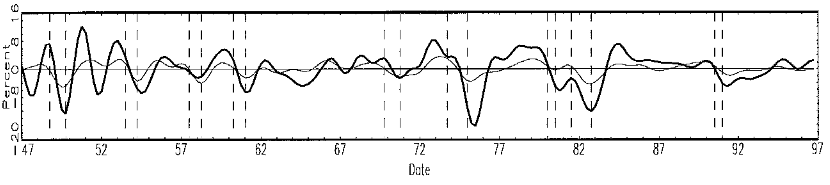

Fig. 3.20. Imports.

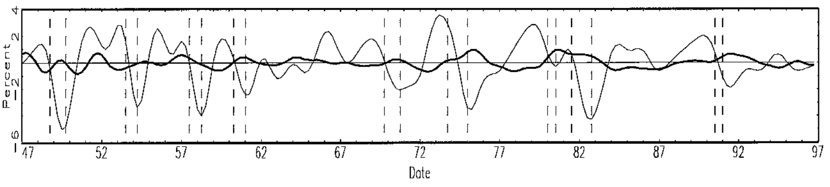

Fig. 3.21. Trade balance (relative to trend GDP).

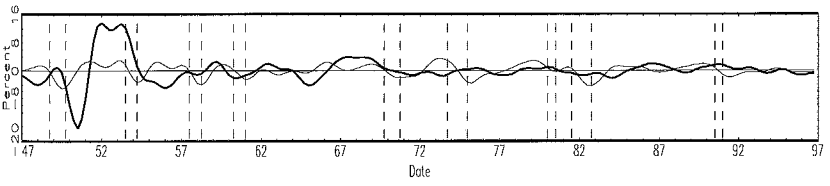

Fig. 3.22. Government purchases.

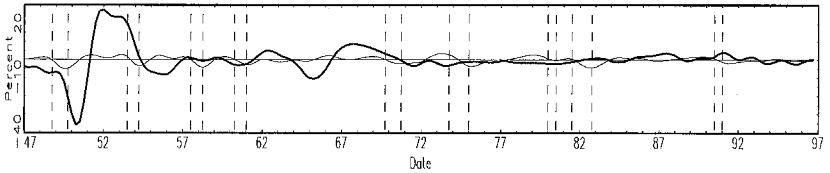

Fig. 3.23. Government purchases (defense).

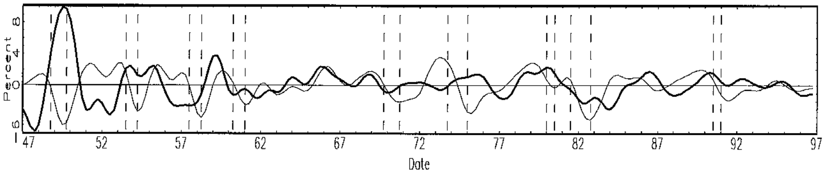

Fig. 3.24. Government purchases (non-defense).

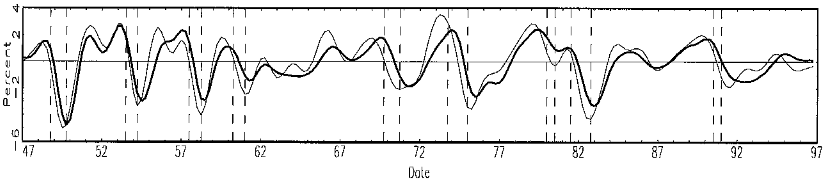

Fig. 3.25. Employment (total employees).

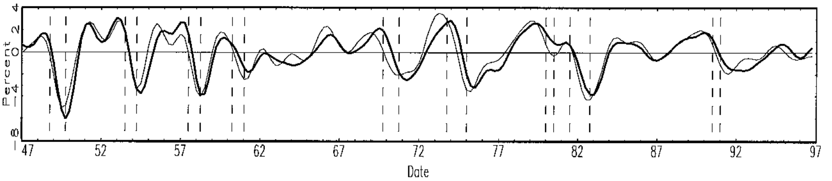

Fig. 3.26. Employment (total hours).

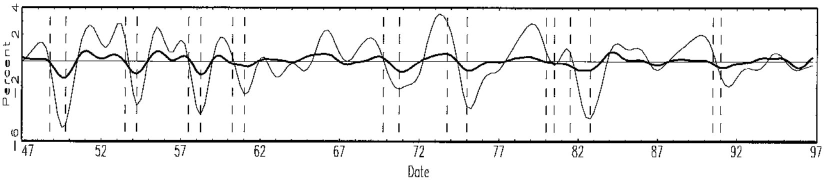

Fig. 3.27. Employment (average weekly hours).

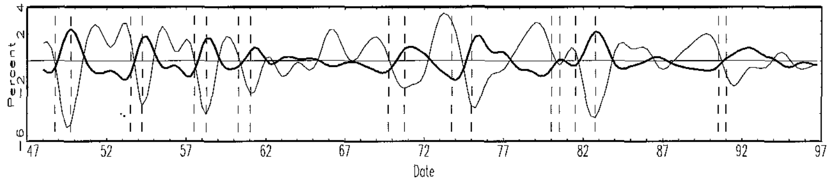

Fig. 3.28. Unemployment rate.

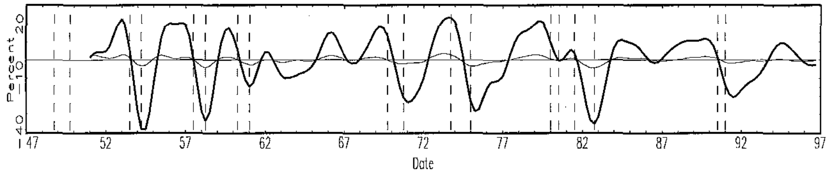

Fig. 3.29. Vacancies (Help Wanted index).

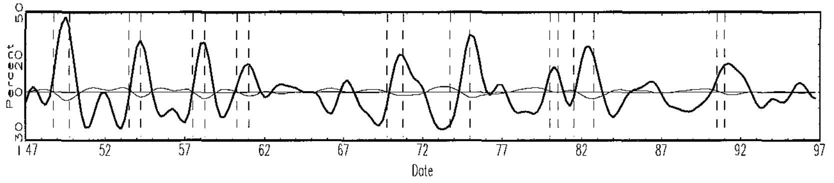

Fig. 3.30. New unemployment claims.

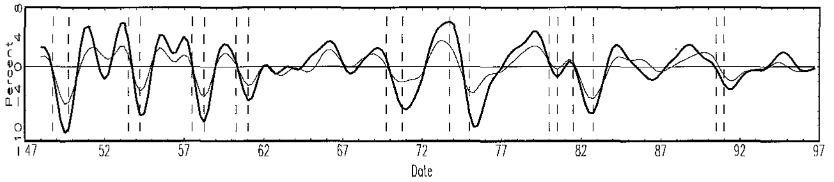

Fig. 3.31. Capacity utilization.

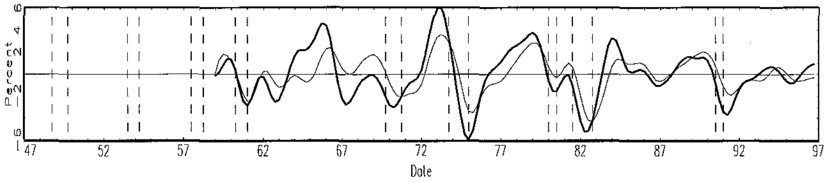

Fig. 3.32. Total factor productivity.

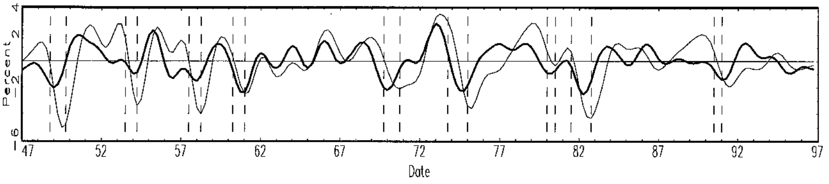

Fig. 3.33. Average labor productivity.

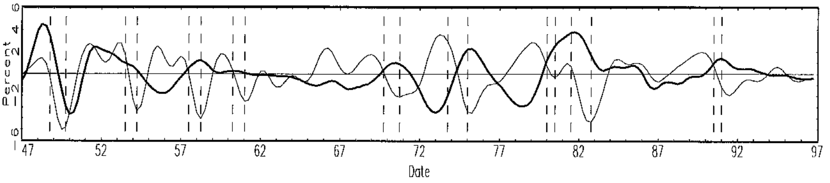

Fig. 3.34. Consumer price index (level).

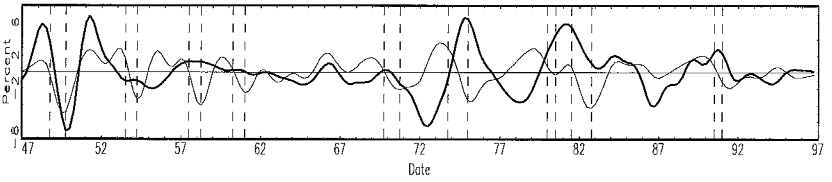

Fig. 3.35. Producer price index (level).

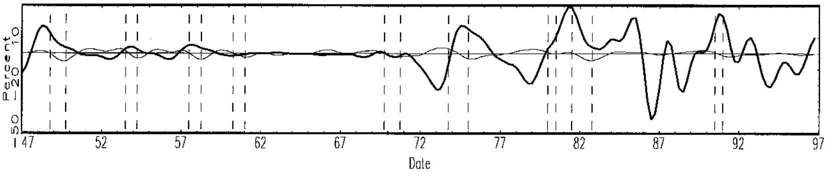

Fig. 3.36. Oil prices.

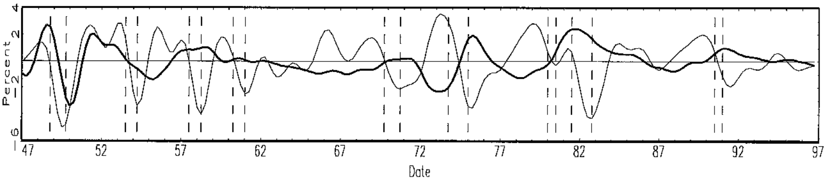

Fig. 3.37. GDP price deflator (level).

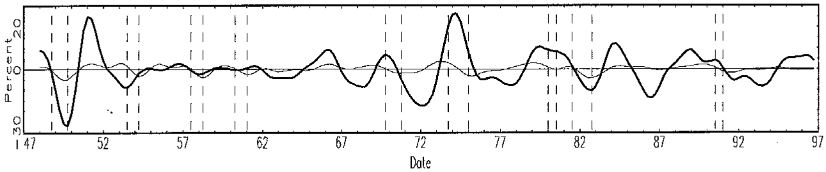

Fig. 3.38. Commodity price index (level).

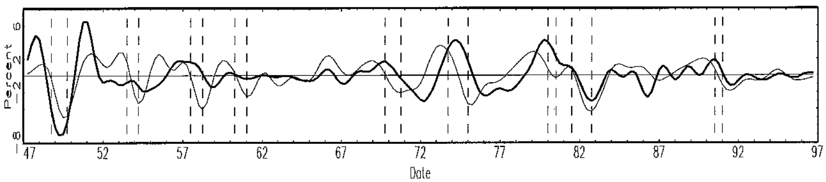

Fig. 3.39. Consumer price index (inflation rate).

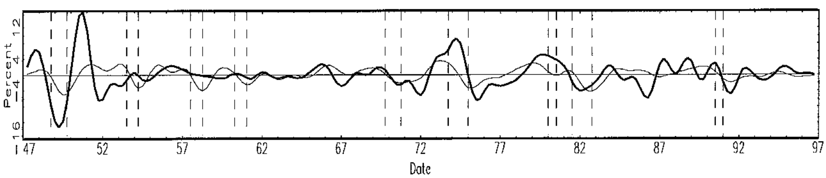

Fig. 3.40. Producer price index (inflation rate).

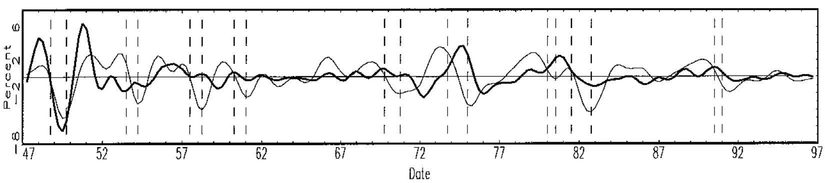

Fig. 3.41. GDP price deflator (inflation rate).

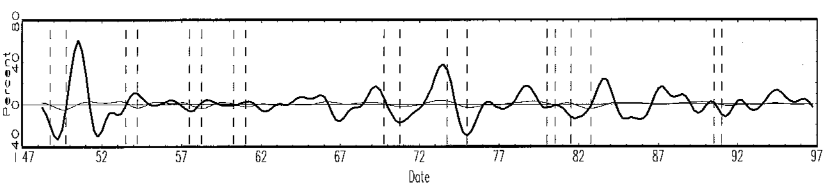

Fig. 3.42. Commodity price index (inflation rate).

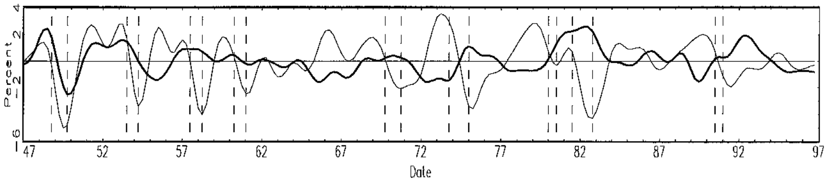

Fig. 3.43. Nominal wage rate (level).

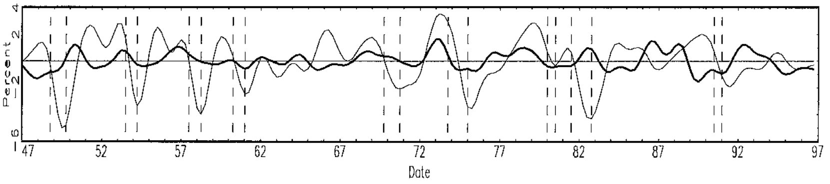

Fig. 3.44. Real wage rate (level).

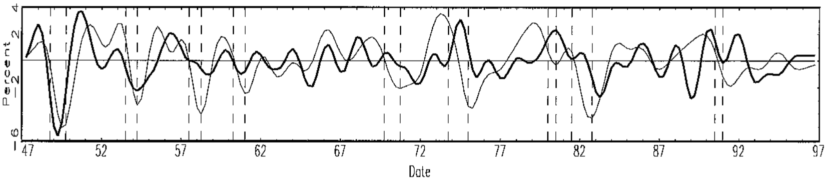

Fig. 3.45. Nominal wage rate (rate of change).

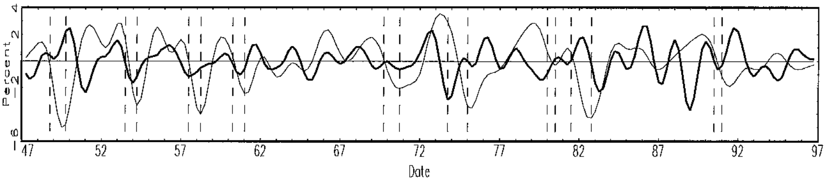

Fig. 3.46. Real wage rate (rate of change).

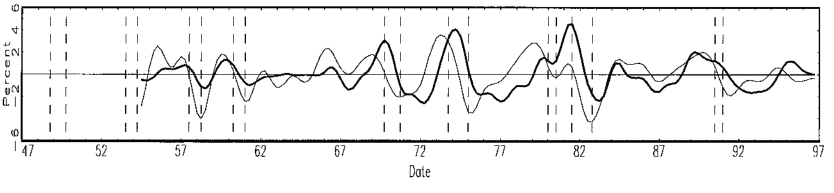

Fig. 3.47. Federal funds rate.

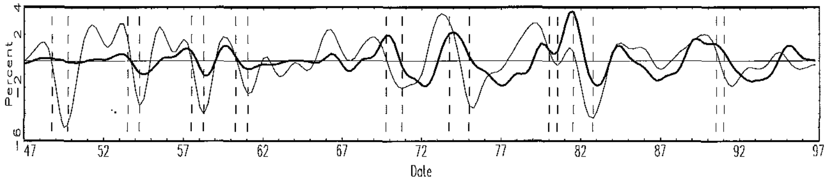

Fig. 3.48. Treasury Bill rate (3 month).

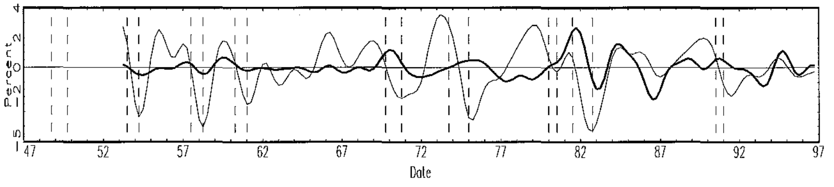

Fig. 3.49. Treasury Bond rate (10 year).

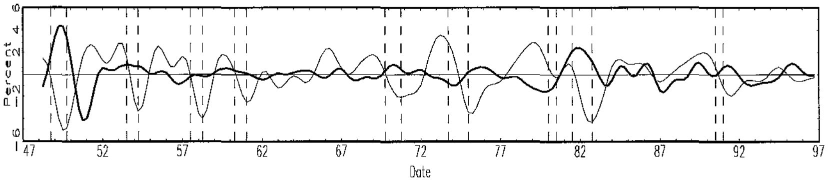

Fig. 3.50. Real Treasury Bill rate (3 month).

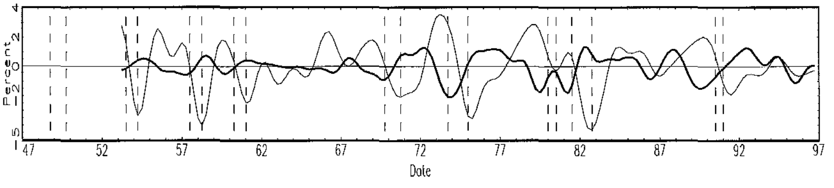

Fig. 3.51. Yield curve spread (long–short).

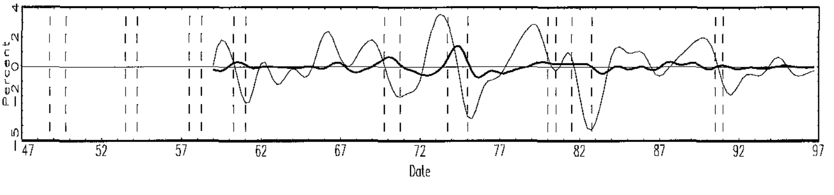

Fig. 3.52. Commercial paper/Treasury Bill spread.

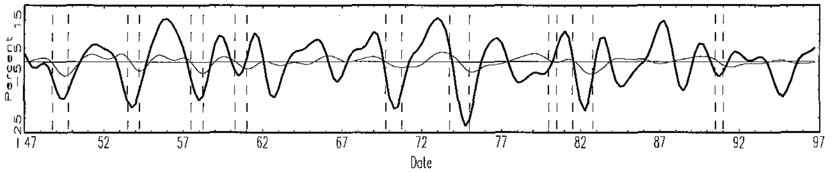

Fig. 3.53. Stock prices.

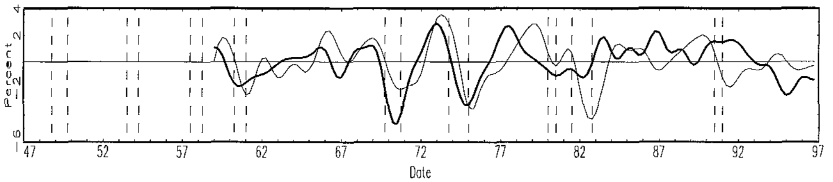

Fig. 3.54. Money stock (M2, nominal level).

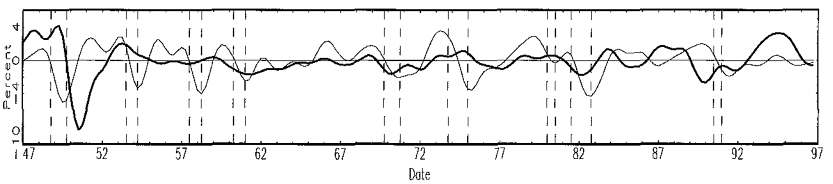

Fig. 3.55. Monetary base (nominal level).

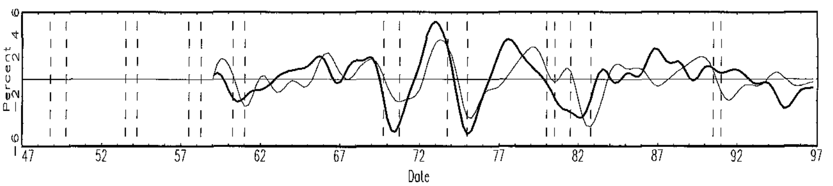

Fig. 3.56. Money stock (M2, real level).

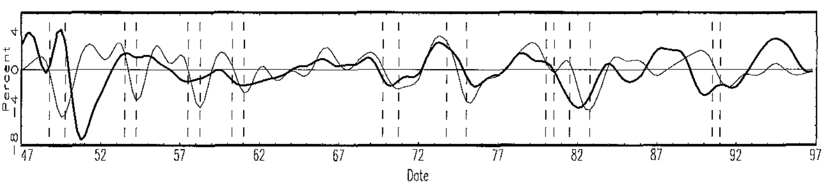

Fig. 3.57. Monetary base (real level).

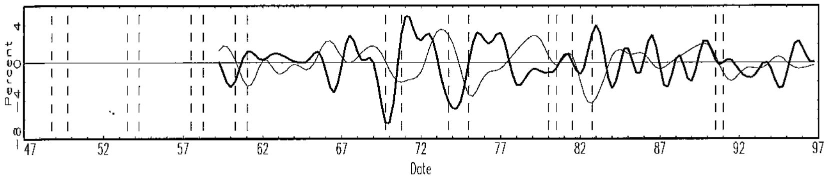

Fig. 3.58. Money stock (M2, nominal rate of change).

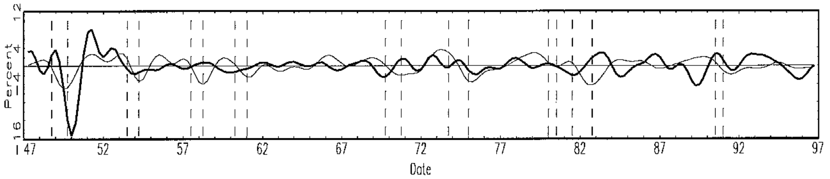

Fig. 3.59. Monetary base (Nominal rate of change).

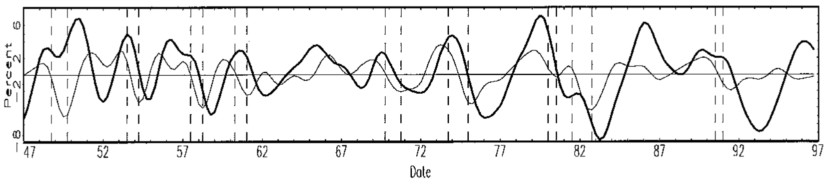

Fig. 3.60. Consumer credit.

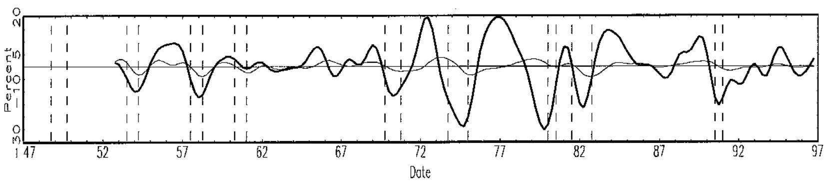

Fig. 3.61. Consumer expectations.

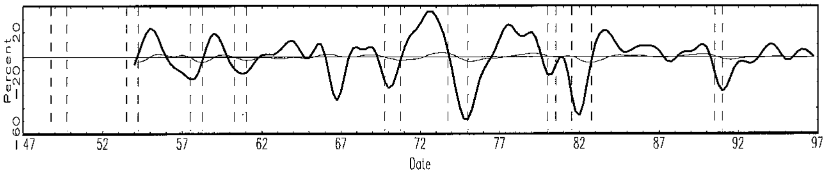

Fig. 3.62. Building permits.

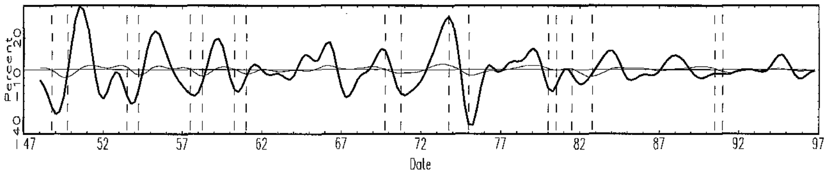

Fig. 3.63. Vendor performance.

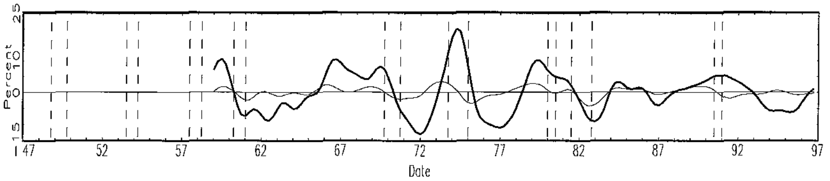

Fig. 3.64. Manufacturers' unfilled orders, durable goods industry.

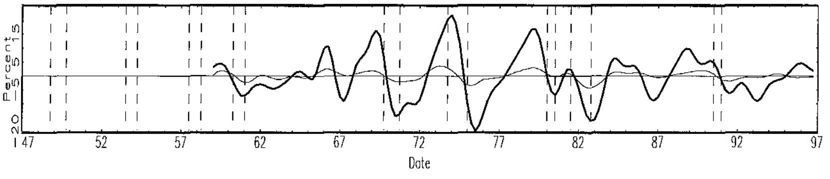

Fig. 3.65. Manufacturers' new orders, non-defense capital goods.

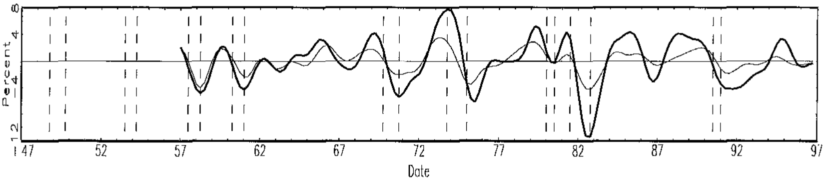

Fig. 3.66. Industrial production, Canada.

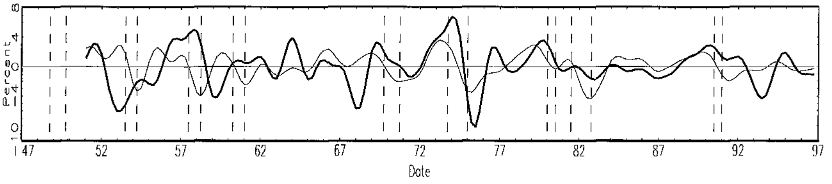

Fig. 3.67. Industrial production, France.

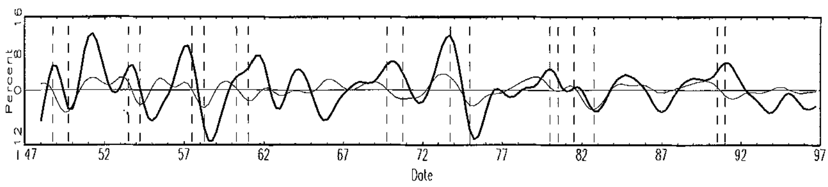

Fig. 3.68. Industrial production, Japan.

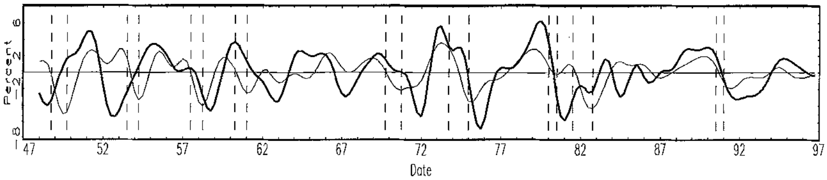

Fig. 3.69. Industrial production, UK.

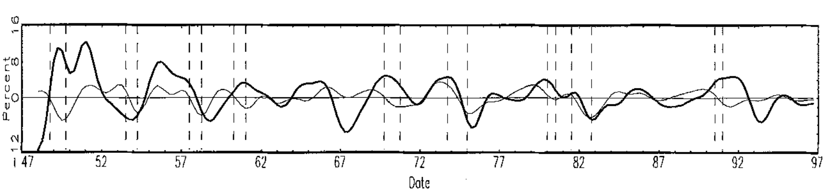

Fig. 3.70. Industrial production, Germany.

Second, the comovements evident in these figures are quantified in Table 2, which reports the cross-correlation of the cyclical component of each series with the cyclical component of real GDP. Specifically, this is the correlation between x_t and y_{t+k}, where x_t is the bandpass filtered (transformed) series listed in the first column and y_{t+k} is the k-quarter lead of the filtered logarithm of real GDP. A large positive correlation at $k=0$ indicates procyclical behavior of the series; a large negative correlation at $k=0$ indicates countercyclical behavior; and a maximum correlation at, for example, $k=-1$ indicates that the cyclical component of the series tends to lag the aggregate business cycle by one quarter. Also reported in Table 2 is the standard deviation of the cyclical component of each of the series. These standard deviations are comparable across series only when the series have the same units. For the series that appear in logarithms, the units correspond to percentage deviations from trend growth paths.

Table 2
Descriptive statistics for cyclical components of series, 1953–1996

Series	Std dev.	Cross correlations with output ($\mathrm{corr}(x_t, y_{t+k})$)												
		−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6
Gross Domestic Product	1.66	−0.29	−0.18	0.03	0.33	0.66	0.91	1.00	0.91	0.66	0.33	0.03	−0.18	−0.29
Sectoral employment														
1. Contract and construction employment	3.75	0.02	0.20	0.39	0.58	0.73	0.80	0.77	0.65	0.44	0.19	−0.04	−0.23	−0.35
2. Manufacturing employment	2.61	−0.06	0.14	0.40	0.67	0.87	0.94	0.84	0.59	0.26	−0.06	−0.30	−0.43	−0.45
3. Finance, insurance and real estate employment	1.01	0.25	0.35	0.43	0.49	0.50	0.46	0.38	0.28	0.15	0.02	−0.10	−0.20	−0.28
4. Mining employment	3.79	0.13	0.19	0.25	0.28	0.25	0.16	−0.00	−0.20	−0.40	−0.53	−0.58	−0.55	−0.45
5. Government employment	0.82	0.51	0.53	0.49	0.43	0.35	0.29	0.23	0.15	0.04	−0.08	−0.21	−0.31	−0.37
6. Service employment	0.83	0.20	0.33	0.49	0.63	0.71	0.69	0.55	0.34	0.08	−0.15	−0.33	−0.44	−0.50
7. Wholesale and retail trade employment	1.20	−0.01	0.21	0.45	0.68	0.83	0.87	0.79	0.60	0.35	0.10	−0.10	−0.24	−0.32
8. Transportation and public utility employment	1.54	0.23	0.42	0.61	0.77	0.83	0.76	0.56	0.26	−0.06	−0.33	−0.49	−0.53	−0.50
NIPA components														
9. Consumption (total)	1.26	−0.39	−0.28	−0.07	0.21	0.51	0.76	0.90	0.89	0.75	0.53	0.29	0.09	−0.06
10. Consumption (nondurables)	1.11	−0.36	−0.24	−0.02	0.25	0.52	0.74	0.83	0.80	0.65	0.43	0.21	0.02	−0.12
11. Consumption (services)	0.64	−0.13	−0.00	0.14	0.31	0.49	0.66	0.78	0.80	0.70	0.51	0.27	0.05	−0.12
12. Consumption (nondurables + services)	0.78	−0.28	−0.15	0.05	0.29	0.55	0.75	0.87	0.85	0.71	0.49	0.25	0.03	−0.13
13. Consumption (durables)	4.66	−0.46	−0.38	−0.19	0.09	0.42	0.70	0.85	0.86	0.73	0.53	0.32	0.15	0.03
14. Investment (total fixed)	4.97	−0.34	−0.19	0.04	0.32	0.61	0.82	0.89	0.83	0.65	0.41	0.18	−0.00	−0.13
15. Investment (equipment)	5.25	−0.06	0.16	0.41	0.65	0.84	0.92	0.88	0.73	0.49	0.23	−0.01	−0.20	−0.31
16. Investment (nonresidential structures)	4.67	0.20	0.40	0.58	0.70	0.74	0.67	0.52	0.30	0.07	−0.14	−0.30	−0.40	−0.44
17. Investment (residential structures)	10.04	−0.49	−0.48	−0.37	−0.18	0.09	0.38	0.62	0.77	0.78	0.69	0.53	0.36	0.20
18. Change in bus. inventories (rel. to trend GDP)	0.38	−0.58	−0.50	−0.32	−0.04	0.28	0.57	0.73	0.72	0.56	0.32	0.08	−0.08	−0.15

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Table 2, *continued*

Series	Std dev.	Cross correlations with output ($corr(x_t, y_{t+k})$)												
		−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6
19. Exports	4.76	0.33	0.42	0.47	0.50	0.48	0.40	0.27	0.09	−0.11	−0.29	−0.43	−0.50	−0.51
20. Imports	4.42	−0.45	−0.28	−0.03	0.27	0.54	0.72	0.78	0.70	0.53	0.34	0.17	0.05	−0.02
21. Trade balance (relative to trend GDP)	0.38	0.54	0.45	0.30	0.10	−0.11	−0.29	−0.42	−0.48	−0.49	−0.48	−0.45	−0.41	−0.35
22. Government purchases	2.49	0.30	0.25	0.22	0.21	0.21	0.19	0.15	0.03	−0.10	−0.20	−0.23	−0.19	−0.09
23. Government purchases (defense)	4.66	0.21	0.18	0.15	0.14	0.12	0.09	0.05	−0.06	−0.18	−0.26	−0.27	−0.20	−0.08
24. Government purchases (non-defense)	1.35	0.21	0.12	0.07	0.08	0.13	0.19	0.22	0.23	0.21	0.18	0.13	0.08	0.01
Aggregate employment, productivity and utilization														
25. Employment (total employees)	1.39	0.07	0.26	0.49	0.72	0.89	0.92	0.81	0.57	0.24	−0.07	−0.31	−0.44	−0.49
26. Employment (total hours)	1.61	−0.06	0.13	0.37	0.63	0.85	0.94	0.88	0.67	0.36	0.03	−0.23	−0.39	−0.45
27. Employment (average weekly hours)	0.37	−0.51	−0.44	−0.24	0.05	0.38	0.66	0.82	0.80	0.64	0.40	0.16	−0.03	−0.15
28. Unemployment rate	0.76	0.13	−0.03	−0.27	−0.55	−0.80	−0.93	−0.89	−0.69	−0.39	−0.07	0.19	0.33	0.37
29. Vacancies (Help Wanted index)	14.52	−0.25	−0.09	0.15	0.43	0.71	0.89	0.93	0.80	0.54	0.23	−0.06	−0.26	−0.38
30. New Unemployment claims	13.19	0.47	0.43	0.27	−0.00	−0.35	−0.67	−0.86	−0.87	−0.71	−0.43	−0.14	0.08	0.21
31. Capacity utilization	3.07	−0.37	−0.23	0.01	0.31	0.63	0.86	0.93	0.83	0.59	0.29	0.02	−0.16	−0.25
32. Total factor productivity	2.29	−0.54	−0.46	−0.29	−0.03	0.27	0.56	0.77	0.86	0.82	0.68	0.50	0.31	0.16
33. Average labor productivity	1.05	−0.49	−0.60	−0.58	−0.41	−0.11	0.24	0.53	0.70	0.72	0.62	0.47	0.32	0.21
Prices and wages														
34. Consumer price index (level)	1.35	0.34	0.24	0.12	−0.04	−0.21	−0.38	−0.51	−0.62	−0.68	−0.67	−0.59	−0.48	−0.34
35. Producer price index (level)	2.26	0.36	0.33	0.27	0.18	0.05	−0.09	−0.24	−0.37	−0.47	−0.54	−0.56	−0.55	−0.50
36. Oil prices	11.12	0.22	0.16	0.09	0.01	−0.08	−0.17	−0.26	−0.35	−0.41	−0.44	−0.42	−0.36	−0.28
37. GDP price deflator (level)	0.91	0.23	0.12	−0.02	−0.18	−0.33	−0.46	−0.54	−0.60	−0.61	−0.59	−0.52	−0.42	−0.30

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Table 2, *continued*

Series	Std dev.	Cross correlations with output ($\mathrm{corr}(x_t, y_{t+k})$)												
		−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6
38. Commodity price index (level)	7.43	0.18	0.28	0.36	0.41	0.41	0.38	0.30	0.18	0.04	−0.11	−0.26	−0.36	−0.43
39. Consumer price index (inflation rate)	1.44	0.34	0.47	0.58	0.64	0.62	0.52	0.35	0.14	−0.08	−0.27	−0.40	−0.48	−0.51
40. Producer price index (inflation rate)	2.64	0.10	0.21	0.33	0.43	0.49	0.49	0.43	0.34	0.21	0.07	−0.05	−0.17	−0.27
41. GDP price deflator (inflation rate)	0.96	0.45	0.55	0.61	0.58	0.48	0.32	0.15	−0.01	−0.14	−0.25	−0.34	−0.41	−0.47
42. Commodity price index (inflation rate)	10.55	−0.28	−0.23	−0.15	−0.03	0.09	0.22	0.33	0.41	0.44	0.39	0.28	0.14	−0.01
43. Nominal wage rate (level)	0.94	0.22	0.13	0.02	−0.09	−0.21	−0.34	−0.45	−0.56	−0.62	−0.62	−0.54	−0.42	−0.27
44. Real wage rate (level)	0.64	−0.16	−0.13	−0.07	0.00	0.08	0.14	0.16	0.14	0.10	0.07	0.05	0.05	0.07
45. Nominal wage rate (rate of change)	1.14	0.31	0.35	0.38	0.41	0.42	0.38	0.29	0.14	−0.05	−0.24	−0.39	−0.47	−0.49
46. Real wage rate (rate of change)	1.10	−0.05	−0.13	−0.18	−0.18	−0.13	−0.05	0.04	0.08	0.08	0.04	−0.00	−0.04	−0.05
Interest rates and stock prices														
47. Federal funds rate	1.47	0.26	0.38	0.50	0.60	0.63	0.56	0.38	0.13	−0.16	−0.41	−0.60	−0.69	−0.71
48. Treasury Bill rate (3 month)	1.09	0.20	0.29	0.40	0.50	0.57	0.54	0.41	0.18	−0.10	−0.38	−0.58	−0.69	−0.71
49. Treasury Bond rate (10 year)	0.71	0.03	0.03	0.07	0.13	0.17	0.16	0.08	−0.07	−0.24	−0.39	−0.49	−0.52	−0.48
50. Real Treasury Bill rate (3 month)	0.71	−0.02	−0.04	−0.05	−0.07	−0.12	−0.19	−0.28	−0.35	−0.38	−0.36	−0.29	−0.20	−0.11
51. Yield curve spread (long–short)	0.76	−0.29	−0.40	−0.52	−0.61	−0.66	−0.64	−0.52	−0.32	−0.07	0.17	0.38	0.52	0.59
52. Commercial paper/Treasury Bill spread	0.32	0.44	0.58	0.66	0.65	0.54	0.33	0.06	−0.20	−0.41	−0.53	−0.54	−0.49	−0.40
53. Stock prices	8.28	−0.23	−0.32	−0.35	−0.28	−0.12	0.10	0.34	0.51	0.57	0.49	0.32	0.11	−0.08
Money														
54. Money stock (M2, nominal level)	1.48	−0.39	−0.35	−0.27	−0.15	0.03	0.22	0.39	0.53	0.59	0.58	0.51	0.40	0.27
55. Monetary base (nominal level)	1.12	−0.06	−0.05	−0.03	0.01	0.07	0.13	0.18	0.19	0.18	0.16	0.13	0.10	0.07
56. Money stock (M2, real level)	2.00	−0.39	−0.30	−0.17	0.00	0.20	0.40	0.57	0.69	0.73	0.71	0.62	0.49	0.33

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Table 2, *continued*

Series	Std dev.	Cross correlations with output ($\mathrm{corr}(x_t, y_{t+k})$)												
		−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6
57. Monetary base (real level)	1.53	−0.18	−0.11	−0.01	0.12	0.25	0.36	0.45	0.49	0.50	0.46	0.40	0.32	0.23
58. Money stock (M2, nominal rate of change)	2.07	−0.08	−0.22	−0.36	−0.48	−0.54	−0.50	−0.38	−0.19	0.01	0.19	0.31	0.37	0.38
59. Monetary base (nominal rate of change)	1.38	−0.01	−0.07	−0.14	−0.18	−0.19	−0.16	−0.08	−0.01	0.05	0.10	0.14	0.17	0.18
60. Consumer credit	3.29	0.30	0.50	0.67	0.75	0.74	0.63	0.46	0.25	0.06	−0.08	−0.15	−0.18	−0.18
Miscellaneous leading indicators														
61. Consumer expectations	9.15	−0.61	−0.64	−0.59	−0.46	−0.25	0.00	0.25	0.44	0.54	0.53	0.44	0.32	0.20
62. Building permits	16.19	−0.51	−0.54	−0.51	−0.41	−0.21	0.07	0.36	0.60	0.74	0.75	0.67	0.52	0.36
63. Vendor performance	10.87	−0.40	−0.40	−0.32	−0.14	0.09	0.34	0.53	0.61	0.58	0.43	0.23	0.04	−0.11
64. Mfrs' unfilled orders, durable goods industry	6.73	0.48	0.60	0.69	0.72	0.70	0.61	0.47	0.28	0.06	−0.15	−0.32	−0.45	−0.50
65. Mfrs' new orders, non-defense capital goods	8.11	−0.09	0.09	0.30	0.53	0.72	0.83	0.83	0.71	0.51	0.26	0.02	−0.16	−0.27
International output														
66. Industrial production – Canada	3.43	−0.19	−0.03	0.19	0.45	0.68	0.84	0.87	0.77	0.56	0.29	0.04	−0.17	−0.30
67. Industrial production – France	2.58	0.03	0.20	0.35	0.44	0.46	0.39	0.26	0.12	−0.01	−0.11	−0.18	−0.21	−0.22
68. Industrial production – Japan	4.46	0.09	0.23	0.37	0.49	0.53	0.49	0.35	0.15	−0.06	−0.23	−0.33	−0.36	−0.33
69. Industrial production – UK	2.60	−0.04	0.11	0.27	0.42	0.51	0.53	0.47	0.39	0.28	0.18	0.10	0.03	−0.02
70. Industrial production – Germany	3.19	0.01	0.08	0.18	0.29	0.38	0.40	0.35	0.24	0.09	−0.07	−0.19	−0.27	−0.31

[a] All statistics are computed using bandpass filtered data. The second column shows the standard deviation of the resulting estimate of the cyclical component. Other columns show the cross correlations of the cyclical component of each series with the cyclical component of GDP, led k periods.

For the other series, the units are the native units of the series as described in the Appendix[7, 8].

The third set of evidence examines the lead–lag relations between these series and aggregate output from a somewhat different perspective. One formulation of whether a candidate series, for example consumption, leads aggregate output is whether current and past data on consumption helps to predict future output, given current and past data on output. If so, consumption is said to Granger-cause output [Granger (1969), Sims (1972)]. The first numerical column in Table 3 reports the marginal R^2 that arises from using five quarterly lags of the candidate series to forecast output growth one quarter ahead, conditional on five quarterly lags of output growth; this is the R^2 of the regression of y_{t+1} on $(y_t, \ldots, y_{t-4}, S_t, \ldots, S_{t-4})$, minus the R^2 of the regression of y_{t+1} on $(y_t, \ldots, y_{t-4})$, where S_t denotes the candidate series. The second numerical column reports the marginal R^2 when the dependent variable is the four-quarter growth in output [$\log(\mathrm{GDP}_{t+4} / \mathrm{GDP}_t)$], using the same set of regressors. The next two columns report these statistics, except that the two variables are reversed; that is, the marginal R^2 measures the extent to which past output growth predicts one- and four-quarter changes in the candidate series, holding constant past values of the candidate series. Care must be taken when interpreting Granger causality test results. Granger causality is not the same thing as causality as it is commonly used in economic discourse. For example, a candidate variable might predict output growth not because it is a fundamental determinant of output growth, but simply because it reflects information on some third variable which is itself a determinant of output growth. Even if Granger causality is interpreted only as a measure of predictive content, it must be borne in mind that any such predictive content can be altered by inclusion of additional variables. Still, the partial R^2s in Table 3 provide a concrete measure of forecasting ability in bivariate relations, with which theoretical economic models should be consistent[9].

Technology and policy have evolved over the postwar period, and this raises the possibility that these bivariate predictive relations might be unstable. The final two columns therefore report the p-values of a test for parameter stability, the Quandt Likelihood Ratio (QLR) test [Quandt (1960)], which tests for a single break in a regression. The column headed "$\mathrm{QLR}_{S \to y}$" reports tests of the hypothesis that the coefficients on the candidate series and the intercept are constant in the predictive regression that produced the one-quarter ahead marginal R^2 reported in the first column. The column headed "$\mathrm{QLR}_{S \to S}$" tests the stability of the coefficients and

[7] To save space, the standard errors for the sample correlations in Table 2 are not reported. The median of all the standard errors of the cross-correlations in Table 2 is 0.10; 10% of the standard errors are less than 0.06, while 10% exceed 0.13.

[8] The empirical results in Table 2 based on the bandpass filter are similar to ones obtained using the Hodrick–Prescott (1981) filter.

[9] The observation that predictive content is not the same thing as economic causality is hardly new. Further discussion of Granger causality can be found in Zellner (1979), Granger (1980) and Geweke (1984).

Table 3
Results from predictive regressions, 1953–1996

Series	$R^2_{y_{t+k}S_t\cdot Y_t}$		$R^2_{S_{t+k}Y_t\cdot S_t}$		$\mathrm{QLR}_{s\to y}$	(Date)	$\mathrm{QLR}_{s\to s}$	(Date)
	$k=1$	$k=4$	$k=1$	$k=4$				
Sectoral employment								
1. Contract and construction employment	0.08	0.21	0.13	0.29	0.24		0.36	
2. Manufacturing employment	0.11	0.19	0.05	0.13	0.15		0.63	
3. Finance, insurance and real estate employment	0.02	0.04	0.01	0.03	0.68		0.01	(74:3)
4. Mining employment	0.10	0.19	0.05	0.02	0.09	(80:1)	0.00	(80:3)
5. Government employment	0.02	0.05	0.03	0.08	0.04	(72:2)	0.01	(89:2)
6. Service employment	0.04	0.04	0.07	0.13	0.32		0.05	(63:1)
7. Wholesale and retail trade employment	0.03	0.03	0.10	0.12	0.47		0.59	
8. Transportation and public utility employment	0.12	0.27	0.22	0.34	0.63		0.00	(82:3)
NIPA components								
9. Consumption (total)	0.13	0.23	0.05	0.12	0.40		0.57	
10. Consumption (nondurables)	0.07	0.08	0.08	0.08	0.62		0.24	
11. Consumption (services)	0.21	0.33	0.04	0.06	0.81		0.00	(68:3)
12. Consumption (nondurables + services)	0.20	0.29	0.03	0.05	0.40		0.00	(72:1)
13. Consumption (durables)	0.03	0.12	0.11	0.29	0.42		0.26	
14. Investment (total fixed)	0.12	0.09	0.08	0.23	0.43		0.95	
15. Investment (equipment)	0.07	0.08	0.12	0.18	0.94		0.95	
16. Investment (nonresidential structures)	0.05	0.10	0.09	0.15	0.56		0.55	
17. Investment (residential structures)	0.17	0.19	0.07	0.28	0.57		0.43	
18. Change in bus. inventories (rel. to trend GDP)	0.11	0.07	0.19	0.11	0.17		0.14	
19. Exports	0.05	0.15	0.11	0.20	0.08	(59:3)	0.56	

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Table 3, *continued*

Series	$R^2_{y_{t+k}S_t \cdot Y_t}$		$R^2_{s_{t+k}Y_t \cdot S_t}$		$\mathrm{QLR}_{s \to y}$	(Date)	$\mathrm{QLR}_{s \to s}$	(Date)
	$k=1$	$k=4$	$k=1$	$k=4$				
20. Imports	0.01	0.03	0.22	0.17	0.33		0.02	(71:3)
21. Trade Balance (relative to trend GDP)	0.05	0.14	0.07	0.09	0.40		0.52	
22. Government purchases	0.02	0.03	0.04	0.09	0.41		0.15	
23. Government purchases (defense)	0.01	0.02	0.01	0.01	0.78		0.00	(66:3)
24. Government purchases (non-defense)	0.06	0.09	0.05	0.03	0.76		0.14	
Aggregate employment, productivity and utilization								
25. Employment (total employees)	0.14	0.24	0.04	0.18	0.64		0.61	
26. Employment (total hours)	0.11	0.22	0.13	0.24	0.15		0.39	
27. Employment (average weekly hours)	0.03	0.03	0.18	0.26	0.06	(75:1)	0.45	
28. Unemployment rate	0.12	0.17	0.05	0.12	0.65		0.74	
29. Vacancies (Help Wanted index)	0.26	0.21	0.02	0.08	0.34		0.95	
30. New unemployment claims	0.12	0.09	0.04	0.06	0.06	(59:3)	0.73	
31. Capacity utilization	0.12	0.15	0.05	0.06	0.19		0.09	(59:2)
32. Total factor productivity	0.07	0.13	0.12	0.25	0.61		0.92	
33. Average labor productivity	0.07	0.11	0.11	0.21	0.83		0.20	
Prices and wages								
34. Consumer price index (level)	0.07	0.21	0.02	0.07	0.20		0.01	(79:2)
35. Producer price index (level)	0.05	0.14	0.04	0.09	0.58		0.00	(73:3)
36. Oil Prices	0.04	0.10	0.03	0.08	0.00	(68:2)	0.00	(85:3)
37. GDP Price deflator (level)	0.04	0.13	0.02	0.06	0.24		0.18	
38. Commodity price index (level)	0.07	0.10	0.05	0.11	0.18		0.02	(73:3)

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Table 3, *continued*

Series	$R^2_{y_{t+k}S_t \cdot Y_t}$		$R^2_{s_{t+k}Y_t \cdot S_t}$		$\mathrm{QLR}_{s \to y}$	(Date)	$\mathrm{QLR}_{s \to s}$	(Date)
	$k=1$	$k=4$	$k=1$	$k=4$				
39. Consumer price index (inflation rate)	0.06	0.18	0.07	0.15	0.20		0.02	(79:2)
40. Producer price index (inflation rate)	0.04	0.13	0.04	0.04	0.58		0.00	(73:3)
41. GDP Price deflator (inflation rate)	0.05	0.11	0.05	0.17	0.24		0.19	
42. Commodity price index (inflation rate)	0.07	0.08	0.02	0.02	0.18		0.03	(73:3)
43. Nominal wage rate (level)	0.05	0.11	0.03	0.07	0.00	(65:2)	0.09	(72:3)
44. Real wage rate (level)	0.01	0.02	0.02	0.02	0.00	(65:1)	0.00	(72:2)
45. Nominal wage rate (rate of change)	0.06	0.11	0.02	0.07	0.00	(65:2)	0.22	
46. Real wage rate (rate of change)	0.01	0.00	0.07	0.07	0.00	(65:1)	0.00	(72:2)
Interest rates and stock prices								
47. Federal funds rate	0.17	0.30	0.09	0.07	0.27		0.00	(79:3)
48. Treasury Bill rate (3 month)	0.12	0.27	0.05	0.04	0.03	(70:1)	0.00	(80:1)
49. Treasury Bond rate (10 year)	0.07	0.15	0.01	0.01	0.01	(59:3)	0.03	(81:1)
50. Real Treasury Bill rate (3 month)	0.03	0.04	0.02	0.04	0.56		0.03	(78:3)
51. Yield curve spread (long–short)	0.10	0.28	0.05	0.11	0.00	(72:1)	0.00	(80:1)
52. Commercial paper/Treasury Bill spread	0.21	0.21	0.01	0.06	0.11		0.00	(74:1)
53. Stock prices	0.10	0.07	0.04	0.07	0.24		0.29	
Money								
54. Money stock (M2, nominal level)	0.07	0.14	0.03	0.09	0.66		0.03	(77:3)
55. Monetary base (nominal level)	0.04	0.09	0.04	0.09	0.02	(72:1)	0.07	(68:3)
56. Money stock (M2, real level)	0.12	0.24	0.02	0.07	0.59		0.09	(74:2)
57. Monetary base (real level)	0.07	0.24	0.04	0.07	0.00	(72:1)	0.07	(81:2)

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Table 3, *continued*

Series	$R^2_{y_{t+k}S_t \cdot Y_t}$		$R^2_{s_{t+k}Y_t \cdot S_t}$		$QLR_{s\to y}$	(Date)	$QLR_{s\to s}$	(Date)
	$k=1$	$k=4$	$k=1$	$k=4$				
58. Money stock (M2, nominal rate of change)	0.04	0.04	0.08	0.13	0.66		0.03	(77:3)
59. Monetary base (nominal rate of change)	0.03	0.06	0.04	0.04	0.02	(72:1)	0.08	(68:3)
60. Consumer credit	0.03	0.01	0.15	0.19	0.99		0.41	
Miscellaneous leading indicators								
61. Consumer expectations	0.10	0.11	0.05	0.16	0.09	(73:3)	0.00	(83:1)
62. Building permits	0.19	0.25	0.06	0.05	0.06	(65:1)	0.71	
63. Vendor performance	0.13	0.08	0.02	0.01	0.38		0.44	
64. Mfrs' unfilled orders, durable goods industry	0.06	0.15	0.04	0.16	0.27		0.14	
65. Mfrs' new orders, nondefense capital goods	0.09	0.17	0.16	0.22	0.63		0.06	(67:3)
International output								
66. Industrial production – Canada	0.13	0.06	0.03	0.04	0.69		0.17	
67. Industrial production – France	0.03	0.05	0.07	0.10	0.10		0.00	(67:3)
68. Industrial production – Japan	0.09	0.10	0.01	0.02	0.28		0.00	(72:1)
69. Industrial production – UK	0.00	0.01	0.12	0.26	0.87		0.15	
70. Industrial production – Germany	0.03	0.05	0.07	0.09	0.86		0.44	

[a] Based on logarithms of the original series (*not* bandpass filtered), subject to the transformations listed in the appendix. Regressions were run from 1953:I–1996:IV, with earlier values for initial conditions. The second and third columns show the partial R^2 from the regression of $y_{t+k}-y_t$ onto $(s_t,\ldots,s_{t-4})$ conditional on $(\Delta y_t,\ldots,\Delta y_{t-4})$ where y_t denotes the logarithm of GDP and s_t denotes the candidate series listed in the first column. Columns four and five show results with the roles of y and s reversed. Column six presents the p-value for the QLR statistic testing the null of stability vs. the alternative that the coefficients on lags of s_t and the constant term are unstable in the regression of Δy_t onto five lags each of s_t and Δy_t. Column seven presents the p-value for the QLR statistic for the univariate autoregression of order 5 for s_t. p-values were computed using the approximation given in Hansen (1997). When the estimated p-value is less than 10%, estimated break dates are shown in parentheses.

intercept in a fifth-order univariate autoregression of the candidate series. In both cases, if the test is significant at the 10% level, then the estimated break date is reported as well [10].

3.2. Discussion of results for selected series

3.2.1. Comovements in employment across sectors

A key notion of the business cycle is that fluctuations are common across sectors. Examination of the statistics for the sectoral employment variables sheds some light on the extent to which activity in different sectors moves with the aggregate cycle. Generally speaking, the cross-correlations in Table 2 indicate a large degree of positive association between these series and the cyclical component of real GDP. The cyclical component of contract and construction employment is more than twice as volatile as the cyclical component of real GDP, as measured by the ratio of the standard deviations of the two filtered series; by this measure, the cyclical component of manufacturing is 50% more volatile than the cyclical component of real GDP. Employment in services, in wholesale and retail trade, and in transportation and public utilities are also strongly procyclical, although the cyclical volatility of these series is much less than for contract and construction employment or for manufacturing employment. All these series have maximal cross-correlations at a lag of one or, for services employment and transportation and public utility employment, two quarters. These patterns are consistent with employment being procyclical with a slight lag and with cyclical fluctuations across industries occurring approximately simultaneously.

The exceptions to this general pattern are employment in finance, insurance and real estate, in mining, and in government; these cross-correlations are distinctly lower than for these other sectors. It is not surprising that government employment exhibits no substantial cyclical movements. Although mining is highly volatile at business cycle frequencies, these movements are generally unrelated to the aggregate business cycle. Mining includes oil and gas extraction, areas in which employment expanded during the sharp energy price increases associated with the 1974–1975 and 1980 recessions.

Not apparent in these plots is the different trend growth rates in sectoral employment. For example, manufacturing employment grew at an average annual rate of 0.3% over

[10] The QLR statistic is computed as follows: First a break date is posited, say date τ. The likelihood ratio statistic, F_τ, testing the null hypothesis of constant regression coefficients, against the alternative hypothesis that the regression coefficients changed at the break τ, is computed by comparing the value of the Gaussian likelihood of the full sample regression to the two relevant subsample regressions. The QLR statistic is $\max_{k_0 \leqslant \tau \leqslant T-k_0} F_\tau$, where k_0 is a trimming value, taken to be 15% of the sample size for the results in Table 3. Although this test was originally developed to detect a single break, it also has good power against alternatives with multiple breaks and slowly evolving coefficients. For a review of the QLR and other break tests, see Stock (1994). P-values for the QLR statistic were computed using the approximation developed by Hansen (1997).

the sample period, while service employment grew at an average annual rate of 4.0%. This produced large changes in the shares of employment in these sectors: the share of total employment in manufacturing fell from 36% in 1947 to 15% in 1996, while the share for services rose from 11% to 29%. This shift from employment in a cyclically volatile sector to employment in a less cyclically volatile sector may be partially responsible for the reduction in the variability in the business cycle variability in aggregate output (Figure 2.5) and aggregate employment (Figure 3.25) over the sample period. See Zarnowitz and Moore (1986) and Denson (1996) for a more detailed discussion of the effect of industrial composition on the business cycle.

3.2.2. Consumption, investment, inventories, imports and exports

Consumption, investment, inventories, and imports are all strongly procyclical. Based on the cross-correlations in Table 2, consumption moves approximately coincidently with the aggregate cycle, but the cyclical volatility of its components varies considerably. Consistent with the smoothing implied by the permanent income hypothesis, consumption of services is considerably less volatile than output over the cycle. In contrast, consumption of durables (which, importantly, measures purchases of durable goods rather than the service flow from those durable goods) is strongly procyclical and is far more cyclically volatile than real GDP or the other consumption measures. This too is consistent with consumers smoothing the stream of services derived from durables but with purchases of durables being concentrated in good economic times.

Some observers have suggested that exogenous shifts in consumption have been the proximate causes of certain cyclical episodes in the United States. For example, Gordon cites the 1955 auto boom as an example of an essentially unexplainable consumption shock which spurred an investment boom, which in turn led to particularly strong economic growth [Gordon (1980), p. 117]. Similarly, Blanchard (1993) puts most of the blame for the 1990–1991 recession on a negative consumption shock, presumably in reaction to the invasion of Kuwait by Iraq. These explanations suggest that changes in consumption might predict changes in output. Alternatively, consumers might observe an exogenous shock to the economy and accordingly adjust their consumption levels; if this adjustment occurs more rapidly on average than the associated adjustment in output, then changes in consumption will help to predict changes in output, although not because of exogenous movements in consumption but rather because of the exogenous shocks observed by consumers. The marginal R^2s in Table 3 are consistent with both views. However, the large values of these statistics should be interpreted cautiously, because many components of quarterly services consumption in particular are constructed by judgmental interpolation from ex post annual surveys and thus incorporates future data; this would tend to produce spurious Granger causality.

Investment in equipment and nonresidential structures is procyclical with a lag, based on the cross-correlations in Table 2. These series also lag output in the sense of Table 3: they produce only moderate improvements in forecasts of output, but output produces large improvements in forecasts of these series and of total investment, especially at the one-year horizon. The cyclical component of the change in business inventories relative to trend GDP is procyclical and large, with a standard deviation that approximately 25% of the total cyclical standard deviation in GDP. In a mechanical sense, this means that changes in business inventories, which constitute but a small fraction of total GDP, account for one-fourth of the cyclical movements in GDP [see Blinder and Holtz-Eakin (1986)].

Investment in structures, especially residential structures, is procyclical and highly volatile. Housing can be thought of as an asset that provides a net revenue stream far into the future or as a consumer durable with a very low depreciation rate. Either way, housing prices will be interest sensitive and sensitive to fluctuations in the aggregate cycle, especially if potential homeowners face liquidity constraints. The strong procyclicality of housing and its good predictive properties for output in Table 3 are consistent with this interpretation.

Although imports are strongly procyclical, exports tend not to move strongly with the aggregate business cycle. On net, this leaves the trade balance countercyclical, as found by de la Torre (1997) for many other developed economies.

It is noteworthy that government nondefense purchases exhibit considerable volatility at business cycle frequencies, but that their movements are largely unrelated to the business cycle. Moreover, government purchases makes a negligible contribution to forecasting fluctuations in real GDP at either the one- or four-quarter horizon. This is consistent with exogenous nondefense spending not being a significant source of the postwar US business cycle [11].

3.2.3. Aggregate employment, productivity and capacity utilization

Like sectoral employment, total employment, employee hours and capacity utilization are strongly procyclical, and the unemployment rate is strongly countercyclical. The employment series lag the business cycle by approximately one quarter, while the capacity utilization rate is approximately coincident with the cycle.

Other labor market series tend to lead the cycle, however, as measured by their cross-correlations and/or by the marginal R^2s in Table 3. For example, the vacancy rate has considerable marginal predictive content for real GDP growth. This accords with Blanchard and Diamond's finding that the vacancy rate has substantial predictive content for new hires, given the lagged unemployment rate and lagged hires [Blanchard

[11] Another explanation which is consistent with these correlations is that non-defense spending is fine-tuned optimally to stabilize output, which would imply that the spending series has no predictive output for future fluctuations in output. While a theoretical possibility, in practice this would require a reaction time and a degree of central control that is implausible in light of the slow and bureaucratic procurement process through which government purchases in the United States are actually made.

and Diamond (1989)][12]. Also, flows into unemployment, as measured by new claims for unemployment insurance, leads the cycle by one quarter in the sense of Table 2.

Both total factor productivity and labor productivity are procyclical and slightly lead the cycle in the sense of Table 2. Both series also make modest contributions to forecasts of output.

3.2.4. Prices and wages

The statistics presented here make it possible to address two questions. First, are prices procyclical or countercyclical? Prices are commonly treated as procyclical, but recent studies by Kydland and Prescott (1990), Cooley and Ohanian (1991), and Backus and Kehoe (1992) present evidence that the cyclical component of prices are countercyclical. Second, are the business cycle properties of different price series similar or different?

First, consider the broad price measures (the Consumer Price Index (CPI) and the GDP deflator). Consistent with the findings of Kydland and Prescott (1990) and Backus and Kehoe (1992), the cyclical component of the level of prices is countercyclical. The evidence in Table 2 suggests that these broad measures lead the cycle by approximately two quarters. This correlation is strong (the cross-correlation with the CPI at a lead of two quarters is −0.68, for example), and inspection of the figures suggests that this countercyclical pattern has been relatively stable since 1953.

Although these price levels are countercyclical, the cyclical components of the rates of inflation of these prices are strongly procyclical and lag the business cycle. This pattern is clearly apparent in the figures: the cyclical component of the CPI inflation rate declines during and after each of the eight recessions since 1953. This distinction between correlations in levels and correlations in first differences matters for the implications of these facts for economic models; see for example Ball and Mankiw (1994).

This pattern of leading, countercyclical price levels and lagging, procyclical rates of inflation is present for some but not all factor prices. The nominal wage index exhibits a pattern quite similar to the CPI. One explanation for this is the contractual indexing of nominal wage to the CPI, a practice that became widespread during the inflation of the 1970s. In contrast, real wages have essentially no contemporaneous comovement with the business cycle. The cross-correlations suggest that changes in real wages lag the cycle by approximately one year, but these cross-correlations are low. Real wages have no predictive content for output growth at the one- or four-quarter horizons. The

[12] Blanchard and Diamond (1989, footnote 24) use a modification of the help-wanted index, which adjusts for trend discrepencies between the help-wanted index and vacancies. These adjustments affect the trend level of the series, which is filtered out of the bandpass filtered version of the series that forms the basis of the results in Table 2.

weak cyclical movements of real wages has been viewed as poorly explained by a variety of macroeconomic theories [see Christiano and Eichenbaum (1992)] [13].

3.2.5. *Asset prices and returns*

Nominal interest rates are contemporaneously procyclical. The cross-correlations in Table 2 also indicate that interest rates are a leading indicator, with positive values of interest rates associated with cyclical declines in output approximately two to six quarters in the future. The leading indicator properties of interest rates, particularly the short-term rates, are also evident in Table 3: both three-month Treasury bills and the Federal Funds rate produce improvements in R^2s exceeding 0.25 at the one-year horizon. Real rates are less cyclical than nominal rates; Table 2 suggests that they are weakly countercyclical and slightly leading, but Table 3 suggests that they have little predictive content for GDP growth at either the one- or four-quarter horizon.

The spread between long- and short-term interest rates has long been recognized as a leading indicator: an inverted yield curve (short rates exceeding long rates) is associated with subsequent declines in economic activity [14]. Although the cross-correlations in Table 2 suggest that the yield curve actually lags the cycle, the considerable predictive content of the yield curve for real GDP at the one and especially four-quarter horizon is evident by the large marginal R^2s in Table 3. It is also noteworthy that this forecasting relationship is unstable: the QLR test rejects at the 1% level and a break is estimated to have occurred in 1972. The risk premium for holding private debt, as measured by the spread between six-month commercial paper and the six-month US Treasury bill rate, is countercyclical with a lead of approximately one year. This series also has considerable predictive power for output [see Friedman and Kuttner (1993) for additional discussion and interpretation].

The statistics for stock prices must be interpreted with particular care. A model that provides a good first approximation is that log stock prices follow a martingale, so that deviations of stock returns from their mean are unforecastable. Thus as discussed in Section 3.1, the strong cyclical fluctuations in stock prices should be understood as a consequence of the bandpass filter; by retaining only fluctuations at these frequencies, the filtered version of stock prices will not be a martingale. Still, it is noteworthy that this filtered version is moderately procyclical and indeed somewhat leads the cycle. These cross-correlations and the marginal R^2s are consistent with stock prices being a leading indicator of the cycle, which in turn is consistent with the principal that stock

[13] Barsky, Parker and Solon (1994) provide evidence that the lack of relation between the real wage and the business cycle is in part an artifact of how the real wage index is constructed, in which the index weights fail to capture changes in the composition of employment over the business cycle. Holding composition constant, they conclude that real wages are procyclical.

[14] See Estrella and Hardouvelis (1991) and Stock and Watson (1989). As of this writing, the spread between ten year US Treasury Bonds and the Federal Funds rate has been included in the composite Index of Leading Economic Indicators [The Conference Board (1996)].

prices reflect market participants' expectations of discounted future earnings. Notably, movements in real GDP do not substantially help to predict stock returns, a finding consistent with view that log stock prices follow a martingale.

3.2.6. Monetary aggregates

In theory, money plays an important role in the determination of the price level and, because of various nominal frictions in the economy, can result in movements in real quantities. In practice, quantifying this link is difficult because it requires defining and measuring "money". The postwar period has seen extraordinary growth in the financial sector and in the diversity of financial instruments available to consumers and businesses, and these changes have made the task of measuring money a difficult one that has attracted considerable attention at central banks over the past decades.

Here, we consider two measures of money, the monetary base, a variable which is essentially under the short-term control of the Federal Reserve Bank, and a broader aggregate, M2. Over the full sample, the log level of nominal M2 is procyclical with a lead of two quarters, and the nominal monetary base is weakly procyclical and leading. Inspection of the plot of their cyclical component, however, suggests that these procyclical movements were more pronounced before 1980 than after; indeed, the contemporaneous cross-correlation between the cyclical components of nominal M2 and real GDP is 0.6 for 1959–1979, but this drops to –0.1 for 1980–1996. In contrast, the growth rates of nominal M2 and the nominal monetary base are countercyclical and lagging. The real monetary aggregates are more strongly procyclical than their nominal counterparts, but this relationship too has weakened since the mid 1980s.

There is a large literature on the empirical relationship between money and output. Over the past two decades, much of this literature has focused on whether money Granger-causes output [seminal works are Sims (1972, 1980)]. The results in Table 3 indicate that the real monetary base and real M2 both have predictive content for output. Like many forecasting relations with narrow definitions of money, those with the monetary base are unstable: the QLR test rejects all specifications with base money at the 1% level, and identifies a break in 1972. Stability is not rejected for the specifications with the broader aggregate, M2. Although the monetary aggregates have predictive power for output in these bivariate relations, once one controls for other aggregate variables, in particular interest rates, the predictive content of real or nominal monetary aggregates for real output is reduced, although nominal M2 is not eliminated from forecasts of nominal income [see Friedman and Kuttner (1992) and Feldstein and Stock (1994)].

3.2.7. Miscellaneous leading indicators

Over the years, economic forecasters have found many series which are precursors of the aggregate cycle but which do not fit neatly into the previous categories. The seminal work on leading economic indicators is Mitchell and Burns (1938). The cyclical properties of a few such leading indicators are summarized in Tables 2 and 3. Building permits (housing starts) are a measure of future housing expenditures, and new orders are a measure of future expenditures on durable goods; both series are both procyclical and have considerable predictive content for output. Expectations of future economic variables play an important role in modern macroeconomic theories, and consumer expectations are procyclical, lead the aggregate cycle, and have some predictive content for output.

3.2.8. International output

The economies of various countries are linked through trade in goods and services, financial markets, and the diffusion of technology. For these and other reasons, developed economies have cyclical components that have some common comovements. Some of these comovements with the US cycle are summarized in Tables 2 and 3 for Canada, France, Japan, the United Kingdom, and Germany. The Canadian and US economies are closely linked, and not surprisingly the Canadian and US business cycles are highly correlated. The cycles in the other four countries are weakly positively correlated with and lag the US cycle. US output predicts UK output, but output from none of these five countries substantially helps to predict US output.

These statistics only scratch the surface of the many important issues involved in the empirical analysis of international cyclical fluctuations, including the international transmission of business cycles, international comovements of consumption, the effect of common supply shocks, and risk sharing using foreign asset markets. These issues are beyond the scope of this survey of the US business cycle, and interested readers are referred to Backus and Kehoe (1992) and Baxter (1995).

3.2.9. Stability of the predictive relations

The QLR tests in Table 3 suggest a considerable amount of instability in these time series models. The hypothesis of stability is rejected at the 10% level in 18 of the 70 bivariate predictive relations, and in 36 of the 70 univariate autoregressions [15]. If the relationships were stable, only seven rejections would be expected by random chance at the 10% level. In the bivariate relations, the rejections are concentrated in regressions involving the monetary base, wage rates, some measures of employment and unemployment, and some interest rates. Although the estimated breaks do not occur at single date, most of the breaks in the bivariate models are estimated to have occurred in the late 1960s or early 1970s, a period associated with the reduction in the trend growth rate of the economy as seen in Figure 2.6.

[15] Stock and Watson (1996b) find similar evidence of instability in their examination of 5700 bivariate relations using US monthly data.

4. Additional empirical regularities in the postwar US data

4.1. The Phillips curve

Over the past 40 years the term "Phillips curve" has been used to denote three distinct characteristics of the unemployment–inflation relationship. The first is a stable statistical relationship between the unemployment rate and the level of inflation [Phillips (1958), Samuelson and Solow (1960)]. The second is a stable statistical relationship between the unemployment rate and changes in inflation (or more generally unanticipated inflation) [Gordon (1982a, 1982b)]. The third is a structural relationship describing the simultaneous adjustments of both real activity and prices to changes in aggregate demand [Friedman (1968); Phelps (1967); Lucas (1972); Taylor (1980)]. In this subsection we present evidence relating to the first two concepts of the Phillips curve as an empirical regularity. There is a large literature related to the third concept of the Phillips curve as a structural economic relation. The key issue in this literature is the econometric identification of aggregate demand shocks. There is a large literature on identifying aggregate shocks, most recently in the context of structural vector autoregressions [see King and Watson (1994) for a discussion in the context of the Phillips curve], but these matters go beyond the scope of this chapter and are not taken up here.

In this subsection we address three questions. First, is there a stable negative relationship between the unemployment rate and the rate of inflation, as first documented by Phillips (1958) for the UK and Samuelson and Solow (1960) for the US? Our answer to this question is a qualified no: while there is no stable relationship between the levels of inflation and unemployment, there is a clear and remarkably stable negative relation between the *cyclical components* of inflation and unemployment. Second, is there a stable negative relationship between the unemployment rate and future *changes* in the inflation rate? Our answer to this question is yes: there are large marginal R^2s associated with adding lags of the unemployment rate to an autoregression of changes in inflation, and the resulting forecasting relation is stable over the sample period. Third, does the empirical Phillips curve provide a useful basis for estimating the level of unemployment at which inflation is predicted to be constant, that is, the Non-Accelerating Inflation Rate of Unemployment (NAIRU)? Here, the answer is a qualified no: estimates of the NAIRU obtained from conventional specifications of the Phillips curve suggest that the NAIRU is well-defined empirically and has been fairly stable over the postwar period, but that the actual value of the NAIRU is imprecisely estimated.

Figure 4.1 is a scatterplot of the level of the unemployment rate and the quarterly inflation rate (computed from the CPI) from 1953:I to 1996:IV. There appears to be little relationship between the series, and indeed the simple correlation between the variables is 0.16. If attention is restricted to sub-periods, however, a negative but unstable relationship emerges (in Figure 4.1, data for the three periods 1953–1970, 1971–1983 and 1984–1996 are plotted using different symbols). Evidently there was

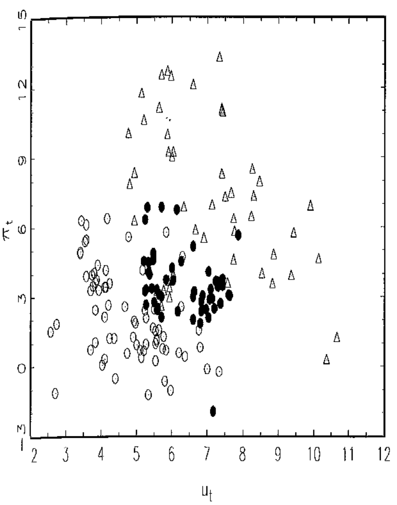

Figure 4.1. Scatterplot of the unemployment and inflation rates in levels. Open circles, 1953–1970; triangles, 1971–1983; solid circles, 1984–1996.

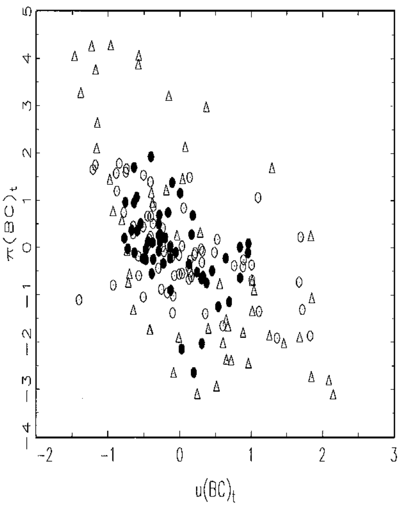

Figure 4.2. Scatterplot of cyclical components of the unemployment and inflation rates. Open circles, 1953–1970; triangles, 1971–1983; solid circles, 1984–1996.

a negative relation in the 1950s and 1960s, but this relation shifted out dramatically in the 1970s, and shifted back somewhat during the 1980s. Controlling for these shifts, there is relative stability: the sample correlation of the observations from 1953–1970 and 1971–1983 is –0.4, and falls to –0.3 in the 1984–1996 sub-period.

This suggests that inflation and the unemployment rate may be negatively related over suitably short horizons, but that this relationship is obscured by their longer-run movements. To investigate this, Figure 4.2 presents a scatterplot of the cyclical components of the unemployment and inflation rates over the same period, computed using the bandpass filter. Recall from Section 2.2 that the bandpass filter eliminates the long-run (zero frequency) movements in these series. A clear negative relation is apparent. Moreover the relationship appears to be quite stable over the sub-samples; the full-sample correlation is –0.6 and ranges from –0.4 to –0.65 in the sub-sample periods. Taken together, Figures 4.1 and 4.2 suggest that there is not a stable relation between the levels of the unemployment and inflation rates but that there is a stable negative relation between the cyclical components of these series.

Figure 4.3 is a scatterplot of the annual change in the annual inflation rate over the next year (more precisely, $100[\ln(\mathrm{CPI}_{t+4}/\mathrm{CPI}_t) - \ln(\mathrm{CPI}_t/\mathrm{CPI}_{t-4})]$) against the current unemployment rate. There is a negative relationship, although it is not quite as distinct as the relationship between the bandpass filtered levels of the series shown in Figure 4.2.

These scatterplots fail to account for the possibly lengthy dynamic adjustment of prices and unemployment to macroeconomic shocks. Nevertheless, the main lessons

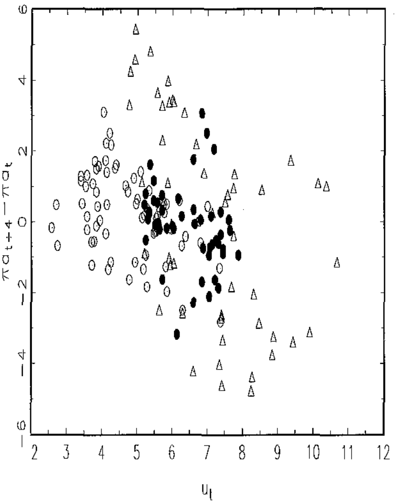

Fig. 4.3. Scatterplot of the unemployment rate and changes in future inflation. Open circles, 1953–1970; triangles, 1971–1983; solid circles, 1984–1996.

from Figures 4.2 and 4.3 are supported by regressions that predict future inflation using lags of both the unemployment rate and inflation. The marginal R^2s from adding four lags of the unemployment rate to a regression predicting inflation over the next k quarters using four quarterly lags of inflation is 0.18 for predicting inflation $k = 1$ quarter ahead, 0.23 two quarters ahead, 0.28 four quarters ahead, and 0.25 eight quarters ahead (these are in-sample marginal R^2s for regressions run from 1953:I to 1996:IV). Moreover these regressions are stable: the QLR statistic for the one-step ahead forecasting regression has a p-value of 27%. Evidently the unemployment rate has considerable predictive content for annual inflation, and the QLR statistic fails to detect instability in this relationship.

The relative stability of the scatterplot in Figure 4.3 has led some to treat the NAIRU as an empirical expression of Friedman's notion of a natural rate of unemployment [Friedman (1968)]. Accordingly, this version of the Phillips curve has come to provide a guidepost for monetary policy: if unemployment persists too long below the NAIRU, inflation is predicted to increase. There is a significant literature on the estimation of the NAIRU, see for example Gordon (1982b, 1998) and the references therein. Currently, regression formulations of the Phillips curve typically include various control variables relating to specific factors such as the 1972–1974 wage and price controls and the energy price shocks of the 1970s in addition to lags of unemployment and inflation. Accordingly, a standard formulation of the Phillips curve is

$$\Delta\pi_{t+1} = \beta(\mathrm{L})(u_t - \bar{u}) + \gamma(\mathrm{L})\Delta\pi_t + \delta(\mathrm{L})X_t + \epsilon_t, \tag{4.1}$$

where $\beta(\mathrm{L})$, $\gamma(\mathrm{L})$, and $\delta(\mathrm{L})$ are lag polynomials, u_t is the unemployment rate, π_t is the rate of inflation, X_t denotes the supply shock control variables, and $\bar{u}$ is the NAIRU. In Equation (4.1), the NAIRU is assumed to be constant; alternatively, the NAIRU could

Table 4
Estimates of the slope of the Phillips curve and of the NAIRU, 1953–1996[a]

Inflation series NAIRU Model	CPI constant	CPI spline	GDP deflator constant	GDP deflator spline
$\beta(1)$	−0.204	−0.367	−0.167	−0.237
(standard error)	(.078)	(.121)	(.064)	(.105)
Estimates of NAIRU ($\bar{u}_t$) and 95% confidence intervals				
70:1	6.11	5.77	5.96	6.31
	(4.91, 7.73)	(4.56, 8.02)	(4.69, 7.39)	(4.86,12.48)
80:1	6.11	7.05	5.96	6.63
	(4.91, 7.73)	(5.38, 8.40)	(4.69, 7.39)	(2.52, 8.28)
90:1	6.11	6.47	5.96	6.29
	(4.91, 7.73)	(4.63, 8.42)	(4.69, 7.39)	(2.76, 9.19)
F-test (p-value) of constant NAIRU	NA	1.53 (0.171)	NA	0.969 (0.448)

[a] Regression: $\Delta\pi_t = \beta(L)(u_{t-1} - \bar{u}_t) + \delta(L)\Delta\pi_{t-1} + \gamma(L)X_t + \epsilon_t$
The regressions were estimated using quarterly data over the period 1953:I–1996:IV. Unemployment is the total civilian unemployment rate. All regressions contain four lags each of the change of inflation and the unemployment rate. The spline model of the NAIRU specifies the NAIRU as evolving according to a cubic spline, with three equidistant knot points. $\beta(1)$ is the sum of the coefficients on lagged unemployment. The confidence intervals for the NAIRU are constructed using Fieller's method. In all specifications, one lag of a food and energy supply shock variable (the difference between food and energy inflation and general inflation) and a variable for the Nixon price controls (taken from Gordon 1982b) were included. For additional discussion and references see Staiger, Stock and Watson (1997).

be expressed as a flexible function of time to allow for potential time variation in the NAIRU.

Table 4 reports estimates of Equation (4.1) for different measures of inflation and for different specifications of the NAIRU. These estimates indicate that $\beta(1)$ (the sum of the coefficients on u_t and its lags) is statistically significant, and in this sense the NAIRU is well defined. There is some evidence that the NAIRU has changed over the postwar period; however, this time variation is moderate, within a range of approximately one percentage point of unemployment. Unemployment and its lags are strongly significant in these regressions.

These results reinforce the conclusion that there is a stable Phillips relation between changes of inflation and unemployment. However, the resulting estimates of the NAIRU are imprecise: most of the actual values of unemployment over this period fall within the reported 95% confidence intervals for the NAIRU. Somewhat more precise estimates of the NAIRU can be obtained using certain (but not all) narrowly defined measures of core inflation. Generally speaking, however, the main findings of a stable Phillips relation, with a NAIRU that is imprecisely measured, and unemployment having considerable marginal forecasting content for inflation are highly robust across specifications, see Staiger, Stock and Watson (1997).

4.2. Selected long-run relations

The focus so far has been on fluctuations over business cycle frequencies. There are however some important relations among macroeconomic variables that might be expected to hold over long horizons, although their relationship might be less transparent over short horizons. In this section, we look at three such empirical relationships: long-run money demand; the spread between short- and long-term interest rates; and the so-called balanced growth relations, which refer to consumption–income and investment–income ratios.

The key hypothesis that permits examining these long-run relations is that linear combinations of the series based on these long-run relations are considerably less persistent than are the series themselves. Thus, although the rates on 90-day Treasury bills and 30-year Treasury bonds are each highly persistent series, the spread (or difference) between these two rates is less persistent and tends to revert to a constant mean. One formulation of this idea is that the long and short rate both have a unit root, but that the spread does not; in this case, the long and short rates are said to be cointegrated, with a cointegrating coefficient of one [Engle and Granger (1987)]. There is now a vast literature on cointegration; see Watson (1994b) for a survey.

The treatment here focuses on examining the stability and reduced persistence of these long-run relations, rather than on the formal methods of cointegration. The main measure of persistence used here is the magnitude of the largest autoregressive roots in the individual series and in the residual from the long-run relation. If this root is large, then shocks to that series are highly persistent; if the root is one, then the effect of that shock persists into the infinite future. On the other hand, if the root is small, then the process decays quickly after a shock.

4.2.1. Long-run money demand

The relation between money and output over the long run has been of enduring interest in economics. Annual data on the logarithm of M1 velocity (the ratio of output, here GNP to M1) and the commercial paper rate over the period 1915–1996 are plotted in Figure 4.4. Evidently both the commercial paper rate and velocity exhibit trend movements, although this trend is variable. At a visual level, there appears to be considerable long-run comovement between these two series, although the comovements over short horizons are less strong, see Lucas (1988).

Estimates of the long-run relation between the logarithm of real money, the logarithm of real GNP, and the nominal interest rate are given in Table 5. Estimates are computed using two methods: a cointegrating regression [specifically, the dynamic OLS (DOLS) method of Stock and Watson (1993)], and a method that does not require exact

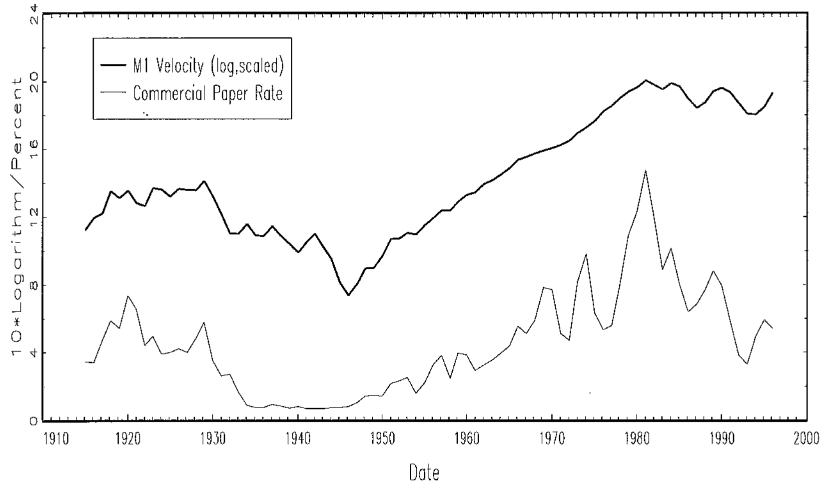

Fig. 4.4. M1 and the commercial paper rate.

cointegration [the full information maximum likelihood method of Stock and Watson (1996a)]. The residuals from the FIML estimates are plotted in Figure 4.5. The point estimates in Table 5 indicate that there is an income elasticity of approximately 0.9 and an interest semi-elasticity of approximately –0.1, values which accord with other estimates of these long-run coefficients [see Hoffman and Rasche (1991)]. In contrast to the series themselves, it is evident from Figure 4.5 that the residuals from the long-run money demand relation exhibit considerable mean reversion. The past twenty years have seen historically large deviations from this long-run relation, but these deviations appear to persist for only a few years.

The standard errors computed using the DOLS method are predicated on the long-run money demand being a cointegrating regression, with log output (y_t) and the interest rate (r_t) having an exact unit root. However, the assumption of an exact unit root is not plausible for interest rates and need not be true for output, so these standard errors are questionable. Alternative 95% confidence regions that do not rely on the

Table 5
Estimates of long-run money demand, 1921–1996[a]

Estimation method	β_y		β_r	
Dynamic OLS (DOLS, Stock and Watson 1993)	0.868	(0.070)	–0.094	(0.018)
Full information maximum likelihood (FIML)	0.874		–0.096	

[a] $m_t = \alpha + \beta_y y_t + \beta_r r_t + u_t$.
Both DOLS and FIML are implemented using two leads and lags of the annual data. For the DOLS estimates, the regressions are run from 1918 to 1994, with earlier values used for initial conditions. Standard errors are in parentheses.

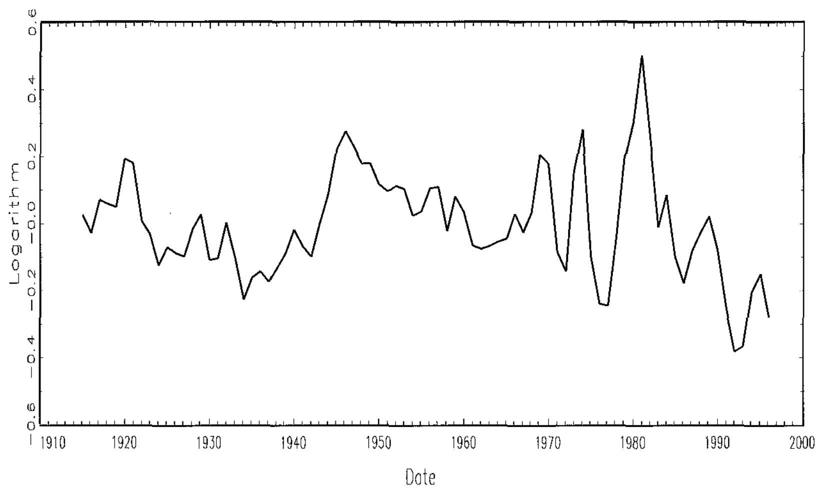

Fig. 4.5. Long run money demand residual.

exact unit root assumption, computed using the methods in Stock and Watson (1996a), contain a unit income elasticity. Thus these results are consistent with there being a stable long-run relation between velocity and interest rates, which can be thought of as a stable long-run money demand relation.

4.2.2. *Spreads between long-term and short-term interest rates*

Annual data on interest rates on long-term high grade industrial bonds and short-term commercial paper and the spread between these two rates are plotted in Figure 4.6

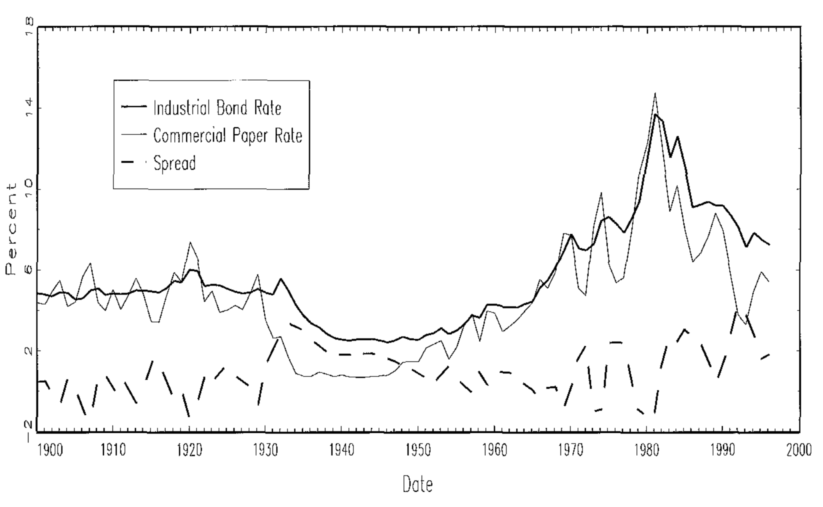

Fig. 4.6. Private interest rates and spread.

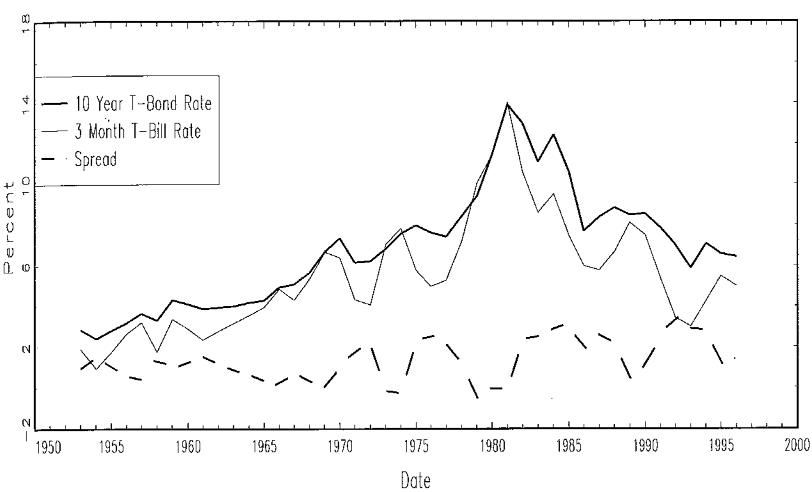

Fig. 4.7. Interest rates on government debt and spread.

over the period 1900–1996. These rates have fluctuated over a fairly large range over this period. They also exhibit considerable persistence: rates were low during much of the Depression and the 1940s, and were high relative to their historical values during the 1970s and 1980s. In contrast, the spread between these two rates is more stable and, during most episodes, exhibits considerably more short-term volatility. A similar pattern is evident in the postwar data in Figure 4.7 on 90-day Treasury bill rates and ten-year Treasury bond rates. Of course, over these periods there have been great

Table 6
Largest autoregressive roots of interest rates and spreads[a]

	Sample period	Largest root		90% confidence interval
		OLS	Median unbiased	
High grade industrial bonds	1900–1996	0.95	1.02	0.91–1.04
Commercial paper	1900–1996	0.86	0.90	0.78–1.03
Spread	1900–1996	0.56	<0.60	<0.60–0.66
10-year Treasury Bond	1953–1996	0.84	1.05	0.83–1.09
90-day Treasury Bill	1953–1996	0.76	0.87	0.61–1.07
Spread	1953–1996	0.22	<0.11	<0.11–0.43

[a] All estimates are based on annual data. OLS refers to ordinary least squares. The median unbiased estimates and the 90% confidence interval are computed by inverting the Dickey–Fuller (1979) unit root test statistic (including a constant and time trend) using the method described by Stock (1991), with the number of lags selected by the Akaike Information Criterion (AIC). Upper bounds (denoted by <) rather than point values are reported for the median unbiased estimate and confidence interval endpoints when these values are less than the smallest values tabulated by Stock (1991).

changes in financial markets, and these changes would arguably induce instabilities in the relation between these rates.

Empirical estimates of persistence, as measured by the value of the largest autoregressive root of each series, are given in Table 6. These estimates support the view that the spreads are considerably less persistent than the interest rates themselves[16]. Indeed, the hypothesis of a unit root cannot be rejected for each of the four interest rates series. In contrast, the largest autoregressive roots for the two spreads are small.

4.2.3. Balanced growth relations

Another set of long-run relations are the so-called balanced growth relations among consumption, income and output. Simple stochastic equilibrium models that incor-

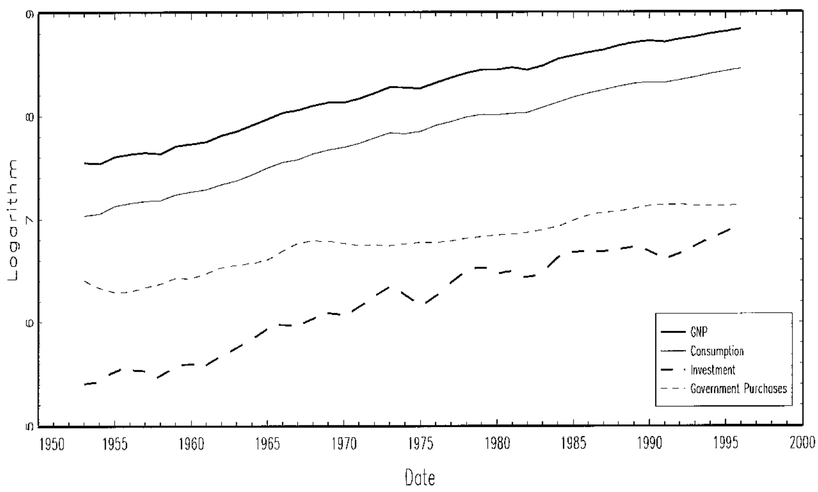

Fig. 4.8. Major macroeconomic aggregates.

porate growth imply that even though these aggregate variables may contain trends, including stochastic trends, their ratios should be stationary; see King, Plosser and Rebelo (1988) and King, Plosser, Stock and Watson (1991). These aggregates are plotted in Figure 4.8, and their log ratios are plotted in Figure 4.9. Although the aggregates have grown significantly since 1953, their ratios have been more stable.

[16] Because the ordinary least squares (OLS) estimator of the largest autoregressive root is biased towards zero, a second, median unbiased estimator of this largest root is reported in Table 6. The median unbiased estimator is constructed following Stock (1991) by inverting the Dickey–Fuller (1979) test for a unit root in the relevant series. Also reported in Table 6 are 90% confidence intervals for this largest root, constructed using the method described by Stock (1991).

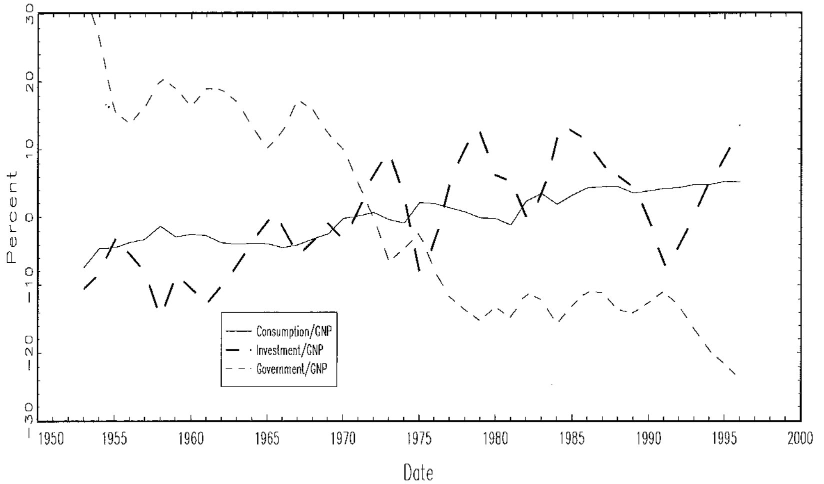

Fig. 4.9. Balanced growth ratios (logs).

Consistent with the high cyclical volatility of total investment in Table 2, the log investment/output ratio has been much more volatile than the log consumption/output ratio.

Statistical evidence on the persistence of these series from 1953 to 1996 is presented in Table 7. The hypothesis of a unit autoregressive root is not rejected in favor of trend

Table 7
Largest autoregressive roots of main NIPA aggregates and their ratios[a]

	Growth rate (% per annum)	Largest root		90% confidence interval
		OLS	Median unbiased	
Log levels:				
GDP (Y)	3.1	0.89	1.06	0.96–1.10
Consumption (C)	3.3	0.92	1.06	0.97–1.10
Investment (I)	3.6	0.66	0.69	0.42–1.05
Govt. (G) purchases	1.8	0.85	0.74	0.48–1.06
Log ratios:				
C–Y	0.3	0.38	0.70	0.43–1.05
I–Y	0.4	0.51	0.32	<0.14–0.67
G–Y	−1.2	0.74	0.72	0.46–1.06

[a] Based on logarithms of annual data, 1953–1996. The method for estimating the largest autoregressive roots and for constructing confidence intervals is described in the notes to Table 6. The mean growth rate of each series was estimated using the Prais–Winston method as described by Canjels and Watson (1997), with the same lag lengths as for the root statistics for that series.

stationarity at the 5% level for output, consumption or investment. Although a unit root cannot be rejected for the consumption–output ratio, the estimates of the largest root for the two balanced growth ratios are small. Although these statistics do not line up perfectly with the simple balanced growth predictions, they do suggest that these ratios are considerably more mean reverting than the aggregate series themselves.

Plots and statistics for government purchases and the log government purchases/income ratio are also contained in these figures and tables. The trend growth rate of government purchases is considerably less than that of the other aggregates. The share of government purchases in output has dropped significantly over the postwar period, and this decline has been offset by an increase in the output shares of consumption and investment.

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Appendix A. Description of the data series used in this chapter

This Appendix contains a description of the data series used in this chapter. Most of the series were obtained from Citibase; for these series, the uppercase names listed below refer to the Citibase labels for the series. The following abbreviations are used: sa = seasonally adjusted; saar = seasonally adjusted at an annual rate; par = percent at an annual rate. The numbers in parentheses in Section A.2 correspond to figure numbers used in Section 3. The series transformation, if any, is given in square brackets. If the QLR test result in Table 3 is based on the first difference of the series, this is noted in the series description by "QLR-FD".

A.1. Series used in Section 1

Industrial Production Index (total, 1992=100, saar). Source: Federal Reserve Board.

A.2. Series used in Section 2

(0) Gross Domestic Product
GDPQ: gross domestic product (bil 92 chained $, saar) [Log], QLR-FD

(1) Contract and Construction Employment
LPCC: employees on nonag. payrolls: contract construction (thous.,sa) [Log], QLR-FD

(2) Manufacturing Employment
LPEM: employees on nonag. payrolls: manufacturing (thous., sa) [Log], QLR-FD
(3) Finance, Insurance and Real Estate Employment
LPFR: employees on nonag. payrolls: fin., insur. & real estate (thous., sa) [Log], QLR-FD
(4) Mining Employment
LPMI: employees on nonag. payrolls: mining (thous., sa) [Log], QLR-FD
(5) Government Employment
LPGOV: employees on nonag. payrolls: government (thous., sa) [Log], QLR-FD
(6) Service Employment
LPS: employees on nonag. payrolls: services (thous., sa) [Log], QLR-FD
(7) Wholesale and Retail Trade Employment
LPT: employees on nonag. payrolls: wholesale & retail trade (thous., sa) [Log], QLR-FD
(8) Transportation and Public Utility Employment
LPTU: employees on nonag. payrolls: trans. & public utilities (thous., sa) [Log], QLR-FD
(9) Consumption (Total)
GCQ: personal consumption expend – total (bil 92 chained $, saar) [Log], QLR-FD
(10) Consumption (Nondurables)
GCNQ: personal consumption expend – nondurables (bil 92 chained $, saar) [Log], QLR-FD
(11) Consumption (Services)
GCSQ: personal consumption expend – services (bil 92 chained $, saar) [Log], QLR-FD
(12) Consumption (Nondurables + Services)
(AC) GCNQ + GCSQ [Log], QLR-FD
(13) Consumption (Durables)
GCDQ: personal consumption expend – durables (bil 92 chained $, saar) [Log], QLR-FD
(14) Investment (Total Fixed)
GIFQ: fixed investment, total (bil 92 chained $, saar) [Log], QLR-FD
(15) Investment (Equipment)
GIPDEQ: private purch. of producers dur. equip. (bil 92 chained $, saar) [Log], QLR-FD
(16) Investment (Nonresidential Structures)
GISQF: purchases of nonres structures – total (bil 92 $, saar) [Log], QLR-FD
(17) Investment (Residential Structures)
GIRQ: fixed investment, residential (bil 92 chained $, saar) [Log], QLR-FD
(18) Change in Business Inventories (Relative to Trend GDP)
(AC) GVQ/GDPQT, where GDPQT is calculated as the low-filtered (Periods – 8 years) component of GDPQ (unitless ratio, not in logarithms)

(19) Exports
GEXQ: exports of goods & services (bil 92 chained $, saar) [Log], QLR-FD
(20) Imports
GIMQ: imports of goods & services (bil 92 chained $, saar) [Log], QLR-FD
(21) Trade Balance (Relative to Trend GDP)
(AC) (GEXQ-GIMQ)/GDPQT, QLR-FD
(22) Government Purchases
GGEQ: gov. consumption exp. & gross investment (bil 92 chained $, saar) [Log], QLR-FD
(23) Government Purchases (Defense)
GGFENQ: nat. defense cons. exp. & gross inv. (bil 92 chained $, saar) [Log], QLR-FD
(24) Government Purchases (Non-Defense)
(AC) GGEQ-GGFENQ [Log], QLR-FD
(25) Employment: Total Employees
LPNAG: employees on nonag. payrolls: total (thous., sa) [Log], QLR-FD
(26) Employment: Total Hours
LPMHU: employee hours in nonagric. est. (bil. hours, saar) [Log], QLR-FD
(27) Employment: Average Weekly Hours
(AC) LPMHU/LPNAG [Log], QLR-FD
(28) Unemployment Rate
LHUR: unemployment rate: all workers, 16 years & over (%, sa), QLR-FD
(29) Vacancies (Help Wanted Index)
LHEL: index of help-wanted advertising in newspapers (1967=100;sa) [Log], QLR-FD
(30) New Unemployment Claims
LUINC: avg wkly initial claims, state unemploy. ins., exc p. rico (thous., sa) [Log], QLR-FD
(31) Capacity Utilization
IPXMCA: capacity util rate: manufacturing, total (% of capacity, sa) (frb), QLR-FD
(32) Total Factor Productivity
(AC) Solow's Residual calculated using GDP less farm, housing and government (GBXHQF-GGEQ), employees on non-agriculture payrolls (LP), quarterly values of the capital stock [constructed by interpolating annual values of the fixed non-residential capital stock (KNQ) using quarterly values of fixed investment (GIFQ)], and a labor share value of 0.65, QLR-FD
(33) Average Labor Productivity
LBOUTU: output per hour all persons: nonfarm business (82=100, sa) [Log], QLR-FD
(34) Consumer Price Index (Level)
PUNEW: cpi-u: all items (82–84=100, sa) [Log], QLR-FD

(35) Producer Price Index (Level)
PW: producer price index: all commodities (82=100, nsa) [Log], QLR-FD
(36) Oil Prices
PW561: producer price index: crude petroleum (82=100, nsa) [Log], QLR-FD
(37) GDP Price Deflator (Level)
GDPD: gdp:implicit price deflator (index, 92=100) (t7.1) [Log], QLR-FD
(38) Commodity Price Index (Level)
PSCCOM: spot market price index:bls & crb: all commodities (67=100, nsa) [Log], QLR-FD
(39) Consumer Price Index (Inflation Rate)
Rate of Change in PUNEW (par), QLR-FD
(40) Producer Price Index (Inflation Rate)
Rate of Change in PW (par), QLR-FD
(41) GDP Price Deflator (Inflation Rate)
Rate of Change in GDPD (par), QLR-FD
(42) Commodity Price Index (Inflation Rate)
Rate of change of PSCCOM (par), QLR-FD
(43) Nominal Wage Rate
LBCPU: compensation per hour: nonfarm business sec (1982=100, sa) [Log], QLR-FD
(44) Real Wage Rate
(AC) LBCPU/GMDC [Log], QLR-FD
(45) Nominal Wage Rate (Change)
Rate of change in LBCPU (par), QLR-FD
(46) Real Wage Rate (Change)
Rate of change in LBCPU/GMDC (par), QLR-FD
(47) Federal Funds Rate
FYFF: interest rate: federal funds (effective) (% per annum, nsa), QLR-FD
(48) Treasury Bill Rate (3 Month)
FYGM3: interest rate: US treasury bills, sec mkt, 3-mo. (% per ann,nsa), QLR-FD
(49) Treasury Bond Rate (10 Year)
FYGT10: interest rate: US treas. const maturities, 10-yr. (% per ann, nsa), QLR-FD
(50) Real Treasury Bill Rate (3 Month)
FYGM3-Forecast of One Quarter of GMDC Growth, QLR-FD
(51) Yield Curve Spread (Long–Short)
(AC) FYGT10-FYGM3
(52) Commercial Paper/Treasury Bill Spread
(AC) FYCP-FYGM6
(53) Stock Prices
FSPCOM: S&P's common stock price index: composite (1941–43=10) [Log], QLR-FD

(54) Money Stock (M2, Nominal Level)
FM2: m2(m1+o'nite rps, euro$, g/p&b/d mmmfs&sav&sm time dep (bil $, sa) [Log], QLR-FD
(55) Monetary Base (Nominal Level)
FMBASE: monetary base, adj for reserve req chgs (frb of st.louis) (bil $, sa) [Log], QLR-FD
(56) Money Stock (M2, Real Level)
(AC) FM2/GDPD [Log], QLR-FD
(57) Monetary Base (Real Level)
(AC) FMBASE/GDPD [Log], QLR-FD
(58) Money Stock (M2, Nominal Rate of Change)
Rate of Change in FM2 (par), QLR-FD
(59) Monetary Base (Real Rate of Change)
Rate of Change in FMBASE (par), QLR-FD
(60) Consumer Credit
(AC) CCIPY*GMPY, Consumer installment credit (bil, saar) [Log], QLR-FD
(61) Consumer Expectations
BCI Series U0M083, The Conference Board [Log], QLR-FD
(62) Building Permits
BCI Series A0m029, The Conference Board [Log]
(63) Vendor Performance
BCI Series A0m032, The Conference Board
(64) Mfrs' Unfilled Orders, Durable Goods Ind.
BCI Series A1M092, The Conference Board [Log], QLR-FD
(65) Mfrs' New Orders, Nondefense Capital Goods
BCI Series A0M027, The Conference Board [Log], QLR-FD
(66) Industrial Production – Canada
IPCAN: Industrial Production: Canada (1990=100, sa) [Log], QLR-FD
(67) Industrial Production – France
IPFR: Industrial Production: France (1987=100, sa) [Log], QLR-FD
(68) Industrial Production – Japan
IPJP: Industrial Production : Japan (1990=100, sa) [Log], QLR-FD
(69) Industrial Production – UK
IPUK: Industrial Production: United Kingdom (1987=100, sa) [Log], QLR-FD
(70) Industrial Production – Germany
IPWG: Industrial Production: West Germany/Germany (1990=100, sa) [Log], QLR-FD

A.3. Additional series used in Section 4

– Industrial Bond Yield:
Yield on Long-Term Industrial Bonds (Highest Quality). Data from 1900–1946 are from the NBER Historical Data Base [see Feenberg and Miron (1997)], series

m13108. Data from 1947–1995 are from Citibase, series FYAAAI. Annual averages of monthly data.

- Commercial Paper Rates:
  Yield on 6-month Commercial Paper. Data from 1900–1946 are from the NBER Historical Data Base, series m13024. Data from 1947–1995 are from Citibase, series FYCP. Annual averages of monthly data.
- Money Supply:
  M1. Data from 1914–1958 are from the NBER Historical database, series m14016 and m14018 [Currency+DD, All Commercial Banks (SA), from Friedman and Schwartz (1963), Table A-1, Col. 7 and Friedman and Schwartz (1970), Table 1]. These were linked to Citibase series –M1 (M1 from the Federal Reserve system) in 1959.
- Real GNP:
  Data from 1900–1928 are from Balke and Gordon (1989). Data from 1929–1995 are from the NIPA.
- GNP Deflator:
  Implicit Price Deflator constructed from ratio of nominal GNP [Balke and Gordon (1989), for data 1900–1928 and NIPA for data from 1929–1995).

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