Okun's Law, Productivity Innovations, And Conundrums in Business Cycle Dating

Robert J. Gordon
Northwestern University and NBER

For Presentation at AEA Session on Business Cycle Dating, ASSA Meetings, Atlanta, January 4, 2010

---

*I am grateful to Jesse Wiener for outstanding research assistance, including extraordinary contributions during the Christmas holiday weeks of late December, 2009.

ABSTRACT

The NBER business cycle dating process has traditionally mixed together the fundamental component of business cycles, changes in real output, with changes of employment. This paper makes the case that these long and variable lags disqualify for business cycle dating all the components of labor market behavior, including aggregate hours of work and payroll employment.

By definition real GDP is equal to output per hour times aggregate hours of work. This "output identity" can be extended to subdivide aggregate hours into the product of hours per employee, the employment rate, and the labor-force participation rate (LFPR). This paper provides a consistent analysis of the output identity, taking as its point of departure Okun's Law, a rough prediction that a cyclical deviation of output from trend would be divided between a 2/3 response of aggregate hours and a 1/3 response of productivity. In turn, the Okun characterization subdivided the 2/3 hours response into 1/3 for the employment rate, 1/6 for hours per employee, and 1/6 for the LFPR.

The paper decomposes data on the components of the output identity into trends and deviations from trends, or "gaps". Its regression analysis reveals regular features of postwar business cycles, including lags of hours and employment behind output and leads of productivity changes ahead of output changes. While Okun's Law was roughly accurate until 1986, regressions for the post-1986 period turn Okun's Law on its head. The elasticity of changes in the hours gap to the output gap was 0.74 before 1986, close to Okun's 2/3, but rose after 1986 to 1.2. Productivity no longer exhibits procyclical fluctuations, rendering as obsolete both the Real Business Cycle model and those aspects of modern macro that include productivity shocks as an explanation of business cycles. Productivity grows slowest in the later stages of the business cycle expansion and most rapidly in the early phase of the business cycle recovery. And this is nothing new. The "end-of-expansion" slowdown in productivity growth and the "early recovery productivity bubble" were identified in economic research more than three decades ago.

Hypotheses suggested here for changes in behavior focus on the role of collapses in profits and the stock market in 2000-02 and 2007-09 in creating unprecedented pressure on business executives (whose compensation more than before depends on stock options) to cut costs drastically. But the 2007-09 downturn was much bigger than 2000-02; for every deck chair thrown off the Titanic in 2000-02, three or four deck chairs were tossed overboard in 2007-09. The much larger response of labor hours to output fluctuations after 1986 is linked with other factors that have reduced labor's bargaining power and have increased income inequality. Increased responsiveness of hours may also reflect incentives to push employees into forced part-time work, as well as the role of the internet in making the labor market more flexible.

Robert J. Gordon, Northwestern University
rjg@northwestern.edu
http://faculty-web.at.northwestern.edu/economics/gordon/indexmsie.html

1. Introduction

A long tradition in macroeconomics dating back to Arthur Okun (1962) and Walter Oi's "labor as a quasi-fixed factor" (1962) regards cyclical productivity fluctuations as an artifact, a residual generated from the incomplete and lagged response of employment and labor hours to demand-driven fluctuations in real output. In Okun's version the counterpart of a one-percent decline in output relative to trend during a recession was divided up roughly into a response of 1/3 of the employment rate, 1/3 of productivity, 1/6 of hours per employee, and 1/6 of labor force participation. In short, the response was 2/3 in aggregate labor hours and 1/3 in productivity. The cyclical response of productivity generated the paradox of "Short Run Increasing Returns to Labor" (SRIRL), that is, a response of output to cyclical fluctuations in aggregate labor hours that was greater than unity (1/(2/3) or 1.5 in the Okun example), much higher than any plausible elasticity of output to labor in a long-run production function.

Yet this tradition has been almost forgotten over the past two decades as a result of the influential work of Kydland and Prescott (1982) in developing the real business cycle (RBC) model. In the original RBC model there is no demand and no prices, and the primary cause of output fluctuations is an exogenous unexplained shock to productivity growth, leading to the criticism that this paradigm proposes that the Great Depression was caused by an extreme episode of technological forgetfulness. In the more enlightened modern macro work on Dynamic Stochastic General Equilibrium Models, aggregate demand and sticky prices have reappeared but most recent papers still include an autonomous "technology shock" as a cause of business cycle fluctuations.

Neither the older nor newer paradigm has paid attention to an evolving structural shift in the relationship between output, hours, and productivity.[1] The last three recessions (1990-91, 2001, and 2007-09) have been followed by "jobless recoveries" in which a revival of output growth in the initial stages of the recovery is accompanied by a burst of productivity growth and a continuing decline in employment, lasting 15 months after the NBER business cycle trough in 1991-92 and 19 months in 2001-03. So far in 2009 employment has continued to decline despite the appearance of a recovery in real GDP since late spring, and productivity growth has exploded with annual growth rates of around 7 percent in the second and third quarters of 2009.

In contrast cyclical recoveries prior to 1990 were accompanied by prompt recoveries in employment and declines in unemployment. For instance, following the November 1982 NBER trough, employment began to grow one month later and within the first twelve months had grown by 3.5 percent. Similarly, after November, 1982, the unemployment rate peaked one month later and within the first twelve months had declined by 2.3 percentage points.

This new divergence of timing between the output and employment cycles has

1. An exception is Gali and Gambetti (2009).

added difficulty to the task of the NBER Business Cycle Dating Committee in choosing the date of the cycle trough and helps to explain why the committee waited until July, 2003 to declare that the previous recession had ended in November, 2001. Implicit in the argument of this paper is that the primary phenomenon that defines business cycles is the deviation of real GDP from its underlying trend, that is, the "output gap." Changes in the structural behavior of the gap in economywide hours and employment in response to changes in the output gap are of secondary interest in business cycle dating although of primary interest for scholarly research on these shifts in structural behavior.

This paper quantifies the structural change in the responses of employment, hours, labor force participation, and productivity to changes in output that are treated as exogenous.[2] Along the way, it provides new estimates of trends in output, hours, and productivity over the postwar period since 1962, and it suggests hypotheses that may help to explain the change in responses. It isolates special features of the 2001-03 recovery that made it particularly "jobless" and predicts that employment will recover and the unemployment rate will decline more rapidly in 2010-11 than in the two previous recoveries. And it shows that unusually rapid growth of productivity in the first few quarters of a business-cycle recovery, as has been observed in 2009:Q2 and 2009:Q3, is old news, already identified in a paper that I published more than three decades ago (Gordon, 1979) and named more recently the "early recovery productivity bubble" (Gordon, 2003). The core question for this paper is whether the previously recognized tendency of hours to grow slowly and productivity to grow rapidly in an output recovery has exhibited a significant change in magnitude over successive business cycles.

The paper includes results of potentially wide interest for macroeconomics. To talk about cyclical output and hours gaps, we must identify trends. The first result of the paper is that bedrock techniques of modern macroeconomics, including the Hodrick-Prescott and bandpass filters, are implausibly sensitive to business cycle fluctuations. According to these trending methods, trend growth in aggregate hours in 2009 was negative! After we arrive at plausible trends in output, hours, and productivity that are independent of business cycle fluctuations, we then examine the behavior of cyclical gaps in output, output per hour, and aggregate hours (and its components hours per employee, the employment rate, and the labor-force participation rate). We find stark changes over the past 50 years in cyclical responses, with much more sensitivity after 1986 of hours to changes in the output gap and a decline to zero sensitivity of productivity.

This paper has major implications for the architects of the Real Business Cycle

---

2. The exogenous output changes are assumed to be caused by shocks to aggregate demand and their propagation through the economy, as well as by price shocks due to changes in the relative price of oil and of imports. Productivity shocks are assumed to take the form of gradual changes in the underlying trend growth of output per hour, and techniques to identify this trend are discussed below.

(RBC) model and its subsequent incarnation in the form of DSGE models. As shown in the regression analysis of this paper, since 1986 there no longer are procyclical responses of productivity. The concept of a procyclical "productivity shock" and "technology shock" is dead, except possibly in reference to particular major changes in the relative price of oil or other commodities. The analysis indirectly raises questions about any analysis in macroeconomics that claims that a source of business cycle fluctuations is a "technology shock" or in the currently popular discourse, "an investment-specific technology shock."

Implications for the NBER business cycle dating process in this paper are implicit. By treating changes in the output gap as the primary driver of the business cycle, and both hours and productivity as passive reactors, this paper enshrines output as the primary concept upon which business cycle dating should be based. As the NBER dating committee is obliged to determine not just a quarter but also a month for each peak and trough, it is reassuring that the committee now has access to monthly GDP as an output-based measure that can be examined with no regard whatsoever to the variable responses of employment to output fluctuations that are the main topic of this paper.

2. The Breakdown between Cycle and Trend

Was the decline of aggregate hours and of employment in 2007-09 unusually large? Relative to what? Was the disjunction in 2001-03 between rising output and falling employment unusually large? Relative to what? Those questions cannot be answered meaningfully by looking at raw unadjusted rates of change. The growth in trend hours and the labor force were much faster than 2007-09 back in the 1980-82 cyclical episode when population growth was more rapid and the movement of women into market employment was at its peak. Gaps can be measured only relative to trends, and thus a prerequisite to the analysis in this or any other paper about changing cyclical responsiveness is the measurement of the underlying trends in potential output, hours, and productivity.

A novel component of this paper is to show that the interpretation of the severity of the 2008-09 recession as measured by output and hours gaps depends greatly on the method used to create the underlying trends. Standard statistical routines, especially the Hodrick-Prescott filter (1982), create a highly implausible trend series for aggregate hours, and we adopt instead the Kalman filter that allows for cyclical feedback. Another novel aspect of this paper is that we use information from outside the cyclical movements of output and hours to create the trends and gaps.

2.1 The Output Identity: Notation and Definitions

Output, hours, and productivity (output per hour) are linked together by a simple definition. This can be extended to include hours per employee, the employment rate, and the labor force participation rate in what has long been called the "output identity" (see Gordon, 1993) and is implicit in Okun's original formulation of his law. We begin with the basic identity which decomposes real GDP *(Y)* into output per hour *(Y/H),* aggregate hours per employee *(H/E),* the employment rate *(E/L)*, the labor-force participation rate or LFPR *(L/N)*, and the working-age population *(N).*[3]

$$Y \equiv \frac{Y}{H} \cdot \frac{H}{E} \cdot \frac{E}{L} \cdot \frac{L}{N} \cdot N \tag{1}$$

At this stage we suppress time subscripts, since all of the variables in (1) and the subsequent versions of the output identity are contemporaneous. The right-hand side of (1) contains four elements that typically display procyclical behavior, albeit with different sets of leads and lags relative to total output *(Y)*, namely output per hour, hours per employee, the employment rate, and the LFPR. We would expect no response of the working-age population *(N)* to the business cycle.

The identity (1) requires that our concept of productivity refer to the total economy rather than the more widely cited published BLS series for the nonfarm private business (NFPB) sector. While it is possible to express the output identity in a form that relates output to NFPB productivity, the difference in sectoral definitions between productivity, household employment, and the labor force require the identity to expand from five terms as in (1) to seven terms, adding the complexity of "link" components that are difficult to interpret (see Gordon, 2003). We can maintain equation (1) in its simple five-component form by defining "total economy productivity" as real GDP divided by total-economy hours, an unpublished series provided upon request by the BLS. Because the total economy includes the government, household, and institutional sectors that are excluded from the NFPB sector, productivity growth for the total economy is almost always slower than for the NFPB sector, albeit by different amounts in different time intervals.

To allow for the subsequent treatment of growth rates and ratios of actual to trend, we take logs of (1) and use lower-case letters to designates the log of upper-case letters. For instance, *y* is the log of *Y* in equation (1) above. Thus the output identity in equation (1) can be restated in logs as follows:

$$y \equiv y-h + h-e + e-l + l-n + n \tag{2}$$

Because logs are additive, we can express output *(y)* as the sum of each of the

3. The employment rate *E/L* is simply unity minus the unemployment rate, that is, *(1-U/L).*

right-hand side components, say x. The trend of the log of real GDP (y^*) is the sum of the same five components x^* as in (2). The log-ratio of actual to trend output $(y' = y - y^*)$, or output gap, also observes the identity (2) and is equal to the sum of the four components $x' = x - x^*$ (actual and trend population growth n and n^* are assumed to be equal so that $n' = 0$). In the same notation, the growth rates of right-hand-side components of (2) are Δx, the growth rate of the trend of the components is Δx^*, and the growth rate of the gap is $\Delta x'$.

2.2 Establishing Trends

To examine the cyclical behavior of components of the output identity, we need to divide actual changes into cyclical and trend elements. To create trends that exhibit smooth rather than jumpy behavior in their rates of change, we consider a two alternative statistical techniques, the Hodrick-Prescott and Kalman filters.

The Hodrick-Prescott filter is the most commonly used detrending method in macroeconomics, presumably because it allows the trend to move continuously and because it is easy to understand and to estimate. Its primary flaw is that the estimated trends from any given time series can exhibit wildly different behavior, depending on the smoothness parameter that is chosen by the user, and that choice of parameter is entirely arbitrary. At one extreme, the choice of a parameter of zero yields a trend that exactly tracks every value of the series being detrended. At the other extreme, a parameter of infinity yields a single straight loglinear trend over the full period of the data, e.g., 1960-2009. Between zero and infinity, a relatively low value for the smoothness parameter creates a trend series that "bends" frequently in response to changes in the actual series and hence implies relatively small deviations of the actual values from trend; a high parameter value creates a relatively smooth trend and relatively larger deviations from trend.

The parameter endorsed by Hodrick and Prescott for quarterly data is a relatively low value (1600) that implies implausibly large accelerations and decelerations of the trend within each business cycle.[4] For instance Kydland and Prescott (1990, chart 2, p. 9) use this parameter to conclude that the entire economic boom of the 1960s resulted from an acceleration of trend,

4. There is no justification for this parameter anywhere in the literature. The justification in the original H-P paper is simply stated as "our prior view." The parameter 1600 is the square of the ratio of a cyclical deviation from trend to the adjustment per quarter of that trend. In their example, a five percent deviation of output from trend would cause the trend growth rate to adjust in the same direction by 1/8 percent per quarter, or ½ percent per year, or by 2 percent per year if that 5 percent output gap were sustained for four years. The value 1600 is the square of the ratio of the cyclical component (5) to the per-quarter adjustment of trend (1/8), i.e., $1600 = (5/.125)^2$. Applying this parameter to 1929-33 and assuming an initial trend growth rate of 3 percent per annum, a sustained 25 percent output gap would cause the growth rate of potential output to decline from +3 percent per year in 1929 to -5 percent per year in 1933.

rather than a deviation of actual output above trend. This conclusion ignores outside information, such as the fact that the unemployment rate was unusually low and that the capacity utilization rate was unusually high.

Similarly, the H-P technique yields implausible estimates for the trend growth rate of aggregate hours. If by the "hours trend" we mean the long-run growth rate of aggregate hours, then for 2009 we would expect this to be relatively steady at approximately the 1.2 percent annual growth rate of the working age population (Δn) with small adjustments for long-term changes in the growth rate of hours per employee (Δh), the employment rate (Δe), and the labor-force participation rate (Δl), i.e., 1.2 percent plus or minus perhaps 0.2 percent for the other components (see the bottom frame of Figure 3 below).

Instead, we see in the top frame of Figure 1 that the H-P trend using the parameter of 1600 generates a trend in hours growth that fell from +0.6 percent per year in 2005:Q2 to -1.5 percent per year in 2009:Q3. The alternative H-P parameter of 6400 declines fairly steadily over a longer period, from +1.9 percent per year in 1995:Q4 to -0.8 percent in 2009:Q3. In each case, the H-P technique exhibits its usual tendency to respond excessively to business cycle movements. By producing trends that show the marked cycles evident in both the H-P 1600 and H-P 6400 lines in the top frame of Figure 1, the H-P technique systematically understates the severity of cycles and muddies the differences between large and small cycles.

Two other series for the hours growth trend in the top frame of Figure 1 are based on the Kalman technique with feedback from outside information on the size of business cycle fluctuations in each episode. These two Kalman trends differ only after 2002. The Kalman trend for hours growth prior to 2002 represented by the solid black line is much more stable than the two H-P trends and exhibits virtually no movements in response to the business cycle. It starts at a trend rate of 1.5 percent in 1962, rises to a peak trend growth rate of 2.0 percent in late 1978, and then declines to roughly 1.0 percent at the end of the business cycle expansion of the 1990s. The Kalman trend reflects factors that we associate with the concept of trend growth in aggregate hours, including the rate of growth of the working age population, and the entry of adult women in the labor force that peaked in the late 1970s. Potential hours growth declined from 2 percent in 1978 to 1 percent in 2000 as the baby-boom cohort of teenage entrants diminished and as the transition of women into the labor force came to an end. The long-run demographic changes are reflected in the Kalman trend, not in the regular oscillations of the H-P filtered trends.

The two Kalman trends coincide until 2002 and then diverge. The grey solid line shows the trend when it is estimated through 2009:Q3. It exhibits a cyclical downturn from 0.8 percent per year in 2006:Q2 to 0.5 percent per year in 2009:Q4. The alternative trend shown by the solid black line is estimated with data through 2006:Q4 and then is arbitrarily held constant through 2009:Q4. This alternative trend estimate represents the view that growth in potential aggregate hours has proceeded unchecked by the recession of 2007-09. The severity of the recession in 2007-09 should be measured by comparing the absolute change in hours with the constrained trend shown by the black line, not the estimated Kalman trend shown by the grey line that bends in response to the business cycle.

The bottom frame of Figure 1 shows the same four trending techniques for the trend in the growth of real GDP. The oscillations of the two H-P trend lines contrast with the relative stability of the Kalman trend line. The H-P trends show substantial volatility in response to the recessions of 1981-82 and 1990-91. In contrast the two Kalman lines (which are identical prior to 2002) show a relatively narrow range in the growth rate of trend real GDP corresponding to the effects of relatively rapid productivity and labor force growth in the 1960s and the productivity growth revival of the late 1990s. After 2002 the four lines exhibit sharp divergences. The two H-P lines decline steadily from around 4 percent in 1997 to alternatively 1.2 and 0.7 percent per year in 2009. The H-P lines tell us nothing about what has been happening to the trend in the last four years; their smoothness criterion forces them to push the impact of the 2008-09 recession backwards to 2002-03.

The two Kalman lines diverge from each other after 2002. The solid black line shows a Kalman trend that is estimated with data through 2006:Q4 and then maintained constant at exactly that rate (2.5 percent per year) through 2009:Q3. The shaded solid line extends the estimation with data through 2009:Q3 and exhibits a substantial uptick in trend growth during the recession. This quite implausible result reflects a theme developed later in the paper. The cyclical correction for all the trend lines in Figure 1 is based on the unemployment gap, as described below. Since the effects of the 2008-09 recession appear to have been greater in the labor market than in the output market, the trending technique sees that there is a huge cyclical recession in the unemployment gap and concludes that the less severe relative decline in output must imply faster growth in the trend. In this paper we prefer to interpret these facts as a structural shift in the cyclical severity of the recession toward a greater employment response relative to the output recession than had occurred before, and this is consistent with the solid black line that assumes that the recession has had no impact on trend real GDP growth either up or down.

2.3 Finding a Cyclical Feedback Variable for the Kalman Trends

For the reasons expressed in the previous section, our preferred technique is the Kalman filter.[5] This can be used to estimate time-varying coefficients in any type of time-series model, whether a complex multi-equation model or a single equation. Our application is even simpler, the estimation of a single time-varying coefficient in a

5. The technique originated in R. E. Kalman (1960). A complete (and highly technical) treatment of the filter is contained in Hamilton (1994, Chapter 13). As Hamilton shows, the Kalman filter has many uses beyond the estimation of time-varying coefficients.

single equation, without allowing the other coefficients in that single equation to change. Detrending methods make little difference for most of the components of the output identity, which tend to evolve smoothly over time, but detrending methods and parameter choices are crucial for productivity growth. For symmetry we apply the same technique to each component of the output identity, equation (1) above. Hence our example of the estimation of time-varying coefficients with the Kalman filter explains the change in a component of the output identity (Δx_t) by a time-varying constant (a_t) and any set of other explanatory variables (βZ_t):

$$(3) \quad \Delta x_t = a_t + \beta Z_t + \omega_t$$

The next step is to specify a time-series process for the time-varying trend, and the most straightforward is a random walk:

$$(4) \quad a_t = a_{t-1} + \upsilon_t$$

The error terms of this two-equation system are:

$$\omega_t \sim N(0,\sigma^2); \quad \upsilon_t \sim N(0,\tau^2)$$

In the estimation of this system a smoothness parameter must be specified to control the variance of the random walk process (τ^2), and this then allows a range of trend rates of change to be obtained, ranging from very jumpy to very smooth, just as in the case of the H-P filter.[6]

Comparing the Kalman and H-P techniques, both share the weakness that the smoothness parameter must be specified by the user. The advantage of the Kalman filter is that any additional number of variables (Z_t) in (3) may be specified to control for determinants of actual changes that do not represent fundamental causes of changes in the trend, for example the Z variables could include changes in unemployment or the output gap, or dislocations caused by short-run dislocations such as strikes or temporary changes in oil prices. In contrast the H-P filter cannot by its design use any outside information, e.g., that slow and even negative productivity growth in the early 1980s occurred at a time when the unemployment rate was unusually high.

The Kalman trends displayed in Figure 1 are based on a time-varying coefficient, as in equations (3) and (4) above. Which variable(s) should be chosen as the cyclical variable intended to eliminate the purely cyclical portion of changes in the components of the output identity. We cannot use the output gap, because the output gap is the ratio of actual to trend, and so one must have answered the question "what

6. Hamilton (1994, p. 400) provides an exposition in which the evolution of the time-varying parameter(s) is governed by an adaptive process in which the current parameter is a weighted average of the lagged parameter and the mean value of the parameter, and the random walk model in (6) is a special case when the weight on the lagged parameter is unity. .

is the trend" before asking it. Some outside piece of information is needed that creates a cyclical gap based on an estimate of potential capacity or employment. The capacity utilization index would be one possibility, but that applies only to a narrow slice of the economy (manufacturing, mining, and utilities).

The outside piece of information used in this paper is the unemployment gap estimated from a time-series inflation model that "backs out" the natural rate of unemployment from an equation that explains the quarterly inflation rate in the PCE deflator by lagged values of inflation, the difference between actual and natural unemployment, and proxies for supply shocks (e.g., changes in the relative price of oil and of imports). If inflation is stable, controlling for the influence of the supply shocks, then the natural rate of unemployment is equal to the actual unemployment rate. If inflation accelerates, then the actual unemployment rate must be below the natural rate, and vice versa. This technique for estimating the natural rate of unemployment based on inflation behavior has been widely used, beginning with the two papers that developed the technique (Gordon, 1997; Staiger-Stock-Watson, 1997).

Figure 2 illustrates the actual unemployment rate, the estimated natural rate of unemployment, and the implied unemployment gap for the period 1962-2009.[7] The natural rate starts out in 1962 at about 5.3 percent, increases to 6.5 percent between 1980 and 1988, and then gradually declines to 5.0 percent by 2009. Much has been written about the reasons for the increased flexibility and efficiency of the labor market in reducing the natural rate over the past two decades, but those issues are beyond the scope of the present paper. What is relevant in Figure 2 is the series on the unemployment gap. Despite the fact that the actual unemployment rate peaked at a higher value in 1982 than in 2009, at least so far, the unemployment gap was higher in late 2009 than in 1982 due to the relatively low level of the natural rate.

The series shown in Figure 2 for the unemployment gap is fed into the Kalman filter to create the trends for growth in hours and real GDP shown respectively in the top and bottom frames of Figure 1. Henceforth in the paper, trend growth for real GDP and the components of the output identity (equations 1 and 2) is based on the Kalman technique using cyclical feedback from the unemployment gap as described above, estimated from data through 2006:Q4, with the 2007-09 trend growth rates constrained to continue at the value of 2006:Q4.

2.4 Trends for Real GDP and Components of the Output Identity

Having chosen the most plausible technique for creating trends, we can now examine more closely the growth trends for real GDP and the components of the output identity in Figure 3 and the deviations from trend (i.e., output and component

7. The natural unemployment rate in Figure 2 is estimated by the same technique first used in Gordon (2007) and most recently updated in Dew-Becker and Gordon (2005) and in Gordon (2008).

"gaps") in Figure 4. The top frame of Figure 3 repeats from the top and bottom frames of Figure 1 the Kalman trends (data ending in 2006:Q4) for output and hours and adds the trend estimated by the same method for total economy output per hour. By definition the sum of the hours and productivity growth trends equals the real GDP growth trend. Here we see more clearly the relative contributions of the hours and productivity trends to the 1970-1987 slowdown in the growth rate of potential output and in its revival through 2000, followed by its decline from 2000 to 2006. The decline in the output trend from 1972 to 1978 was slower than that of the productivity trend, as it was buffered by the rise in the hours trend. Its further decline from 1978 to 1987 reflects the slowdown in the hours trend at a time that the productivity growth trend was steady.

Perhaps the most interesting phenomenon in the top frame of Figure 3 is the offsetting movement of the productivity and hours trends in the 1997-2006 period. Some of the 2002 peak in the productivity trend was offset by a temporary dip in the hours trend, raising the question of chicken and egg. Was the partial offset of the slump in the hours growth trend by the productivity trend due to technological innovation that reduced the demand for labor in a way that is not picked up by the cyclical unemployment gap variable? Or rather was part of the productivity growth boom in 2001-04 the counterpart of a temporary slump in trend hours growth that was caused by a structural change in the labor market?

The bottom frame of Figure 3 decomposes the hours trend into its four components. By definition as in equation (2) above hours growth *(h)* equals the sum of growth in hours per employee *(h-e),* the employment rate *(e-l),* the labor force participation rate LFPR *(l-n),* and the rate of population growth *(n).* The bottom frame shows that the 1962-78 rise in the hours trend and subsequent decline was initially due to changes in the growth rate of the working-age population, with rapid growth in the LFPR largely offset by a decline in hours per employee as females entering the labor force went disproportionately into part-time jobs. Declining population growth after 1972 was partially offset by a recovery of growth in hours per employee, and growth in aggregate hours in the late 1990s was maintained by growth in all four components of the identity.

Population growth was relatively steady after 1990, and so the pronounced slump in hours growth from 1997 to 2003 was associated with a return to negative growth of hours per employee, together with a decline in growth of the LFPR. Several commentators have suggested that the decline in trend growth of hours per employee and in the LFPR during this period reveals weakness in the labor market that is concealed by the official unemployment rate. But others who have examined the micro data suggest that most of the changes are explained by structural factors, including the aging of the baby boom generation that tips them over to the low participation 60+ age group, a decline in the LFPR of youth due to higher educational attainment, and an increase of the LFPR among the age 60-70 generation due to a reversal of the earlier trend toward early retirement.[8] Note that changes in the trend growth of the employment rate *(E/L)* are modest, and these are by definition the changes in the time-varying NAIRU plotted in Figure 2 converted into the employment rate *(E/L = 1-U/L).*

2.5 Cyclical Gaps for Real GDP and Components of the Output Identity

Now that we have separated trend and cycle, we can examine the behavior of cyclical gaps in real GDP and the components of the output identity. Here we use the adjective "gap" as synonymous with the percent log ratio of actual to trend. The top frame of Figure 4 displays the gaps for output, hours, and productivity. The history of the output gap is familiar, with relatively large positive output gaps in the 1960s and late 1990s, and the largest negative output gaps in 1982-83 and 2009. By definition the output gap equals the sum of the hours and productivity gaps, and the back-to-back recessions of 1980-81 and 1981-82 illustrates the classic Okun's law response, with roughly two-thirds of the decline in the output gap taking the form of a negative hours gap and the remaining one-third the form of a negative productivity gap.

However, for the other periods in the graph, Okun's law does not appear to hold. The hours gap traces the output gap almost exactly in the boom of the 1960s, the slump of 1974-77, and the hours gap fluctuates more than the output gap during the expansions of the late 1980s and late 1990s, the opposite of the Okun's Law prediction. Our regression analysis below confirms this tendency since 1986 of the hours gap to react to the output gap with a coefficient well above unity.

Has the 2008-09 recession experienced a larger gap than the 1981-82 recession? The top frame of Figure 4 identifies a key aspect of structural change, in that the maximum negative output gap (-10.4 percent) was larger than the maximum negative hours gap (-6.3 percent) in 1981-82 , as is consistent with Okun's Law, whereas in 2009 the maximum negative hours gap (-8.9 percent) was larger than the maximum negative output gap (-7.4 percent). Thus the 2008-09 slump is worse than 1980-83 for the labor market but not quite as bad for output.

The bottom frame of Figure 4 divides up the hours gap into the respective contribution of hours per employee (H/E), the employment rate (E/L), and the LFPR (L/N). The E/L gap is most responsive in the two big recessions of the early 1980s and 2008-09, whereas in the 1960s expansion the H/E gap contributed as much as the E/L gap, while in the 1990s expansion the H/E gap contributed more than the E/L gap. The strength of the H/E gap in the 1960s and late 1990s was associated with ample overtime pay, widespread opportunities for part-time workers to move to full-time employment, both of which contributed to a decline of inequality or, in the case of the late 1990s, a temporary cessation of a secular movement toward more inequality in the income distribution.

---

8. For further development of these points see especially Aaronson *et al.* (2006).

3. Uncovering Structural Change: Coefficient Shifts and the Behavior of Residuals

We have now created time series for trends and cyclical gaps for real GDP and the four components of the output identity (other than the working-age population). How unusual was labor market behavior over the past decade, namely the continuing decline of hours and employment for many months after the November 2001 NBER business cycle trough, and the marked decline in hours and employment during the 2007-09 recession? To answer these questions about shifts in business cycle behavior, we use the output identity of equations (1) and (2) above to carry out a regression analysis of the response of each component of the output identity to changes in the output gap.

Changes in cyclical behavior over the postwar period are assessed by fitting regressions alternatively for the 1962-86 and 1986-2009 sample periods. Do standard statistical tests reveal significant changes in cyclical responses across these two sample periods? Then we examine residuals, i.e., actual vs. fitted values, particularly for the post-2000 period. Relative to the predictions of the alternative regression equations for the two sample periods, how large were the residuals? These residuals are compared in size with previous business cycles and then become the puzzles that we try to explain by substantive hypotheses.

3.1 A Dynamic Specification for the Components of the Output Identity

Our primary interest in developing a dynamic specification suitable for regression analysis is to provide the best possible representation of average cyclical responses of the components of the output identity across 47 years of history. The point of departure for the dynamic specification is Sims (1974) and my earlier work on cyclical productivity dynamics (Gordon, 1979, 1993, 2003). Here we examine the dynamic response to output changes of each of the four components of the right-hand side of the log version of the output identity (equation 2 above), as well as for a two-component version consisting only of productivity and aggregate hours. Each of these dependent variables is expressed as the first difference of the log of the variable, say Δx, minus the first difference of the log of its trend Δx^*, and in the notation introduced above, this change in the gap is $\Delta x'_t$. This is regressed on a series of lagged dependent variable terms and on the first differences of deviations of the log of real GDP from its trend $(\Delta y'_t)$.

The output deviation variable in principle can enter with leads, the current value, and lags. The lags can be interpereted as reflecting adjustment costs and, for such components as the employment rate (E/L) and the LFPR (L/N), delays in hiring and firing. The use of leads was introduced by Sims (1974) in his analysis of Granger causality between hours and output. We provide a separate treatment of the productivity component of the output identity, specifying the productivity-to-output relation as a regression with productivity leading output.

Two additional variables are added to the traditional regression that relates first differences of component-of-identity deviations *($\Delta x'_t$)* to first differences of output deviations *($\Delta y'_t$)*. The first is an error-correction term. The concept of error correction has been linked to that of cointergration, which can be defined informally as the notion that a linear combination of two series — for example, the hours deviation and the output deviation — is stationary.[9] When two such variables are cointegrated, a regression consisting entirely of differenced data will be misspecified, while a regression consisting entirely of level data will omit important constraints. The solution is to estimate a regression of the first difference of one variable on the first difference of the other, plus an error correction variable consisting of the lagged log ratio of one variable to the other.[10] In our application of this technique, we impose stationarity on the error-correction term by entering it as the lagged log ratio of actual to trend of the variable in question, whether it is productivity, aggregate hours, the employment rate, or the other components of the identity. In summary, our specification explains the rate of change of a deviation from trend by the rates of change of the deviation from trend of the lagged dependent variable and of output, and the *level* of the deviation of the dependent variable from its own trend.

3.2 The End-of-Expansion Effect

In my 1979 work, verified and extended in 1993 and 2003, I identified a tendency for labor input to grow more rapidly than can be explained by output changes in the late stages of the business expansion.[11] I dubbed this tendency toward overhiring the "end-of-expansion" (EOE) effect and argued that it was balanced by a tendency to underhire in the first two years or so after the end of the expansion. If productivity is held down at the end of expansions by overhiring, then that same overhiring should be evident in some combination of the employment rate, the LFPR, and hours per employee. I labeled the tendency to underhire in the early stages of the business cycle recovery, and the complementary temporary spurt in productivity growth, as the "early recovery productivity bubble." This was particularly evident in 1991-92 and in 2001-03. It is interesting to reassess the EOE and early recovery bubble effects now, in light of the sharp decline in hours and employment in 2007-09 and the remarkably rapid productivity growth registered in 2009:Q2 and 2009:Q3.

The EOE effect is introduced into the dynamic specification through a set of six

---

9. For a formal definition of stationarity and co-integration, see Engle and Granger (1987, pp. 252-53).

10. A complete taxonomy of the possible forms of dynamic specification in a bivariate model is presented in Hendry, Pagan, and Sargan (1984, pp. 1040-49).

11. Gordon (1979, 1993, 2003).

dummy variables, corresponding to six end-of-expansion episodes since 1962.[12] These are not 0,1 dummies; rather, they are in the form 1/M, -1/N, where M is the length in quarters of the period of the initial interval of excessive labor input growth, and N is the length of the subsequent correction. By forcing the sum of coefficients on each variable to equal zero, the regression is forced to recognize that any overhiring in the initial phase is subsequently corrected. Any tendency for overhiring that is *not* balanced by subsequent underhiring will result in a small and insignificant coefficient on the EOE dummy and will either come out in the equation's residual or in the coefficients of other variables.

Gordon (1993) determined the dating of the EOE dummies by referring to the distinction between the NBER business cycle and the growth cycle. According to the NBER definition, the expansion ends when real output reaches its absolute peak. This can be distinguished from the earlier peak of the growth cycle when the output gap reaches its highest level. Gordon (1993) set the first M quarters as the period between the peak in the growth cycle and the peak of the NBER cycle. The timing and duration, N, of the subsequent correction period was determined by examining residuals in equations that omit the dummies entirely. The amplitude of the EOE effect is allowed to differ across business cycles by allowing the dummy variable for each cycle to have its own coefficient. In each estimated equation our results presented below in Tables 1 and 2 also include a test as to whether these coefficients can be pooled into a single coefficient.[13]

Combining these explanatory variables, the basic equation to be estimated for the components of the output identity is:

$$\Delta x'_t = \sum_{i=1}^{4} \alpha_i \Delta x'_{t-i} + \sum_{j=0}^{4} \beta_j \Delta y_{t-j} + \phi x'_{t-1} + \sum_{k=1}^{6} \gamma_k D_k + \varepsilon_t \tag{5}$$

where $D_k = 0$ in all quarters except the EOE and subsequent correction period. Here the α_i are the coefficients on the lagged dependent variable; the β_j are the current and lagged coefficients on the change in the real GDP deviation from trend; φ is the coefficient on the error-correction term; and the γ_k are the coefficients on the EOE dummies. The γ_k coefficients are interpreted according to which dependent variable is being explained; labor-market variables like hours of labor input or the employment rate, would be expected to have a positive EOE coefficient, whereas a regression with

---

12. This research has previously tracked the output identity since 1955. However in this paper the starting point is instead 1962, due to the reliance on the inflation equation for the PCE deflator to identify the unemployment gap. Comparable data for the PCE deflator are available from the BEA only back to 1959:Q1, and the need to include lagged values moves the starting quarter of the inflation regressions up to 1962:Q1.

13. Gordon (1993, p. 291, footnotes 33 and 34) discusses several arbitrary choices that were made in carrying out this definition of the M quarters. This paper takes the definition of the EOE dummies from Gordon (1993), with a few minor changes.

productivity as the dependent variable would be expected to have a negative coefficient.

3.3 Estimation for Two Components of the Output Identity

Our results in estimating equation (5) are presented in two tables. First, in Table 1 we examine results for two of the identity components, that is, the simplest identity that defines the change in real GDP as equal to the change in productivity (output per hour) plus the change in aggregate hours. Table 1 has four columns corresponding to the two alternative dependent variables, each expressed as in equation (5) as the first difference of a log ratio of the actual value to the trend value. The left two columns in Table 1 display coefficients estimated for the early sample period (1963:Q1 to 1986:Q1), and the right two columns display coefficients estimated for the late sample period (1986:Q1 to 2009:Q3). The coefficients are presented in rows corresponding to their order in equation (5), and the bottom of the table provides alternative estimates of the γ_k coefficient for the EOE effect that imposes the constraint that all these coefficients are equal.

Let us focus initially on the aggregate hours results in the first column of Table 1 for the early period and the third column for the late period. The sums of coefficients on the output deviation are 1.10 and 1.14 respectively, little difference. But the long-run responses (defined as the coefficients on output divided by unity minus the sum of coefficients on the lagged dependent variable) are quite different, 0.74 and 1.27 respectively. This increase in the long-run response of hours to output is one of the most important results in this paper. The error-correction terms have the expected negative sign, indicating a mean-reversion mechanism in which a high value of the lagged ratio of hours relative to its trend tends to push down subsequently on the growth rate of aggregate hours relative to its trend. The EOE coefficients have the expected positive sign only for the first two business cycles shown, 1968-71 and 1973-78. When the EOE coefficients are constrained to be equal, the result is a highly significant coefficient of 1.88 in the early regression but a small and insignificant 0.30 in the late regression.

We now turn to the parallel results when cyclical deviations from the growth rate of total-economy productivity are used as dependent variable in place of the cyclical deviations in aggregate hours. A familiar aspect of productivity dynamics is that aggregate hours respond with a lag to cyclical movements in output, and this lagged adjustment of hours implies that productivity *leads* output movements. While there is no problem in running a regression with the specification of equation (5) in which *leads* on the output deviation term replace lags, this has the practical disadvantage that a guesstimate must be made about the change in the output gap four quarters after the final quarter of estimation, namely 2009:Q3. We deal with this problem by creating forecasts for output growth in the subsequent four quarters based on those of the commercial firm Macroeconomic Advisers.

The second and fourth columns of Table 1 present the results for the cyclical deviation in productivity growth. Here we see that the sum of coefficients on the output deviation term drops from a highly significant 0.36 in the early regression to 0.05 in the late regression. The corresponding long-run responses drop substantially from 0.22 to 0.03. Neither error-correction term is significant, while the sum of coefficients on the lagged dependent variable is highly significant with a roughly similar negative value for both the early and late regressions. This indicates that changes in the cyclical deviation of productivity growth are highly noisy and negatively correlated, consistent with the view that short-term productivity fluctuations are a residual reflecting lags in hours behind output rather than as an exogenous technologically driven process as imagined in the RBC model literature.

The EOE dummy variables are larger and more significant for the productivity regressions than for the hours regressions. Four of the six estimated EOE dummy variables in columns 2 and 4 are highly significant, as are the coefficients when the EOE dummies are constrained to be the same within the early and late regressions, respectively. Of substantial interest is the fact that the constrained EOE dummies in the productivity equations are almost the same in the early and late regressions, respectively -2.38 and -2.69. These indicate that during the EOE period the *level* of total-economy output per hour is held down by roughly 2.5 percent but rebounds by the same 2.5 percent in the first stages of the expansion. Going back to 1968-71 there is ample precedent for the "early recovery productivity bubble," i.e., buoyant productivity growth as observed during 2009:Q2 and 2009:Q3, although as we shall see below that productivity gains during these two quarters went far beyond the predictions of these equations.

Table 1 also displays Chow tests on the significance of structural change across the early and late sample periods for both hours and productivity, both when the EOE dummies are estimated separately and also when the EOE dummies are constrained to be equal. Of the four Chow test F-ratios displayed in Table 1, the only one which reaches statistical significance is the shift in the hours regression when the EOE dummies are constrained to be equal (the F(11,165) ratio is 2.32, well above the 1.87 critical value at the 5 percent significance level. Thus we arrive at the puzzling result that both the short-run and long-run response of productivity change to output change declines from significantly positive to zero between the early period and late period, but this structural change is not statistically significant. This lack of statistical significance remains in an alternative version that omits the EOE dummy variables.

A final result presented in Table 1 in the second-to-bottom line is the mean lag or lead response of hours and productivity to cyclical output changes. The hours lag increases slightly from 0.98 in the early period to 1.39 quarters in the late period, while the productivity lead is little changed from -1.87 to -1.91 quarters. These regressions thus characterize the structural change before and after 1986 as primarily involving sums of coefficients rather than changes in the structure of the lags. This may seem surprising in light of the long 19-month period in 2001-03 when employment continued to decline while output grew. Nevertheless these results are interesting because they show that productivity changes lead output changes by roughly two quarters both before and after 1986.

A closer examination of the data comparing actual to trend GDP growth shows that a primary reason for the employment decline during that 2001-03 period was not a structural change in behavior, but simply that the output recovery was so weak. Instead of becoming *less* negative as usually occurs in a recovery, the output gap actually became 1.5 percentage points *more* negative during the six quarters 2001:Q4 to 2003:Q2. Stated another way, the actual growth rate of GDP was *slower* than the trend growth of GDP by an annual rate of 1.0 percent per year during those six quarters. Similarly in the 1991-92 recovery actual real GDP growth was faster than trend real GDP growth by only 0.2 percent per annum. In contrast during the first eight quarters of the 1983-84 recovery actual real GDP growth was faster than trend real GDP growth by a starkly different 3.5 percent per annum.

We can discuss more briefly Table 2, which decomposes the hours response into the three components of the employment rate, the LFPR, and Hours per Employee. Shifts in coefficients imply that long-run responses of all three components of hours increased between the early 1962-86 period and the 1986-2009 late period. As shown on the bottom line of Table 2, the increase for the employment rate was between 0.40 to 0.64, for the LFPR from 0.03 to 0.15, and for hours per employee from 0.28 to 0.34. Mean lags increased for the employment rate and hours per employee but fell by half for the LFPR. The Chow tests reveal that only the employment rate equation exhibits a significant structural shift, and only when the EOE dummy variables are constrained to be identical within a single regression. Those constrained EOE dummies are have the expected positive sign in all equations and are significant only in the early period for the employment rate and LFPR equations.

3.4 Okun's Law Revisited: Long-run Responses to Changes in the Output Gap

The central conclusion of the regressions is the structural shift in the long-run responses as listed at the bottom of Tables 1 and 2. These are shown graphically in Figure 5 as a bar chart that displays the long-run responses in two bars for each sample period. The hours bar is divided into three slices corresponding to the three components of the identity *(H/E, E/L, and L/N),* while the productivity bar shows only that single variable.

Okun's (1962) original decomposition places perspective on Figure 5. In his version, a deviation of output from trend was accompanied by a 2/3 response in labor hours and 1/3 response in productivity. In turn, the 2/3 response of labor hours was decomposed into 1/3 for the employment rate, 1/6 for the LFPR, and the remaining 1/6 for hours per employee. Inverting the employment rate response led to the famous Okun result that the output gap fluctuated by three times as much as the employment (or unemployment) rate. Okun's analysis has long been criticized as being static and ignoring dynamic responses, especially the lag of response in labor variables relative to output. Decades of research has shown that the employment rate response in the long run after allowance for lags is closer to 0.5 than to 0.33.

The responses listed at the bottom of Tables 1 and 2 and summarized in Figure 5 show that Okun was roughly right for the 1962-86 period (after Okun wrote) in his 2/3 to 1/3 division between hours and productivity; the corresponding long-run responses from our 1962-86 regressions are 0.74 and 0.22. Our 0.40 response of the employment rate is not far from Okun's 1/3, while the remaining 1/3 is almost entirely due to fluctuations in hours per employee with virtually no role for cyclical fluctuations in the LFPR.

These responses changed radically after 1986. The hours response and that of all of its three components are much higher and that of productivity is zero. Because after 1986 productivity did not respond in any systematic way to output fluctuations, even allowing for the lead of productivity in advance of output, the concept of a "productivity shock" that is the centerpiece of modern business cycle macroeconomics appears to be obsolete. Not only is the RBC idea of the productivity shock dead, but so is the old concept of short-run increasing returns to labor. Diminishing returns are reborn in the relationship between output and changes in labor hours.

4. Unique Aspects of Behavior: What the Regressions Cannot Explain

We now have the tools to determine how much of hours and productivity growth is predicted by the early and late-period equations and how much emerges in the unexplained residual of these equations. Even though the coefficients are allowed to shift after 1986, there are still residuals that help to quantify unique aspects of the 2007-09 business cycle. Thus we quantify two dimensions of change – a longer term structural change that dates back to the late 1980s and unique aspects of the 2008-09 episode. We can also examine the residuals to see what was unique about the disjunction between the 2001-03 recovery of output and decline of employment that bedeviled the dating decision of the NBER Business Cycle Dating Committee.

4.1 Plots of Actual Values, Fitted Values, and Residuals

The top frame of Figure 6 displays the hours growth trend (the same as in the top frames of Figures 1 and 3) together with the actual four-quarter change in hours and the predicted values from the equations of Table 1. The predicted values from the 1962-86 equation are shown for that period and the predicted values from the 1986-2009 equations are shown for the corresponding interval. We impose a particularly demanding test on the period starting in 2001:Q1, after which the predicted values are generated by a dynamic simulation which calculates the lagged dependent variable terms endogenously rather than taking them from the historical data.

The estimated equations appear to predict the actual changes quite well, with a few notable exceptions, as highlighted by the plot of residuals in the bottom frame of Figure 6. Actual hours growth was higher than predicted in the late 1970s and was lower than predicted in 1983, 1986, and especially for a protracted period in 2008-09.

Thus, despite allowing coefficients to shift after 1986, the decline in hours in 2008-09 appears to be an outlier in its magnitude. This is also evident in the large relative size of the hours gap relative to the output gap in the top frame of Figure 4.

Figure 7 has the same format as Figure 6 and displays actual, trend, and fitted values for labor productivity in the top frame and the corresponding residuals in the bottom frame. Productivity growth is highly volatile, reflecting the interaction between fluctuations in the output gap, the lagged response of the hours gap, and the additional irregularity introduced by the EOE dummy variables. Nevertheless, the four-quarter fluctuations in actual productivity growth as plotted in the top frame are tracked remarkably well by the equations of Table 1, especially prior to 1986.

The most important productivity puzzles appear to be why productivity growth was so slow during 1978-81(the counterpart of the hours residual in Figure 6) and also why it was so slow for a prolonged period between 1993 and 1995 (when there is no corresponding prolonged positive residual for hours in Figure 6). The productivity residual thus far in 2009 is the largest displayed in the bottom frame of Figure 6, although it is quite similar to the positive residual registered in 1986.

4.2 Cumulative Residuals

It is evident from the bottom frame of Figure 7 that the productivity residuals show a pronounced tendency to be positive after 1999. What is the magnitude of this unexplained excess of actual productivity growth over that predicted by the equation estimated over the 1986-2009 period? How are those positive residuals balanced by the equations for hours and its components?

Table 3 cumulates residuals over three periods of interest, 1986-2000, 2001-07, and 2008-09. The left set of five columns cumulates residuals for these intervals using the coefficients of the early regression estimated for 1963-86, and the right set of five columns does the same for the 1986-2009 regression. The left set of columns shows that, compared to the economy's cyclical behavior before 1986, the 2008-09 period is characterized by a large cumulative unexplained positive 2.15 percentage point residual for productivity that is more than balanced by a large negative -3.05 point residual for hours. In turn the hours residual is divided up into separate effects of the employment rate (-1.51), the LEPR (-0.67), and hours per employee (-0.26).

Part of this unusual behavior in 2008-09 can be explained by the structural shift in cyclical responses represented by the changes in coefficients from the 1963-86 regressions to the 1986-2009 regressions for which the residuals are cumulated in the right side of Table 3. As would be expected all the residuals drop substantially and the hours per employee residual even changes sign. Now the cumulative productivity residual is 0.63 points, more than balanced by an hours residual of -1.55 percent of which is mostly due to the employment rate residual.

Average residuals over the 1986-2000 and 2001-07 intervals are much smaller, although there is still a substantial positive productivity residual for both sample periods during the 2001-07 interval. Because there is a partially offsetting negative residual for productivity over the 1986-2000 period, the average residual over the entire post-1986 period averages out very close to zero in both the left and right set of columns. While the sum of residuals in OLS equations is zero by definition, in the equations used here there is no constant term, and this deliberate omission of the constant term explains why the sum of residuals at the bottom of Table 3.

The final display of residuals is presented in Figure 8, where the residual for aggregate hours is decomposed into its three components. Most interestingly, all of the negative aggregate hours residual in 2008-09 has as its counterpart a negative residual for the employment rate. In short, the employment rate declined more and the unemployment rate increased more in 2008-09 than would have been expected, given the output gap and given average responses over the 1986-2009 period. However, the employment rate residual in 2008-09 is not unique in duration or magnitude when the entire post-1964 period is examined. Hours per employee display a continuous positive residual throughout all of the 1960s. And residuals for hours per employee were as high for most of the 1990s as during the 1960s. There is much less action in the LFPR residuals, which displays only a few short-lived residuals of which the largest is a positive residual in 1979. Apparently the time-varying Kalman trend captures most of the important movements of growth in the LFPR.

4.3 The Early-Recovery Productivity Growth "Bubble"

Productivity growth was extremely rapid in the initial quarters after the NBER-dated cyclical troughs in 1991 and 2001, and productivity growth has also been very rapid in 2009:Q2 and 2009:Q3 (the NBER has not yet determined the trough date for the most recent recession, but it is likely to be 2009:Q2). But this is nothing new. A similar period of rapid productivity growth has been observed in the first few quarters of almost every postwar recovery, and in every case it has been followed by a return of productivity growth back to or below trend growth in the subsequent phase of the expansion. This "early-recovery productivity growth bubble" is consistent with the EOE effect, for in the first few quarters of the recovery profits are still squeezed, and business firms are aggressively attempting to cut costs by reducing labor input to correct their previous overhiring.

Table 4 summarizes this little-noted cyclical phenomenon. The top panel reports, in the first column, the average growth rate of actual productivity relative to trend in the first four recovery quarters after each trough quarter for real GDP in seven cyclical recoveries going back to 1971. The bottom panel reports the same measure for the eight quarters following the first four quarters of the recovery. At the bottom of each panel is the average over the five cyclical episodes. The remaining columns report averages over each interval of the predicted value from the productivity regression in table 1, as well as the statistical contribution of the EOE dummy variables to that prediction; the prediction minus the EOE contribution; and finally the statistical residual.

The bottom line in each panel of table 8 shows the averages over the seven episodes in that panel and reveals a striking difference between the first four, "bubble" quarters of the average recovery and the following eight quarters. Productivity grows, on average, 1.49 percentage points a year faster than trend in the first four quarters but only 0.04 percentage points faster than trend over the next eight quarters. This difference is almost entirely captured by our dynamic model of cyclical productivity behavior, with an average residual of only -0.08 percentage points in the first four quarters and only -0.06 percentage points in the subsequent eight quarters. The predicted change in the first four quarters is 1.58 percentage point compared with 0.10 points in the subsequent eight quarters.

How does the model explain the early-recovery bubble? As shown for the average of the first four quarters, about half of the predicted 1.58-percentage-point early-recovery productivity growth is attributable to the EOE reversal effect and the remaining half to the other variables, mainly the role of unusually rapid output growth in the first four quarters in stimulating rapid productivity growth. In the subsequent eight quarters, the EOE effect (which by then equals zero in most episodes) diminishes to -0.14 points while the remaining variables, slower output growth and the error correction term, both hold down productivity growth relative to trend to a negative predicted growth rate.

The 2001-03 recovery featured a continuing explosion of productivity growth together with a decline of employment that perplexed the NBER's Business Cycle Dating Committee. Table 4 places the behavior of productivity growth in this episode in perspective. The unusual aspect of 2001-03 was not the growth of productivity in the first four quarters but rather the subsequent growth in the next eight quarters. The equation predicts none of the positive above-trend productivity growth in the subsequent eight quarters, and as a result the residual is even larger than the actual change. In contrast the equation predicts about two-thirds of the rapid productivity growth that occurred in the first four quarters of the recovery.

In short, the regression specification does not shed much light on the behavior of productivity growth in 2002-04 and correspondingly does not help us understand the negative growth of employment between late 2001 and mid-2003. Looking back at Figure 4 we note that much of the slow growth of hours during this period took the form of an unwinding of the positive hours gap of the late 1990s. The hours gap in 2001-03 was remarkably small in the context of previous recessions. The most likely explanation of the 2001-03 period is most likely to lie in a correction of previous excess hiring and also above-normal rise in hours per employee. We return to hypotheses to explain this period in the next section.

5. Hypotheses to Explain Changes in the Cylical Behavior of Hours and Output per Hour

Okun's Law no longer accurately describes the response of aggregate hours (and its three definitional components) to cyclical changes in the output gap. The analysis in this paper has uncovered at least three dimensions of this structural shift that are relevant to understanding macroeconomic behavior, as well as relevant to the task of dating business cycle. First, since 1986 the division of a cyclical change in the output gap has changed, with a much larger response in aggregate hours and its three components (H/E, E/L, L/N) and no response of productivity growth at all. Second, the 2001-03 recovery and the 2008-09 reflect further aspects of unusual behavior that are not captured by the regressions, despite our allowing coefficients to shift before and after 1986. The 2001-03 recovery is characterized by labor market weakness that is partly hidden in the downward dip of the hours growth trend as displayed in the top frame of Figure 3, and is partly reflected in the negative hours residual evident in the bottom frame of Figure 6 for 2003-04. The 2008-09 recession has featured an unusually large decline in both hours and the employment rate relative to the output gap. This is partly reflected in the changes in coefficients between the pre-1986 and post-1986 sample periods, and partly is evident in the large and persistent residuals in the bottom frame of Figure 6.

We divide our discussion into three parts. First we discuss unique aspects of the 2001-03 period. Then we treat the 2008-09 slump. Third we put together our conclusions, for the cyclical fluctuations of components of the output identity in 2001-03 and 2008-09 drive a substantial share of the shifts in coefficients between the early and late sample periods evident in Tables 1 and 2.

5.1 Unusual Aspects of the 2001-03 Recession and Recovery

What caused the unusually large and protracted decline in employment and aggregate hours during the 2001 recession and the first 19 months of the recovery? Was the explosive growth of output per hour in 2002-04 an autonomous event or just the counterpart of those factors causing weakness in employment and hours? I suggested (Gordon, 2003, that both the weakness of hours growth and strength of productivity growth were the result of two complementary phenomena, savage corporate cost cutting that caused labor input to be reduced more (relative to the output gap) than in previous recessions and recoveries, and spillover lagged benefits of the late 1990s boom of investment in information and communication technology (ICT) investment. The savage cost cutting delayed the recovery of employment and hours while the spillover lagged benefits of the ICT investment boom explains how firms were able to produce so much output with so few workers.

The intensity of cost cutting reflected the interplay between executive compensation, the stock market, and corporate profits. While NIPA profits peaked in 1997, the S&P concept of profits grew by 70 percent between early 1998 and early 2000 and then declined by more than half between early 2000 and early 2001. Nordhaus (2002) attributes a substantial role in this "most unusual pattern" to a wide variety of shady accounting tricks to which corporations turned as they desperately attempted to pump up reported profits during 1998-2000 in an environment in which true profits were declining. In Nordhaus's words, these tricks led to the "enrichment of the few and depleted pension plans of the many." Overall, Nordhaus estimates that reported S&P earnings for 2001 were held down by about 30 percent by a combination of normal cyclical and extraordinary accounting impacts.

The unusual trajectory of S&P reported profits in 1998-2001 placed unusual pressure on corporate managers to cut costs and reduce employment. During the 1990s corporate compensation had shifted to relying substantially on stock options (by one estimate the share of executive compensation taking the form of stock option income rose from 45 to 70 percent during the 1990s), leading first to the temptation to engage in accounting tricks during 1998-2000 to maintain the momentum of earnings growth, and then sheer desperation to cut costs in response to the post-2000 collapse in reported S&P earnings and in the stock market. The stock market collapse had an independent impact on the pressure for corporate cost cutting, beyond its effect on the stock-option portion of executive compensation, by shifting many corporate-sponsored defined-benefit pension plans from overfunded to underfunded status.

The unusual nature of corporate cost cutting in 2001-02 was widely recognized. As the *Wall Street Journal* put it:

> The mildness of the recession masked a ferocious corporate-profits crunch that has many chief executives still slashing jobs and other costs. . . . Many CEOs were so traumatized by last year's profits debacle that they are paring costs rather than planning plant expansions.[14]

After I had suggested the "savage cost-cutting hypothesis" in my 2003 paper, Oliner, Sichel, and Stiroh (2007) suggested an interesting test. They showed with cross-section industry data that those firms that had experienced the largest declines in profits between 1997 and 2002 also exhibited the most significant declines in employment and increases in productivity. While it is difficult to translate a concept like "draconian cost cutting" into the context of time-series macro analysis, the Oliner *et al.* evidence using micro data across industries does lend credibility to the basic idea.

This chain of causation from the profits "debacle" to the 2002-03 productivity surge seems plausible as the leading explanation of the unusual productivity behavior documented in previous sections. But it raises a central question: How were corporate managers able to maintain output growth while cutting costs so savagely? Why didn't the massive layoffs cause output to fall, as it would have if productivity growth had stagnated? This brings us to the puzzle of explaining how productivity growth surged after 2000 even as ICT investment growth was collapsing along with corporate profits and the stock

---

14. Jon E. Hilsenrath, "While Economy Lifts, Severe Profit Crunch Haunts Companies; Nervous CEOs Could Slow Recovery by Continuing Layoffs, Plant Closings," *Wall Street Journal*, April 1, 2002, p. A1.

market.

Standard growth accounting requires that the full productivity payoff from the use of computers occur at the exact moment that the computer is produced.[15] Assuming no delay between production and installation, the computer produces its ultimate productivity benefit on the first day of use. Numerous observers, led by Paul David,[16] argue instead that there is in fact a substantial delay in reorganizing business practices to take advantage of new hardware and software. Since growth accounting fails to take such delay into account, it exaggerates the contribution of ICT capital deepening to the post-1995 revival during the years of peak ICT investment. Then, in the period 2001-03 when ICT investment declined, it understates the contribution of ICT capital by omitting the delayed benefits from previous ICT investment. This would lead the method to understate the acceleration of TFP growth in the years of peak ICT investment (1997-2000) and to overstate it during the period of declining ICT investment (2001-02).

David's delay hypothesis was based on a general analogy between the invention of electricity and computers. The role of business reorganization and process improvement in the form of "intangible capital" that is complementary to ICT investment has been the focus of recent interpretations of the post-1995 productivity growth revival by Susanto Basu and coauthors and by Shinkyu Yang and Erik Brynjolfsson.[17] Both groups of authors argue that measured investments in computer hardware and software require complementary, unmeasured investments in intangible capital, including business reorganization, new business processes, retraining, and general acquisition of human capital. The direction of mismeasurement is the same as implied by the David delay hypothesis: it overstates the extent of the productivity growth revival between 1995 and 2000 but understates it in the first few years afterward.

The intangible capital hypothesis is intriguing, because it offers a possible explanation of the puzzling second acceleration of productivity growth after 2000, in the wake of the collapse in the ICT investment boom. Intangible capital is complementary to ICT and contributes to measured output. When the share of output devoted to intangible investment is changing, the effect on measured productivity and its growth rate can be dramatic. A 1-percentage-point increase in the share of output devoted to intangible investment, say, from 3 to 4 percent, reduces measured output relative to total output almost point for point. If this increase takes one year, measured output growth is biased downward by 1 percentage point for one year; if it takes five years, the growth rate bias is one-fifth as large, or 0.2 percent a year.

---

15. Recall that the GDP statistics on which they rely measure output by production and treat any unsold goods as inventory accumulation, a part of GDP.

16. David (1990).

17. Basu and others (2003); Yang and Brynjolfsson (2001).

This hypothesis has implications for earlier years as well.. The share of spending on computer hardware was growing rapidly, particularly during 1972-87, the interval that led Robert Solow to utter his famous quip, which later became known as the Solow paradox, that "we see the computer age everywhere except in the productivity statistics." Going beyond the specific restrictions imposed by particular models, the role of delayed benefits from the rapid growth in ICT investment in the late 1990s seems incontrovertible. Jeffrey R. Immelt, chief executive officer of General Electric, refers to the delayed benefits of ICT spending by saying, "It takes one, two, three years to get down the learning curve and figure out new ways to use it." Cisco CEO John Chambers estimates the learning curve at more like five to seven years.[18]

5.2 The 2008-09 Collapse in Hours and Employment

As we have seen above, most notably in Figure 4, the 2008-09 recession period was very different from the previous cyclical episodes in 1990-92 and 2001-03. The decline in the output gap was much greater in 2008-09, whereas in constrast during 2001-02 the output gap barely turned negative. Employment responded much more to the output gap than in 1991-92 or 2001-03, and productivity growth was actually above trend during most of the recession, especially at the end. What hypotheses can be offered to explain these unique aspects of behavior in 2008-09?

Just as in 1991-93 and 2001-03 the hours gap in 2008-09 responded with an elasticity greater than unity to the decline in the output gap, but in 2008-09 the output decline was much larger than in the previous two recessions. Some of our analysis of 2001-03 laid out above applies as well to 2007-09, including the collapse in the stock market and in corporate profits. From monthly peak to monthly trough the decline in the stock market S&P 500 index was 46.4 percent between September, 2000 and October, 2002, and was 52.8 percent between November, 2007 and March, 2009. The decline in NIPA pre-tax corporate profits between 1997:Q3 and 2001:Q4 was 28.3 percent, less than the decline between 2007:Q2 and 2008:Q4 of 38.4 percent. This decline in profits created even more pressure for cost cutting in 2007-09 than in 2001-02.

However, mere comparisons of stock market and profit data do not take into account the psychological trauma of the fall of 2008 and winter of 2009, when respected economists were predicting that an economic calamity was occurring that could bring about a replay of at least some aspects of the Great Depression. Fear was evident in risk spreads on junk bonds and in the stock market itself. Business firms naturally feared for their own survival and tossed every deck chair overboard, slashing

18. Quotes from Peter Coy, "Still Getting Stronger," *Business Week,* September 15, 2003, pp. 32-35. Brynjolfsson and Hitt (2003) find evidence of a delay in computer effects on firm-level productivity, and Bresnahan, Brynjolfsson, and Hitt (2002) find direct evidence of large, time-consuming organizational investments that complement computer investments on production functions.

both employment and fixed investment. We have seen above the dimensions of the radical surgery in employment and aggregate hours; the cost slashing was also evident in the unprecedented annual growth rates of gross private domestic investment in the three quarters starting in 2008:Q4: -24.2, -50.5, and -23.7 percent respectively. The quarterly NIPA data do not reveal in their history since 1947 any other episode with three consecutive quarters of an investment decline in excess of 20 percent at an annual rate, even in 1981-82.

5.3 The Shift in Coefficients after 1986

Perhaps the most dramatic finding of this paper is that Okun's Law in its original form is dead, and that aggregate labor hours for at least the past two decades have fluctuated more rather than less than aggregate output. The previous concept of procyclical labor productivity has become obsolescent as well. To the extent that utilized capital input fluctuates in proportion to labor hours, then the "Solow residual" which refers to total factor productivity has also lost its procyclical character. Business cycle theories which rely on procyclical fluctuations in the Solow residual as a source of cyclical fluctuations are obsolete as well.

What broader aspects of macroeconomic behavior might have caused an increased cyclical responsiveness of the aggregate hours gap to the output gap? Two hypotheses seem plausible. First, the shift in cyclical behavior has occurred at the same time as a much-discussed increase in income inequality. Leaving aside the rise in executive compensation relative to the bottom 90 percent, there has been a well-documented increase of income inequality at the 90th percentile and below which has been attributed to a combination of causes. These include a decline in the real minimum wage, a decline in the penetration of labor unions and a more generalized weakness in labor bargaining power, the role of low-cost imports in destroying jobs and further weakening labor's position, and competition from low-skilled immigrants for jobs held by native-born American workers. All of these factors may interact to embolden firms to respond to cyclical fluctuations by reducing hours of work in proportion or more than in proportion to the decline in output, in contrast to the world of Walter Oi's (1962) "labor as a quasi-fixed factor" in which labor was regarded at least in part as a capital good.

One problem with this linkage of growing inequality and greater hours responsiveness is that job qualifications have generally shifted toward greater skills, more white-collar work, and less reliance on brute-force manual labor. Yet as David Autor and his co-authors (2008) have pointed out with their "polarization" hypothesis, the middle tier of the white-collar office workforce is uniquely vulnerable to replacement by computers or outsourcing. Thus information technology may play a role in raising the cyclical responsiveness of labor input to output.

As a second complementary hypothesis is that the increased responsiveness of labor hours to the output gap could reflect greater flexibility in American labor markets. Here the problem is to distinguish between the *level* of flexibility that has long differentiated American labor markets from those in Europe, from the required positive *change* in flexibility that would be required to explain why labor input is more responsive to output shocks after 1986. The contrast between labor market institutions in the United States and in Europe has been on the front burner of comparative macroeconomics since the mid-1980s, when economists on both sides of the Atlantic started trying to explain why European unemployment had increased from below the American level in the 1960s to above it after 1985.[19] The question is whether the past two decades have seen a significant further movement in the direction of flexibility in the U.S. labor market that could have facilitated corporate cost cutting and the achievement of faster productivity growth.

A possible piece of evidence in favor of increased flexibility is the disproportionate rise of involuntary part-time unemployment in the 2008-09 recession. This as a percentage of the labor force was 6.0 percent in November, 2009, the same as at the previous peak of forced part-time employment in January, 1983. But the rise in the recent episode is higher. If the recessions of 1980 and 1981-82 are combined into one event, the increase in the part-time percentage was 2.5 percentage points compared to 3.0 percentage points in 2007-09.

Another possible cause of increased labor market flexibility is the development of internet-based job matching. Firms can reduce employment and hours with impunity if they no longer value the human capital embodied in their experienced workers and have confidence that via the internet they can find replacement employees with equivalent skills, and an ability to learn rapidly the necessary specific human capital to function well on the job. As above, the perverse role of the internet in causing an increase of labor hours responsiveness may be related to the Autor polarization hypothesis that middle-level white collar employees have been turned into mere commodities by the ubiquity of substitution between people and computers, both at home and overseas.

6. Conclusion and Implications for Business Cycle Dating

The point of departure for this paper is the static and ancient "Okun's Law" that predicts that roughly two-thirds of a cyclical deviation of output from trend will be accompanied by a deviation in the same direction of aggregate hours, and the remaining 1/3 by output per hour. Our basic conclusion is that Okun's Law was approximately correct for the cyclically volatile period between 1962 and 1986, but that since 1986 a marked structural shift has occurred in the responses of hours and productivity to cyclical fluctuations in real GDP.

No paper can discuss or analyze cyclical gaps in output, hours, productivity, or employment until they have done their preliminary homework of determining the

---

19 See, for instance, Lawrence and Schultze, 1987).

underlying growth trends from which the "gaps" are a deviation. A major conclusion of this paper is that the standard statistical technique in modern macroeconomics to separate trend from cycle, the Hodrick-Prescott (H-P) filter (and its near-equivalent, the band-pass filter) generates trends that are implausibly sensitive to observed business cycles. This is particularly evident for the components of labor hours. A H-P growth trend for aggregate hours in 2009 is negative, an implausible conclusion in the context of ongoing growth in the working-age population at a rate of about 1.2 percent per year. It is unlikely that changes in the trend growth of hours per employee or the LFPR could add or subtract more than a few tenths of a percent per year.

This tendency of purely statistical trends estimated from a single data series extends to the frequently used "band-pass filter." In other work, I have shown that the band-pass filter so widely used in contemporary macroeconomics implies with utter implausibility that trend growth in real GDP soared to 9.2 percent at an annual rate in 1925:Q1, collapsed to -7.8 percent in 1930:Q1 (only one quarter after the stock market crash), and then soared again to +14.0 percent in 1941:Q3, the quarter prior to Pearl Harbor.

As a preferable alternative, the trends in this paper are developed from the Kalman method that, unlike the H-P method, allows feedback from outside information in order to remove the business cycle component from the trend growth rates of the variables of interest. The cyclical feedback variable comes from the behavior of inflation, corrected for the effect of supply shocks, in my own ongoing studies of the U. S. inflation process. From inflation behavior it is possible to "back out" a plausible estimate of the time-varying NAIRU (or "natural rate of unemployment"), and the unemployment gap between actual and NAIRU unemployment is the cyclical adjustment factor inserted into the Kalman procedure to create trend growth rates.

Once the trends have been created, the ratios of actual to trend (or "gaps") can be examined. An important finding is that volatility in the cyclical gap for labor hours has gradually increased relative to the output gap. The two biggest recessions of the postwar period, 1981-82 vs. 2008-09, differ in the relative magnitude of the output and hours gap. In 1981-82 the hours gap was only about 2/3 of the output gap, consistent with Okun's Law. In contrast in 2008-09 the hours gap has been about 120 percent larger than the output gap, refuting Okun's Law.

As a counterpart to the large response of hours to output, there is no room left for procyclical productivity growth fluctuations. Econometric regression analysis suggests that before 1986 the long-run response of hours and productivity was not too far from Okun's informal 1962 suggestion, that the cyclical hours gap would respond roughly by 2/3 of the cyclical output gap, whereas the response of the productivity gap would make up the remaining 1/3. Our statistical analysis of the pre-1986 period suggests a split of 74 to 22 percent, not too far from Okun's original guesstimate.

However in the period since 1986 the original Okun result has disappeared.

Hours now respond more than in proportion to changes in the output gap, instead of by a fraction like 2/3. In the post-1986 period the division of responsiveness between hours and productivity to changes in the output gap has shifted from 74 to 22 percent, to 127 to 3 percent. Since 1986 and indeed in several cyclical episodes prior to 1986 there has been no procyclical fluctuation of output per hour and by implication of multifactor productivity, that is, "Solow's residual." Theories of business cycles that include "productivity shocks" or "technology shocks" are rendered obsolete by the results in this paper.

The paper quantifies the changing responsiveness of labor hours to output not only by splitting the sample period of the regressions, but also by examining residuals. Even allowing the cyclical responses to be driven by the 1986-2009 regression equation, and even when pre-1986 responses are ignored, there still is a large negative residual in the hours and employment rate equations for 2008-09. Simply put, the recently ended recession has been a much bigger deal for the labor market than for the output market, exactly the reverse of the relationship in the 1981-82 recession.

Other interesting results emerge from the regression analysis. Since 1986 there has been a shift toward a longer lag of changes in hours behind output and a longer lead of productivity ahead of output. There is a continuing tendency dating back to the 1960s for productivity to grow relatively slowly in the late stages of the business cycle expansion (the "End-of-Expansion" effect) and to growth relatively rapidly in the early stages of the recovery (the "Early Recovery Productivity Bubble"). However, the regression analysis in this paper cannot explain why the early recovery bubble lasted for so long in 2002 and 2003, and it cannot explain the magnitude of the sharp increases of productivity observed in 2009:Q2 and 2009:Q3.

The paper suggests a set of complementary hypotheses to explain this change in behavior. The overall shift in structural responses after 1986 is linked to the increase in the inequality of the income distribution. The declining minimum wage, the decline of unionization, the increase of imported goods, and the increased immigration of unskilled labor have undermined the bargaining power of American workers. As a result, employers can reduce labor hours with impunity and without restraint in response to a decrease in the output gap, in contrast to the period before 1986 when their behavior was more constrained by the countervailing power of labor.

The unique aspects of the recession/recovery period of 2001-03 and the recession period of 2008-09 require supplementary explanations. Our primary explanation for the large hours reductions in 2001 and the continuing reductions of 2002-03 combine two main hypotheses. A combination of increased reliance of executive pay on stock options, together with a collapse of profits and of the stock market, created a unique set of incentives to cut costs beyond anything that had been contemplated before. Complacency and overhiring was replaced by desperation and job-shedding.

The recent 2007-09 recession involved much of the same mechanism, but with the added elements of a much more significant decline in the output gap and a sense of sheer panic in the fall of 2008 and winter of 2009 that capitalism was on the verge of collapsing. For every deck chair that was thrown overboard in 2001-2003, perhaps three or four were tossed in 2008-09. One may optimistically hope that this process of cost-cutting was overdone, and that very soon employment and hours will begin to bounce back in response to a more vigorous output recovery than occurred in 2001-03. Current forecasts are for considerably more rapid real GDP growth in 2010-11 than actually occurred in 2002-03. In fact the analysis of this paper shows that the output gap did not shrink at all between 2001:Q4 and 2003:Q2 but in fact widened slightly. More robust output growth in the current recovery by itself would create a turnaround in employment and unemployment with a shorter lag than the 19 months experienced in the previous recovery. Adding to that possibility is the conjectured role of the ICT intangible capital hypothesis discussed in section 5.1 above. To the extent that there was less revolutionary innovation in 2004-07 than in 1997-2000, there is less of a lagged spillover benefit from previous ICT investment to buoy output growth in 2010-11, and hence more of an incentive for firms to rehire workers.

What are the implications for the NBER Business Cycle Dating Committee (BCDC). This paper has documented a subtle and complex set of interactions between the cyclical gaps of output and of labor hours. Any attempt by the BCDC to weight together indicators reflecting changes in output and indicators reflecting changes in hours or employment is guaranteed to become an effort in frustration. Hours and employment respond to output with variable lags. If output growth is weak enough, as in 2001-03, employment growth may be negative. The NBER is bound by tradition to a definition of business cycles that uses absolute levels, that ignores all the subtleties of defining trend growth, and that is incapable from the outset of examining the nuances in this paper employed to construct the twin concepts of trends and cyclical gaps. The NBER BCDC would be best served by an extremely simple procedure which ignores trends, gaps, and the divergence between output and employment. It should look primarily at monthly GDP. And if the peak or trough of that series is ambiguous, then it can turn to a cyclically sensitive output measure like the Index of Industrial Production, and leave the variable lags between output and employment to the research community rather than to the agenda of the BCDC.

REFERENCES

Aaronson, Stephanie, Fallick, Bruce, Figura, Andrew, Pingle, Jonathan, and Wascher, William (2006). "The Recent Decline in the Labor Force Participation Rate and Its Implications for Potential Labor Supply," *Brookings Papers on Economic Activity*, no. 1, 69-154.

Autor, David, Katz, Lawrence F., and Kearney, Melissa S. (2008). "Trends in U. S. Wage Inequality: Revising the Revisionists," *Review of Economics and Statistics* 90(2), May, 300-23.

Basu, Susanto, John G. Fernald, Nicholas Oulton, and Sylaja Srinivasan (2004). "The Case of the Missing Productivity Growth, or Does Information Technology Explain Why Productivity Accelerated in the United States But Not in the United Kingdom?" *NBER Macroeconomics Annual 2003.* MIT Press.

Bresnahan, Timothy F., Brynjolfsson, Erik, and Hitt, Lorin M. (2002). "Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence," *Quarterly Journal of Economics* 117(1), 339-76.

Brynjolfsson, Erik and Hitt, Lorin (2003). Computing Productivity: Firm-level Evidence, *Review of Economics and Staitstics* 84(4), November.

Dew-Becker, Ian, and Gordon, Robert J. (2005). "Where Did the Productivity Growth Go? Inflation Dynamics and the Distribution of Income," *Brookings Papers on Economic Activity,* 2005:2, 67-150.

Engle, Robert F., and Granger, C. W. J. (1987). "Co-Integration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55(2): 251-76.

Galí, Jordi, and Gambetti, Luca (2009). "On the Sources of the Great Moderation," *American Economic Journal: Macroeconomics* 1(1), January, 26-57.

Gordon, Robert J. (1979). "The `End-of-Expansion' Phenomenon in Short-run Productivity Behavior." *Brookings Papers on Economic Activity*, no. 1, 447-61.

_________ (1993). "The Jobless Recovery: Does it Signal a New Era of Productivity-led Growth?" *BPEA, 1:1993*, 217-306.

_________ (1997). "The Time-Varying NAIRU and its Implications for Economic Policy," *Journal of Economic Perspectives*, 11 (Fall), 11-32.

__________ (2003). "Exploding Productivity Growth: Context, Causes, and Implications," *Brookings Papers on Economic Activity,* no. 2, pp. 207-79.

__________ (2008). "The History of the Phillips Curve: An American Perspective," presented as the A. W. H. Phillips Invited Lecture at the Australasian Meetings of the Econometric Society, July 9.

Hamilton, James D. (1994). *Time Series Analysis.* Princeton, N.J.: Princeton University Press.

Hendry, David F., Pagan, Adrian R., and Sargan, J. Denis (1984). "Dynamic Specification," in *Handbook of Econometrics,* vol. 2, edited by Zvi Griliches and Michael D. Intriligator. Amsterdam: North Holland.

Hodrick, Robert J., and Prescott, Edward C. (2001). "Postwar U. S. Business Cycles: An Empirical Investigation." Discussion Paper 451. Minneapolis, Minn.: University of Minnesota (May).

Kalman, R. E. (1960). "A New Approach to Linear Filtering and Prediction Problems," *Journal of Basic Engineering, Transactions of the ASME,* Series D, 82: 35-45.

Kydland, Finn E., and Edward C. Prescott (1990). "Business Cycles: Real Facts and a Monetary Myth," *Federal Reserve Bank of Minneapolis Quarterly Review.* 14(2): 3-18.

Nordhaus, William D. (2002). "The Recent Recession, the Current Recovery, and Stock Prices," *Brookings Papers on Economic Activity, 1:2002,* 199-220.

Oi, Walter Y. (1962) "Labor as a Quasi-Fixed Factor," *Journal of Political Economy* 70:6 (December), 538-55.

Okun, Arthur M. (1962). "The Gap between Actual and Potential Output," *Proceedings of the American Statistical Association.* Reprinted in Edmund S. Phelps, ed., *Problems of the Modern Economy.* New York: Norton, 1965.

Oliner, Stephen D., Daniel E. Sichel, and Kevin J. Stiroh (2007). "Explaining a Productivity Decade," *Brookings Papers on Economic Activity, 1:2007,* 81-137.

Sims, Christopher A. (1974). "Output and Labor Input in Manufacturing." *BPEA, 3:1974,* 695-728.

Staiger, Douglas, Stock, James H., and Watson, Mark W. (1997). "The NAIRU, Unemployment, and Monetary Policy," *Journal of Economic Perspectives* 11 (Fall): 33-49.

Yang, Shinkyu, and Erik Brynjolfsson (2001). "Intangible Assets and Growth Accounting: Evidence from Computer Investments," MIT working paper, March.

Figure 1a. Annualized Quarterly Growth of Trend in Aggregate Total Economy Hours, 1962:Q1 - 2009:Q3

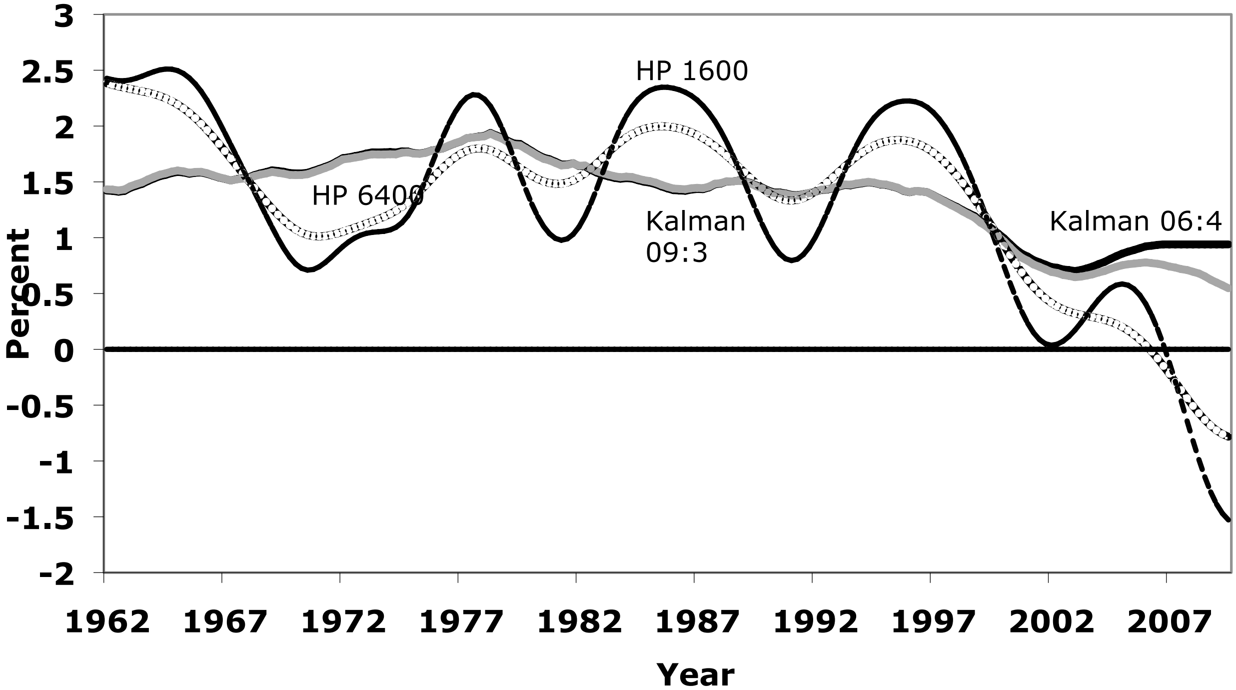

Figure 1b. Annualized Quarterly Growth of Trend in Real GDP, 1962:Q1 - 2009:Q3

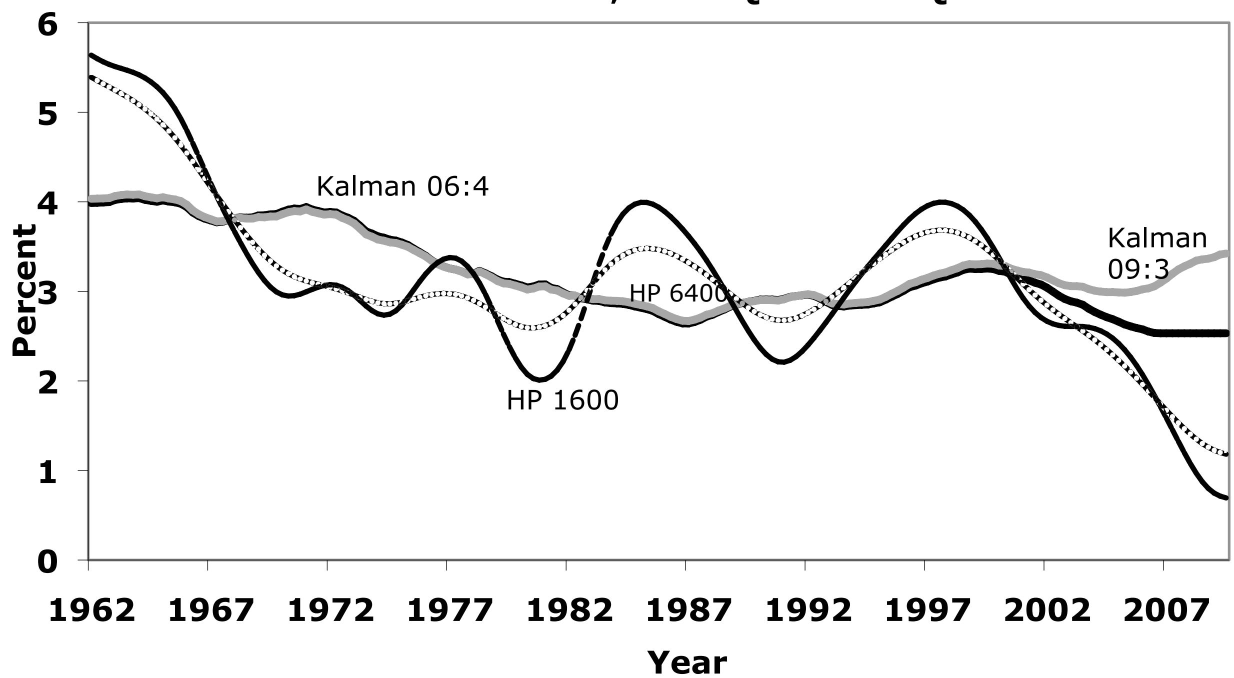

Figure 2. Actual Unemployment Rate, Time-Varying NAIRU, and Implied Unemployment Gap, 1962:Q1 - 2009:Q3

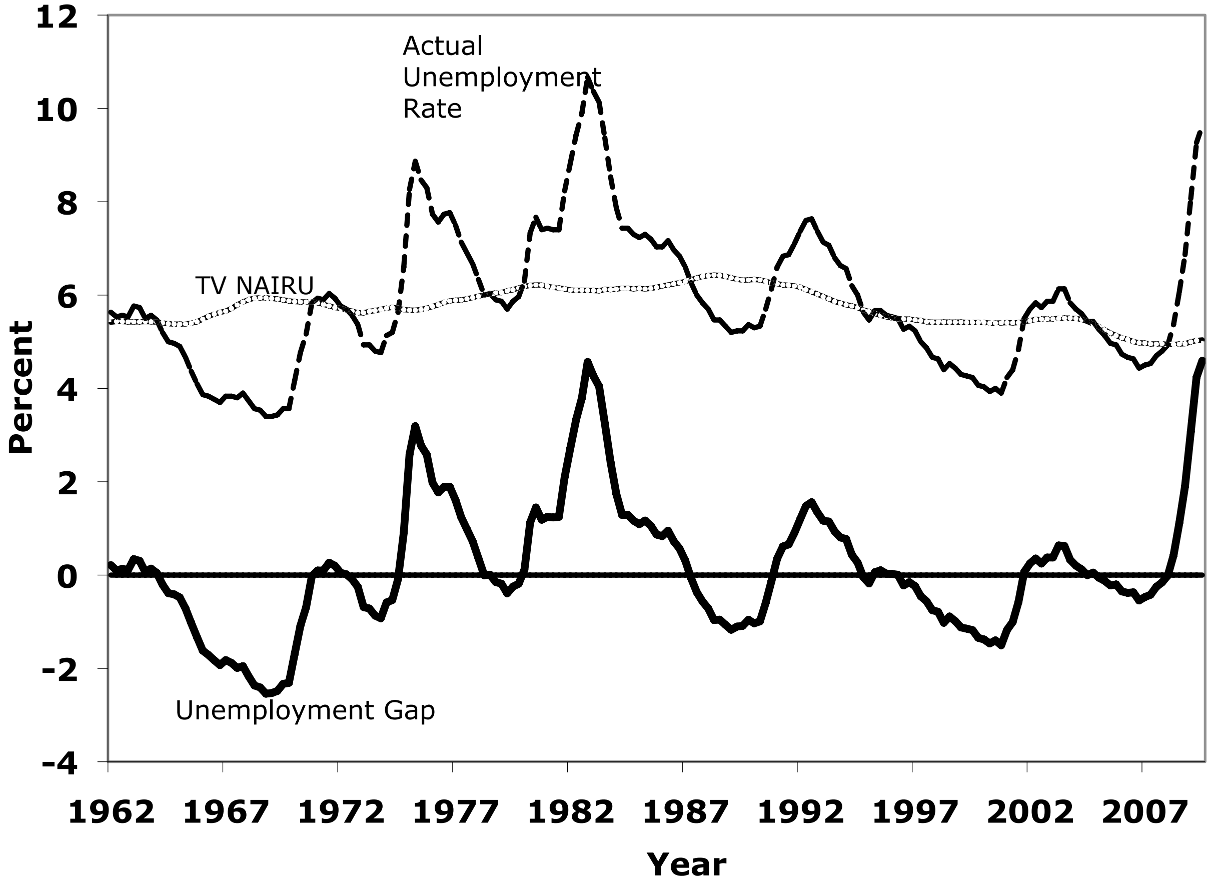

Figure 3a. Annualized Quarterly Growth of Trend a in Total Economy Output per Hour, Hours, and Real GDP, 1962:Q1 - 2009:Q3

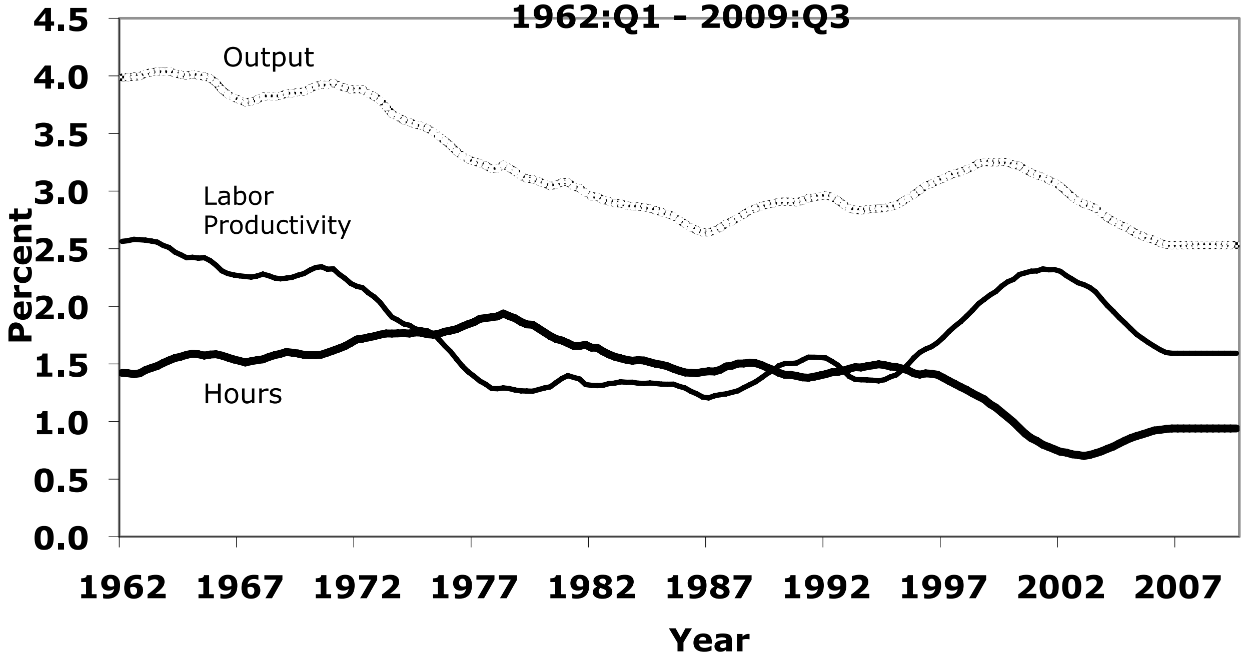

Figure 3b. Annualized Quarterly Growth of Trend in Hours per Employee, Employment Rate, LFPR, and Working-age Population, 1962:Q1 - 2009:Q3

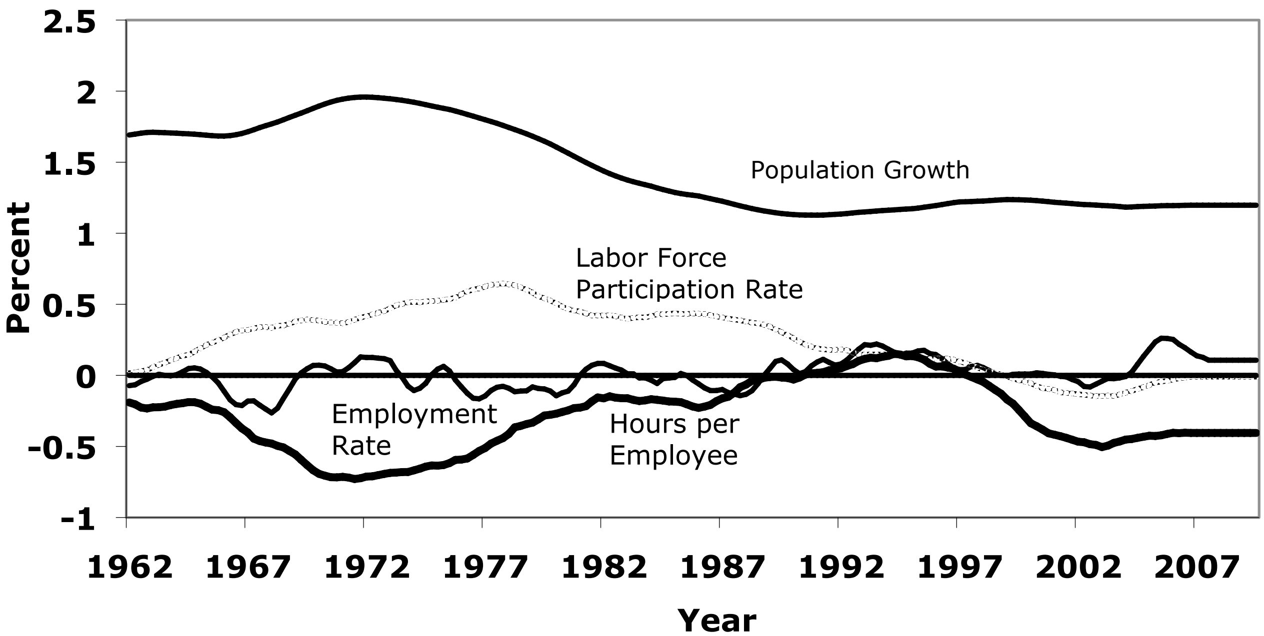

Figure 4a. Log Ratios of Actual to Trend for Real GDP, Total Economy Hours, and Total Economy Output per Hour, 1963:Q1 - 2009:Q3

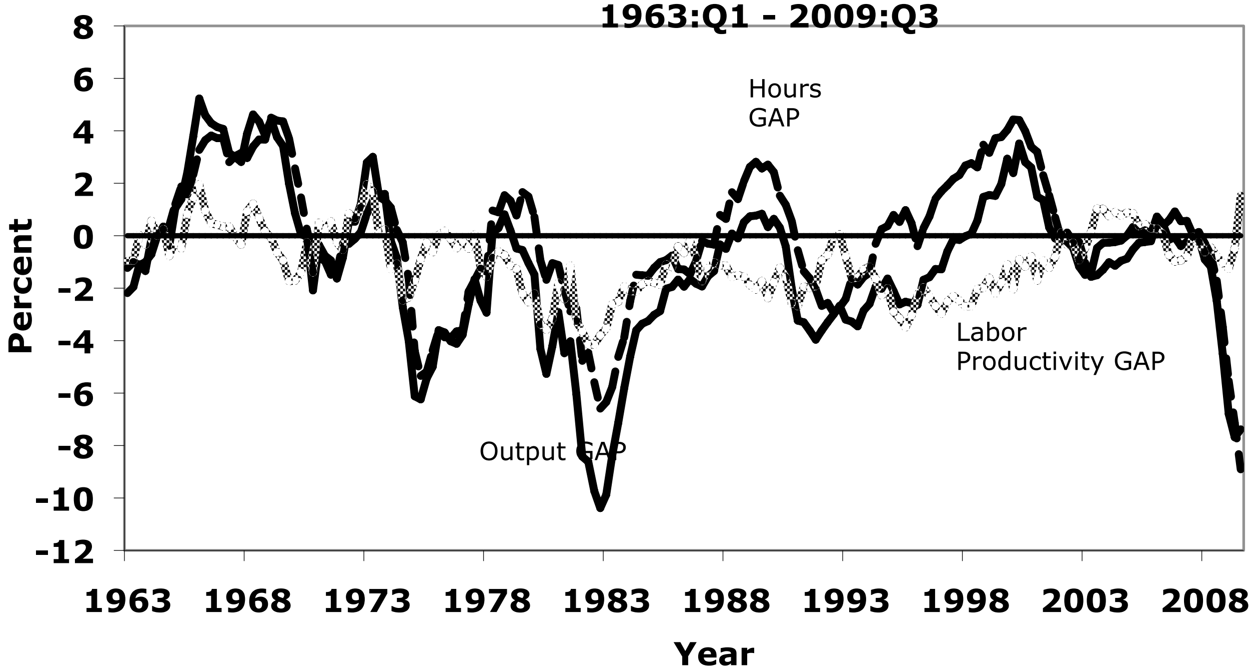

Figure 4b. Log Ratios of Actual Hours per Employee Gap, Employment Rate Gap, and Labor Force Participation Rate Gap, 1963:Q1 - 2009:Q3

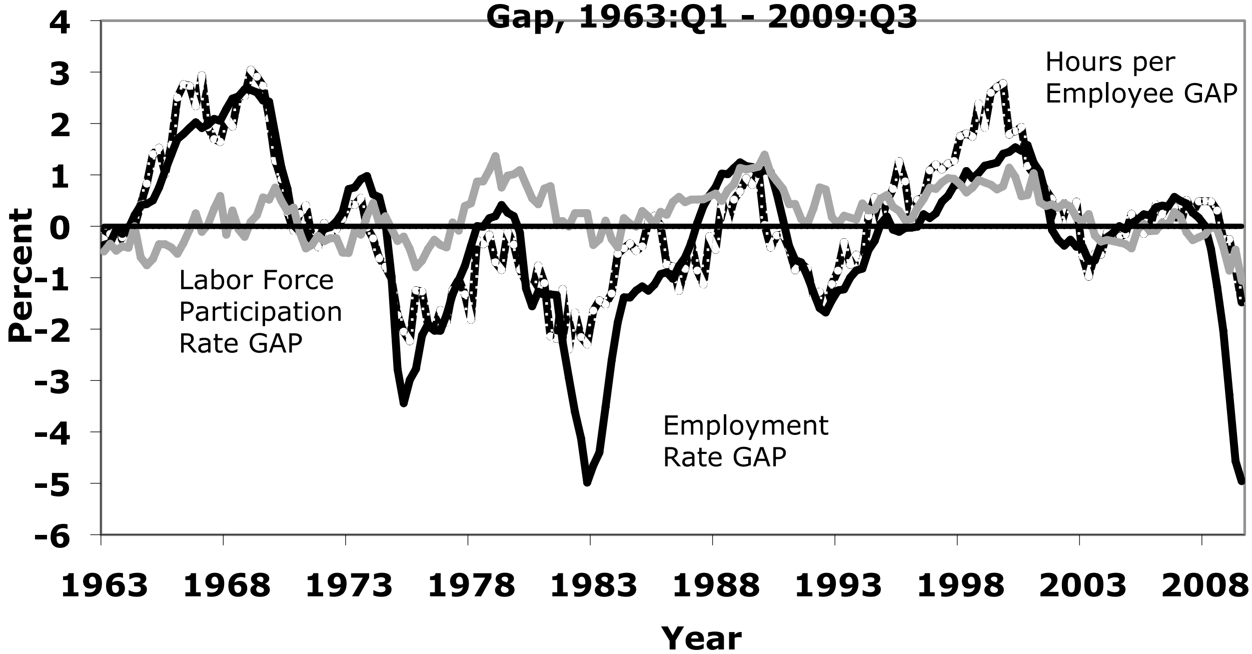

Figure 5. Long Run Response of Labor Productivity and Hours by Components using 1963:Q1 - 1986:Q1 vs 1986:Q1 - 2009:Q3 Coefficients

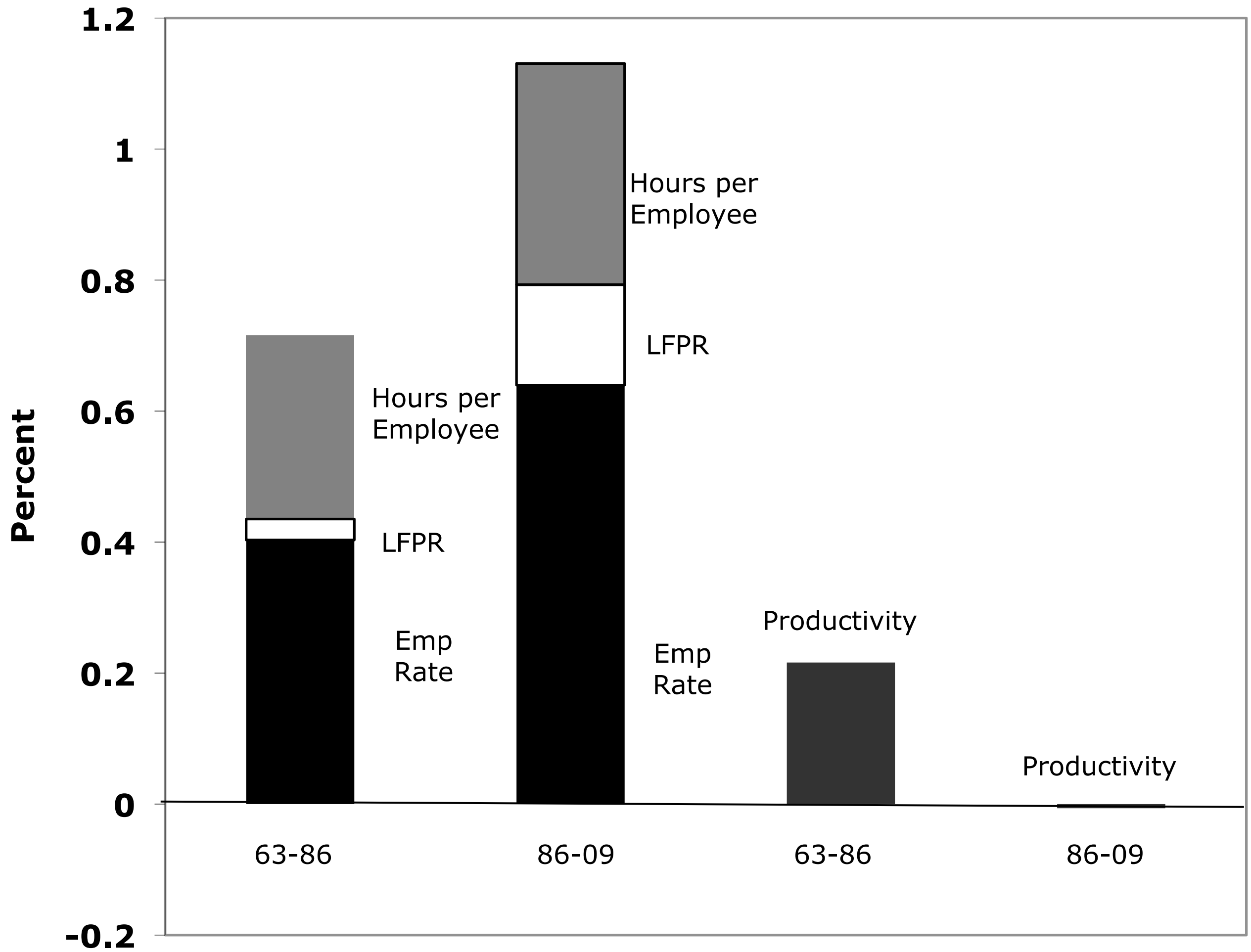

Figure 6a. Annual Growth Rates of Actual and Trend Aggregate Hours, and Fitted Hours, 1964:Q1 - 2009:Q3

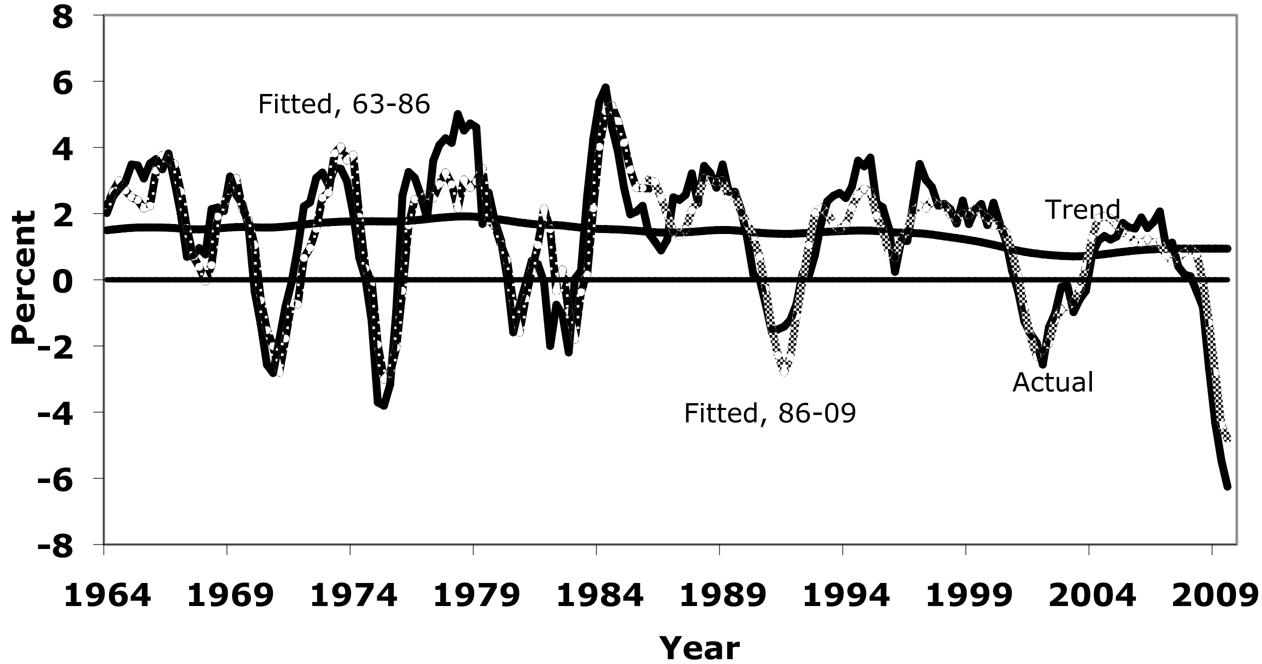

Figure 6b. Hours Residuals (Actual minus Fitted), 1964:Q1 - 2009:Q3

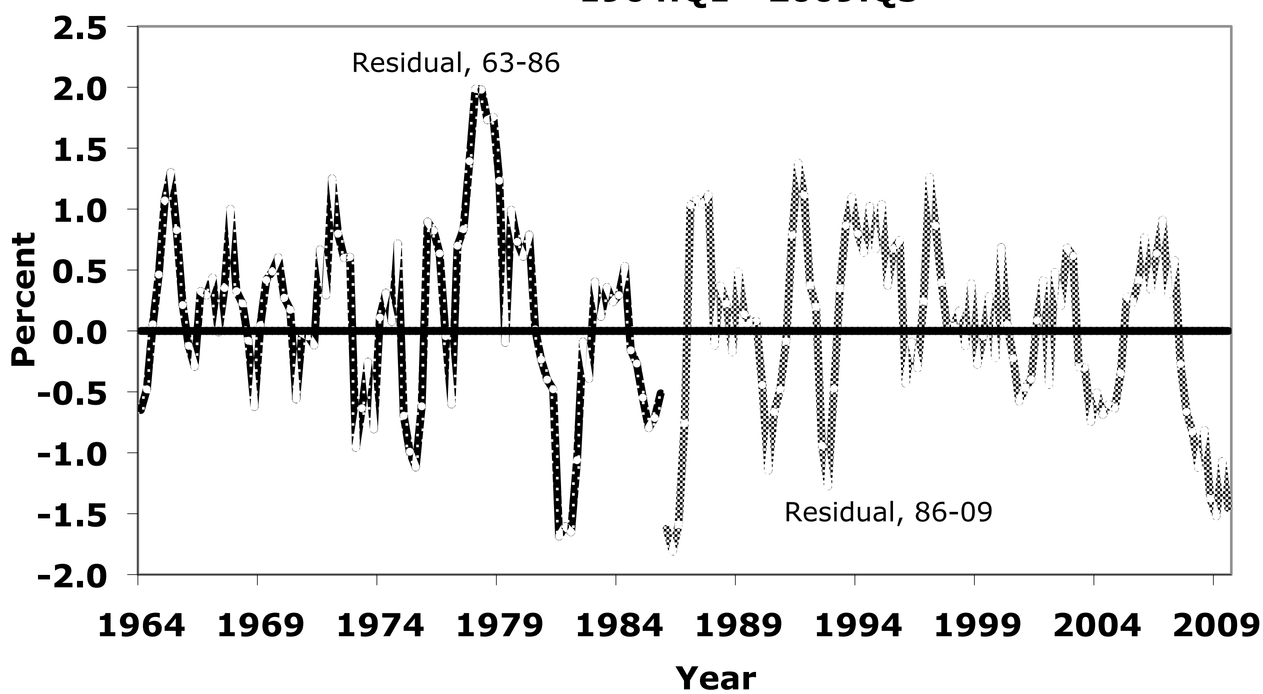

Figure 7a. Annual Growth Rates of Actual and Trend Output per Hour and Fitted Output per Hour, 1964:Q1 - 2009:Q3

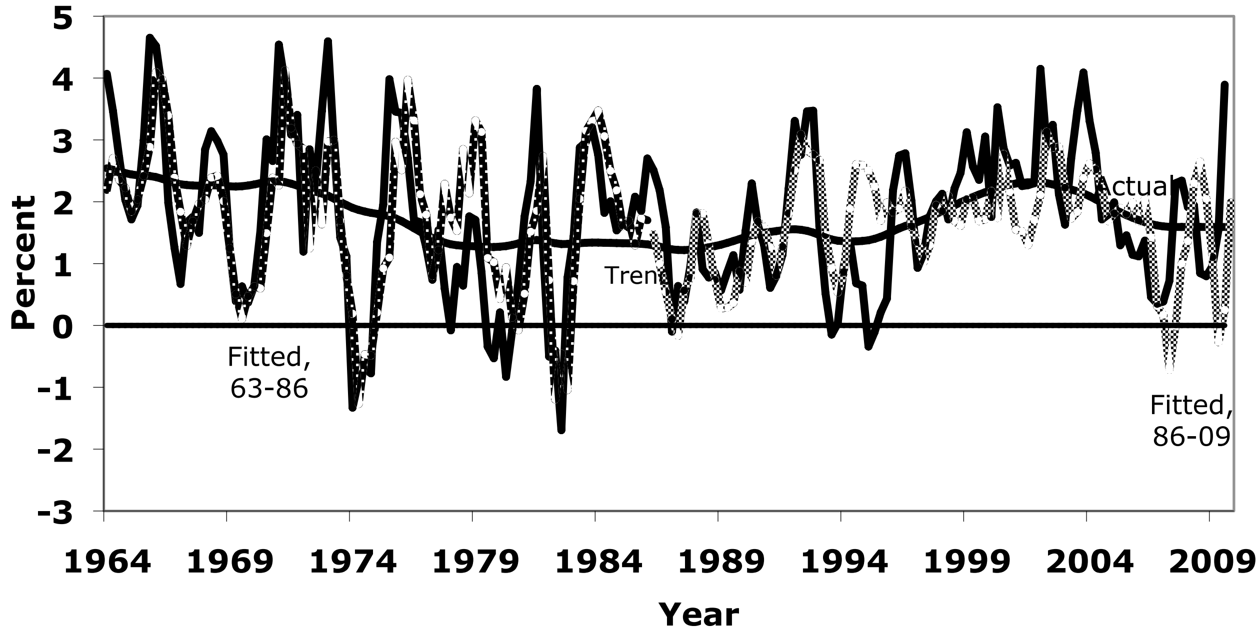

Figure 7b. Output per Hour Residuals (Actual minus Fitted), 1964:Q1 - 2009:Q3

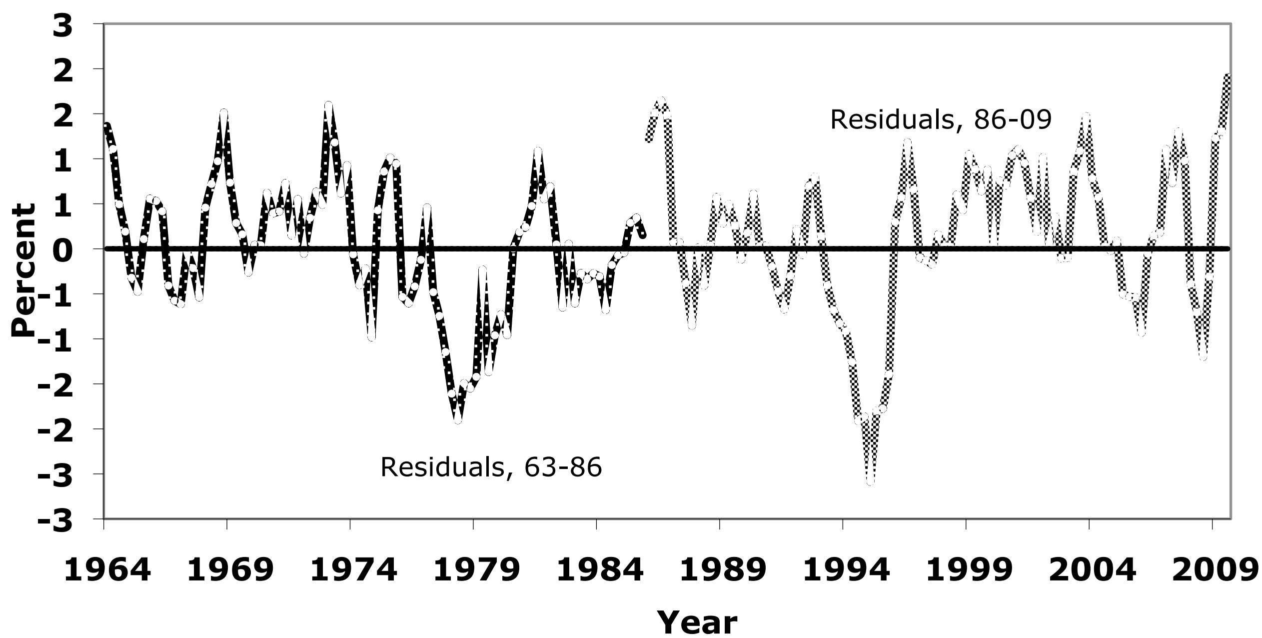

Figure 8. Residuals for Hours per Employee, Employment Rate, and LFPR, 1964:Q1 - 2009:Q3

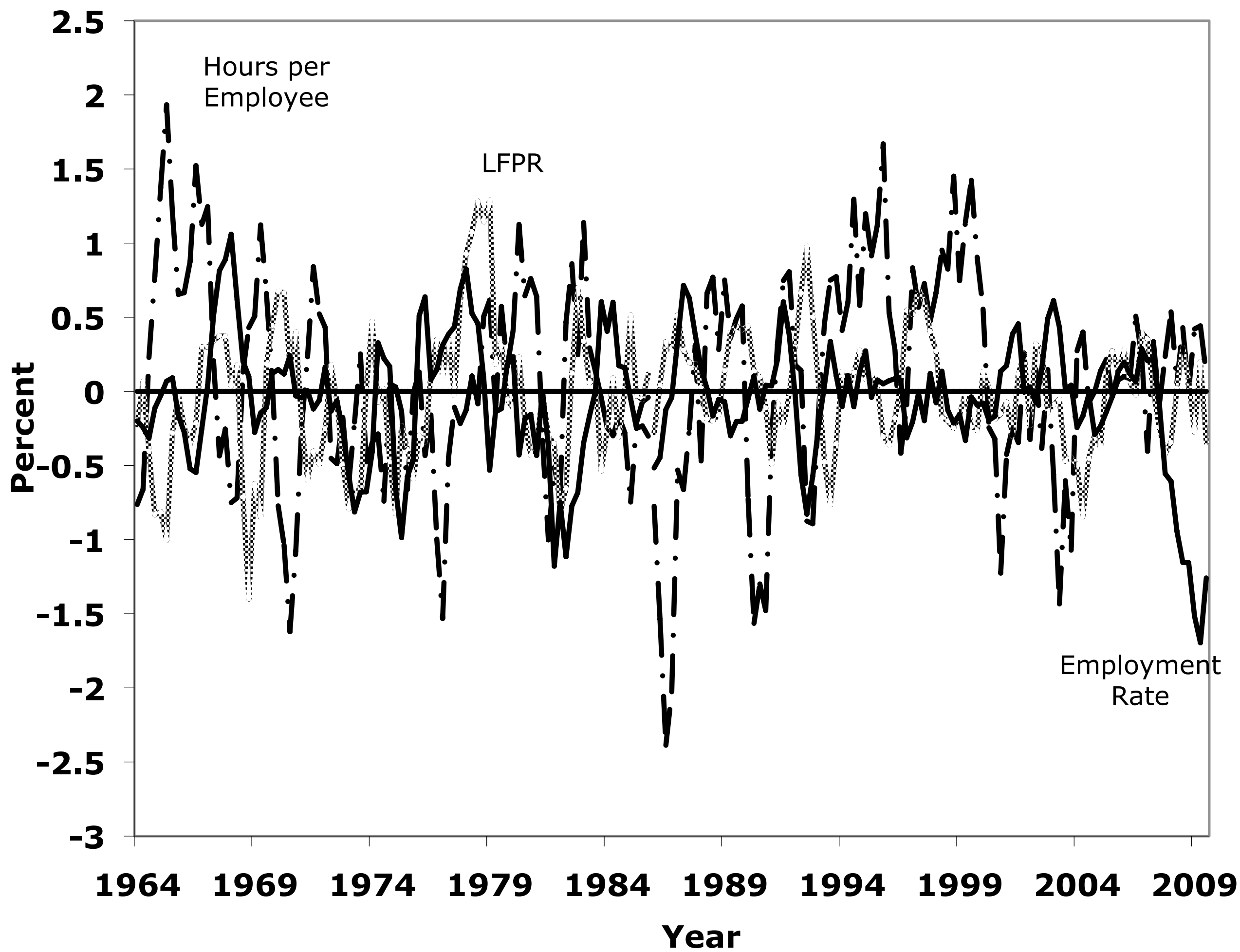

Table 1. Regressions Explaining Cyclical Deviations from Trend in Output Identity Components[a], 2006:4 Trend End

Independent Variable	Dependent variable, 1963:1 - 1986:1 Hours	Dependent variable, 1963:1 - 1986:1 Output per Hour[b,g]	Dependent variable, 1986:1 - 2009:3 Hours	Dependent variable, 1986:1 - 2009:3 Output per Hour[b,g]
Lagged dependent variable[c]	-0.50 *	-0.65 **	0.10	-0.69 **
Output deviation from trend[d]	1.10 **	0.36 **	1.14 **	0.05
Error correction term[e]	-0.14	-0.09	-0.19	-0.16
End-of-expansion (EOE) dummy variables[f]				
1968-71	2.37 **	-3.10 **	----	----
1973-76	2.36 *	-2.91 **	----	----
1978-83	1.07	-0.99	----	----
1988-92	----	----	0.50	-3.22 **
2000-03	----	----	-0.17	-1.42
2006-10	----	----	0.96	-4.02 **
Summary Statistic:				
Adjusted R^2	0.70	0.69	0.61	0.39
Standard error of estimate	1.67	1.61	1.53	1.68
Sum of squared residuals	223.23	208.59	191.79	232.74
Chow Test[h]			1.22	0.35
***Addendum:* all EOEs are constrained to be equal**				
EOE	1.88 **	-2.38 **	0.30	-2.69 **
Standard error of estimate	1.67	1.65	1.52	1.72
Sum of squared residuals	228.57	221.97	194.65	249.30
Chow Test[h]			2.32 *	0.54
Mean Lag/Lead Response to Output Changes	0.98	-1.88	1.39	-1.91
Long Run Response to Output Changes[i]	0.74	0.22	1.27	0.03

Source: Author's regresions using equation 7 in the text and data from sources and methods described in appendix A.

a. *indicates coefficient or sum of coefficients is statistically significant at the 5 percent level, ** indicates significance at the 1 percent level.

b. Data are for the total economy.

c. Four lags are used

d. Current value and four lags are used for all but Output per Hour. For Output per hour, use current value and four leads

e. Lagged log ratio actual to trend of the dependent variable.

f. Values of the variable are in the form 1/M or 1/N, where M is the length in quarters of the initial interval of excessive labor input growth, and N the length of the subsequent correction. See appendix A.

g. Lag for Hours, Lead for Output per Hour

h. The value of SSR for the whole sample is 475.23 for Hours and 459.57 for LP when there are varying coefficients on EOE, and 488.73 for Hours and 488.27 for LP when coefficients on EOE are constrained to be equal

i. All estimates use the coefficient on output deviation from trend.

Table 2. Regressions Explaining Cyclical Deviations from Trend in Output Identity Components[a], 2006:4 Trend End						
	Dependent variable, 1963:1 - 1986:1			Dependent variable, 1986:1 - 2009:3		
Independent Variable	Emp Rate	LFPR	Hours per Employee[b]	Emp Rate	LFPR	Hours per Employee[b]
Lagged dependent variable[c]	-0.41 *	-0.10	-0.92 **	0.37 *	-0.72 *	-0.60 *
Output deviation from trend[d]	0.57 **	0.03	0.54 **	0.41 **	0.25 **	0.55 **
Error correction term[e]	-0.08	-0.68 *	-0.19	-0.15	-0.19	-0.34
End-of-expansion (EOE) dummy variables[f]						
1968-71	0.82	0.88	1.67 *	----	----	----
1973-76	1.42 **	0.83	0.05	----	----	----
1978-83	0.83	0.65	-0.78	----	----	----
1988-92	----	----	----	0.11	0.51	0.68
2000-03	----	----	----	0.06	0.00	-0.73
2006-10	----	----	----	0.38	-0.09	0.60
Summary Statistic:						
Adjusted R^2	0.70	0.16	0.38	0.73	0.15	0.16
Standard error of estimate	0.92	1.03	1.52	0.62	0.77	1.58
Sum of squared residuals	67.74	85.56	185.46	31.68	49.18	205.57
Chow Test[h]				1.06	0.59	0.08
***Addendum:* all EOEs are constrained to be equal**						
EOE	0.98 **	0.79 *	0.25	0.15	0.10	0.05
Standard error of estimate	0.92	1.02	1.55	0.62	0.77	1.59
Sum of squared residuals	68.83	85.69	197.86	31.92	49.97	211.17
Chow Test[h]				2.04 *	1.16	0.29
Mean Lag/Lead Response to Output Changes	0.90	2.82	1.18	1.35	1.41	1.50
Long Run Response to Output Changes[i]	0.40	0.03	0.28	0.64	0.15	0.34

Source: Author's regresions using equation 7 in the text and data from sources and methods described in appendix A.

a. *indicates coefficient or sum of coefficients is statistically significant at the 5 percent level, ** indicates significance at the 1 percent level.

b. Data are for the total economy.

c. Four lags are used

d. Current value and four lags are used for all but Output per Hour. For Output per hour, use current value and four leads

e. Lagged log ratio actual to trend of the dependent variable.

f. Values of the variable are in the form 1/M or 1/N, where M is the length in quarters of the initial interval of excessive labor input growth, and N the length of the subsequent correction. See appendix A.

g. Lag for Hours, Lead for Output per Hour

h. The value of SSR for the whole sample is 112.02 for Employment Rate, 144.20 for LFPR, and 394.82 for Hours per Employee when there are varying coefficients on EOE, and 114.44 for Employment Rate, 146.19 for LFPR, and 416.83 for Hours per employee when coefficients on EOE are constrained to be equal

i. All estimates use the coefficient on output deviation from trend.

Table 3. Mean Residuals, 2006:4 Kalman Trend End										
	Dependent variable, 1963:1 - 1986:1					Dependent variable, 1986:1 - 2009:3				
Range	**Hours**	**Output per Hour**	**Emp Rate**	**LFPR**	**Hours per Employee**	**Hours**	**Output per Hour**	**Emp Rate**	**LFPR**	**Hours per Employee**
1986:1 - 2000:4	0.18	-0.26	0.05	0.43	0.08	-0.02	-0.24	-0.01	0.09	0.11
2001:1 - 2007:4	-0.18	0.15	-0.02	-0.06	0.05	-0.08	0.29	0.03	-0.05	-0.03
2008:1 - 2009:3	-3.05	2.15	-1.51	-0.67	-0.26	-1.55	0.63	-1.09	-0.01	0.17
1986:1 - 2009:3	-0.16	0.04	-0.09	0.20	0.05	-0.15	-0.02	-0.08	0.04	0.07

Table 4. The Early-Recovery Productivity Growth Bubble across Seven Cyclical Episodes, 1971-2009					
Episode	***Change in Productivity Deviation from Trend***	***Predicted Value***	***Contribution of EOE Effect to Predicted Value***	***Predicted without EOE Effect***	***Residual***
First four quarters after real GDP trough					
1971:1-1971:4	1.14	0.74	1.14	-0.40	0.40
1975:2-1976:2	1.75	2.43	1.27	1.16	-0.68
1983:1-1983:4	1.86	2.27	-0.60	2.87	-0.41
1991:2-1992:1	1.75	1.77	1.50	0.27	-0.02
2001:4-2002:3	0.96	0.68	0.62	0.06	0.29
Average	1.49	1.58	0.79	0.79	-0.08
Next eight quarters					
1972:1-1973:4	0.25	-0.31	-0.45	0.14	0.56
1976:2-1978:1	-0.80	-0.07	-0.20	0.12	-0.72
1984:1-1985:4	0.37	0.47	-0.44	0.91	-0.10
1992:2-1994:1	-0.12	0.47	0.35	0.12	-0.60
2002:4-2004:3	0.52	-0.03	0.05	-0.09	0.55
Average	0.04	0.10	-0.14	0.24	-0.06

Source: Regression estimates in table 1, column 1-2 and 1-4