NBER WORKING PAPER SERIES

THE CYCLICAL BEHAVIOR OF INDUSTRIAL LABOR MARKETS: A COMPARISON OF THE PRE-WAR AND POST-WAR ERAS

Ben S. Bernanke

James L. Powell

Working Paper No. 1376

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
June 1984

Ben S. Bernanke is Associate Professor of Economics at the Stanford Graduate School of Business and a Research Associate of the National Bureau of Economic Research. James L. Powell is Assistant Professor of Economics at the Massachusetts Institute of Technology. We thank Frank Brechling, Ken Rogoff, Larry Summers, and our discussants for useful comments. The research reported here is part of the NBER's research program in Economic Fluctuations. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

NBER Working Paper #1376
June 1984

The Cyclical Behavior of Industrial Labor Markets:
A Comparison of the Pre-War and Post-War Eras

ABSTRACT

This paper studies the cyclical behavior of a number of industrial labor markets of the pre-war (1923-1939) and post-war (1954-1982) eras. In the spirit of Burns and Mitchell we do not test a specific structural model of the labor market but instead concentrate on describing the qualitative features of the (monthly, industry-level) data.

The two principal questions we ask are: First, how is labor input (as measured by the number of workers, the hours of work, and the intensity of utilization) varied over the cycle? Second, what is the cyclical behavior of labor compensation (as measured by real wages, product wages, and real weekly earnings)? We study these questions in both the frequency domain and the time domain.

Many of our findings simply reinforce, or perhaps refine, existing perceptions of cyclical labor market behavior. However, we do find some interesting differences between the pre-war and the post-war periods in the relative use of layoffs and short hours in downturns, and in the cyclical behavior of the real wage.

Ben S. Bernanke
Stanford Graduate School of Business
Stanford, CA 94305

(415) 497-2763

James L. Powell
Department of Economics
M.I.T.
Cambridge, MA 02139

(617) 253-1526

The Cyclical Behavior of Industrial Labor Markets: A Comparison of the Pre-War and Post-War Eras

Ben S. Bernanke and James L. Powell

I. Introduction

The purpose of this paper is to provide a comparison of the cyclical behavior of a number of industrial labor markets of the pre-war (1923-1939) and post-war (1954-1982) eras. The methodology of this study follows that of the traditional Burns and Mitchell (1946) business cycle analysis, in at least two ways: First, the data employed are relatively disaggregated (we use monthly data at the two- or three-digit industry level). Second, we have not formulated or tested a specific structural model of labor markets during the cycle but instead concentrate on measuring qualitative features of the data. As did Burns and Mitchell, we see descriptive analysis of the data as a useful prelude to theorizing about business cycles. Thus, although the research reported in this paper permits no direct structural inferences, it should be useful in restricting the class of structural models or hypotheses which may subsequently be considered.

The principal questions of interest studied in this paper are also two in number:

First, what are the means by which labor input is varied over the business cycle? We consider the intensity of utilization (as measured by gross labor productivity), hours of work per week, and the number of workers employed. Both the timing and relative magnitudes of the changes in these quantities over the cycle are examined.

Second, what are the relationships over the cycle of output and labor input to measures of labor compensation? We look at the cyclical behavior of product wages and real weekly earnings, as well as of real wages.

As might be expected, many of our findings are not novel; rather, they tend to support and perhaps refine existing perceptions of cyclical labor market behavior. However, we do reveal some interesting differences between the pre-war and the post-war periods in the relative use of layoffs and short hours in downturns, and in cyclical movements of the real wage. Another finding is that labor productivity may behave in an anomalous manner in more severe recessions. Finally, a number of the familiar regularities are documented in a previously little-used data set, over an unusually long sample period, and by means of some alternative methodologies.

The paper is organized as follows: Section II reviews previous empirical work on the cyclical behavior of labor market variables. Sections III and IV introduce and describe the data set used in the present paper. The behavior of key variables over the business cycle is analyzed by frequency domain methods in Section V and by a time domain approach in Section VI. Section VII focuses on labor market phenomena in four particularly severe recessions. Results are summarized and conclusions drawn in Section VIII.

II. Previous Work: Some Regularities and Some Puzzles

There has been a great deal of empirical work that relates, sometimes directly and sometimes tangentially, to the cyclical behavior of labor markets. Without attempting to make an exhaustive survey, this section of the paper will try to summarize the major empirical findings of the literature. We will also include some brief discussion of how various authors have interpreted these findings. The reader is warned, however, that because the focus of the present paper is description rather than structural analysis, the results we will present later will do little to resolve existing disputes about interpretation.

The discussion of this section will be organized around the two questions of interest raised in the Introduction, i.e., the means by which labor input is varied over the cycle and the cyclical relationship of labor input and labor compensation. It might be said that by concentrating on these two questions, rather than on such phenomena as the frequency and duration of unemployment spells, cyclical variations in participation rates, etc., we are emphasizing the "demand side" of the labor market at the expense of the "supply side." This imbalance is unfortunate but is dictated by the nature of the available pre-war data.[1]

1. The cyclical pattern of labor utilization. The earliest empirical work on the variation of labor input over the cycle was done in the context of NBER business cycle research. Among the hundreds of data series whose business cycle patterns were painstakingly analyzed by Wesley Mitchell, and later by Mitchell and Arthur Burns, were a number of labor market variables. For example, Mitchell (1951) documented the high conformity of employment and weekly hours with output. (However, Mitchell was perhaps more interested in labor cost measures; see below.)

An early NBER finding was the strong tendency of weekly hours (that is, the length of the average work-week) to lead output and employment over the cycle (Moore (1955), Bry (1959)). Weekly hours subsequently became a component of the Bureau's well-known index of leading indicators. (For a relatively recent discussion and updating of this index, see Zarnowitz and Boschan (1975).) Other labor market variables identified as leading the cycle by the NBER included accession and layoff rates and initial claims for unemployment insurance (Shiskin (1961)). Employment and unemployment were found to be coincident with the cycle.

Arguably the most important contribution of the NBER research program in this area was the classic paper by Hultgren (1960). With the purpose of investigating an hypothesis of Mitchell about labor cost, Hultgren collected monthly data on output, aggregate hours worked, and payrolls for 23 industries. (The sample period was 1932-58.) With these and other data, Hultgren discovered that output per worker-hour is procyclical (or, equivalently, that employment and hours worked vary relatively less over the cycle than does output.)

The finding of procyclical labor productivity, or "short-run increasing returns to labor" (SRIRL), spawned a voluminous literature. Important early contributions were made by Kuh (1960, 1965), Okun (1962), Eckstein and Wilson (1964), and Brechling (1965). (Okun's famous "law" is, of course, SRIRL applied to the aggregate economy.) These and numerous other studies (including, notably, Ball and St. Cyr (1966), Masters (1967), Brechling and O'Brien (1967), and Ireland and Smyth (1967)) found the SRIRL phenomenon to be ubiquitous: It occurs at both high and low levels of output aggregation, for both production and non-production workers, and in virtually all industrial countries.

Because of the neoclassical presumption of diminishing marginal returns to factors of production, SRIRL was perceived originally (and, to some extent, still is) as a deep puzzle. One favored explanation was that, because of the existence of specific human capital, firms "hoard" labor during downturns (Oi (1962), Solow (1968), Fair (1969)); the hoarded labor is utilized more fully as demand recovers, giving the illusion of increasing returns. For empirical purposes, the labor hoarding model has become closely identified with a model in which increasing marginal costs of adjusting the labor stock induce the firm to move toward the desired level of employment only gradually (Brechling (1965), Coen and Hickman (1970)); conceptually, however, the two models are not quite the same. Another popular explanation of SRIRL is that it is a reflection of unobserved (by the econometrician) variations in capital utilization rates that are associated with changes in labor input (Ireland and Smyth (1967), Lucas (1970), Solow (1973), Nadiri and Rosen (1973), and Tatom (1980)).

What is probably the most general current view is that SRIRL is the outcome of a complex dynamic optimization problem solved by the firm, in which labor is only one of a number of inputs, each with a possibly different degree of quasi-fixity. For example, Nadiri and Rosen (1973) emphasized that the rate at which employment will be varied depends not only on the costs of adjusting labor stocks but also the costs of adjusting all other inputs (including inventories and rates of utilization); Morrison and Berndt (1981) showed that these interactions could result in the SRIRL phenomenon even if labor itself were a perfectly variable factor.

Overall, the research which followed Hultgren's original paper has made two valuable contributions to knowledge: First, from Brechling (1965) to Nadiri and Rosen (1973) to Sims (1974), there has been generated a wealth of empirical material on the sluggish short-run response of employment to output change, and on the relationship over the cycle of employment to hours worked, inventories, and other factors of production. Second, the general dynamic optimization model of firm input utilization developed in this literature has proved to be a most useful and flexible research tool. (For example, it has permitted the incorporation of rational expectations; see Sargent (1978) or Pindyck and Rotemberg (1982).)

We may summarize the received findings on the cyclical behavior of labor inputs, as follows: Employment and weekly hours are procyclical. Productivity is also procyclical, i.e., employment and worker-hours vary less than output over the cycle. Finally, weekly hours lead output, while employment coincides with or possibly lags output over the cycle.

2. Labor compensation over the cycle. While the qualitative behavior of labor inputs over the business cycle seems relatively well established, there is very little agreement about how to characterize the cyclical movements of labor compensation, especially of real wages. The debate about real wages began when Keynes (1936) conjectured that, again because of diminishing marginal returns, labor's marginal productivity and hence the real wage should be countercyclical.[2] Empirical studies by Dunlop (1938) and Tarshis (1939) purported to show that this conjecture was false; but these studies were in turn disputed (see Bodkin (1969) for references.) The debate prompted Keynes (1939) to aver that countercyclical real wages were in fact not an essential implication of his theory.

Postwar research has done little to resolve the question of the cyclical behavior of real wages. One can find papers supporting procyclicality (Bodkin (1969), Stockman (1983)), countercyclicality (Neftci (1978), Sargent (1978), Otani (1978), Chirinko (1981)), and acyclicality (Geary and Kennan (1982)). Altonji and Ashenfelter (1980) have argued that the best statistical model of the real wage is the random walk. It would not be of much help for us to present a detailed comparison of these papers here. Instead, we simply list some of the major methodological issues that have arisen in this literature:

First, researchers have typically found that their results are sensitive to whether the nominal wage is deflated by an index of output prices, such as the WPI or PPI, or by a cost-of-living index, such as the CPI. (See Ruggles (1940), Bodkin (1969), or Geary and Kennan (1982).) This does not seem unreasonable, since the wage divided by the output price (henceforth, the "product wage") corresponds conceptually to the "demand price" of labor, while the wage deflated by the cost of living (henceforth, the "real wage") corresponds to the "supply price"; it is not difficult to think of conditions under which the short-run behaviors of these two variables might differ. Unfortunately, however, the difference in behavior does not seem to vary systematically across studies.

Second, there is some dispute over whether the contemporaneous correlation of the real wage and output (or employment) is an interesting measure of the real wage's cyclical pattern. Neftci (1978) and Sargent (1978) have argued that, because of the complex dynamics of the wage-employment relationship, it is necessary to look at correlations at many leads and lags. (See also Clark and Freeman (1980).)

Finally, it has been found that empirical results concerning the short-run behavior of wages may be particularly sensitive to aggregation biases, both when the aggregation is over individuals (Stockman (1983)) and when it is over industries (Chirinko (1981)).

The apparently very weak relationship of real wages and the business cycle has posed a problem for some prominent theories of cyclical fluctuations (or at least for simple versions of those theories; see, for example, Altonji and Ashenfelter (1980) and Ashenfelter and Card (1982)). However, attempts to reconcile the low correlation of wages and the cycle with theories of short-run employment fluctuations have also led to a number of interesting lines of research: These include disequilibrium modelling of the cycle (Solow and Stiglitz (1968), Barro and Grossman (1971)); contracting approaches that divorce wage payments and short-run labor allocations (see Hall (1980) for a discussion); Lucas's (1970) theory of capacity and overtime; and others.

Real and product wages are not the only measures of labor compensation whose cyclical behavior have been studied, although they have absorbed a large part of the research effort. Mitchell theorized in very early work that unit labor costs might play an important role in the business cycle; Hultgren's (1960, 1965) studies found that, in reasonably close correspondence to Mitchell's prediction, labor costs lag the cycle. Various other compensation measures were studied by the NBER analysts: nominal labor income, for example, was reported by Shiskin (1961) to be coincident with the cycle.

Another variable that has commanded some attention is the nominal wage. In an NBER occasional paper, Creamer (1950) studied monthly wage rates in a number of industries for the 1919-31 period. (His aggregate wage rate series extended to 1935.) Creamer's most important conclusion was that nominal wage rates lagged business activity by nine months or more, a finding that was viewed by some subsequent authors as supporting the "stickiness" of wages. (Creamer also showed that the cyclical behaviors of an index of wage rates and of average hourly earnings were similar, a very useful result given the paucity of direct information on wage rates.) "Stickiness" was also a major issue for later students of the nominal wage:

For example, Sachs (1980) has argued that wages became relatively more rigid after World War II, while Gordon (1982) has found U.S. postwar wages to be stickier than those of the U.K. and Japan. Gordon's result is the opposite of earlier characterizations by Sachs (1979) and others.

Overall, the question of how to characterize the cyclical behavior of labor compensation remains rather unsettled. This is unfortunate, given the central role of wages in much of macroeconomic theory.

III. The Data

The present paper reassesses the qualitative empirical findings described in the last section, with particular attention paid to possible differences between the pre-war and post-war eras. This section introduces our data set and compares it briefly with what has been employed by others.

The data we use are monthly, roughly at the level of the "industry", and cover the time periods 1923-1939 and 1954-1982. We felt that the high-frequency data were necessary if short-run relationships were to be distinguished; the industry-level data were used both to reduce aggregation bias and to avoid reliance on the aggregate production indices, which are poorly constructed for our purpose (see below). In contrast to our approach, few studies since Hultgren have used monthly, industry-level data (Fair (1969) is an important exception). Also, little recent work has used pre-war data; the exceptions have typically looked at only annual, highly aggregated numbers.

There were many variables that we could have chosen to study. Considerations of data availability and economic relevance led to the following short list (with mnemonic abbreviations):

1. IP Industry output or production
2. EMP Employment (number of production workers)
3. HRS Hours of work per week (per production worker)
4. PROD Gross labor productivity = IP/(EMPxHRS)
5. WR Average hourly earnings (nominal) divided by a cost-of-living index; the "real wage."
6. WP Average hourly earnings divided by the industry wholesale output price; the "product wage"
7. EARN Real weekly earnings per production worker = HRSxWR.

In the analysis below, we concentrate not on the levels of the above variables but on the log-differences (roughly, the monthly growth rates). From now on, therefore, the mnemonic names just defined should be understood to denote log-differences.

The above variables were collected for eight pre-war manufacturing, eight post-war manufacturing, and three post-war non-manufacturing industries. These industries are listed in Table 1. Note that the eight

--Table 1 about here--

pre-war and post-war manufacturing industries are approximately a "matched set." This was done to facilitate comparison of the two eras. We did not have comparable pre-war data for the three non-manufacturing industries. However, we included these industries because they represent major sectors of the economy (mining, utilities, and construction), and because it seemed to us that non-manufacturing industries have been slighted somewhat (relative to manufacturing industries) by students of the business cycle.

Some explanation should be given for the rather miscellaneous character of the manufacturing industries chosen. For the pre-war period, the eight industries included represent the largest class for which complete and reasonably consistent data were available. In particular, our desire to have series on hours of work restricted us to industries regularly surveyed, beginning in the early 1920's, by the National Industrial Conference Board. The Bureau of Labor Statistics, which surveyed many more industries, did not collect hours data before 1932. Also, we included only industries whose output indices were based on direct measures of physical output (e.g., number of automobiles) rather than on scaled-up input measures (e.g., manhours). A wider selection of industries is available for the post-war, of course, but because of the burden of collecting and entering the data, only those manufacturing industries "matching" the available pre-war industries were used. In terms of employment or value added, the industries here studied made up about one-fifth of total manufacturing in the pre-war era and about one-sixth of total manufacturing after the war.

A nice fringe benefit of using the Conference Board data rather than that from the BLS is that it gives us a pre-war data set that has not been previously analyzed, except in a partial and desultory way by some earlier NBER studies. In particular, it is quite different from the data set used by Hultgren (1960).

A potential problem with studying only manufacturing industries which have more-or-less continuous identities since the 1920's is that it biases the sample toward older, often declining industries, at the expense of new and growing fields. However, for the purpose of studying cyclical (as opposed to trend) behavior of labor market variables, this sample bias is probably not important. In particular, our informal comparisons of the declining manufacturing industries with the expanding manufacturing and non-manufacturing industries did not reveal obvious differences in cyclical behavior.

For the purposes of comparison with the industry-level findings, we also analyzed pre-war and post-war monthly data for aggregate manufacturing. Although these data obviously have broader coverage than the industry data, we have less confidence in the results using aggregates, for three reasons: (1) Aggregation across industries introduces well-known cyclical biases. (2) The aggregate production indices are heavily contaminated with input-based measures of output. (3) The pre-war output, price, and labor input series are not perfectly mutually consistent. (See the data appendix for an explanation, and for a more detailed discussion of all the data and their sources.)

IV. Some Basic Statistics

Most of the analysis discussed below follows the application of a deseasonalization process and the removal of means from the log-differenced series. As a preliminary step, this section looks at some features of the raw log-differences.

Tables 2 and 3 present the means of the variables for each industry and for the pre-war and post-war periods separately. The means are multiplied by 100 and thus can be interpreted approximately as percentage rates of growth *per month*.

--Table 2 about here--

Considering first the productivity column in Table 2, we note that average pre-war rates of productivity growth compared well to those of the post-war. Rates of productivity growth were higher during 1923-1939 than during 1954-1982 in five of the eight manufacturing industries, as well as in aggregate manufacturing. The pre-war rate of productivity growth reached rather exceptional levels in automobiles, paper and pulp, and iron and steel. The rapid expansion of pre-war productivity observed in these data supports the view that the period between the world wars (particularly the 1920's) was a time of transformation of industrial technologies, leading to sharp reductions in costs; see Jerome (1934) and Bernstein (1960). In the post-war, the best productivity performance among our manufacturing industries was by paper and allied products; best overall in the post-war sample was by electric services.

Productivity growth is, of course, definitionally equal to output growth minus the sum of employment and hours growth. Examining these constituents of productivity, we note first that the fastest pre-war growth in output was experienced by automobiles and by paper and pulp; in the post-war period, paper took the output growth honors for manufacturing, with electric services again doing best overall. It appears that the high output industries were also the high productivity industries; the rank correlation between output growth and productivity growth is .945 for the eight pre-war industries, .913 for the eleven post-war industries.

Despite the Depression of the 1930's, employment growth in the pre-war manufacturing industries studied tended to exceed that in their post-war counterparts (seven of eight cases); this was also true for the aggregates. This difference largely reflects serious long-term declines by a number of the post-war industries: In wool textiles, leather tanning and finishing, and footwear, pre-war tendencies toward decline accelerated after the war; in iron and steel, pre-war growth in employment changed to post-war shrinkage. The strongest employment growth in the sample took place in two post-war non-manufacturing industries (electric services and construction). As a whole, the employment column of Table 2 is consistent with the often-noted secular fall in the fraction of total employment absorbed by manufacturing.

The behavior of the last component of productivity, hours of work, was quite different in the two sample periods. Weekly hours declined steadily during the pre-war in all industries, most precipitously in iron and steel (a notorious "long-hours" industry during the early 1920's, in which 84-hour work-weeks were not uncommon). This fall reflected changes in work organization during the 1920's (in a few cases as a response to the pressure of public opinion against long hours), and the "work-sharing" of the depressed 1930's (sometimes initiated by employers, sometimes the result of New Deal legislation or union demands); see Zeisel (1958) for further discussion. In contrast, the post-war work week was almost perfectly stable.

Finally, we may consider the mean rates of growth of the alternative measures of production worker compensation (Table 3). It is interesting

--Table 3 about here--

that, although productivity gains during the pre-war period were larger than during the post-war in only five of the eight manufacturing industries studied, real wage growth was significantly larger during the pre-war in <u>all</u> eight industries, as well as in the aggregate. Pre-war product wages also rose sharply, except in boots and shoes. Within the major sample periods, the rank correlation of real wage growth with productivity growth was .815 for the eight pre-war industries, .864 for the eleven post-war industries.

(Although these correlations are high, note that they are somewhat lower than the correlations of productivity and output growth reported above.) The large pre-war growth in real wages was not fully reflected in increases in worker buying power, as the last column of Table 3 shows; because of the sharp declines in hours of work, real weekly earnings rose much more slowly than real wages.

Turning from the first to the second moments: Tables 4 and 5 contain

--Table 4 about here--

--Table 5 about here--

the standard deviations of the raw log-differences, multiplied by 100 so as to be interpretable as percentages. We will not comment on these figures , except to note, first, how surprisingly large the variability of the industry data often is, and, second, that aggregation seems to reduce measured variability somewhat. To see how much of total variability was attributable to business cycles, we used a frequency domain technique to wipe out the variance associated with the high-frequency (i.e., seasonal) and the low-frequency (i.e. trending or long-wave) bands. The resulting standard deviations for five key variables are in Table 6. Three facts are

--Table 6 about here--

obvious from the table: First, the share of total variability of the data to be associated with business cycles is relatively small, both in the pre-war and post-war periods. Second, the business cycle has dampened considerably during the post-war. Third, in most industries the cyclical variance of hours of work per week has, between the pre-war and post-war periods, been reduced relatively more than that of employment.

This last observation, which is also confirmed in the raw data (Table 4) and in Section VII below, is worth remarking on a bit further. Why have post-war employers relied relatively more heavily on layoffs, rather than on short work-weeks, to reduce labor input in downturns? Two possible sources of the change are the greater post-war importance of unions and the advent of unemployment insurance programs. Union objective functions might be such that layoffs of a relatively small number of junior workers are preferred to a general reduction of hours. (Cross-sectional evidence that unions prefer layoffs was presented in Medoff (1979). Medoff also cited a study by Slichter et al. (1960) which claimed that unions, which initially approved of some work-sharing, moved towards a preference for layoffs in the early post-war period.) Perhaps more important than unionism is the fact that in the United States, fully unemployed workers can receive government compensation but the partially unemployed can not. See Baily (1977) for a formal analysis.

V. Analysis in the Frequency Domain

We turn now to the study of these variables over the business cycle. In order to obtain characterizations of "typical" cyclical patterns, we subjected the data to both frequency domain and time domain analysis. In the frequency domain work we followed the approach suggested by Granger and Hatanaka (1964); in the time domain our analysis is in the spirit of Sims (1980). (There are, of course, close formal connections between these two approaches; this is evidenced by the similarity of the results obtained.) The results from the frequency domain will be discussed here. Those from the time domain are presented in Section VI.

The data used in the frequency domain work (as well as in the time domain) were the deseasonalized log-differences of the basic series. (Deseasonalization was done by the use of seasonal dummies; see the data appendix.) Each variable was analyzed separately by industry and for the pre-war and post-war sample periods.

Spectra of these data showed power in the business-cycle-frequency range, but rarely were clear peaks apparent in that range. (Sargent (1979, p. 254) warns that this is to be expected.) We decided to investigate the properties of cycles with periods exceeding one year (so as to exclude remaining seasonal and other high-frequency influences) but less than eight years. (According to the NBER chronology, the longest business cycle in our sample - the one extending from 1929 to 1937 - was eight years in length.) For each industry/sample period, we calculated the coherences and phase relationships of the variables over the one- to eight-year band.

The coherences of six variables (the rates of growth of employment, weekly hours, productivity, real wages, product wages, and real weekly earnings) with the rate of growth of industry output over the business cycle range are reported in Table 7. (Standard errors of the coherence estimates

--Table 7 about here--

are also included. See the appendix for a description of how these were calculated.) Coherence is a measure of the degree of association of a pair of variables over a prescribed set of frequencies; a coherence of zero indicates the minimum association, a coherence of one the maximum. The table suggests that employment and hours bear the strongest relationship to output over the business cycle. Productivity and earnings also are strongly related to output, for most industries. The connection between the two wage measures and output is erratic across industries and, on the whole, is weaker; this is especially true in the post-war period. Note, however, that the coherences of wages and output appear to be statistically significant in both periods.

A particularly informative exercise in the frequency domain is the calculation of phase relationships. For a given frequency, think of variables as tracing out sine curves over time. Then the "phase lead" of variable A with respect to variable B is the number of months after A reaches a given point on its sinusoidal path that B reaches the corresponding point. We shall say that a variable that has a phase lead with respect to output of near zero is "procyclical"; a variable whose phase lead with respect to output is approximately half the period of the full cycle is "countercyclical." (There are, however, some caveats to this interpretation of phase leads; see Hause (1971).)

The phase leads of six variables with respect to output growth, plus standard errors, are given in Table 8. The phase leads are evaluated

--Table 8 about here--

at the frequency with period of fifty-four months, the period at the center of the range considered. (See the appendix for more discussion.) We find that employment, hours, and earnings are roughly procyclical. Productivity is procyclical but slightly leading in the post-war; its lead over output is greater in the pre-war period. Hours typically leads, though by less than productivity, while employment consistently lags a few months behind output. Earnings is approximately coincident.

The interrelationship of productivity, hours, output, and employment, is essentially stable between the pre-war and post-war and, except for the introduction of some subtleties in timing, is consistent with earlier findings. In conjunction with the dynamic model of the firm discussed in Section II, this interrelationship suggests a simple economic interpretation: Cycles are dominated by demand changes. Firms anticipating an increase in demand respond first by increasing nonlabor inputs and asking for more work effort; this increases productivity. As demand strengthens, hours of work expand. Finally, as the increase in demand assumes greater permanence, firms make the hiring and training investments needed to add to the workforce. This story is hardly original (see, for example, Baily (1977)), and we emphasize again that we have done no explicitly structural test. Still, it is interesting that this interpretation seems at least to be consistent with the facts for so many disparate industries, and for both the pre-war and post-war eras.

This stability across industries and sample periods is not shared by the relationship of wages and output. There seems to be a definite difference between the pre-war and post-war behavior of wages. Let us concentrate on real, rather than product, wages: During the pre-war period, real wages lagged output significantly - not quite enough to be called countercyclical, but still "half out-of-phase."[3] (A well-known example of this is the positive growth of real wages in 1931-32, even as output and employment plunged.) In contrast, during the post-war period real wages were nearly in phase (procyclical), even leading the cycle in some industries.

Why did the cyclical behavior of real wages change between the pre-war and post-war periods? A satisfactory answer to this question would require an explicit structural model, which we do not attempt in this paper. However, we do present a simple heuristic example which suggests that this change may be related to one of our earlier findings, that layoffs have become relatively more important than work-sharing in the post-war period.

Suppose that, because of fixed costs, workers can hold only one job at a time. (This example will generalize as long as an individual's work effort is not infinitely divisible among employers.) Then the labor market is cleared not by the hourly wage, but by the total utility available to the worker in a job. Assume that workers get utility from total real compensation Y and disutility from hours of work per week H. If, for simplicity, the marginal utilities of income and leisure are taken to be constant, then instantaneous utility at time t, U_t, can be written as

$$U_t = Y_t - \alpha H_t$$

where α is a parameter.

To retain their labor forces, firms must provide workers with (Y_t, H_t) combinations such that workers' utility equals or exceeds $\bar{U}$, the (exogenous) utility level obtainable elsewhere in the economy. Assuming for purposes of this example that business cycles are regular sine waves, and that $\bar{U}$ is procyclical, we can write

$$\bar{U}_t = \bar{U}_0(1 + a \sin t) \qquad (2)$$

where $\overline{U}_0$ is average obtainable utility, and a is a positive parameter measuring the cyclical sensitivity of $\overline{U}$.

Firms' choices about which (Y_t, H_t) combinations to offer (from among those combinatins that satisfy the external utility constraint) will arise from a maximization calculation that takes into account the nature of the production function, the existence of specific human capital or adjustment costs, etc. For this heuristic example we do not explicitly specify the firm's maximization problem but simply assume (realistically) that its outcome will imply a procyclical workweek:

$$H_t = H_0 \, (1 + b \sin t) \tag{3}$$

where H_0 is the average workweek over the cycle and b measures the workweek's cyclical sensitivity. (3) is to be interpreted as a reduced form; the parameter b may well depend on the other parameters in the problem.

The three equations just given, plus the assumption that real earnings are just high enough to meet the external utility constraint, imply that the cyclical behavior of real earnings per worker is:

$$Y_t = (\overline{U}_0 + \alpha H_0) + (a + \alpha b) \sin t \tag{4}$$

Average earnings Y_0 equal $\overline{U}_0 + \alpha H_0$.

In this example, the measured "real wage" W_t is just Y_t/H_t. Under what circumstances will the measured wage be procyclical (i.e., have a positive sensitivity to the exogenous cycle)? It is easy to show that the necessary and sufficient condition for real wage procyclicality is

$$a > b \tag{5}$$

That is, wages are procyclical if reservation utility has a greater sensitivity to the cycle than do hours of work.

It is difficult to say what has happened over time to the cyclical sensitivity of reservation utility; perhaps reservation utility has become less cyclical in the post-war, which would work against the present argument. However, in Section IV we introduced evidence that b, the cyclical sensitivity of hours, has fallen in the post-war. The example shows that, everything else being equal, reduced cyclical sensitivity of hours tends to be associated with greater observed procyclicality in real wages. Thus, two of the novel findings of this paper - that hours have become less procyclical and real wages more procyclical in the post-war - may be related.

An important question is whether the cyclical relationships described in Tables 7 and 8 are the same in long and short business cycles. Closely related is the issue of whether it is useful to study "reference cycles." Burns and Mitchell frequently measured timing relationships in terms of "stages" of a standard "reference cycle" instead of in calendar time. For this to be worthwhile, it must be the case that cyclical lead/lag relationships are roughly constant fractions of the cycle length, rather than constant when measured in calendar time; that is to say, phase angles must be constant across business cycle frequencies.

Some insight on this question is provided by Table 9. That table gives

--Table 9 about here--

the estimates of the phase leads of the six variables for the deseasonalized-high-frequency band (2-12 months); for short cycles (1-2 years); and for long cycles (2-8 years). (The business cycle band was broken up in that particular way because there are approximately as many frequencies with periods between 12 and 24 months as there are with periods between 24 and 96 months.) Also reported for each variable are the results of a statistical test for constancy of phase angles between short and long business cycles. Inspection of Table 9 suggests two observations:

First, while not much systematic emerges in the high-frequency band, the qualitative pattern of leads and lags is the same in the short and long business cycles ranges (the (b) and (c) rows in the table). For example, productivity still leads the cycle, employment still lags.

Second, there appears to be a bit of support for the "reference cycle" construction (and, by implication, for the "time deformation" approach to cycles recently suggested by Stock (1983)). The hypothesis of constant phase angles between short and long business cycles, which is implied by the reference cycle approach, is not usually rejected by the data. (Exceptions are the pre-war meat-packing industry, and, to some extent, aggregate manufacturing in both the pre-war and post-war.) Thus, assuming that leads and lags are proportional to cycle length does not seem unreasonable. On the other hand, it should be noted that this evidence in favor of reference cycles may possibly be spurious: As an example in Hause (1971) shows, two variables with a fixed distributed lag relationship in the time domain may also exhibit a phase relationship which is roughly proportional to the period of the cycle.

The observations we have made so far apply to more or less all of the industries in the sample, with a few distinctions having been drawn between the patterns visible in the pre-war period and those in the post-war. We had hoped to be able to make more cross-sectional distinctions (e.g., like the finding of Nadiri and Rosen (1973) that input responses are much more rapid in durable goods industries.) Unfortunately, much less cross-sectional variation than we expected was evident when we grouped the industries in the obvious ways.

To see if the industries might be grouped by the nature of their cyclical behavior, we estimated the coherences and phases between industry outputs and the aggregate index of output, for the pre-war and post-war periods separately. These are presented in Table 10. An odd result is that

--Table 10 about here--

almost all of the phase leads are positive; this may be due to the inclusion of input-based measures of output in the aggregate index. The coherence estimates suggest that cyclical influences became relatively less important for the industries in the post-war period. There is also a tendency in the post-war sample for durable goods industries to exhibit a relatively higher coherence with the cycle than non-durable industries. However, except for meat-packing, there is surprisingly little evidence of this pattern in the pre-war. Overall, cross-sectional differences still seem less significant than cross-sectional similarities.

VI. Analysis in the Time Domain

To complement the frequency domain analysis of the data, we employed time-domain methods, primarily vector autoregression (VARs). Separate VARs, using twelve monthly lags of four variables (output, hours, employment, and real wages), were estimated for each of the pre-war and post-war industries, and for the aggregates. The data were the same centered and seasonalized log-differences described in Section V. As in Sims(1980), the estimated VARs were used to do three things: First, we looked at the statistical significance of blocks of coefficients in order to search for patterns of causality (in the Granger sense). Second, we calculated the percentages of the forecast errors attributable to (triangularized) innovations in the right-hand-side variables, for four forecast horizons. Finally, the implied impulse-response diagrams were examined for systematic timing relationships among the variables. We briefly discuss each of these exercises.

Table 11 summarizes the results of the Granger-causality F-tests.

--Table 11 about here

There is one matrix for each dependent variable. In each matrix, the rows designate the industry to which the VAR applies, the columns give the block of independent variables being tested. One, two, or three asterisks in a given cell of a matrix implies that the twelve monthly lags of the independent variable jointly "explain" the dependent variable (for the given industry and period) at the .10, .05, or .01 level of significance. No asterisks in a cell implies that the joint contribution of all lags of the given regressor is not significant at the ten per cent level.

Table 11 suggests that, for all industries taken together:

(1) Output growth tends to be relatively exogenous (in the Granger sense), at least in comparison with the growth rates of employment and hours. (Thus hours may be a "leading indicator" without having incremental predictive value for output. See Neftci (1979).) Output seemed to be much more "persistent" in the post-war period, in the sense that lagged growth rates of output became much stronger predictors of the current growth rate.

(2) Hours and employment are rarely found to be Granger-exogenous; they respond both to each other and to output. The two variables are also found to be persistent , in the sense just defined, in both the pre-war and post-war samples. The persistence of employment will be an appealing finding to supporters of the view that there are "adjustment costs" to changing employment. Are there also adjustment costs to changing hours of work? The data seem consistent with this.

(3) The real wage seems to vary nearly independently of the three other variables, neither consistently predicting nor being predictable by them. A remarkably strong finding about the real wage is that, like output, its persistence significantly increased between the pre-war and post-war periods.

The results of the forecast error decomposition exercise are given in

--Table 12 about here--

Table 12. To save space, we report results for three industries only: iron and steel (a durables goods industry), paper and pulp (non-durables), and leather tanning and finishing (semi-durables). Results for the manufacturing aggregates are also reported. The pre-war and post-war forecast error decompositions are placed side-by-side in the table, for

easier comparison. Also, note that, since the growth in productivity is just a linear combination of the growth in output, hours, and employment (all of which were included in the VARs), it is possible to report decomposition for this variable as well.

As the reader familiar with these methods is aware, the attribution of forecast error at different horizons to the (triangularized) innovations in the regressors is not invariant to the ordering of the variables. The ordering used here (and for the construction of the impulse-response diagrams, below) is as follows: (log-differences of) output, hours, employment, real wages. Given that the data are monthly, and that forecast horizons up to 48 months are studied, the choice of ordering is not likely to be crucial to the results.

The pattern of relationships suggested by Table 12 is, perhaps not surprisingly, very similar to that revealed by the F-tests reported in Table 11. Note, for example, that the relatively exogenous output variable (IP) is shown in Table 12 to be largely "self-caused," even at the four-year forecast horizon. (This tendency seems to be even greater in the post-war period than in the pre-war.) Hours and employment are fairly sensitive to output innovations except, for some reason, in the post-war leather industry. The "persistence" of both hours and employment is apparent; this persistence increases markedly for hours in the post-war. The productivity variable is largely driven by innovations in output, especially in the post-war, although productivity's other components (employment and hours) also play a role.

Again, a most striking finding is the relationship (or lack of a relationship) between real wages and the other variables: Innovations in the real wage appear to have virtually no predictive power for output, employment, and weekly hours; and, in the other direction, no variable except the real wage itself is of much use in forecasting the real wage. This essential independence of the real wage and the other variables is more pronounced in the post-war period.

The final exercise in the time domain was the use of the estimated VARs to generate impulse-response (IR) diagrams. These diagrams show the movement over time of each variable in the VAR in response to a (triangularized) innovation to one of the regressors. (The response of productivity to innovations in the other variables was also analyzed.) The ordering of the variables was the same as in the forecast error decompositions, above. Since the data are in log-differences, we printed out cumulative-response diagrams; this allowed us to interpret the patterns in terms of log-levels. These diagrams were useful for gaining a qualitative appreciation of "typical" short-run patterns in the data.

The number of industries, variables, and sample periods meant that there were potentially hundreds of IR diagrams to study. We chose to look carefully only at the three representative industries (iron and steel, paper, leather); we also looked closely at construction. The reader will be burdened with only a few sample IR diagrams (see Figures 1-2). These show

--Figures 1 - 2 about here--

the 48-month response pattern of (the log-levels of) output, hours, employment, real wages, and productivity to a one-standard-deviation innovation in output growth in the iron and steel industry. Figures 1(a) through 1(d) are for the pre-war period; Figures 2(a) through 2(d) are for the post-war. The path of output is included in each diagram, for reference.

From our examination of all the IR diagrams, we drew the following conclusions:

(1) Generally, the IRs reinforce the characterization of the cycle obtained in the frequency domain. For example, the conclusion of Section V that productivity is highly coherent with output and that it tends to lead the cycle by a few months emerges distinctly from the IR diagrams; this is true no matter which disturbance term provides the initial shock. Similarly, the high coherence and the lead/lag patterns for hours and employment found by frequency domain techniques recur almost exactly in the IRs. Figures 1(a), 1(b), 1(d), 2(a), 2(b), and 2(d) are here perfectly representative.

(2) As the frequency domain analysis was less clear about the cyclical characteristics of the real wage, so it is the case in the time domain. The pictures show a real wage behavior which is not very stable across industries and which is also sensitive to the source of the initial shock, especially in the pre-war sample. However, as in Section IV, there still appear to be noticeable differences between pre-war and post-war wage movements. (See Figures 1(c) and 2(c)). During the post-war, in the cases when there is a visible relationship between output and wages, the IRs show the real wage to be a roughly coincident, procyclical variable. In the pre-war data, the real wage is usually "half out-of-phase," either lagging (the typical response to output shocks; see Figure 1(c)) or leading (when there is an employment shock). There is also an interesting contrast between the pre-war and post-war periods with regard to the effect of a wage shock on the rest of the system: A pre-war wage shock tends to result in declining

output and employment, while a wage shock in the post-war sample typically has just the opposite effect.

(3) Finally, the diagrams show a post-war decline in cyclical variability (given a "typical" shock), which is consistent with several findings already discussed. Output and real wages in particular (reflecting their increased "persistence"?) are much less prone to gyrations in the post-war sample.

VII. Four Major Recessions

The analysis so far has been "democratic" in its use of the data, allowing every sample observation an equal weight in the calculations. This is consistent with the view that business cycles are realizations of stationary stochastic processes. An alternative view is that serious recessions or depressions are "special" occurrences, governed by different laws of probability than the "normal" parts of the sample. (This idea is investigated more formally by the Blanchard-Watson paper in this volume.) In the spirit of this alternative view, this section looks briefly at the behavior of labor market variables during four major downturns - two pre-war and two post-war.

The four downturns studied are 1929 III-1933 I; 1937 II-1938 II; 1973 IV - 1975 I; and 1981 III-1982 IV, where Roman numerals denote quarters. Note that, except for the first, the recessions are of comparable length. (The peak and trough quarters are from the official NBER chronology.)

--Table 13 about here--

For each of the four downturns, Table 13 gives (for each of the seven labor market variables studied) the ratio of the average value of the level of the variable in the trough quarter to its average value in the preceding peak quarter. (The data are detrended and deseasonalized.) The purpose of this is to get a rough measure of the behavior of these variables in individual major recessions. (Alternatives would have been to construct multi-stage Burns-Mitchell "reference cycles" or to look at all quarters of the downturns. We experimented with both of these but did not find them much more informative.)

A preliminary point that should be made is that the designated peaks and troughs are based on aggregate economic variation, which may not coincide exactly with the industry-level cycles. Nevertheless, there is obviously a strong correlation between aggregate and industry output: In Table 13 the trough-to-peak ratio for (detrended) production exceeds one only four times in thirty-eight cases.

The trough-to-peak ratios for most of the variables displayed in Table 13 do not seem too far out of line with our findings of previous sections. Employment and hours display their strong procyclicality throughout. As in Section IV, we see again here that post-war employers seemed to rely more on layoffs than on short weeks as the means of reducing labor input in the trough, while pre-war employers relied relatively more heavily on part-time work. Real wages show little systematic peak-to-trough change, which is indicative of the low coherence of real wages and output. Product wages are more variable than real wages; they also show some tendency to countercyclicality. Weekly real earnings, as would be predicted , are clearly procyclical.

A variable which is somewhat puzzling is productivity. The standard finding that productivity is procyclical implies that its trough-to-peak ratio should be less than one. This ratio is actually below one only about half of the thirty-four cases in which output declines between peak and trough. Productivity is most procyclical in the heavy durable-goods industries (iron and steel, automobiles); in the other industries productivity is more likely to rise than fall, peak-to-trough.

A partial explanation of these results may follow from our earlier finding that productivity, although essentially procyclical, may lead the cycle by a number of months. Thus productivity at the output peak has already fallen from its highest level, while at the output trough it has already begun to recover. (A similar observation is made by Gordon (1980).) The recovery of productivity in the trough may also be particularly strong in very deep recession, in which financial pressure on firms increases the costs of hoarding labor or permitting inefficient production. These considerations serve at least to reduce this new productivity puzzle, although they probably do not eliminate it.

Putting the productivity question aside, Table 13 does suggest that there are qualitative similarities between major recessions and less dramatic economic fluctuations. This should be encouraging to forecasters and policy-makers, whose tasks would be impossible if every severe fluctuation were essentially a unique event.

VIII. Conclusion

This exercise in "measurement without theory" has supported some existing perceptions about the cyclical behavior of labor markets and has uncovered a few additional facts. To summarize the most important findings:

1. Procyclical labor productivity (SRIRL) appears to be present in every industry, in both the pre-war and post-war periods. (This paper is the first to document SRIRL for the pre-1932 period, as far as we know.) However, in confirming this standard empirical result, we have found two qualifications: First, productivity is a leading, rather than coincident, variable. Second, SRIRL may be less pronounced in major recessions.

2. Weekly hours and employment are strongly procyclical. Hours lead output, while employment lags. Our evidence that employment is lagging rather than coincident is somewhat novel; otherwise, these observations replicate previous results.

3. A new finding is that there has been an increased reliance in the post-war period on layoffs, rather than short work-weeks, as a means of reducing labor input.

4. The relationship of the real wage to other variables over the business cycle is weak, and has been weaker in the post-war period. On the question of whether any cyclical sensitivity of the real wage exists at all, the results from the frequency domain analysis are much more affirmative than those for the time domain. The difference between the two approaches probably arises from the fact that the frequency domain analysis blocks out some high-frequency interference which the time domain analysis does not; this permits the frequency domain approach to recover a relationship at business cycle frequencies which is less apparent in the time domain. The noisiness of the wage-employment relationship in the time domain may explain the inability of Geary and Kennan (1982) to reject the hypothesis that these two series are independent.

5. To the extent that the real wage is related to the cycle, there seems to be a definite difference between its pre-war and post-war

behaviors. The real wage was procyclical (essentially coincident) in the post-war period, but "half out-of-phase" (usually lagging) in the pre-war. This difference has not been noticed before for real wages, although Creamer (1950) found that nominal wages lagged the cycle in the early pre-war period.

6. The relationship of product wages to the cycle is, if anything, weaker and more erratic than that of real wages. Real weekly earnings are strongly procyclical in both major samples.

7. Cyclical variation is a relatively small part of the total variation of the labor market variables. (A similar finding is in Bernanke (1983).) The postwar data exhibit more stability (i.e., less total variance and and less business cycle variance). They also are more serially persistent than the data from the earlier period, which may be interpreted either as being consistent with Sachs' (1980) finding of greater rigidity, or as being simply a reflection of a more stable economy.

We hope that this and similar analyses will lead to a better understanding of the cyclical behavior of labor markets. However, we emphasize once again that this research is intended to be a complement to, not a substitute for, structural modelling of these phenomena.

Notes

1. This is not to say that no empirical work on cyclical aspects of labor supply exists for the pre-war period; for a fascinating example, see Woytinsky (1942).

2. Bodkin (1969) notes that the French economist Rueff made the same prediction in 1925.

3. This is reminiscent of Creamer's (1950) result for nominal wage rates. See Section II.

Data Appendix

I. Sources

The sources of the pre-war industry data used in this study are as follows:

1) Earnings, hours, and employment data are from Beney (1936) and Sayre (1940). These data are the result of an extensive monthly survey conducted by the National Industrial Conference Board from 1920 until 1947.

All of the industries in the sample paid at least part of their workforce by piece rates (see the Monthly Labor Review, vol. 41, no. 3, September 1935, pp. 697-700). No correction was made for this.

2) Industrial production data are from the Federal Reserve Board. See "New Federal Reserve Index of Industrial Production," Federal Reserve Bulletin, August 1940, pages 753-69 and 825-74.

3) Wholesale price indexes are from the Bureau of Labor Statistics. See the following publications of the U.S. Department of Labor: Handbook of Labor Statistics (1931 ed., Bulletin 541; 1936 ed., Bulletin 616; 1941 ed., Bulletin 694), and Wholesale Prices 1913 to 1927 (Washington: U.S.G.P.O., 1929, Bulletin 473). For the automobile industry we merged two BLS series of motor vehicles prices. Neither series covered 1935; the price series on all metal products was used to interpolate the automobiles price series for that year.

4) The consumer price series is from Sayre (1948).

All basic data were seasonally unadjusted. The span of the pre-war sample is January 1923 to December 1939. Although some of the data exist before 1923, there are two major problems with extending the sample further back: 1) Some of the industrial production data are missing. 2) There is a six month gap in the NICB survey in 1923. The December 1939 stop date was chosen so as to avoid consideration of the many special features of the wartime economy.

The sources of the post-war industry data are as follows:

1) Earnings, hours, and employment data are from *Employment and Earnings, United States*, (Bureau of Labor Statistics).

2) Industrial production indexes for industries 1-10 are from the Federal Reserve Board. (See Board of Governors, Federal Reserve Board, *Industrial Production* (1976). Updates are from the *Federal Reserve Bulletin*, and some unpublished series were obtained directly from the Board.) The output index for construction was obtained by dividing the value of new construction (as reported by the Survey of Current Business) by the Department of Commerce construction cost index (also available in the *SCB*).

3) Wholesale prices are again from the Bureau of Labor Statistics. See *Wholesale Prices and Price Indexes, 1963* (BLS Bulletin 1513), *Producer Price Indexes*, and the *Monthly Labor Review*.

4) The consumer price series used to calculate real wages is the Department of Labor's consumer price index (all items, wage earners and clerical workers, revised.)

Again, the basic data are seasonally unadjusted. The span of the post-war sample is 1954-82, except for the wool textile industry, where the data begin in January 1958. Adequate data on output prices (and, therefore, on product wages) are missing for wool textiles after 1975 and for electric services before 1958.

The total manufacturing series were as follows:

1) For the pre-war period, output was measured by the industrial production index for manufacturing. Employment, hours, and earnings data come from the National Industrial Conference Board, as reported in Beney (1936) and Sayre (1940). The NICB series are based on 25 major manufacturing industries; the coverage is similar but not identical to that of the industrial production index. The manufacturing output price, used only in the construction of the product wage variable, is the BLS wholesale price index for non-agricultural, non-fuel goods. Again, the coverage is similar but not identical to that of the IP index.

2) For the post-war period, again the IP index for manufacturing is used to measure output. Employment, hours, and earnings data are for manufacturing production workers; the output price is the wholesale price index for total manufactuerers. Those data are from Business Statistics and the Survey of Current Business and, as far as we can tell, are mutually consistent.

II. Stationarity

The log-differenced data series appeared in general to be stationary. We arrived at this conclusion by studying the autocorrelations and partial autocorrelations of the log-differenced data and by testing for the presence of trend shifts and higher-order trend terms in the log-levels. Rejections of stationarity were sufficiently infrequent and weak that, for the sake of uniform treatment of the data, we decided to ignore them.

III. Reduction of High-Frequency Noise

The spectra of most of the series exhibited considerable power in the higher frequencies; high-frequency noise (primarily seasonality) may interfere with the analysis of the data at business-cycle frequencies. To reduce this noise, we regressed each log-differenced series against a constant, seasonal dummies, and (where applicable) dummy variables for strike periods. (There was no pooling of regressions across industries or between the two major sample periods. There also appeared to be no need to allow for shifts of the regression coefficients within subsamples.) The residuals from these regressions, "cleaned" of much of the very high- and low-frequency noise of the original series, were treated as the basic data in the frequency and time domain analyses.

(NOTE: APPENDIX CONTINUES NEXT PAGE)

IV. Details of Frequency Domain Calculations

The entries of Tables 7 through 10 were constructed by simple averaging of the finite Fourier transforms (evaluated at evenly-spaced intervals on $(0, \pi)$) for each data series. Since the pre- and post-war sample sizes differed, the frequencies corresponding to the "business cycle" varied as well; thus, each calculation involved averages of about 7% (that is, 1/12–1/96) of the number of periodogram ordinates calculated for each variable.

Table 6 gives square roots of the cumulated periodogram ordinates (between 12 and 96 months) for each variable. These calculations (and those in the remaining tables) will not be affected by the seasonal or strike adjustments made for the log-differenced data.

Standard errors for the sample coherence $\hat{\rho}$ and phase $\hat{\theta}$ between each pair of variables were computed using the following formulae, adapted from Hannan (1970, Chapter 7):

$$[SE(\hat{\rho})]^2 = \nu^{-1/2}(1-\hat{\rho}^2), \quad \text{and}$$

$$[SE(\hat{\theta})]^2 = \nu^{-1/2}\left(\frac{1-\hat{\rho}^2}{\hat{\rho}^2}\right)^{1/2},$$

where ν is twice the number of periodogram ordinates in the 12 to 96 month range. Since these expressions are derived from the asymptotic behavior of finite Fourier transforms, the resulting confidence intervals are only approximate, and will be poorly behaved for $\hat{\rho}$ near zero or one; still, the standard errors are useful guides to the precision of the estimates.

The estimated phase leads of Tables 8 through 10 were expressed in months by dividing the estimated phase angle $\hat{\theta}$ (and its standard error) by the frequency corresponding to the period in the center of the bandwidth considered. That is, the phase leads calculated for the 12 to 96, 2 to 12, 12 to 24, and 24 to 96 month bandwidths correspond to cycles with period lengths 54, 7, 18, and 60 months, respectively. These period lengths are uniformly higher than the period lengths corresponding to the average frequency in the bandwidth (which is, for example, about $2/(1/12 + 1/96) = 21.33$ months for the 12 to 96 bandwidth). Since the coherences and phase angles are implicitly assumed to be constant within each frequency band, the phase lead for any frequency in the interval can be obtained by rescaling; that is, to obtain a phase lead for a "typical" 20 month cycle, the reported phase lead (and its standard error) for the 12 to 24 month bandwidth can simply be multiplied by 20/18. The tests of equality of phase angles in Table 9 do not use the "scaled" phase leads above; rather, t-statistics for the difference in phase angles are constructed directly from the standard error formulae reported above (and use the large-sample independence of the phase estimates for the pre- and postwar periods).

All calculations were carried out using the RATS statistical package (see Doan and Litterman (1981)). Other, more theoretical references to frequency domain methods are the texts by Hannan (1970) and Anderson (1971).

TABLE 1: Industries included in data set

I. Manufacturing Industries (pre-war and post-war data)

Pre-War Industry Title	Post-War Industry Title (SIC Code)
1. Iron and steel (STEEL)	Blast furnaces and steel mills (331)
2. Automobiles (AUTOS)	Motor vehicles and equipment (371)
3. Meat packing (MEAT)	Meat packing plants (201)
4. Paper and pulp (PAPER)	Paper and allied products (26)
5. Boots and shoes (SHOES)	Footwear, except rubber (314)
6. Wool textiles (WOOL)	Weaving and finishing mills, wool (223)
7. Leather tanning (LEATH) and finishing	Leather tanning and finishing (311)
8. Lumber and millwork (LUMBR) (excluding furniture)	Lumber and wood products (24)
9. All manufacturing (ALL MFG) industries	All manufacturing industries

II. Non-Manufacturing Industries (post-war data only)

10. NA (COAL)	Bituminous coal and lignite mining (12)
11. NA (ELECT)	Electric services (491)
12. NA (CONST)	Construction (no code)

TABLE 2: Monthly rates of growth (per cent) of output, employment, weekly hours, and productivity

Industry	Period	IP	EMP	HRS	PROD
STEEL	1923 - 39	0.18	0.07	-0.25	0.35
	1954 - 82	-0.12	-0.26	-0.01	0.14
AUTOS	1923 - 39	0.34	0.07	-0.14	0.42
	1954 - 82	0.16	-0.09	0.00	0.25
MEAT	1923 - 39	0.04	0.05	-0.08	0.07
	1954 - 82	0.18	0.02	-0.01	0.17
PAPER	1923 - 39	0.33	0.06	-0.12	0.39
	1954 - 82	0.33	0.03	0.00	0.29
SHOES	1923 - 39	0.01	-0.07	-0.14	0.22
	1954 - 82	-0.13	-0.22	-0.01	0.10
WOOL	1923 - 39	0.04	-0.08	-0.12	0.24
	1958 - 82	-0.14	-0.43	0.01	0.28
LEATH	1923 - 39	-0.09	-0.14	-0.10	0.15
	1954 - 82	-0.17	-0.29	0.00	0.12
LUMBR	1923 - 39	-0.07	-0.14	-0.10	0.17
	1954 - 82	0.18	-0.06	0.01	0.23
ALL MFG	1923 - 39	0.22	-0.01	-0.12	0.34
	1954 - 82	0.27	-0.02	0.00	0.29
COAL	1954 - 82	0.18	-0.13	0.06	0.26
ELECT	1954 - 82	0.48	0.11	0.00	0.36
CONST	1954 - 82	0.13	0.11	0.02	0.00

TABLE 3: Monthly rates of growth (per cent) of real wages, product wages, and real weekly earnings

Industry	Period	WR	WP	EARN
STEEL	1923 - 39	0.31	0.29	0.06
	1954 - 82	0.16	0.10	0.15
AUTOS	1923 - 39	0.31	0.30	0.17
	1954 - 82	0.11	0.16	0.11
MEAT	1923 - 39	0.29	0.29	0.21
	1954 - 82	0.06	0.15	0.04
PAPER	1923 - 39	0.24	0.24	0.12
	1954 - 82	0.13	0.15	0.13
SHOES	1923 - 39	0.11	-0.01	-0.03
	1954 - 82	0.03	0.05	0.02
WOOL	1923 - 39	0.21	0.20	0.08
	1958 - 82	0.05	0.31 (1)	0.06
LEATH	1923 - 39	0.27	0.25	0.17
	1954 - 82	0.05	0.03	0.05
LUMBR	1923 - 39	0.28	0.27	0.17
	1954 - 82	0.09	0.13	0.10
ALL MFG	1923 - 39	0.26	0.27	0.14
	1954 - 82	0.09	0.10	0.09
COAL	1954 - 82	0.12	-0.04	0.18
ELECT	1958 - 82	0.13	0.05 (2)	0.13
CONST	1954 - 82	0.09	0.03	0.11

Notes:

(1) Sample period is 1958 - 75.
(2) Sample period is 1958 - 82.

TABLE 4: Standard deviations (per cent) of monthly growth rates of output, employment, weekly hours and productivity

Industry	Period	IP	EMP	HRS	PROD
STEEL	1923 - 39	13.40	4.70	6.85	8.00
	1954 - 82	16.09	11.53	2.25	7.06
AUTOS	1923 - 39	30.12	10.37	8.13	22.47
	1954 - 82	7.80	9.69	4.14	8.69
MEAT	1923 - 39	9.91	4.03	3.16	7.95
	1954 - 82	2.82	1.80	1.84	3.87
PAPER	1923 - 39	5.71	1.83	2.47	5.15
	1954 - 82	1.83	1.06	0.98	2.06
SHOES	1923 - 39	11.87	3.18	5.39	10.08
	1954 - 82	4.05	2.86	2.58	5.63
WOOL	1923 - 39	12.04	6.09	4.93	8.64
	1958 - 82	9.30	2.71	2.01	10.17
LEATH	1923 - 39	5.52	2.93	3.52	5.46
	1954 - 82	3.39	2.32	1.71	4.82
LUMBR	1923 - 39	6.80	5.63	4.88	6.79
	1954 - 82	2.85	2.47	1.87	3.62
ALL MFG	1923 - 39	4.70	2.36	2.59	2.92
	1954 - 82	3.28	1.36	1.17	2.58
COAL	1954 - 82	14.00	16.05	8.18	11.74
ELECT	1954 - 82	1.45	0.91	0.91	1.94
CONST	1954 - 82	7.88	6.17	2.87	5.25

TABLE 5: Standard deviations (per cent) of monthly growth rates of real wages, product wages, and real weekly earnings

Industry	Period	WR	WP	EARN
STEEL	1923 - 39	2.14	2.24	7.02
	1954 - 82	1.32	1.50	2.96
AUTOS	1923 - 39	1.90	2.24	8.32
	1954 - 82	1.69	1.87	5.21
MEAT	1923 - 39	2.24	4.81	3.25
	1954 - 82	1.29	4.05	2.43
PAPER	1923 - 39	1.30	2.14	2.43
	1954 - 82	0.83	3.61	1.36
SHOES	1923 - 39	2.70	2.47	5.41
	1954 - 82	0.95	1.80	2.60
WOOL	1923 - 39	2.14	2.97	4.79
	1958 - 82	1.06	1.48 (1)	2.37
LEATH	1923 - 39	1.47	3.03	3.37
	1954 - 82	0.92	2.96	2.12
LUMBR	1923 - 39	4.14	4.74	5.25
	1954 - 82	1.32	1.99	2.37
ALL MFG	1923 - 39	1.24	1.48	2.55
	1954 - 82	2.30	2.34	2.69
COAL	1954 - 82	1.95	2.19	9.04
ELECT	1954 - 82	0.90	1.11 (2)	1.44
CONST	1954 - 82	1.05	1.02	2.80

Notes:

(1) Sample period in 1958 - 75.
(2) Sample period in 1958 - 82.

TABLE 6: Standard deviations (per cent) of monthly growth rates of five variables; business cycle frequencies (12 to 96 months) only

Industry	Period	IP	EMP	HRS	PROD	WR
STEEL	1923-39	3.96	1.59	1.73	1.53	0.59
	1954-82	2.28	1.05	0.48	1.15	0.27
AUTOS	1923-39	4.54	2.72	1.46	2.93	0.36
	1954-82	1.85	1.43	0.47	0.77	0.31
MEAT	1923-39	1.66	1.05	0.49	1.01	0.49
	1954-82	0.46	0.27	0.19	0.36	0.21
PAPER	1923-39	1.33	0.60	0.65	0.76	0.36
	1954-82	0.56	0.30	0.16	0.27	0.14
SHOES	1923-39	1.26	0.47	0.94	0.78	0.68
	1954-82	0.71	0.39	0.38	0.60	0.17
WOOL	1923-39	3.16	1.69	1.06	0.99	0.67
	1954-82	1.56	1.01	0.61	1.74	0.22
LEATH	1923-39	1.19	0.97	0.77	0.82	0.47
	1954-82	0.59	0.49	0.22	0.52	0.14
LUMBR	1923-39	1.75	1.48	0.85	1.19	0.70
	1954-82	0.87	0.61	0.21	0.44	0.23
ALL MFG	1923-39	1.53	0.97	0.67	0.48	0.33
	1954-82	0.60	0.39	0.15	0.21	0.20
COAL	1954-82	0.92	0.71	0.61	0.84	0.25
ELECT	1954-82	0.22	0.16	0.10	0.28	0.13
CONST	1954-82	0.69	0.75	0.21	0.77	0.15

TABLE 7: Coherences of growth rates of six variables with growth rate of output

Bandwidth: 12 months to 96 months

1. Pre-War Data

Industry	EMP	HRS	PROD	WR	WP	EARN
STEEL	.828 (.060)	.883 (.042)	.915 (.031)	.272 (.175)	.230 (.179)	.854 (.051)
AUTOS	.854 (.051)	.583 (.125)	.692 (.099)	.252 (.177)	.271 (.175)	.568 (.128)
MEAT	.773 (.076)	.657 (.107)	.836 (.057)	.541 (.134)	.330 (.168)	.292 (.173)
PAPER	.661 (.106)	.870 (.046)	.721 (.091)	.610 (.119)	.507 (.140)	.836 (.057)
SHOES	.717 (.092)	.836 (.057)	.651 (.109)	.098 (.187)	.142 (.185)	.794 (.070)
WOOL	.934 (.024)	.878 (.043)	.783 (.073)	.449 (.151)	.429 (.154)	.797 (.069)
LEATH	.754 (.082)	.742 (.085)	.341 (.167)	.473 (.147)	.634 (.113)	.823 (.061)
LUMBR	.749 (.083)	.784 (.073)	.276 (.175)	.354 (.165)	.659 (.107)	.638 (.112)
ALL MFG	.935 (.024)	.916 (.031)	.567 (.128)	.567 (.128)	.607 (.119)	.902 (.035)

Note:

Standard errors are in parentheses

TABLE 7: (Continued)

2. Post-War Data

Industry	EMP	HRS	PROD	WR	WP	EARN
STEEL	.898 (.027)	.895 (.028)	.863 (.036)	.527 (.102)	.180 (.137)	.829 (.044)
AUTOS	.912 (.024)	.724 (.067)	.479 (.109)	.733 (.065)	.578 (.094)	.809 (.049)
MEAT	.592 (.092)	.585 (.093)	.618 (.087)	.430 (.115)	.706 (.071)	.648 (.082)
PAPER	.911 (.024)	.771 (.057)	.856 (.038)	.360 (.123)	.735 (.0.65)	.672 (.078)
SHOES	.714 (.069)	.594 (.092)	.503 (.106)	.159 (.138)	.094 (.140)	.590 (.092)
WOOL	.418 (.127)	.295 (.141)	.586 (.101)	.252 (.144)	.573 (.123)	.294 (.141)
LEATH	.620 (.087)	.412 (.117)	.416 (.117)	.164 (.138)	.368 (.122)	.385 (.120)
LUMBR	.881 (.032)	.845 (.040)	.658 (.080)	.378 (.121)	.489 (.108)	.779 (.056)
ALL MFG	.941 (.016)	.839 (.042)	.684 (.075)	.378 (.121)	.314 (.128)	.693 (.073)
COAL	.603 (.090)	.710 (.070)	.331 (.126)	.371 (.122)	.063 (.141)	.676 (.077)
ELECT	.290 (.129)	.359 (.123)	.734 (.065)	.287 (.130)	.203 (.148)	.413 (.117)
CONST	.568 (.096)	.344 (.125)	.384 (.121)	.274 (.131)	.507 (.105)	.397 (.119)

TABLE 8: Phase leads of growth rates of six variables with respect to growth rate of output, in months

Bandwidth: 12 months to 96 months

1. Pre-War Data

Industry	EMP	HRS	PROD	WR	WP	EARN
STEEL	-4.7 (1.11)	1.8 (0.9)	2.3 (0.7)	-5.3 (5.7)	-0.3 (6.9)	1.2 (1.0)
AUTOS	-0.5 (1.0)	10.4 (2.3)	-2.9 (1.7)	-10.6 (6.2)	-6.0 (5.8)	9.8 (2.4)
MEAT	-6.0 (1.3)	2.2 (1.9)	4.6 (1.1)	-22.2 (2.5)	-7.6 (4.7)	-5.1 (5.3)
PAPER	-7.3 (1.8)	2.4 (0.9)	2.3 (1.6)	-19.3 (2.1)	26.5 (2.8)	-0.5 (1.1)
SHOES	-6.3 (1.6)	-2.4 (1.1)	9.0 (1.9)	-11.5 (16.6)	9.0 (11.3)	-3.0 (1.2)
WOOL	-2.6 (0.6)	2.1 (0.9)	2.7 (1.3)	-15.8 (3.2)	24.7 (3.4)	-0.6 (1.2)
LEATH	-5.7 (1.4)	2.8 (1.5)	11.1 (4.5)	-14.6 (3.0)	26.5 (1.9)	-0.7 (1.1)
LUMBR	-3.8 (1.4)	2.0 (1.3)	11.2 (5.7)	-19.1 (4.3)	27.0 (1.9)	-0.7 (2.0)
ALL MFG	-3.9 (0.6)	2.3 (0.7)	9.3 (2.4)	-11.6 (2.4)	-19.5 (2.1)	-0.3 (0.8)

Note:

Standard errors are in parentheses.

TABLE 8: (Continued)

2. Post-War Data

Industry	EMP	HRS	PROD	WR	WP	EARN
STEEL	-2.8 (0.6)	1.1 (0.6)	2.2 (0.7)	3.1 (2.0)	9.3 (6.6)	1.6 (0.8)
AUTOS	-2.5 (0.5)	4.5 (1.2)	5.0 (2.2)	3.6 (1.1)	3.9 (1.7)	4.1 (0.9)
MEAT	-4.1 (1.7)	2.3 (1.7)	1.8 (1.6)	0.1 (2.6)	-1.6 (1.2)	1.3 (1.4)
PAPER	-4.4 (0.6)	2.1 (1.0)	3.9 (0.7)	7.2 (3.2)	10.0 (1.1)	3.5 (1.3)
SHOES	-5.9 (1.2)	1.6 (1.7)	3.8 (2.1)	-7.6 (7.6)	11.9 (12.9)	0.8 (1.7)
WOOL	-3.4 (2.8)	-1.0 (4.1)	1.5 (1.8)	4.9 (4.9)	24.3 (2.0)	0.5 (4.1)
LEATH	-2.3 (1.5)	3.5 (2.7)	1.7 (2.7)	-5.4 (7.3)	12.4 (3.1)	1.8 (2.9)
LUMBR	-3.9 (0.7)	2.0 (0.8)	6.4 (1.4)	-1.2 (3.0)	25.7 (2.2)	1.0 (1.0)
ALL MFG	-2.4 (0.5)	2.1 (0.8)	4.4 (1.3)	0.7 (3.0)	8.4 (3.7)	1.6 (1.3)
COAL	-5.1 (1.6)	-0.1 (1.2)	9.1 (3.5)	-10.4 (3.0)	-21.3 (19.2)	-1.7 (1.3)
ELECT	-16.0 (4.0)	-0.3 (3.2)	1.9 (1.1)	2.8 (4.1)	-5.4 (4.9)	1.3 (2.7)
CONST	-4.2 (1.8)	4.2 (3.3)	5.0 (2.9)	11.6 (4.3)	12.3 (2.0)	6.7 (2.8)

TABLE 9: Phase leads of growth rates of six variables with respect to growth rate of output, in months

(a) Bandwidth: 2 months to 12 months
(b) Bandwidth: 12 months to 24 months
(c) Bandwidth: 24 months to 96 months

1. Pre-War Data

Industry		EMP	HRS	PROD	WR	WP	EARN
STEEL	(a)	-0.4	0.0	0.2	-1.9	2.5	-0.1
	(b)	-1.6	0.6	0.8	2.2	2.4	0.8
	(c)	-5.0	2.1	2.5	-13.8***	-13.5***	-0.4
AUTOS	(a)	0.3	0.5	-0.2	-1.4	-1.2	0.4
	(b)	-0.3	4.1	-0.9	-2.2	-1.2	4.0
	(c)	0.1	6.6	-3.6	-15.3	-9.4	5.0*
MEAT	(a)	-1.0	-0.1	0.2	-2.0	-1.2	-0.2
	(b)	-2.2	0.6	1.1	-8.2	-5.5	0.2
	(c)	-5.8	23.9***	10.4***	-16.1*	0.3***	-18.9***
PAPER	(a)	-1.4	-0.6	0.3	-3.0	-2.4	-0.9
	(b)	-3.1	0.7	0.8	-7.1	-8.9	0.1
	(c)	-4.5	3.4	2.7	-18.1	27.8	-2.7
SHOES	(a)	-0.3	-0.1	0.1	2.8	2.6	0.1
	(b)	-1.9	-0.9	3.0	-7.4	4.4	-1.1
	(c)	-8.6	-1.1	9.8	-5.0	0.6	-2.3
WOOL	(a)	-0.6	-0.1	0.4	-2.6	-3.4	-0.3
	(b)	-0.6	0.6	0.6	-5.3	-8.9	0.2
	(c)	-4.4	2.9	5.3	-17.5	25.6	-3.5
LEATH	(a)	0.0	-0.1	0.0	1.9	-3.3	0.2
	(b)	-2.4	0.8	3.5	-4.9	8.8	0.1
	(c)	-3.2	4.0	18.7	-15.9	29.5	-4.0
LUMBR	(a)	-0.4	0.6	-0.1	-2.6	-3.0	0.4
	(b)	-1.8	0.4	4.6	-7.4	-8.8	-0.5
	(c)	-1.3***	5.7	-0.9*	-5.7	28.8	0.8
ALL MFG	(a)	-0.5	-0.1	0.6	3.4	-3.2	-0.1
	(b)	-1.7	0.6	2.3	-3.9	-7.2	0.0
	(c)	-3.3*	3.4	19.9***	-12.8	-20.0	-0.7

Note: Asterisks denote significance of t-tests of difference of phase angles between frequency bands (b) and (c), at marginal significance levels of 10% (*), 5% (**), and 1% (***).

TABLE 9: (Continued)

2. Post-War Data

Industry		EMP	HRS	PROD	WR	WP	EARN
	(a)	-0.4	0.0	0.1	0.7	0.9	0.1
STEEL	(b)	-0.9	0.1	0.5	0.8	0.8	0.3
	(c)	-3.3	2.9***	4.4*	4.7	17.6	3.4
	(a)	-0.2	-0.1	1.7	-0.2	-0.1	-0.1
AUTOS	(b)	-0.8	1.5	1.6	1.2	2.0	1.4
	(c)	-2.7	4.6	6.1	3.9	-0.7*	4.3
	(a)	-1.3	0.1	0.0	-0.6	-0.4	-0.1
MEAT	(b)	-1.3	0.9	0.5	1.0	-0.2	0.9
	(c)	-4.9	1.9	2.4	-5.6*	-2.4	-1.5
	(a)	0.4	-0.6	0.0	2.7	-2.0	-0.4
PAPER	(b)	-1.2	0.3	1.0	-2.8	3.1	0.1
	(c)	-5.5	3.6	5.8*	8.7	12.0	5.8*
	(a)	0.3	0.5	0.1	1.0	1.2	0.5
SHOES	(b)	-1.9	0.9	0.6	-3.5	5.3	0.5
	(c)	-6.7	0.8	8.3	-5.6	10.9	0.1
	(a)	0.0	0.1	0.0	0.5	2.5	0.1
WOOL	(b)	-1.9	-1.9	0.5	1.0	-5.2	0.5
	(c)	-2.2	3.7	0.8	7.1	25.2**	4.6
	(a)	0.7	0.7	-0.1	0.7	1.8	0.7
LEATH	(b)	-0.4	1.5	-0.1	-3.3	-8.5	0.7
	(c)	-3.2	3.0	4.2	-2.6	13.3	1.7
	(a)	-0.2	0.1	0.0	0.4	1.2	0.3
LUMBR	(b)	-1.4	0.7	1.3	-2.6	-7.7	0.2
	(c)	-6.2	0.8	18.7***	-8.5	29.1	0.2
	(a)	-0.0	0.2	0.1	0.6	0.7	0.1
ALL MFG	(b)	-0.7	0.0	1.0	-1.8	2.8	-0.7
	(c)	-2.9	4.7***	9.5**	5.7**	9.3	9.5**
	(a)	-0.2	-0.2	0.1	-2.7	-1.6	-0.2
COAL	(b)	-1.1	-0.3	0.7	-3.7	-3.2	-1.1
	(c)	-6.2	0.8	18.7***	-8.5	29.0	0.2
	(a)	2.1	0.7	-0.1	-2.2	0.6	0.3
ELECT	(b)	-5.7	1.1	0.3	-3.3	-4.4	-0.8
	(c)	-16.5	-9.0*	3.1	8.5***	-0.1	5.2
	(a)	0.0	0.2	0.0	-3.4	-3.1	0.2
CONST	(b)	-0.8	1.6	0.6	7.0	5.6	3.2
	(c)	-6.7	1.5	8.5	4.9***	10.3**	4.0

Table 10: Coherences and phase leads of growth rates of output in each industry with respect to growth rate of "all manufacturing" output

Bandwidth: 12 months to 96 months

Industry	Period	Coherence (SE)	Phase lead (SE)
STEEL	1923-39	94.7 (2.0)	1.3 (0.6)
	1954-82	64.6 (8.2)	0.2 (1.4)
AUTOS	1923-39	78.0 (7.4)	-4.1 (1.3)
	1954-82	78.6 (5.4)	0.2 (1.0)
MEAT	1923-39	19.5 (18.2)	1.2 (8.2)
	1954-82	26.2 (13.2)	4.8 (4.5)
PAPER	1923-39	86.7 (4.7)	2.3 (0.9)
	1954-82	79.7 (5.2)	1.2 (0.9)
SHOES	1923-39	73.9 (8.6)	6.7 (1.5)
	1954-82	46.4 (11.1)	4.9 (2.3)
WOOL	1923-39	80.1 (6.8)	3.5 (1.2)
	1954-82	31.9 (13.9)	1.4 (3.9)
LEATH	1923-39	75.0 (8.3)	0.6 (1.4)
	1954-82	38.8 (12.0)	3.7 (2.9)
LUMBR	1923-39	88.0 (4.3)	1.0 (0.9)
	1954-82	73.9 (6.4)	5.3 (1.1)
COAL	1954-82	28.4 (13.0)	-5.4 (4.1)
ELECT	1954-82	44.7 (11.3)	-2.1 (2.4)
CONST	1954-82	57.4 (9.5)	6.3 (1.7)

TABLE 11: VAR F-tests

(*) denotes F-test significant at .10 level
(**) denotes F-test significant at .05 level
(***) denotes F-test significant at .01 level

1. Pre-War Data

Dependent Variables	Industry	Independent Variables: IP	HRS	EMP	WR
IP	STEEL	**	*		***
	AUTOS	***		***	
	MEAT		**		**
	PAPER			**	
	SHOES	***	**		*
	WOOL	*		***	
	LEATH		*		
	LUMBR	***	***		***
	ALL MFG	***			
HRS	STEEL	***	***	***	***
	AUTOS		***		
	MEAT		**	*	*
	PAPER	***	*		*
	SHOES	***	***	***	
	WOOL	***	**	***	
	LEATH	***	***	***	
	LUMBR	**	***		
	ALL MFG	***	*	***	

TABLE 11: VAR F-tests (continued)

1. Pre-War Data

Dependent Variables	Industry	Independent Variables: IP	HRS	EMP	WR
EMP					
	STEEL	*			
	AUTOS	***	***	**	*
	MEAT	**	**		
	PAPER	**		**	
	SHOES	**	**	***	
	WOOL	***		***	
	LEATH	***		**	
	LUMBR	**		**	
	ALL MFG	**	*		
WR					
	STEEL				
	AUTOS		**		
	MEAT				
	PAPER			**	
	SHOES	**	**		
	WOOL				
	LEATH	**			
	LUMBR	***	*	*	***
	ALL MFG			*	

TABLE 11: VAR F-tests (continued)

2. Post-War Data

Dependent Variables	Industry	Independent Variables: IP	HRS	EMP	WR
IP	STEEL	*			
	AUTOS	*		***	
	MEAT	***	**		*
	PAPER	***		**	***
	SHOES	***	***	**	
	WOOL	***	***		
	LEATH	***	**		
	LUMBR	***		***	***
	ALL MFG	***	**	***	
	COAL	***		*	
	ELECT	***			***
	CONST	***			**
HRS	STEEL	**	***	**	
	AUTOS		***		
	MEAT	**	***		**
	PAPER	***	***	*	
	SHOES	***	***	***	
	WOOL	*	***	***	***
	LEATH		***	**	*
	LUMBR		***		
	ALL MFG	***	***	**	
	COAL	***	***	*	**
	ELECT		***		
	CONST		***		

TABLE 11: VAR F-tests (continued)

2. Post-War Data

Dependent Variables	Industry	Independent Variables: IP	HRS	EMP	WR
EMP	STEEL	***	**		
	AUTOS	***	**	***	
	MEAT	***		**	
	PAPER	***	***	***	
	SHOES	**	***	***	
	WOOL	***	***	***	***
	LEATH		***	***	
	LUMBR	***		***	**
	ALL MFG	***		**	
	COAL	*		***	
	ELECT		**	***	
	CONST			**	
WR	STEEL				***
	AUTOS	***		***	***
	MEAT	*			**
	PAPER				***
	SHOES		**		***
	WOOL		*		***
	LEATH				***
	LUMBR			**	
	ALL MFG				***
	COAL				***
	ELECT	**		***	***
	CONST				***

Note:
The F-tests whose outcomes are reported are tests of the joint significance of all 12 lags of the independent variable in the explanation of the dependent variable. (All variables are in growth rates.)

TABLE 12: Percentages of forecast error k months ahead produced by each innovation (pre-war/post-war)

1. Iron and Steel

Forecast error in:	k	Triangularized innovation in: IP	HRS	EMP	WR
IP	6	89/91	2/3	3/5	6/1
	12	79/87	5/4	4/6	13/2
	24	66/85	8/5	5/8	21/2
	48	63/85	8/5	6/8	23/2
EMP	6	31/55	1/1	63/41	5/3
	12	29/52	4/6	59/39	8/4
	24	29/51	5/7	53/38	12/4
	48	29/51	6/7	51/38	15/4
HRS	6	40/43	40/52	19/4	2/1
	12	41/41	34/50	19/7	7/2
	24	40/41	31/49	17/8	12/2
	48	39/41	31/49	17/8	13/2
WR	6	3/4	3/8	6/1	88/86
	12	6/6	5/9	7/4	82/82
	24	8/6	6/9	8/4	78/81
	48	8/6	7/9	8/4	77/81
PROD	6	57/76	29/10	3/12	11/2
	12	49/74	30/10	5/13	16/2
	24	40/73	30/11	7/14	24/3
	48	39/73	30/11	7/14	24/3

TABLE 12: (Continued)

4. Paper and Pulp

Triangularized innovation in:

Forecast error in:	k	IP	HRS	EMP	WR
IP	6	83/92	3/2	10/5	4/0
	12	75/83	6/3	11/7	8/7
	24	71/80	8/3	12/7	10/9
	48	71/80	8/3	12/7	10/9
EMP	6	21/31	1/5	72/62	6/2
	12	19/30	5/6	68/57	8/7
	24	19/30	5/6	65/55	11/10
	48	19/30	5/6	65/54	11/10
HRS	6	30/11	61/86	3/2	6/2
	12	32/14	56/80	4/3	8/3
	24	32/14	54/79	4/4	10/4
	48	32/14	54/79	4/4	10/4
WR	6	9/1	10/2	2/2	80/96
	12	13/2	10/3	8/3	69/93
	24	13/3	10/4	10/3	67/91
	48	13/3.	10/4	10/3	66/91
PROD	6	50/64	26/18	19/17	5/1
	12	45/60	27/16	20/18	8/6
	24	43/58	26/17	19/18	12/8
	48	43/58	26/17	19/18	12/8

TABLE 12: (Continued)

7. Leather tanning and finishing

Triangularized innovation in:

Forecast error in:	k	IP	HRS	EMP	WR
IP	6	84/90	5/3	8/5	3/2
	12	80/87	8/5	7/5	4/3
	24	78/85	10/7	8/5	5/4
	48	78/85	10/7	8/5	5/4
EMP	6	21/8	8/9	69/82	2/2
	12	23/8	9/10	65/78	4/4
	24	29/8	9/10	58/78	4/4
	48	29/8	10/10	56/78	5/4
HRS	6	19/3	69/89	7/3	6/5
	12	21/5	65/84	8/6	6/6
	24	23/5	61/82	9/6	7/7
	48	24/5	60/81	9/6	7/7
WR	6	8/3	12/1	7/3	72/92
	12	14/4	14/3	8/5	64/88
	24	16/5	16/3	9/5	59/87
	98	16/5	16/3	9/5	58/87
PROD	6	24/58	36/14	37/26	3/1
	12	33/55	34/17	30/25	4/3
	24	34/54	34/17	28/25	4/4
	48	35/53	34/17	28/25	4/4

TABLE 12: (Continued)

9. All manufacturing firms

Triangularized innovations in:

Forecast error in:	k	IP	HRS	EMP	WR
IP	6	94/93	1/2	3/4	2/1
	12	77/86	8/4	8/7	7/3
	24	71/82	12/6	10/9	7/3
	48	70/80	12/6	11/10	7/4
EMP	6	64/59	1/2	33/39	2/0
	12	57/57	9/3	31/39	3/2
	24	54/57	11/4	30/38	5/2
	48	53/56	11/4	31/38	5/2
HRS	6	51/22	38/74	9/4	1/1
	12	47/21	38/71	12/5	2/3
	24	46/22	37/68	14/6	4/4
	48	46/22	37/68	14/6	4/4
WR	6	7/2	5/3	11/1	77/94
	12	7/3	9/3	14/2	70/92
	24	13/4	9/3	15/2	62/91
	48	14/4	9/3	16/2	61/91
PROD	6	22/18	41/47	36/34	2/1
	12	22/18	39/44	34/35	5/3
	24	20/19	39/42	35/36	5/3
	48	21/19	39/42	35/36	5/3

TABLE 13: Trough-to-peak ratios of seven variables for four selected recessions

I:	1933 I /1929 III
II:	1938 II/1937 II
III:	1975 I /1973 IV
IV:	1982 IV/1981 III

Industry	Cycle	IP	EMP	HRS	PROD	WR	WP	EARN
STEEL	I	.17	.50	.56	.62	.91	.84	.50
	II	.36	.72	.65	.77	.95	.92	.62
	III	.87	.96	.95	.95	1.00	.81	.95
	IV	.57	.68	.96	.87	.99	1.05	.94
AUTOS	I	.18	.40	.76	.58	.99	.88	.75
	II	.36	.49	.85	.86	1.02	.90	.87
	III	.60	.74	.93	.88	.95	.92	.88
	IV	.96	.87	1.01	1.10	.97	.97	.97
MEAT	I	.91	.77	.95	1.25	.95	1.50	.90
	II	1.07	.93	1.03	1.12	.99	1.12	1.02
	III	.97	.98	.99	1.00	1.01	1.17	1.00
	IV	.90	.96	1.00	.94	.94	.94	.94
PAPER	I	.59	.74	.79	1.01	.99	.87	.79
	II	.71	.87	.86	.95	1.06	1.13	.91
	III	.74	.88	.95	.89	.96	.82	.91
	IV	.98	.95	.99	1.05	1.02	1.02	1.01
SHOES	I	.79	.89	.92	.96	.99	.95	.91
	II	.82	.93	.73	1.20	1.00	1.02	.73
	III	.81	.87	.91	1.03	.95	.98	.86
	IV	.87	.91	.98	.97	1.00	1.01	.98

TABLE 13: (continued)

Industry	Cycle	IP	EMP	HRS	PROD	WR	WP	EARN
WOOL	I	.62	.73	.88	.95	.94	1.23	.83
	II	.44	.68	.80	.80	1.01	1.21	.81
	III	.47	.57	.71	1.16	.91	1.23	.65
	IV	.77	.77	.82	1.22	.99	NA	.82
LEATH	I	.76	.80	.91	1.04	.98	1.43	.89
	II	.71	.79	.85	1.06	1.03	1.23	.87
	III	1.03	.99	.99	1.06	.95	1.24	.94
	IV	.88	.90	1.01	.97	1.02	1.07	1.03
LUMBR	I	.32	.42	.74	1.04	.92	1.13	.68
	II	.67	.86	.87	.89	1.02	1.22	.88
	III	.75	.78	.94	1.01	.96	1.21	.91
	IV	1.10	.99	1.02	1.09	1.01	1.06	1.02
ALL MFG	I	.50	.72	.79	.89	.96	1.01	.76
	II	.62	.73	.81	1.05	.97	1.04	.78
	III	.81	.88	.96	.96	.97	.88	.93
	IV	.90	.90	.99	1.01	.99	1.02	.98
COAL	III	1.05	1.20	1.01	.87	.96	.68	.97
	IV	.83	.84	.91	1.09	1.02	1.02	.93
ELECT	III	.96	.98	.97	1.00	.96	.80	.94
	IV	.93	1.00	1.01	.93	1.02	1.00	1.02
CONST	III	.78	.87	.98	.92	.94	.89	.92
	IV	.99	.93	.98	1.09	1.00	1.04	.98

Note:
The variables from which the ratios are formed are detrended, deseasonalized, quarterly averages of levels (not growth rates). Peak and trough quarters are from the official NBER chronology.

Figure 1

Response of log-levels to innovation in output growth

Prewar, iron and steel

Figure 1a here

Figure 1b here

Figure 1c here

Figure 1d here

Figure 2

Response of log-levels to innovation in output growth

Postwar, iron and steel

Figure 2a here

Figure 2b here

Figure 2c here

Figure 2d here

FIGURE 1A

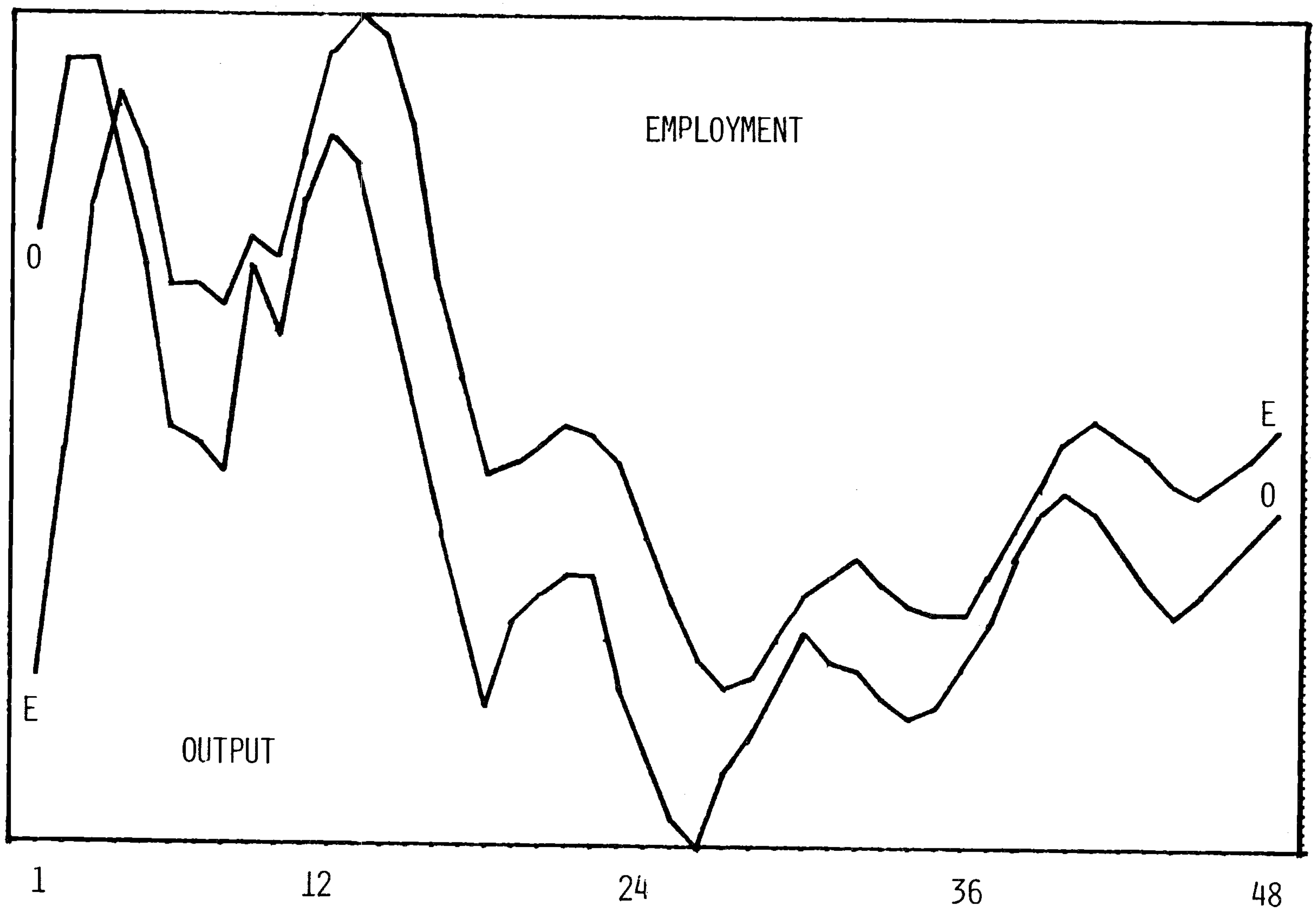


FIGURE 1B

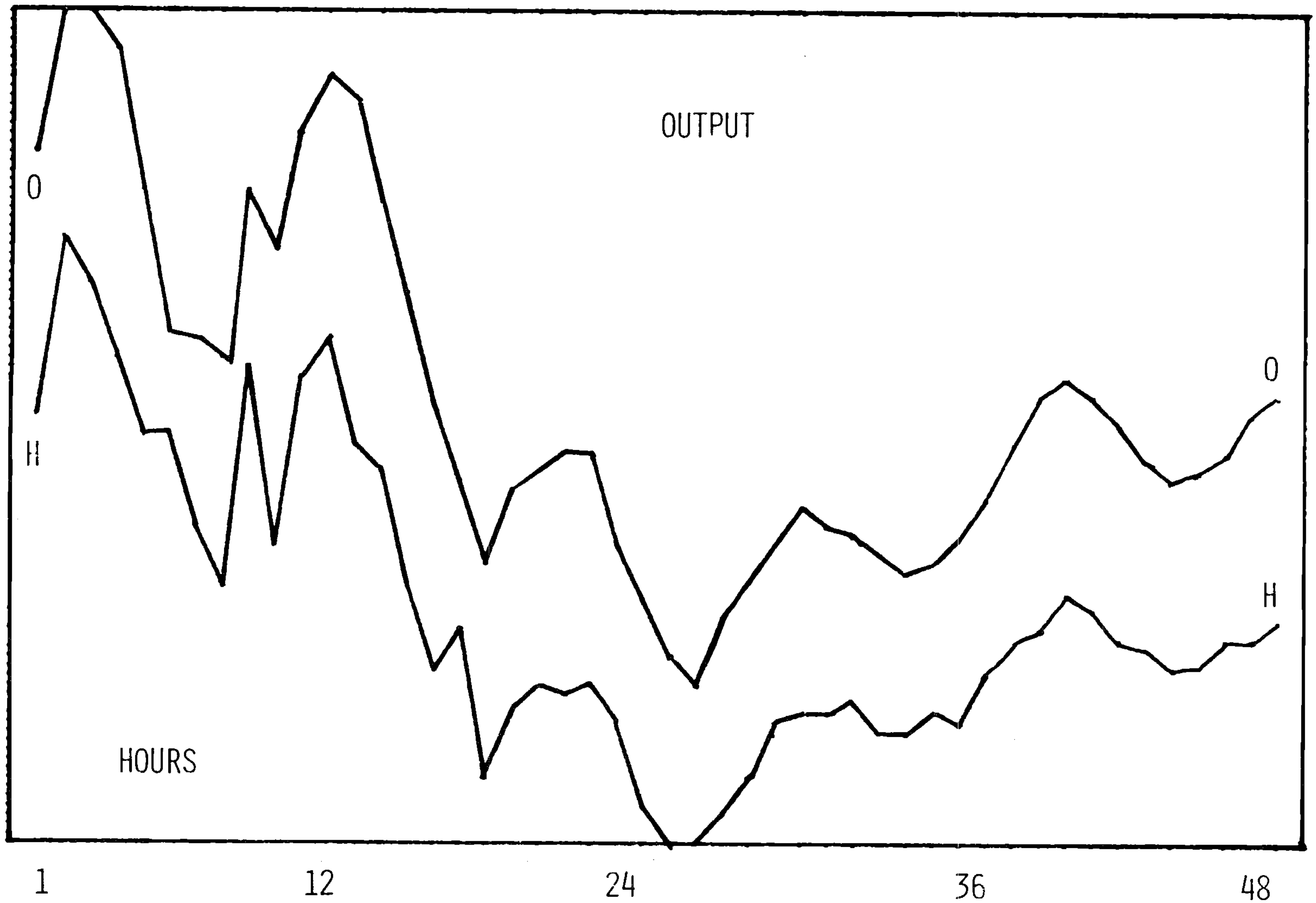


FIGURE 1c

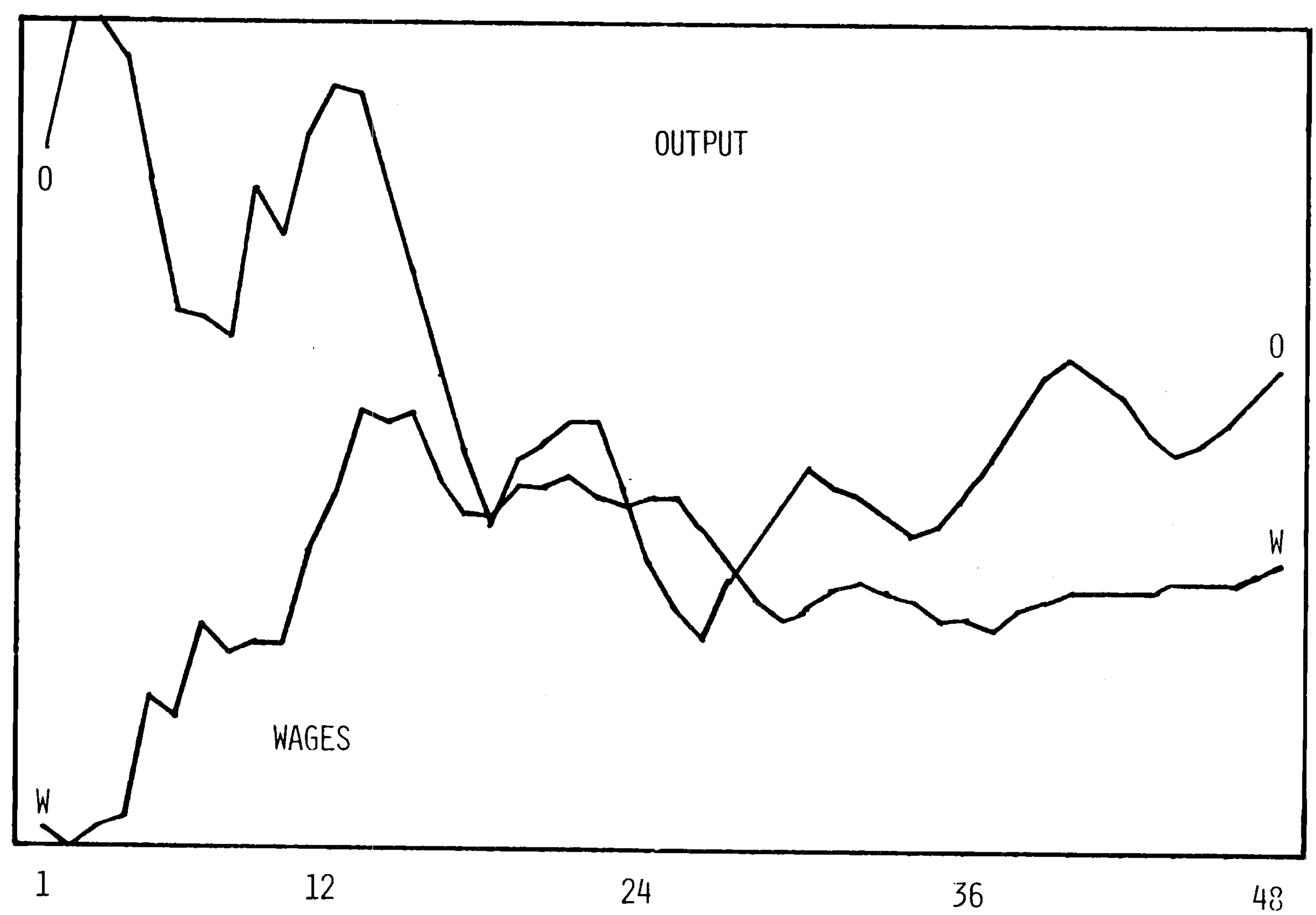


Figure 1d

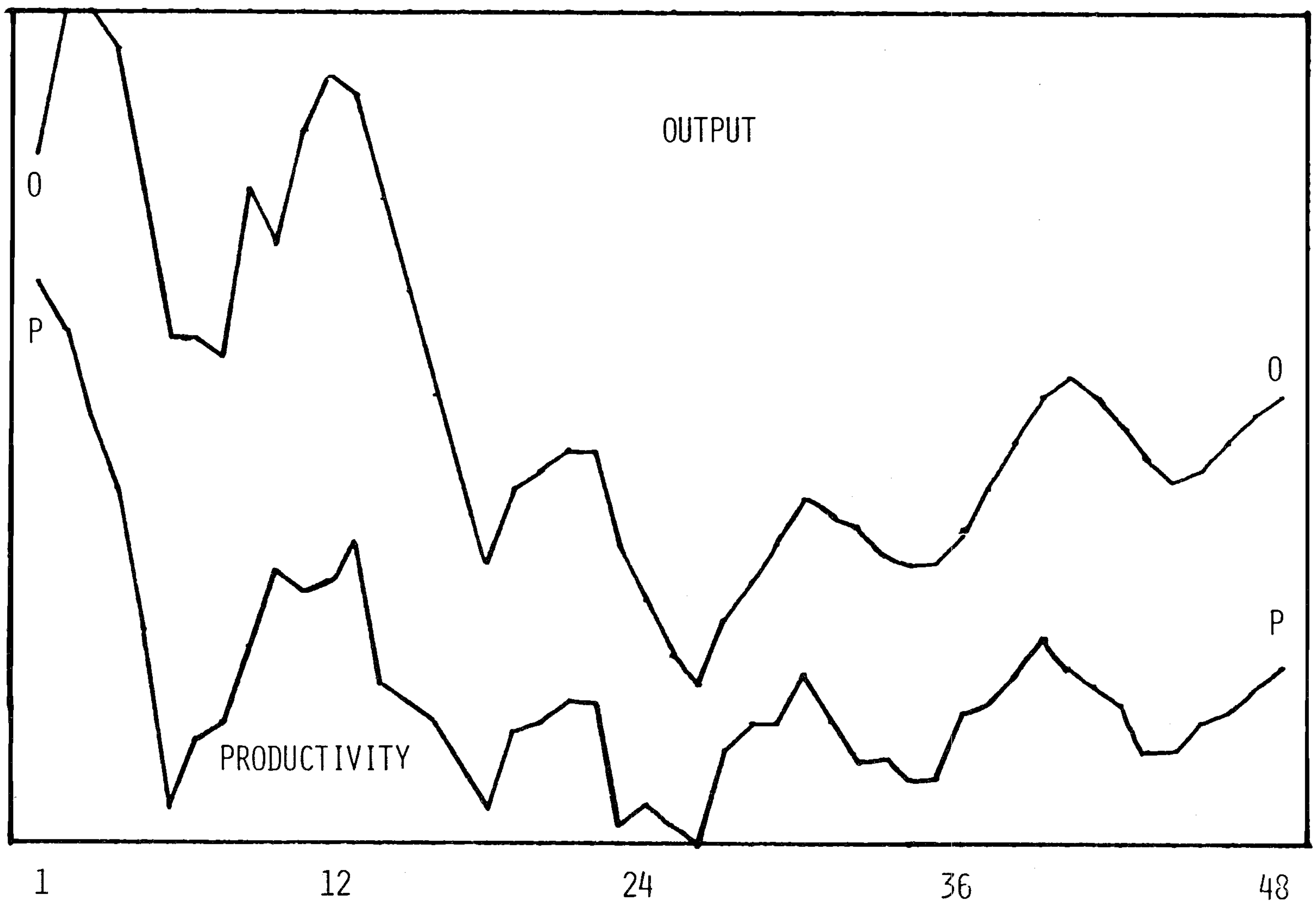


Figure 2A

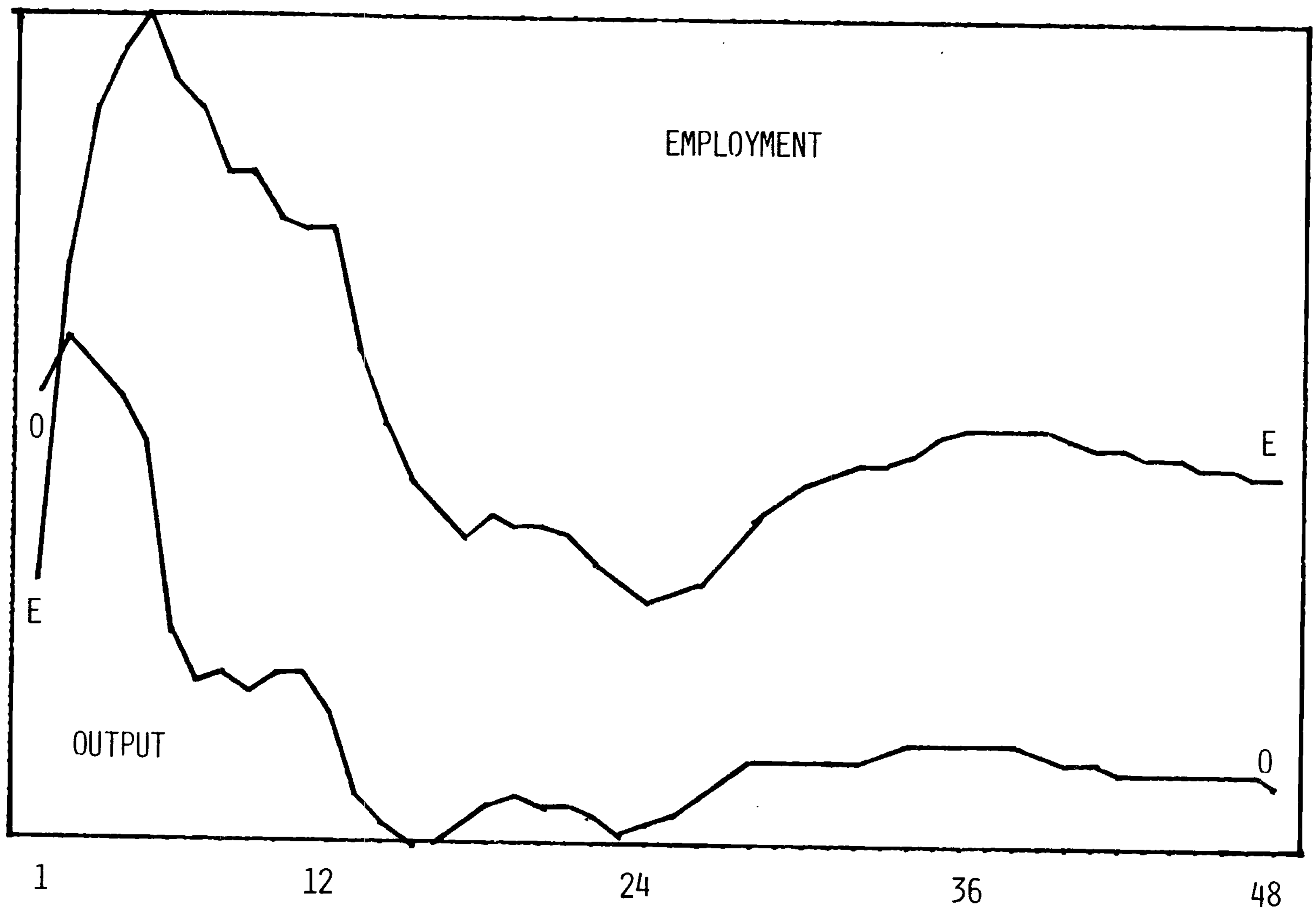


FIGURE 2B

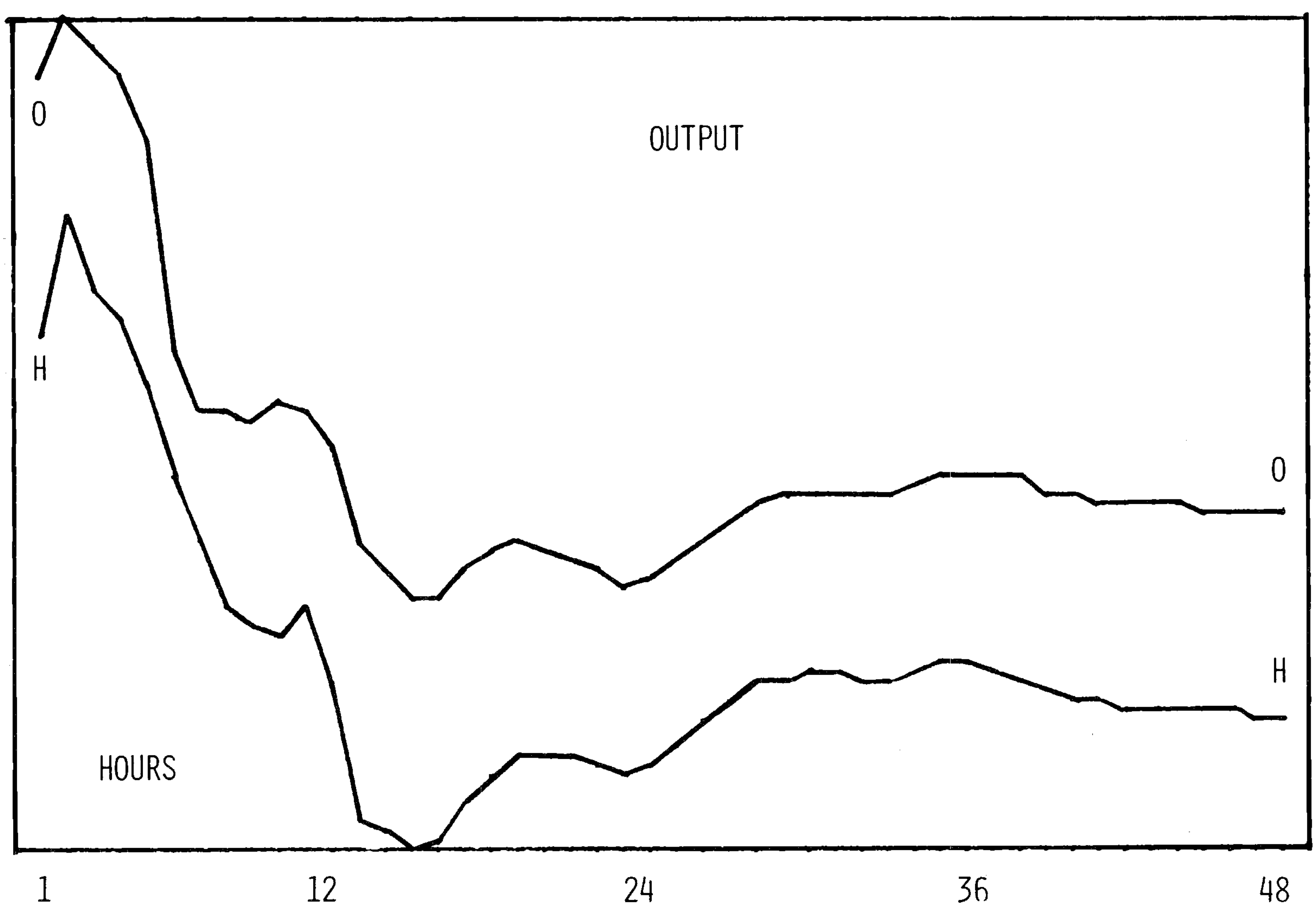


FIGURE 2C

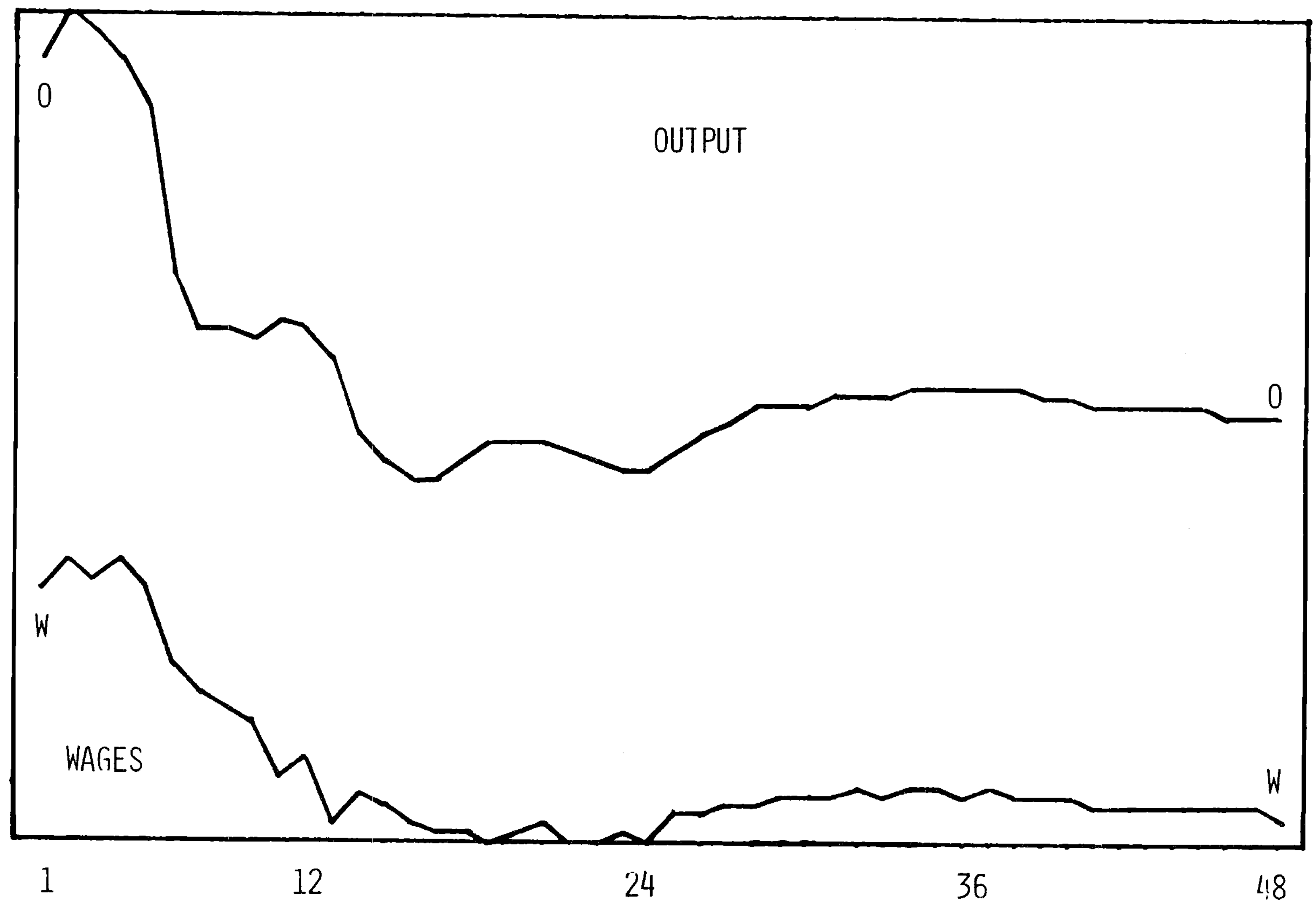
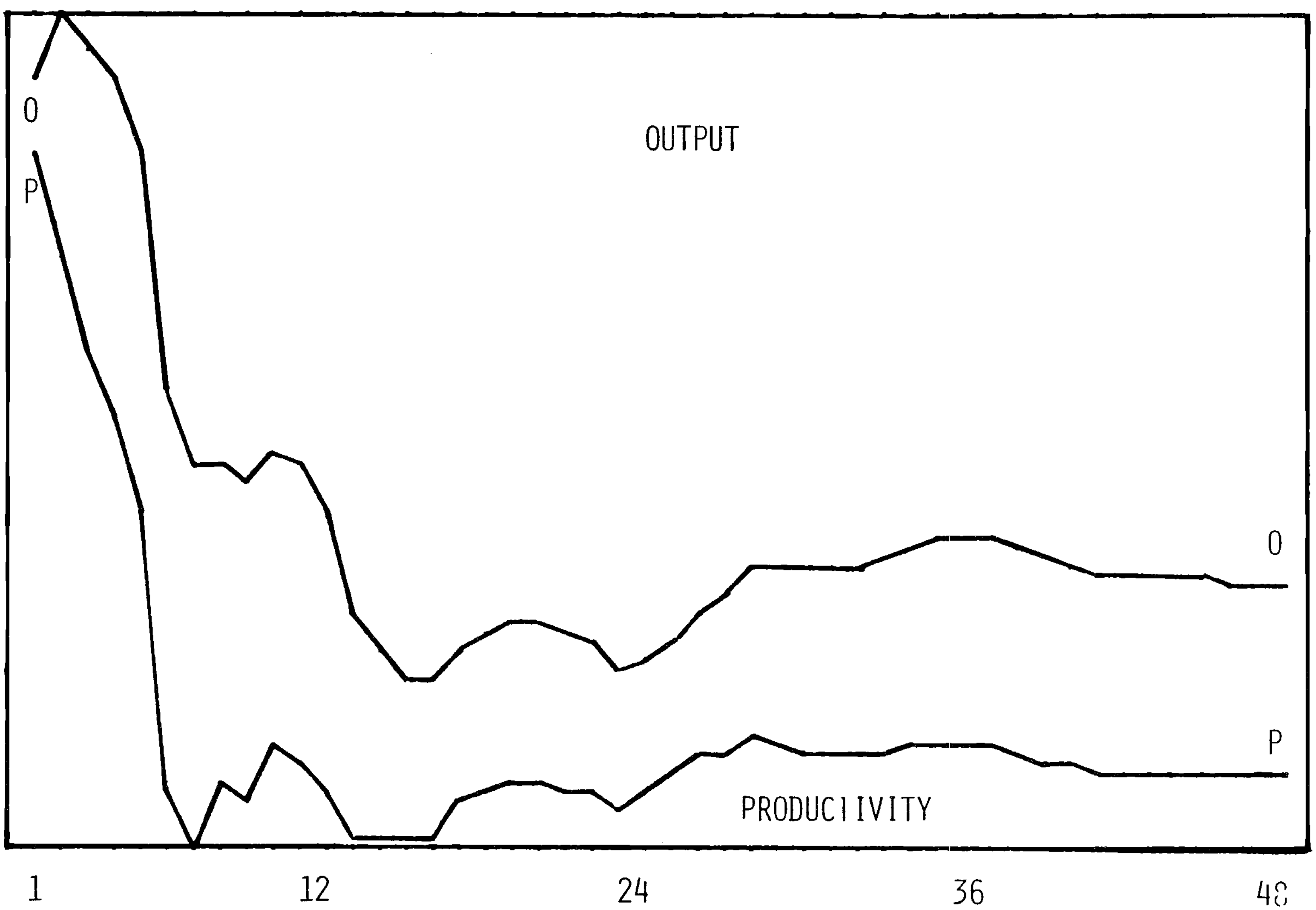


FIGURE 2D



References

ALTONJI, JOSEPH AND ORLEY ASHENFELTER [1980], "Wage Movements and the Labour Market Equilibrium Hypothesis," *Economica*, Vol. 47, pp. 217-45.

ANDERSON, T. W. [1971], *The Statistical Analysis of Time Series*, New York: Wiley.

ASHENFELTER, ORLEY AND DAVID CARD [1982], "Time Series Representations of Economic Variables and Alternative Models of the Labour Market," *Review of Economic Studies*, Vol. 49, pp. 261-82.

BAILY, MARTIN NEIL [1977], "On the Theory of Layoffs and Unemployment," *Econometrica*, Vol. 45, pp. 1043-63.

BALL, R. J. AND E. B. A. ST. CYR [1966], "Short-term Employment Functions in British Manufacturing Industry," *Review of Economic Studies*, Vol. 33, pp. 179-207.

BARRO, ROBERT J. AND HERSCHEL I. GROSSMAN [1971], "A General Disequilibrium Model of Income and Employment," *American Economic Review*, Vol. 61, pp. 82-93.

BENEY, M. ADA [1936], *Wages, Hours, and Employment in the United States, 1914-1936*, New York: National Industrial Conference Board.

BERNANKE, BEN S. [1983], "On the Sources of Labor Productivity Variation in U.S. Manufacturing, 1947-1980," *Review of Economics and Statistics*, Vol. 65, pp. 214-24.

BERNSTEIN, IRVING [1960], *The Lean Years: A History of the American Worker, 1920-1933*, Boston: Houghton-Mifflin.

BODKIN, RONALD G. [1969], "Real Wages and Cyclical Variations in Employment: A Re-examination of the Evidence," *Canadian Journal of Economics*, Vol. 2, pp. 353-74.

BRECHLING, F. P. R. [1965], "The Relationship Between Output and Employment in British Manufacturing Industries," *Review of Economic Studies*, Vol. 32, pp. 187-216.

BRECHLING, F. P. R. AND P. O. O'BRIEN [1967], "Short-run Employment Functions in Manufacturing Industries: An International Comparison," *Review of Economic Studies*, Vol. 99, pp. 277-87.

BRY, GERHARD [1959], "The Average Workweek as an Economic Indicator," occasional paper no. 69, NBER.

BURNS, ARTHUR F. AND WESLEY C. MITCHELL [1947], *Measuring Business Cycles*, New York: National Bureau of Economic Research.

CHIRINKO, ROBERT [1980], "The Real Wage Over the Business Cycle," *Review of Economics and Statistics*, Vol. 62, pp. 459-61.

CLARK, KIM B. AND RICHARD B. FREEMAN [1980], "How Elastic Is the Demand for Labor?," *Review of Economics and Statistics*, Vol. 62, pp. 509-20.

COEN, ROBERT M. AND BERT G. HICKMAN [1970], "Constrained Joint Estimation of Factor Demand and Production Functions," *Review of Economics and Statistics*, Vol. 52, pp. 287-300.

CREAMER, DANIEL [1950], "Behavior of Wage Rates During Business Cycles," occasional paper no. 34, NBER.

DOAN, T. A. AND R. B. LITTERMAN [1981], *RATS User's Manual, Version 4.1*, Minneapolis: VAR Econometrics.

DUNLOP, JOHN T. [1938], "The Movement of Real and Money Wage Rates," *Economic Journal*, Vol. 48, pp. 413-34.

ECKSTEIN, OTTO AND THOMAS A. WILSON [1964], "Short-run Productivity Behavior in U.S. Manufacturing," *Review of Economics and Statistics*, Vol. 46, pp. 41-54.

FAIR, RAY C. [1969], *The Short-run Demand for Workers and Hours*, Amsterdam: North-Holland.

GEARY, PATRICK T. AND JOHN KENNAN [1982], "The Employment - Real Wage Relationship: An International Study," *Journal of Political Economy*, Vol. 90, pp. 854-71.

GORDON, ROBERT J. [1980], "The 'End-of-Expansion' Phenomenon in Short-run Productivity Behavior," Working Paper 427, NBER.

——— [1982], "Why U.S. Wage and Employment Behavior Differs From That In Britain and Japan," *Economic Journal*, Vol. 92, pp. 13-44.

GRANGER, C. W. J. AND M. HATANAKA [1964], *Spectral Analysis of Economic Time Series*, .

HALL, ROBERT E. [1980], "Employment Fluctuations and Wage Rigidity," *Brookings Papers on Economic Activity*, Vol. 1, pp. 91-124.

HANNAN, E. J. [1970], *Multiple Time Series*, New York: Wiley.

HAUSE, JOHN C. [1971], "Spectral Analysis and the Detection of Lead-Lag Relations," *American Economic Review*, Vol. 61, No. 1, pp. 213-17..

HULTGREN, THOR [1960], "Changes in Labor Cost During Cycles in Production and Business," occasional paper no. 74, New York: NBER.

———[1965], *Costs, Prices, and Profits: Their Cyclical Relations*, New York: NBER.

IRELAND, J. J., AND D. J. SMYTH [1967], "Short-term Employment Functions in Australian Manufacturing," *Review of Economics and Statistics*, Vol. 49, pp. 537-44.

JEROME, HARRY [1934], *Mechanization in Industry*, New York: National Bureau of Economic Research.

KEYNES, JOHN MAYNARD [1936], *The General Theory of Employment, Interest, and Money*, London: MacMillan.

———[1939], "Relative Movements of Real Wages and Output," *Economic Journal*, Vol. 49, pp. 34-51.

KUH, EDWIN [1960], "Profits, Profit Markups, and Productivity," Joint Economic Activity paper no. 15.

———[1965], "Cyclical and Secular Labor Productivity in United States Manufacturing," *Review of Economics and Statistics*, Vol. 97, pp. 1-12.

LUCAS, ROBERT E., JR. [1970], "Capacity, Overtime, and Empirical Production Functions," *American Economic Review*, Vol. 60, pp. 23-27.

MASTERS, STANLEY H. [1967], "The Behavior of Output per Man During Recessions: An Empirical Study of Underemployment," *Southern Economic Journal*, Vol. 33, pp. 388-94.

MEDOFF, JAMES L. [1979], "Layoffs and Alternatives under Trade Unions in U.S. Manufacturing," *American Economic Review*, Vol. 69, pp. 380-95.

MITCHELL, WESLEY C. [1951], *What Happens During Business Cycles*, Cambridge, Ma.: Riverside Press for NBER.

MOORE, GEOFFREY H. [1955], "Business Cycles and the Labor Market," *Monthly Labor Review*, Vol. 78, pp. 288-92.

MORRISON, CATHERINE J. AND ERNST R. BERNDT [1981], "Short-run Labor Productivity in a Dynamic Model," *Journal of Econometrics*, Vol. 16, pp. 339-65.

NADIRI, M. ISHAQ AND SHERWIN ROSEN [1973], *A Disequilibrium Model of Demand for Factors of Production*, New York: Columbia U. Press for NBER.

NEFTCI, SALIH N. [1978], "A Time-Series Analysis of the Real Wages - Employment Relationship," *Journal of Political Economy*, Vol. 86, pp. 281-91.

———[1979], "Lead-Lag Relations, Exogeneity, and Prediction of Economic Time Series," *Econometrica*, Vol. 47, pp. 101-13.

OI, WALTER Y. [1962], "Labor as a Quasi-Fixed Factor," *Journal of Political Economy*, Vol. 70, pp. 538-55.

OKUN, ARTHUR M. [1962], "Potential GNP: Its Measurement and Significance," American Statistical Association, Proceedings of the Business and Economics Section, pp. 98-104.

OTANI, ICHIRO [1978], "Real Wages and Business Cycles Revisited," *Review of Economics and Statistics*, Vol. 60, pp. 301-04.

PINDYCK, ROBERT S. AND JULIO J. ROTEMBERG [1982], "Dynamic Factor Demands and the Effects of Energy Price Shocks," Research Paper , M.I.T..

RUGGLES, RICHARD [1940], "The Relative Movements of Real and Money Wage Rates," *Quarterly Journal of Economics*, Vol. 55, pp. 130-49.

SACHS, JEFFREY [1979], "Wages, Profits, and Macroeconomic Adjustment: A Comparative Study," *Brookings Papers on Economic Activity*, Vol. 2, pp. 269-319.

———[1980], "The Changing Cyclical Behavior of Wages and Prices: 1890-1976," *American Economic Review*, Vol. 70, pp. 78-90.

SARGENT, THOMAS J. [1978], "Estimation of Dynamic Labor Demand Schedules Under Rational Expectations," *Journal of Political Economy*, Vol. 86, pp. 1009-44.

SARGENT, THOMAS [1979], *Macroeconomic Theory*, New York: Academic Press.

SAYRE, R. A. [1940], "Wages, Hours, and Employment in the United States, 1934-1939," *Conference Board Economic Record 2*, Vol. 10, pp. 115-37.

——— [1948], *Consumers' Prices, 1914-1948*, New York: National Industrial Conference Board.

SHISKIN, JULIUS [1961], "Signals of Recession and Recovery," occasional paper no. 77, NBER.

SIMS, CHRISTOPHER A. [1974], "Output and Labor Input in Manufacturing," *Brookings Papers on Economic Activity*, Vol. 3, pp. 695-728.

——— [1980], "Macroeconomics and Reality," *Econometrica*, Vol. 48, No. 1, pp. 1-48.

SLICHTER, SUMNER H., JAMES J. HEALY, AND E. ROBERT LIVERNASH [1960], *The Impact of Collective Bargaining on Management*, Washington.

SOLOW, ROBERT M. [1968], "Distribution in the Long and Short Run." In Jean Marchal and Bernard Ducrois, *Proceedings of a conference held by the International Economics Association at Palermo*, New York: St. Martin's Press.

——— [1973], "Some Evidence on the Short-run Productivity Puzzle." In Jagdish Bhagwati and Richard Eckaus, *Development and Planning: Essays in Honour of Paul Rosenstein-Rodan*, London: Allen and Unwin.

SOLOW, ROBERT M. AND JOSEPH E. STIGLITZ [1968], "Output, Employment, and Wages in the Short Run," *Quarterly Journal of Economics*, Vol. 82, pp. 537-60.

STOCK, JAMES H. [1983], *Economic Models Subject to Time Deformation*, PhD Thesis, University of California at Berkeley.

STOCKMAN, ALAN C. [1983], "Aggregation Bias and the Cyclical Behavior of Real Wages," Research Paper , U. of Rochester.

TARSHIS, LORIE [1939], "Changes in Real and Money Wages," *Economic Journal*, Vol. 49, pp. 150-54.

TATOM, JOHN A. [1980], "The 'Problem' of Procyclical Real Wages and Productivity," *Journal of Political Economy*, Vol. 88, pp. 385-94.

WOYTINSKY, W. S. [1942], *Three Aspects of Labor Dynamics*, Washington: Committee on Social Security - Social Science Research Council.

ZARNOWITZ, VICTOR AND CHARLOTTE BOSCHAN [1975], "Cyclical Indicators: An Evaluation and New Leading Indexes," *Business Conditions Digest*, Vol., pp. v-xix.

ZEISEL, JOSEPH S. [1958], "The Workweek in American Industry, 1850-1956," *Monthly Labor Review*, Vol. 81, pp. 23-29.