The Demise of Okun's Law and of Procyclical Fluctuations in Conventional and Unconventional Measures of Productivity

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For Presentation at CREI/CEPR Macro-Labor Conference, Barcelona, November 5, 2010

*I am grateful to Marco Corrao for outstanding research assistance, and to John Bishop, Roger Brinner, Martin Feldstein, John Fernald, James Stock, Mark Watson and other participants for helpful comments at presentations of earlier versions of this paper at the Federal Reserve Bank of San Francisco, the Atlanta AEA meetings in January 2010, and the NBER Summer Institute in July 2010. Thanks also go to Bob Hall for flagging the existence of a BLS series on aggregate labor hours based on the household survey. A drastically shortened summary of an earlier version of this paper appeared under the title "Okun's Law and Productivity Innovations," *American Economic Review Papers and Proceedings* 100 (May 2010, no. 2), 11-15.

ABSTRACT

The point of departure is Okun's Law, a rough prediction that a cyclical deviation of output from trend would be divided between a 2/3 procyclical response of aggregate hours and a 1/3 procyclical response of productivity. The main conclusion of the paper is that the procyclical productivity response of Okun's Law is obsolete in U. S. data since the mid-1980s. These results cast doubt not only on Okun's original law, but on the convention in modern macro theory of assuming that unexplained procyclical productivity shocks drive part or all of business cycle fluctuations.

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A definitional identity links output, productivity, aggregate hours, and the employment rate. 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. Productivity grows slowest in the later stages of the business cycle expansion and most rapidly in the early phase of the business cycle recovery.

The paper proposes a joint explanation, the "disposable worker hypothesis," of increased cyclical labor-market responsiveness and increased inequality of the income distribution. A set of factors has gradually over the past three decades boosted managerial power and reduced the bargaining power of workers. These factors include the shift of executive compensation towards stock options which has led to increased emphasis on maximizing shareholder value. Worker power has been diminished by a lower real minimum wage, the declining importance of labor unions, increased imports, and increased low-skill immigration. 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. The marked increase in unemployment in the U.S. in 2007-09 stands in marked contrast to Europe, where the collapse of output was similar or worse, but unemployment increased much less.

A novelty in this paper is the recognition that alternative measures are available for the output numerator and the hours denominator of productivity. An "unconventional" measure of productivity is developed based on Gross Domestic Income in the numerator and household-based aggregate hours in the denominator. This measure provides a new perspective on medium-term historical movements in labor productivity in the U. S. since 1995. This finding raises the possibility that previous attempts to explain the peculiar 2001-04 upsurge of productivity growth and concurrent "jobless recovery", may at least in part have been addressing a measurement illusion.

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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 the labor force participation rate (hereafter LFPR). 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", 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.

1.1 The Demise of Okun's Law and of Procyclical Productivity Fluctuations

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 are 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 (DSGE) models, aggregate demand and sticky prices have reappeared, but most recent papers still include an autonomous "technology shock" as a partial cause of business cycle fluctuations.

Neither the older nor newer paradigm has paid sufficient 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, 19 months in 2001-03, and six months in 2009. In the current episode private nonfarm labor hours fell by 11.0 percent (in logs) between 2007:Q2 and 2009:Q3 and as of 2010:Q2 had recovered by only 1.3 percent, leaving labor hours a massive 9.7 percent below their previous peak and even more relative to ever-rising potential hours.

In contrast cyclical recoveries prior to the mid-1980s 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

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1. A notable exception is Gali and Gambetti (2009). See also Van Zandweghe (2010).

twelve months had risen 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.

The assumption of procyclical fluctuations in productivity is shared in common by Okun, by RBC advocates, and by the builders of modern DSGE models. This paper shows that since the mid-1980s this procyclical behavior on which so much research has been based is not visible in U. S. data. The concept of a procyclical "productivity shock" and "technology shock" is no longer relevant to the analysis of business cycles, except in reference to sharp swings in the relative price of oil or other commodities.

1.2 Conventional vs. Unconventional Measures of Labor Productivity

Most research on the cyclical behavior of labor productivity uses the published BLS indexes of private sector labor productivity, usually for the nonfarm private business sector (NFPB). A problem arises when one wants to examine in parallel changes in the cyclical behavior of productivity and labor market variables including the employment rate, hours per employee, and the labor-force participation rate (LFPR), which apply to the total economy rather than the NFPB sector. As shown in Gordon (2003) several "bridging" terms are required to translate movements in output and NFPB labor productivity into consistent movements in employment, hours per employee, and the LFPR.

To understand the relationship between real GDP, employment, and unemployment, it is desirable to shift away from the published NFPB sector concept of productivity to labor productivity in the total economy, defined as real GDP divided by total economy aggregate hours of work. The BLS readily provides its unpublished series on total economy hours; this series multiplies payroll nonfarm employment (including government and household sector workers) by a series on hours per employee based on the payroll survey.

But sole reliance on real GDP (Y) and aggregate payroll hours (H^P) as the source data for total economy labor productivity can be questioned. These are not the only possible numerator and denominator for a measure of productivity. The path-breaking Nalewaik (2010) article points out that two definitions of total output, GDP and Gross Domestic Income (GDI) should in principle be equal but in fact are not. Over the past three decades GDI has exhibited a more pronounced business cycle than GDP. This is important, because flaws in the GDP measure may understate the severity of the cylical downturn in output compared to the downturn in labor input, thus overstating the growth rate of labor productivity in 2009 and early 2010 and overstating the shift in hours responsiveness relative to output responsiveness.

There is a further distinction regarding the denominator. While most news reports on the monthly employment release focus on payroll employment (E^P) and household unemployment *(U)*, that same release provides equivalent detail on the household measure of employment *(E^H)*. Many observers (including Kitchen 2003) noticed and commented upon the decline in the ratio of payroll to household employment that occurred especially in the three-year interval 2001-04.

Corresponding to the two different measures of employment (E^P and E^H) there are two competing measures of aggregate hours of work. The unpublished payroll-based measure can be obtained from the BLS, but the household-based measure is less visible. It is obtained by multiplying household employment *(E^H)* by household-based hours per week. The resulting measure of aggregate hours of labor input *(H^H)* can be contrasted with the BLS calculation of payroll-based data on aggregate hours *(H^P)*.

What if GDP is partly wrong and GDI is at least partly right, as suggested by Nalewaik (2010)? What if household employment is at least partly right and payroll employment is partly wrong? There would be an impact in particular of our interpretation of productivity behavior in 2001-04, when E^H recovered earlier and by a larger amount than E^P, implying that the previously mysterious upsurge in productivity growth in 2001-04 in part disappears with a productivity measure based on E^H. The disagreement among these measures poses a problem of choosing the best measure of productivity for cyclical analysis. With two alternative numerators (GDP and GDI) and two alternative denominators, payroll hours *(H^P)* and household hours *(H^H)*, we are left with the daunting task of evaluating four alternative measures of labor productivity.

To limit the scope of this paper, we do not examine the behavior of all four of these possible mixes of two numerators and two denominators. Instead, we simplify the problem by contrasting results based on the "conventional" concept (GDP/H^P) with the "unconventional" concept (GDI/H^H).

1.3 Plan of the Paper

The paper includes results of potentially wide interest for macroeconomists. To talk about cyclical output and hours gaps, we must identify trends. The first result of the paper in Part 2 is to show that standard detrending techniques of modern macroeconomics, including the Hodrick-Prescott and bandpass filters, are implausibly sensitive to business cycle fluctuations. According to these detrending methods (see Figure 1 below), trend growth in aggregate hours in 2009-10 was declining at almost 2 percent per annum, despite population growth of more than 1 percent per year! To measure cyclical deviations from trend (i.e., cyclical "gaps"), we need estimates of trend growth that are not sensitive to the ups and downs of the business cycle itself. An important difference between the approach in this paper and in the recent literature on potential output growth is that our measure of the output trend makes no use of data on capital input and makes no effort to distinguish between growth in labor productivity and in multi-factor productivity.[2] Since our main topic is the cyclical behavior of labor productivity and labor input, we view the absence of measures of capital utilization for the entire economy as a basic handicap in trying to calculate cyclical changes in productivity from both labor and capital input.

After we arrive at plausible trends for the conventional measure of output, hours, and productivity in Part 2, then in Part 3 we contrast these with similarly constructed trends for the unconventional concepts of output, hours, and productivity. We examine substantial differences in the trend growth rates of the conventional and unconventional measures of labor productivity, particularly in 1996-2001 as contrasted with 2001-07.

Then in Part 4 the paper carries out a regression analysis of cyclical gaps in output per hour and aggregate hours (and its three components hours per employee, the employment rate, and the labor-force participation rate). The cyclical analysis in this version of the paper is based on the conventional measure of productivity, both to link the results more closely to previous research and also because the denominator of the unconventional measure (household hours) exhibits noisy short-term behavior.

We find 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 in the procyclical sensitivity of productivity nearly to zero. In Part 5 regression residuals are then examined to determine how well the equations explain particular episodes of historic interest, especially the productivity growth upsurges in 2001-04 and 2009. How much of the buoyant productivity growth in these episodes can be explained by the equations and how much remains as a residual?

Then the paper develops substantive hypotheses fo explain the shifts in structure pre- and post-1986 and also the unexplained elements of hours and productivity growth observed in 2001-03 and in 2008-10. An overriding theme is the reduced bargaining power of employees, creating the "disposable American worker." This paper suggests that the increase of income inequality over the past three decades goes hand-in-hand with the increased responsiveness of labor input to output fluctuations. Subsidiary hypotheses are suggested to explain the jobless recoveries of 2001-03 and 2009-10.

The final part of the paper uses the regression coefficients to forecast the behavior of productivity, aggregate hours, and its components over the next several years. This projection exercise can answer such questions as "how fast does real GDP have to grow in order to reduce the unemployment rate to 6 percent by 2012? By 2016?"

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2. For a paper summarizing the state of the art of production-function-based measures of potential output growth, see Basu and Fernald (2009).

2. The Decomposition 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 slower in 2007-09 than in the previous major back-to-back recessions of 1980-82 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 of changing cyclical responsiveness is the measurement of the underlying trends in potential output, hours, and productivity.

The first step in 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. A 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 Conventional and Unconventional Output Identities: 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 LFPR 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]

$$Y \equiv \frac{Y}{H} \cdot \frac{H}{E} \cdot \frac{E}{L} \cdot \frac{L}{N} \cdot N \qquad (1)$$

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

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

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.

There are two problems in the use of the identity (1) to link the cyclical behavior of productivity *(Y/H)* to that of labor input *(H)*. First, since *E, L, and N* refer to the household survey measures for the total economy, there must be a bridge between productivity based on the payroll survey and the other variables based on the household survey. Here we use "P" superscripts to identify data series coming from the payroll survey and "H" superscripts to identify data series coming from the household survey. The GDP measure of output is abbreviated Y^P, where the "P" stands for "product." Thus the "conventional" measure of output, labor productivity, aggregate hours, and its components can be abbreviated:

(2)
$$Y^P \equiv \frac{Y^P}{H^P} \cdot \frac{H^P}{E^P} \cdot \frac{E^P}{E^H} \cdot \frac{E^H}{L} \cdot \frac{L}{N} \cdot N$$

In previous versions of this paper I made the mistake of omitting the third term on the right-hand side of equation (2) and of calling H^P/E^H "hours per employee," leading to puzzlement as to why this measure of hours per employee should have declined so much in 2001-04. This hybrid term combines apples and oranges with quite different causes, the actual change in the payroll measure of hours per employee (H^P/E^P) and the E^P/E^H ratio that reflects measurement differences and errors rather than changes in behavior and exhibited a particularly notable decline in 2001-04..

The corresponding definition of the "unconventional" measure of output, labor productivity, aggregate hours, and its components can be expressed as follows, where the superscript "I" refers to the GDI measure of real output and the "H" superscripts as above designating those data series that come from the household survey.

(3)
$$Y^I \equiv \frac{Y^I}{H^H} \cdot \frac{H^H}{E^H} \cdot \frac{E^H}{L} \cdot \frac{L}{N} \cdot N$$

Notice that this expression contains five right-hand terms compared to six for the conventional measure, and that the final three terms in both equations are identical.

At this point we drop the superscripts and develop further expressions for the conventional measure of equation (2). To simplify the notation we use "R" to designate the E^P/E^H ratio. To allow for the subsequent treatment of growth rates and ratios of actual to trend, we take logs of (2) and use lower-case letters to designates the log of upper-case letters. For instance, *y* is the log of *Y* in equation (2) above. Thus the conventional output identity in equation (2) can be restated in logs as follows:

(4) $$y \equiv y\text{-}h + h\text{-}e + r + e\text{-}l + l\text{-}n + n$$

Because logs are additive, we can express output (y) as the sum of each of the right-hand side components, say x . The trend of the log of real GDP (y^*) is the sum of the same six components x^* as in (4). The log-ratio of actual to trend output $(y' = y - y^*)$, or output gap, also observes the identity (4) 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 (4) 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 and the closely related band-pass filter are the most commonly used detrending methods in macroeconomics, presumably because they allow the trend to move continuously and because they is easy to understand and to estimate. Their common flaw is that they are univariate, so that the only information used in the formula is the actual changes in the series from which a trend is to be extracted. When that actual value declines precipitously as in the Great Contraction of 1929-33, the resulting trend which by definition is supposed to show a partial response to actual movements is forced to decline. In another context I have shown that the application of the band-pass filter with standard parameters to quarterly data for the interwar period leads to the remarkable result that the trend growth of real GDP was +9.2 percent in mid-1924 and -7.8 percent in mid-1930 Gordon and Krenn, 2010, p. 7).

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

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 to the per-quarter adjustment of trend

to conclude that the entire economic boom of the 1960s resulted from an acceleration of trend, 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 ($\Delta(h\text{-}e)$), the employment rate ($\Delta(e\text{-}l)$), and the labor-force participation rate ($\Delta(l\text{-}n)$), i.e., 1.2 percent plus or minus perhaps 0.2 to 0.5 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 -1.7 percent per year in 2010:Q2. The alternative H-P parameter of 6400 declines fairly steadily over a longer period, from +1.9 percent per year in 1995:Q2 to -1.1 percent in 2010:Q2. In each case, the H-P technique exhibits its usual tendency to respond excessively to business cycle movements, thus understating the severity of cycles and muddying the differences between large and small cycles.5

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 clotted 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 in 1955, dips to a low rate of 0.9 percent in 1957, rises to a peak trend growth rate of 2.0 percent in late 1978, and then declines to roughly 0.7 percent in early 2003. 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 0.7 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 dotted black line shows the trend when it is estimated through 2010:Q1. It exhibits a cyclical downturn to 0.6

(1/8), i.e., 1600 = $(5/.125)^2$.

5. The recent study by Van Zandweghe bases its analysis entirely on H-P trends of output, hours, and productivity.

percent per year in 2009:Q3. The alternative trend shown by the solid black line is estimated with data through the NBER business cycle peak quarter of 2007:Q4 and then is arbitrarily held constant through 2010:Q2. 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 dotted black 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 lines. The H-P trends show substantial volatility in response to the recessions of 1981-82 and 1990-91, and especially 2007-09. The HP 1600 trend growth rate declines from 4.0 percent in 1997 to 0.3 percent in 2009:Q2. 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.

The two Kalman lines diverge from each other after 2002. The solid black line shows a Kalman trend that is estimated with data through 2007:Q4 and then maintained constant at exactly that rate (2.7 percent per year) through 2010:Q2. The dotted black line extends the estimation with data through 2010:Q1 and exhibits an uptick in trend growth during the recession to 3.0 percent per year. This implausible result reflects a theme developed later in the paper, that is the distortion of freely estimated trend estimates due to the unusual behavior of labor hours in the 2007-09 recession.

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 2007-09 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 output 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 extrapolates the 2007:Q4 trend growth rates and thus 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.[6] 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 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 conventional output identity, equation (2) above, except for the E^P/E^H ratio that we assume has no cyclical component. 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 (α_t) and any set of other explanatory variables (βZ_t):

$$(5) \quad \Delta x_t = \alpha_t + \beta Z_t + w_t$$

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

$$(6) \quad \alpha_t = \alpha_{t-1} + v_t$$

The error terms of this two-equation system are:

$$w_t \sim N(0,\sigma^2); \quad v_t \sim N(0,\tau^2)$$

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.[7]

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 equation (5) above may be specified to control for determinants of actual changes. For example the Z variables could include changes in the unemployment gap or in the rate of capacity utilization, 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.

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6. 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.

7. 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. .

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 is the trend" before calculating the gap. 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 a time-varying natural rate of unemployment (or "TV-NAIRU") 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 1955-2010.[8]
The natural rate starts out in 1955 at about 5.3 percent, increases to between 6.3 and 6.5 percent between 1980 and 1988, and then gradually declines to 4.7 percent by 2006-07. Despite the fact that the actual unemployment rate peaked at a higher value in 1982 than in 2009, the unemployment gap was higher in 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 are based on the Kalman technique using cyclical feedback from the unemployment gap as described above, estimated from data through 2007:Q4, with the 2008-10 trend growth rates constrained to continue at the value of 2007:Q4.

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8. The natural unemployment rate in Figure 2 is estimated by the same technique first used in Gordon (1997) and most recently updated in Dew-Becker and Gordon (2005) and in Gordon (2010a).

3. Conventional versus Unconventional Measures of Trends and Gaps

Virtually all previous research on productivity has defined labor productivity for the total economy as real GDP divided by a payroll survey concept of aggregate hours of work, as in equation (2) above. However, an alternative "unconventional" concept of perhaps equal validity is a measure of labor productivity defined as real gross domestic income (GDI) divided by aggregate labor hours based on the household rather than the payroll survey. In this section we report on some of the differences in behavior of the unconventional (hereafter "U" concept of labor productivity compared to the conventional (hereafter "C") concept. The C concept of the output identity is equation (2) above, and the U measure of the output identity is equation (3).

3.1 Conventional and Unconventional Growth Trends

The difference between the C and U measures of labor productivity is not trivial. The top frame of Figure 3 displays Kalman trends (estimated as in Figure 1 above) for the C and U versions of aggregate hours and output. The payroll measure of hours grew faster than the household measure from 1955 to 1975, then grew roughly the same until 1998, but then the payroll measure grew more slowly, particularly in 1999-2003. Also shown in the top frame is that the C and U measures of trend output growth were very similar until 1990, but then the U measure (i.e., GDI) grew faster in the 1990s and then slower after 2001.

Most important, the C and U measures of productivity grew at different rates over long intervals, as shown in the bottom frame of Figure 3. The U measure grew much more rapidly than the H measure from 1955 to 1975 and from 1993 to 2000, but grew much less rapidly than the C measure from 2000 to 2007. The previously mysterious upsurge in labor productivity recorded by the C measure between 2001 and 2004 did not occur at all for the U measure. The trend growth rate of U productivity over the past 15 years peaked at a rate of 2.1 percent in 1998:Q3 and by 2007:Q4 had declined to 1.0 percent, far below the 2007:Q4 trend growth rate of C productivity of 1.8 percent.

Productivity experts who placed a major emphasis on the role of information-communication technology (ICT) investment in explaining the productivity growth revival of the late 1990s were astonished that productivity growth was even faster in 2001-04 than in 1996-2001 despite the post-2000 collapse of ICT investment. However, this true only for the C measure in the bottom frame of Figure 3; the U measure suggests a closer correspondence to the share of ICT investment, peaking in 1998-99 and turning down from then until 2007.

Table 1 provides average growth rates over specified intervals for the alternative C and U measures of hours, output, hours per employee, and output per hour. Also shown is the difference between the C and U growth rates and the average of the C and U growth rates. The table displays from left to right the full 1954-2010 period divided at 1987, then the 1954-87 period divided at 1972, and finally the 1987-2010 period divided at 1996, 2001, and 2007. Over the long periods in the first two columns the differences in the growth rates of the C and U measures are relatively small.

But over shorter intervals there are appreciable differences. Most important is shown on the bottom section of Table 1, second and third columns from the right. The C measure of average trend productivity growth was slightly higher in 2001-07 than in 1996-2001, but the U measure was much lower in 2001-07 than in 1996-2001. As a result there was a sharp turnaround between the difference between the C and U average growth rates from -0.23 to +0.90. Thus hypotheses such as those discussed below in Part 6 to explain the post-2001 speedup in the trend of C productivity growth are not needed for the slowing trend growth of U productivity.

3.2 Trends for Real GDP and Components of the Output Identity

Since the average trend growth rate of the alternative C and U measures is probably more accurate than either taken separately, we now examine in Figure 4 the average trends of the C and U measures of output and the components of the output identity from equations (2) and (3) above.

The top frame of Figure 4 displays the average of the C and U trends from Figure 3 for hours, output, and labor productivity. Here we see a mild tendency for trend growth of hours and labor productivity to be negatively correlated. Between 1965 and 1980 the hours trend increased and the productivity trend decreased. Both then showed little movement between 1980 and 1995, and then hours growth slowed while productivity growth speed up. A corollary to this partial negative correlation is that the growth trend of output varied less than that of labor productivity.

The bottom frame of Figure 4 decomposes the hours trend into its five components. By definition as in equation (4) above hours growth *(h)* equals the sum of growth in hours per employee *(h-e)*, the ratio of payroll to household employment *(r)*, the employment rate *(e-l)*, the 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.

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 from positive to negative, and unusual negative growth in the link term payroll employment relative to household employment. 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 previous trend toward early retirement.[9] 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 $(E^H/L = 1-U/L)$.

3.3 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 shorthand for the percent log ratio of actual to trend. The top frame of Figure 5 displays the gaps for output, hours, and productivity, using the averages of the C and U measures. 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 2009-10. 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. The Okun's law pattern of a partial response of the hours gap to the output gap is also visible in the boom of the 1960's.

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 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 (-9.1 percent) was larger than the maximum negative hours gap (-6.5 percent) in 1981-82 , as is consistent with Okun's Law, whereas in 2009 the maximum negative hours gap (-10.6 percent) was larger than the maximum negative output gap (-9.2 percent). Thus the 2008-09 slump is almost exactly of the same magnitude for output but much worse for labor hours.

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

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. The strength of the $H/E^{=P}$ 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.

4. 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 E^P/E^H ratio and 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 2008-09 recession? To answer these questions about shifts in business cycle behavior, we use the conventional output identity (equation 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 1954-86 and 1986-2010 sample periods. Do standard statistical tests reveal significant changes in cyclical responses across these two sample periods? 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.

4.1 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 56 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 4 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.[10] 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.[11] 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.

4.2 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.[12] 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

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

11. 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).

12. Gordon (1979, 1993, 2003).

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 the four quarters 2009:Q2 to 2010:Q1.

The EOE effect is introduced into the dynamic specification through a set of eight dummy variables, corresponding to eight end-of-expansion episodes since 1954. 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 can be allowed to differ across business cycles by allowing the dummy variable for each cycle to have its own coefficient. However, in past work we have determined that the specification can be simplified by forcing these separate EOE coefficients to be equal across episodes.[13]

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

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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). The definition of the EOE dummies for 2000-03 is taken from Gordon (2003) and for the recent recession and early recovery is determined by the same procedures. The actual dates of the EOE dummies are provided in the data appendix.

(7) $$\Delta x'_t = \sum_{i=1}^{4} \alpha_i \Delta x'_{t-i} + \sum_{j=0}^{4} \beta_j \Delta y_{t-j} + \phi x'_{t-1} + \sum_{k=1}^{8} \gamma_k D_k + \varepsilon_t$$

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 productivity as the dependent variable would be expected to have a negative coefficient. In this paper the basic estimates in Tables 2 and 3 below force the coefficients on the different EOE dummy variables to be equal, i.e.,$\gamma_k = \gamma$.

4.3 Estimation for Two Components of the Output Identity

To limit the number of tables in the paper we do not display the regression results for the U definition of the output identity, equation (3) above, and limit our presentation of results to those for the C definition in equation (2). The regression coefficients are of the same sign and similar magnitude when the U data are used in Table 1. However, the U data are more noisy, with the standard deviation of the annualized quarter-to-quarter change in the labor productivity gap for 1986-2010 of 3.25, a full point higher than 2.16 for the C definition. For hours the respective standard deviations are 3.64 in the U data and 2.56 in the C data. This noise reduces the significance of the explanatory variables.

Our results in estimating equation (7) are presented in two tables. First, in Table 2 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 2 has four columns corresponding to the two alternative dependent variables. The left two columns display coefficients estimated for the early sample period (1954:Q1 to 1986:Q1), and the right two columns display coefficients estimated for the late sample period (1986:Q1 to 2010:Q2). The coefficients are presented in rows corresponding to their order in equation (7).

Let us focus initially on the aggregate hours results in the first column of Table 2 for the early period and the third column for the late period. The sums of coefficients on the output deviation are an identical 1.18 and 1.18, no 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, 0.76 and 1.20 respectively, as shown on the bottom line of Table 2. 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, and vice versa. 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 0.67 in the late regression.

We now turn to the parallel results when changes in the gap of total-economy productivity are used as dependent variable. 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 (7) 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 2010:Q2. We deal with this problem by creating forecasts for output growth in the subsequent four quarters based on those reported regularly by the commercial firm Macroeconomic Advisers.

The second and fourth columns of Table 2 present the results for productivity growth. Here we see that the sum of coefficients on the output deviation term drops from a highly significant 0.37 in the early regression to an insignificant 0.13 in the late regression. The corresponding long-run responses drop substantially from 0.21 to 0.09. The error-correction term is insignificant in the early-period regression and significant in the late period, while the 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. Of substantial interest is the fact that the EOE dummies in the productivity equations are almost the same in the early and late regressions, respectively -2.16 and -2.49. 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 1955-57 there is ample precedent for the "early recovery productivity bubble," i.e., buoyant productivity growth as observed during 2009:Q2-2010:Q1, although as we shall see below that productivity gains during these four quarters were somewhat larger than the equation is able to predict.

Table 2 also displays Chow tests on the significance of structural change across the early and late sample periods for both hours and productivity. Neither of the two Chow test F-ratios displayed in Table 1 is significant at the 5 percent 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.

A final result presented in Table 2 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 0.90 in the early period to 1.40 quarters in the late period, while the productivity lead shrinks from -2.19 to -1.70 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.

We can discuss more briefly Table 3, 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 1954-86 period and the 1986-2010 late period. As shown on the bottom line of Table 2, the long-run increase for the employment rate increased from 0.44 to 0.63, for the LFPR from 0.02 to 0.15, and for hours per employee from 0.12 to 0.39. The Chow tests find that only the employment rate equation comes close to exhibiting a significant structural shift. The EOE dummies have the expected positive sign and are significant in the early period for the employment rate and LFPR equations, but the sign is negative (albeit insignificant) in the early-period equation for hours per employee.

4.4 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 2 and 3. These are shown graphically in Figure 6 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 6. 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.

The responses listed at the bottom of Tables 2 and 3 and summarized in Figure 6 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 1954-86 regressions are 0.76 and 0.21. Our 0.44 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 declines to 0.09. 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.

Table 4 displays the long-run responses implied by the regression estimates of the output identity components for the C and U measures. The shift in coefficients from the early to late sample periods is more muted with the U definition, as the long-run hours response jumps by 0.27 points from 0.65 to 0.92, in contrast to the C definition which leaps by 0.44 points from 0.76 to 1.20. Note also that the sum of the hours and productivity responses in the late period are greater than unity with both the C and U measures, 1.29 for the C measure and 1.08 for the U measure. Overall the shift in the coefficients away from the original Okun formulation toward a greater response of labor hours is still present but is less pronounced in the U definition than in the C data.

5. 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 2008-09 recession and its aftermath. Thus we quantify two dimensions of change – a longer term structural change that dates back to the late 1980s and shorter-term aspects specific to the 2008-10 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.

5.1 Plots of Actual Values, Fitted Values, and Residuals

The top frame of Figure 7 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 2. The predicted values from the 1954-86 equation are shown for that period and the predicted values from the 1986-2010 equations are shown for the corresponding interval.

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 7. Actual hours growth was higher than predicted in the late 1970s and was lower than predicted in 1983, 1986, and 2008-09. The 1977-78 bulge in hours growth can be traced directly to the Federal government's New Jobs Tax Credit that was in effect for those two years.[14] The decline in hours in 2008-09, evident in the large relative size of the hours gap relative to the output gap in the top frame of Figure 5, generates a residual that is surprisingly small.[15]

Figure 8 has the same format as Figure 7 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 2, 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 7) 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 of 2009 is no larger than that of 2001-04 and so far is of about the same duration. The positive productivity residual of 2009 is smaller than the positive productivity residuals of 1983-84 or 1986-87.

5.2 Cumulative Residuals

It is evident from the bottom frame of Figure 8 that the productivity residuals show a pronounced tendency to be positive after 2003. What is the magnitude of this unexplained excess of actual productivity growth over that predicted by the equation estimated over the 1986-2010 period? How are those positive residuals balanced by the equations for hours and its components?

Table 5 provides annualized averages of actual, predicted, and residual values for selected time intervals for the hours and productivity equations estimated in Table 2 for the 1986-2010 period. The first four rows indicate averages over four sub-intervals within 1986-2010 period, by the average for the full 1986-2010 sample period. Note that the residuals for the full sample period, while small, are not exactly zero, and this is because there is no constant term in the regression specification (equation 7 above).

The left half of the table refers to aggregate payroll hours and the right to the

14. I am grateful to John Bishop for pointing out the connection between the hours residual and the NJTC. See Bartik and Bishop (2009), especially Appendix B.
15. This residual was larger in earlier versions of this paper, but the GDP revisions of late July, 2010, substantially increased the severity of the 2008-09 output decline and thus improved the predictive performance of the hours equation.

conventional definition of total-economy productivity. There are two residuals that are relatively large, the hours and productivity residuals for 2007-10. Yet these values of +/- 0.44 are small compared to the widespread perception that productivity growth in 2009 was inexplicably rapid, reaching 4.8 percent in the four quarters ending in 2010:Q1. The equation explains the upsurge of productivity growth by the lags in the hours equation (which are longer after 1986), by the sharp turnaround in output growth from sharp decline to sharp increase in mid-2009, and by the EOE dummy coefficient. Also, the equation yields negative productivity residuals for 2007-2008 that almost entirely offset the larger positive residuals for 2009-10. Productivity growth was remarkably slow in 2005-08 even relative to the prediction of the EOE effect.

We now turn to Table 6 to see how for the same intervals as in Table 5 the hours residuals were distributed among the three components (hours per employee, the employment rate, and the LFPR). An additional element of Table 4 is that the predictions for the post-1986 intervals are calculated both with the pre-1986 and post-1986 coefficients. Not surprisingly the pre-1986 coefficients that support the original Okun's Law responses yield *much* larger residuals. They fail to capture the productivity explosions of 2001-04 and 2007-10 and the corresponding shortfall of hours growth. The coefficients are allowed to shift in 1986 to provide a better explanation of these outcomes. For instance, the productivity residual during 2007-10 drops from +2.16 with the early-period coefficients to +0.44 with the late-period coefficients.

How was the shortfall of hours growth in 2007-10 divided among the three components of the identity using the late-period coefficients? Most of the hours shortfall of -0.44 is attributed to the employment rate, with virtually zero residuals for the LFPR and *H*/*E* equations. The counterpart of the widely cited fact that forced part-time work has been at a record in 2009-10 is captured by the fitted values of the *H*/*E* equation (column 6 in Table 3) with a near-zero residual.

The final display of residuals is presented in Figure 8, where the residual for aggregate hours is decomposed into its three components. How unusual was labor-market behavior in the Great Recession? The most important fact that stands out in Figure 8 is that residuals of the three labor-market components in 2008-10 were not unusually large. The residual for hours per employee was much smaller than positive and negative residuals in several episodes going back to 1986.

5.3 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 was also very rapid in 2009:Q2 through 2010:Q1. Is this a new, unprecedented phenomenon? 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 7 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 NBER-dated trough quarter for real GDP in six 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 six cyclical episodes (five episodes for the bottom half of the table). The remaining columns report averages over each interval of the predicted value from the productivity regression in table 2, as well as the statistical contribution of the EOE dummy variables to that prediction, as well as the prediction minus the EOE contribution, and finally the statistical residual.

The bottom line in each panel of table 7 shows the averages over the 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, 1.37 percentage points a year faster than trend in the first four quarters but only 0.02 percentage points faster than trend over the next eight quarters. This difference is largely captured by our dynamic model of cyclical productivity behavior, with an average residual of 0.07 percentage points in the first four quarters and 0.16 percentage points in the subsequent eight quarters. The predicted change in the first four quarters is 1.30 percentage point compared with -0.14 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 68 percent of the predicted 1.30 percentage-point early-recovery productivity growth is attributable to the EOE reversal effect and the remaining 32 percent 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 -0.02 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 lasted 19 months after the NBER trough (November 2001) until June 2003. Table 7 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. The equation overall also fails to predict more than about one-sixth of the rapid productivity growth that occurred in the first four quarters of the recovery.

As shown in the top frame of Figure 3, the unusual growth of labor productivity during the 2001-04 interval was much less with the unconventional (U) measure than with the conventional (C) measure. When Table 7 is redone with the U measures, the average change in the productivity gap in the first column for the full 12-quarter period 2001:Q4-2004:Q3 declines almost by half from 0.60 to 0.34, and the equation residual declines by more than half from 0.94 to 0.39. Thus even with the U measure productivity growth was high relative to (a much slower growing) trend but only by about as half as much, and the "miss" of the equation in explaining this episode is much lower as well.

6. Hypotheses to Explain Changes in the Cyclical Behavior of Hours and Productivity

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. First, since 1986 the cyclical response of labor-market variables to changes of the output gap has altered compared to the pre-1986 interval, with a much larger response in aggregate hours and its three components (H/E, E/L, L/N) and almost no response of productivity growth. Second, the recoveries of 2001-03 and 2009-10 reflect further aspects of unusual behavior that are not captured by the regressions, despite 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 7 for 2002-03. 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 residuals in the bottom frame of Figure 7.

What substantive hypotheses can explain these residuals and structural shifts? 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 suggest a broader set of explanations that may in part explain the shifts in coefficients between the early and late sample periods evident in Tables 2, 3, and 4.

6.1 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 (Hilsenrath 2002).

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 input costs so aggressively? 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 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.[16] 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 (1990), 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 (2004) and by Shinkyu Yang and Erik Brynjolfsson (2001). 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

16. 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.

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. 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.[17]

The distinction in this paper between conventional (C) and unconventional (U) measures of output, hours, and productivity show in Figure 3 above that the 2002-04 peak in trend productivity growth applies only to the C measure, while the U measure exhibits a steady decline in trend productivity growth after its 1998 peak. The average of the C and U measures, shown separately in the top frame of Figure 4, is a compromise measure that exhibits flat trend growth between roughly 1998 and 2002. This average measure still leaves room for the cost-cutting and intangible capital explanations without requiring them to explain why the productivity growth upsurge extended beyond 2002 to 2004.

6.2 The 2008-10 Collapse in Hours and Employment

As we saw above in the top frame of Figure 5, the 2008-09 recession caused a collapse in the hours gap that was greater than that of the output gap, as contrasted with 1980-82 when the decline in the hours gap was substantially less than that of the output gap.

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17. 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.

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 2008-09, 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 March, 2000 and October, 2002, and was 52.8 percent between October, 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 might lead to a repeat 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 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 four quarters starting in 2008:Q3: -12.5, -36.8, -42.2, and -18.5, for an average annual rate of decline of -27.5 percent. The quarterly NIPA data do not reveal in their history since 1947 any other episode with four quarters of an investment decline in excess of 20 percent at an annual rate, even in 1981-82.

6.3 The Disposable Worker, Shareholder Value, and Increased Labor-market Flexibility

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 since the 1970s 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.

The relative increase in managerial power and the decline in labor power that contribute both to the rise of inequality and the increased cyclical labor-market responsiveness can be called the "disposable worker hypothesis," a variant of Uchitelle's (2006) "the disposable American." Uchitelle traces the rise of job security to a peak in the 1950s and 1960s, followed by a subsequent decline beginning in the 1970s (at about the same time that inequality began to increase). Using examples of particular workers and firms, he traces numerous aspects of increased managerial power, including overuse of layoffs, wasteful mergers, outsourcing, the loss of union protection, wage stagnation, and psychological damage to the victims of layoffs.

Sinai (2010, p. 27) attributes structural labor-market change, including successive jobless recoveries since 1991, to the combination of increased costs of fringe benefits, especially health care costs, and to a shift in corporate values towards maximizing shareholder value. "Maximizing shareholder value is now the mantra of U. S. business, especially since 1990." He cites many of Uchitelle's consequences, including outsourcing and mergers which reduce administrative costs, as well as the increased use of temporary workers, to this shift of corporate philosophy. Sinai's emphasis on shareholder value is consistent with my hypothesis (Gordon, 2003, and in section 6.1 above) that a fundamental underlying cause was the 1990s shift of executive compensation toward much greater use of stock options, together with the dot.com bubble and shady accounting that contributed to the severity of the 2000-02 stock market crash and accompanying desperation to cut labor costs.

On the surface it may appear paradoxical that the greater tendency of management to treat workers as disposable has been accompanied by a shift in job qualifications 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.

A second hypothesis, complementary to the disposable worker view, 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 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.

7. Conclusions

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 1954 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.

This paper also introduces a novel distinction between "conventional" and "unconventional" measures of productivity growth. Most research on U. S. productivity uses data on output per hour in the nonfarm private business (NFPB) sector. This sectoral approach is difficult to link to aggregate data on employment, unemployment, and labor-force participation. Our "conventional" measure of productivity applies to the entire economy and is equal to real GDP divided by an unpublished BLS index of aggregate hours of work based on the payroll survey.

But this is not the only feasible measure of productivity for the total economy. An alternative numerator to GDP is Gross Domestic Income (GDI), which Nalewaik (2010) has shown to exhibit consistently different cyclical behavior and to be more reliable. An alternative denominator to payroll-based hours is household-based aggregate hours. Thus as an alternative to the conventional definition of labor productivity for the total economy, we define the unconventional measure as GDI divided by household-survey-based aggregate hours.

No paper can discuss or analyze cyclical gaps in output, hours, productivity, or employment until they have done their preliminary homework of determining the underlying growth trends from which the "gaps" are a deviation. An important 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. A H-P growth trend for aggregate hours in 2009-10 is -1.7 percent per annum, an implausible conclusion in the context of ongoing growth in the working-age population at a rate of about 1.2 percent per year..

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. This unemployment gap is thus created from outside information on the inflation process rather than from the fluctuations of the cyclical variables that we want to smooth into cycle-free trends.

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 volatility of 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 7/6 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. Okun's informal 1962 suggestion was 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 76 to 21 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 76 to 21 percent, to 120 to 9 percent..

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. While the regression of the model captures most of the collapse of hours and surge of productivity growth in 2009, there is still a negative residual for hours and a positive residual for productivity. 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.

The paper suggests a set of complementary hypotheses to explain these changes in behavior. The most important of these is the "disposable worker" hypothesis. Starting in the 1990s business firms began to increase their emphasis on maximizing shareholder value, in part because of a shift in executive compensation toward stock options. The overall shift in structural responses in the labor market after 1986 reflects many of the same causal factors that have previously been proposed to explain the increase in American inequality. These include the role of the stock market in boosting compensation at the top, together with several forces that have increased income dispersion in the bottom 90 percent of the distribution. These include the declining minimum wage, the decline of unionization, the increase of imported goods, and the increased immigration of unskilled labor. Taken together these factors have boosted incomes at the top and have increased managerial power, while undermining the power of the increasingly disposable workers in the bottom 90 percent of the income distribution. 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 the same mechanism, but with the added element of a much steeper 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. This comes out in the fact that the hours gap relative to trend in 2009-10 was larger than the output gap, in contrast to 1982 when the hours gap was about two-thirds of the output gap.

While most of our analysis is based on the conventional measure of labor productivity, we devote substantial attention to the implications of the unconventional measure. The most important finding is that the trajectory of trend productivity growth over the 1995-2007 period is completely different in the unconventional series. In the conventional measure labor productivity growth was 2.13 percent per year in 2001-07, slightly faster than the 2.11 growth rate registered in 1996-2000. But the unconventional measure shows substantially faster 2.34 percent growth in 1996-2000 but much slower growth of 1.23 percent in 2001-07. The main benefit of treating the unconventional measure as the twin brother of the conventional measure is that a radically new perspective is placed on the previously puzzling upsurge of U. S.

productivity growth in 2001-04.

This paper does not contain attempts to forecast the future of growth in hours, employment, and productivity that would accompany various output growth paths. A simple relationship between the hours gap and the output gap would require a higher output gap (faster growth in actual output than trend) to achieve a reduction in the hours gap. Consensus estimates of trend real GDP growth around 2.5 percent per year would thus require actual real GDP growth of 2.5 percent to maintain the hours gap and the unemployment rate constant.

However, deep within our regression results is a reason for optimism. In Table 2, column 3, there is a very significant error correction term, indicating that *independent of the growth of real GDP a negative hours gap tends to self-correct toward a zero output gap.* This implication of the analysis suggests that even if output continues to grow slowly, hours could begin soon to grow substantially and the unemployment rate could begin to decline. Given all the changes in labor market structure documented in this paper, one is hesitant to push a single error-correction coefficient toward a rosily optimistic forecast for the U. S. unemployment rate.

DATA APPENDIX

Data Sources

All data, with the exception of payroll and CPS (Current Population Survery) aggregate hours, were obtained from the websites of the Bureau of Labor Statistics (BLS; www.bls.gov) and the Bureau of Economic Analysis (BEA; www.bea.gov), were current as of August 8, 2010, and were retrieved for the period 1950:Q1 to 2010:Q2. Payroll aggregate hours data were unpublished data for the period 1950:Q1 to 2010:Q2 and were received from the Bureau of Labor Statistics Office of Productivity and Technology on August 8, 2010.

The BLS data are identified below by their symbol in the paper (see equations 2 and 3) and by their BLS series identifier. "NFPB" refers to the non-farm private business sector:

Gross Domestic Product (Y^P)	BEA Table 1.1.6
Gross Domestic Income (Y^I)	BEA Table 1.7.6
NFPB Payroll Aggregate Hours (H^P)	BLS Office of Productivity and Technology
NFPB Household Hours per Week	BLS Series LNU02033120
NFPB Payroll Employment Level (E^P)	BLS series CES0000000001
NFPB CPS Employment Level (E^H)	BLS series LNS12000000
NFPB CPS Unemployment Rate	BLS Series LNS14000000
NFPB Labor Force Participation Rate (L/N)	BLS Series LNS11300000
Working Age Population (N)	BLS Series LNU00000000

The NFPB household survey (CPS) employment rate $\frac{E^H}{L}$ was calculated as unity minus the CPS unemployment rate from BLS series LNS14000000. NFPB CPS aggregate hours H^H was calculated by first seasonally adjusting NFPB weekly hours data from BLS series LNU02033120 for the time period 1976:Q3 to 2010:Q1 and extrapolating it back to 1950:Q1 by ratio linking the series to H^P/E^P) in 1976:Q3, and then this NFPB weekly hours data for the time period 1950:Q1 to 2010:Q1 was aggregated with the NFPB CPS employment level from BLS series LNS12000000 and annualized. The seasonal adjustment of NFPB WWH data was done using X11 with multiplicative decomposition.

Timing of End-of-Expansion Dummy Variables

The end-of-expansion (EOE) dummy variables are shown below in table A1, where *k* represents the number of the dummy (corresponding to the D_k coefficients in equation 7). As explained in the text, each of the eight dummy variables equals 1/*M* during the "on" quarters shown in the table, and -1/*N* during the "off" quarters, where *M* is the length in quarters of the initial interval of excessive labor input growth, and *N* is the length of the subsequent correction.

Table A1. Timing of End-of-Expansion Dummy Variables, 1955 - 2010[a]

Dummy Variable (k)	M	D(k) = 1/M *during*	N	D(k) = -1/N *during*
1	7	1955:4 - 1957:2	4	1957:3-1958:2
2	8	1958:3-1960:2	8	1961:1-1962:4
3	7	1968:2-1969:4	6	1970:2-1971:3
4	7	1973:1-1974:3	7	1974:4-1976:2
5	11	1978:4-1981:2	4	1982:3-1983:2
6	8	1988:2-1990:1	8	1991:1-1992:4
7	5	2000:1-2001:1	7	2001:4-2003:2
8	7	2006:2-2007:4	4	2009:2-2010:1

a. *The D(k) variables would be entered as 1/M and -1/N if the data were annual. With quarterly data, as in this paper, they are instead defined as 4/M and -4/N.*

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Figure 1a. Annualized Trend Growth Rate of Aggregate Hours, Alternative Methods, Conventional Identity, 1955:Q1 - 2010:Q2

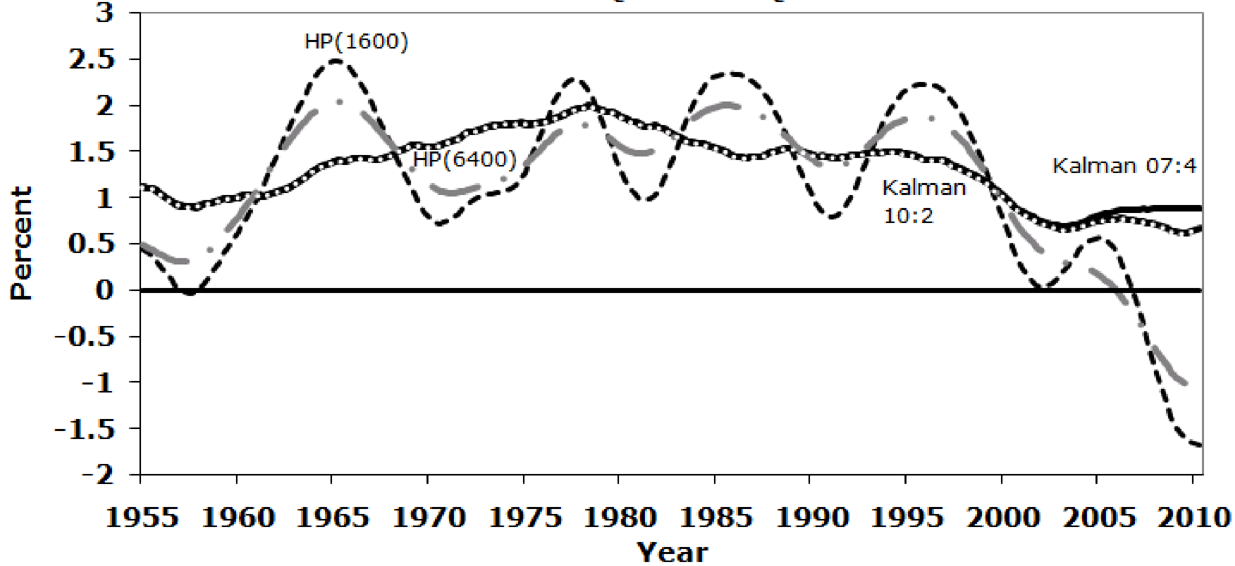


Figure 1b. Annualized Trend Growth Rate of Output, Alternative Methods, Conventional Identity, 1955:Q1 - 2010:Q2

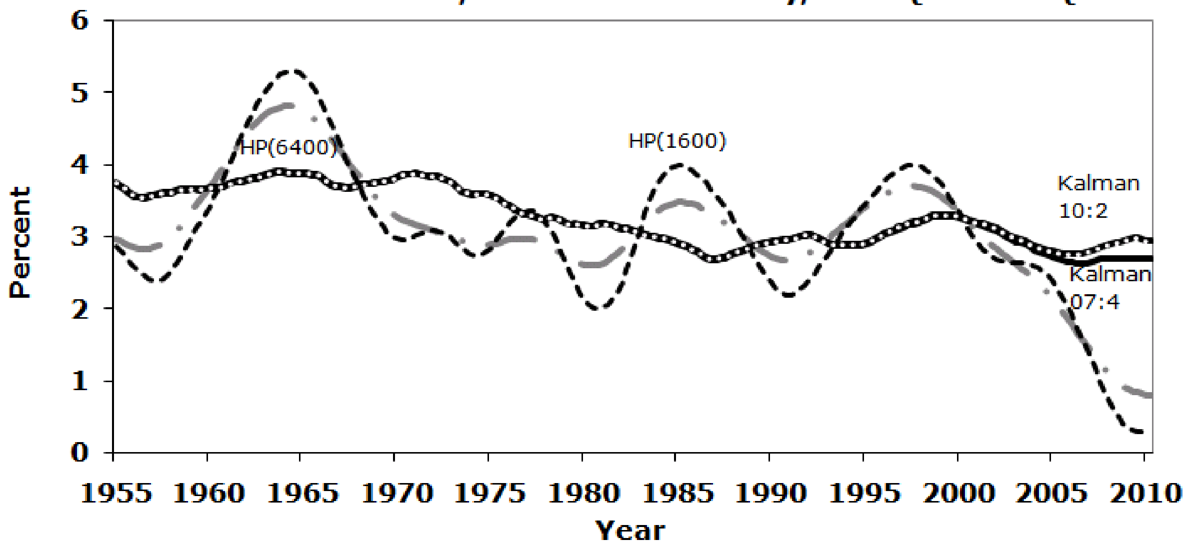


Figure 2. Actual Unemployment Rate, Time-Varying NAIRU, and Implied Unemployment Gap, 1955:Q1 - 2010:Q2

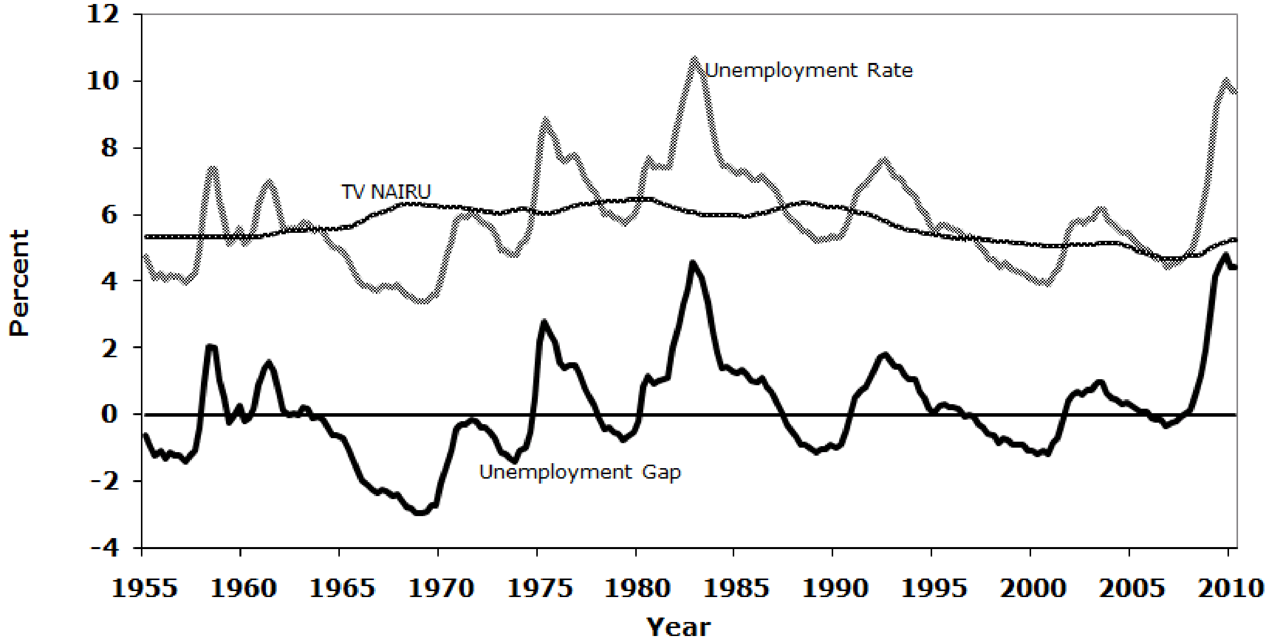


Figure 3a. Annualized Quarterly Growth of Output and Aggregate Hours Trends, Conventional vs.Unconventional Measures, 1955:Q1 - 2010:Q2

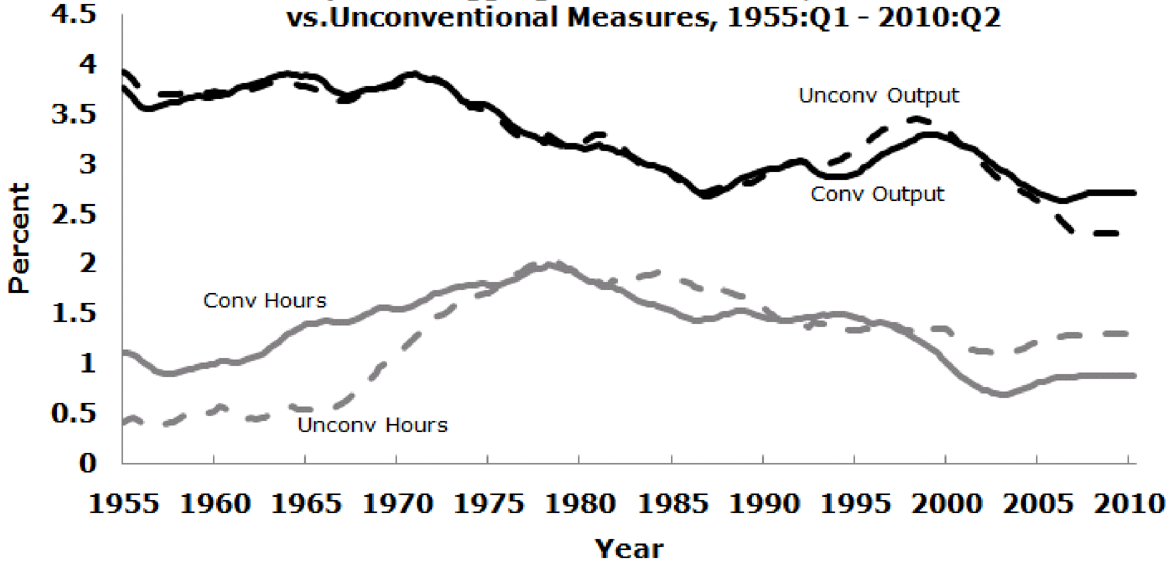


Figure 3b. Annualized Quarterly Growth of Labor Productivity, Conventional vs.Unconventional Measures, 1955:Q1 - 2010:Q2

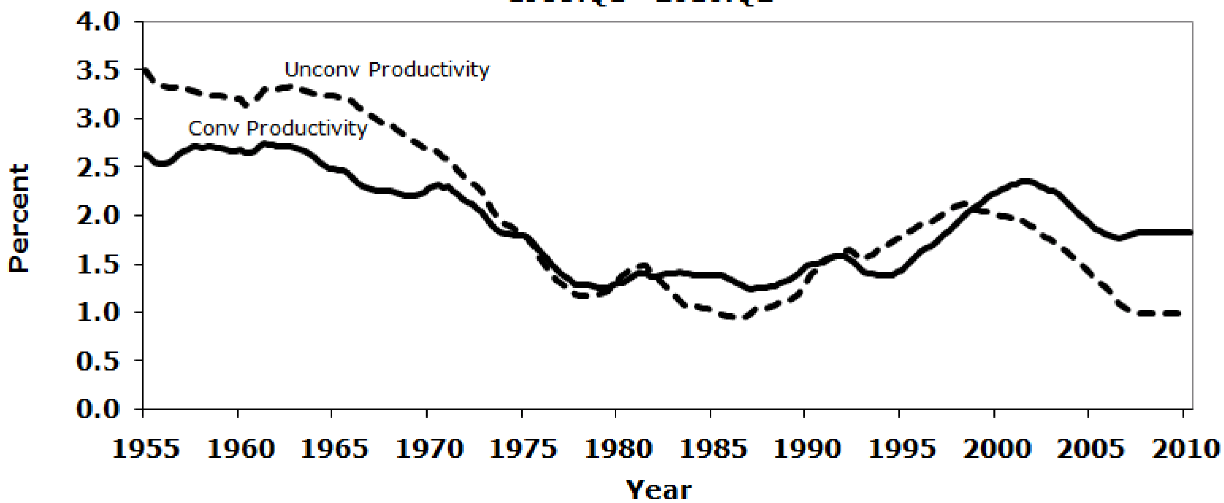


Figure 4a. Annualized Trend Growth of Labor Productivity, Hours, and Output, Estimated through 2007:Q4 and then Held Constant, Average Identity, 1955:Q1 - 2010:Q2

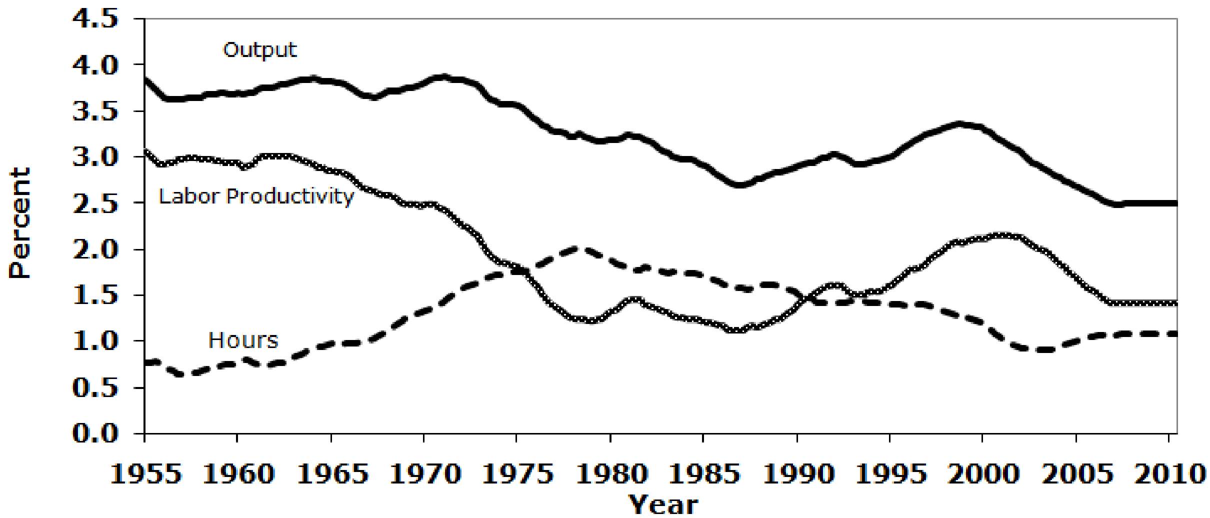


Figure 4b. Annualized Trend Growth of Hours per Employee, the Employment Rate, the Labor Force Participation Rate, and Working-Age Population, Average Identity, 1955:Q1 - 2010:Q2

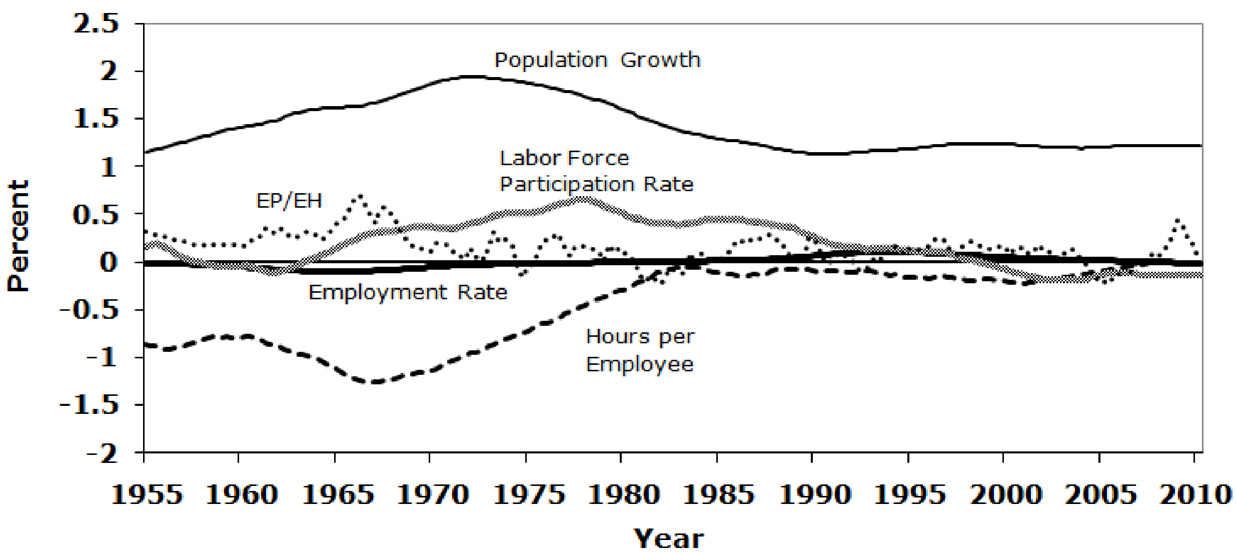


Figure 5a. Log Percent Gaps of Actual Relative to Trend for Output, Aggregate Hours, and Labor Productivity, Average Identity, 1955:Q1 - 2010:Q2

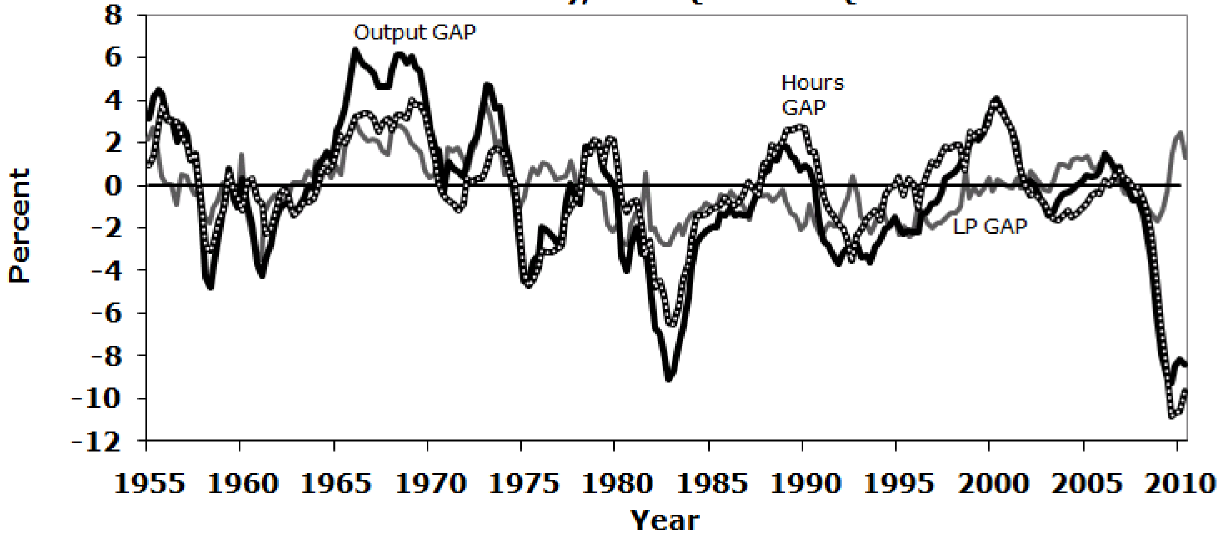


Figure 5b. Log Percent Gaps of Actual Relative to Trend for Hours per Employee, the Employment Rate, and the Labor Force Participation Rate, Average Identity, 1955:Q1 - 2010:Q2

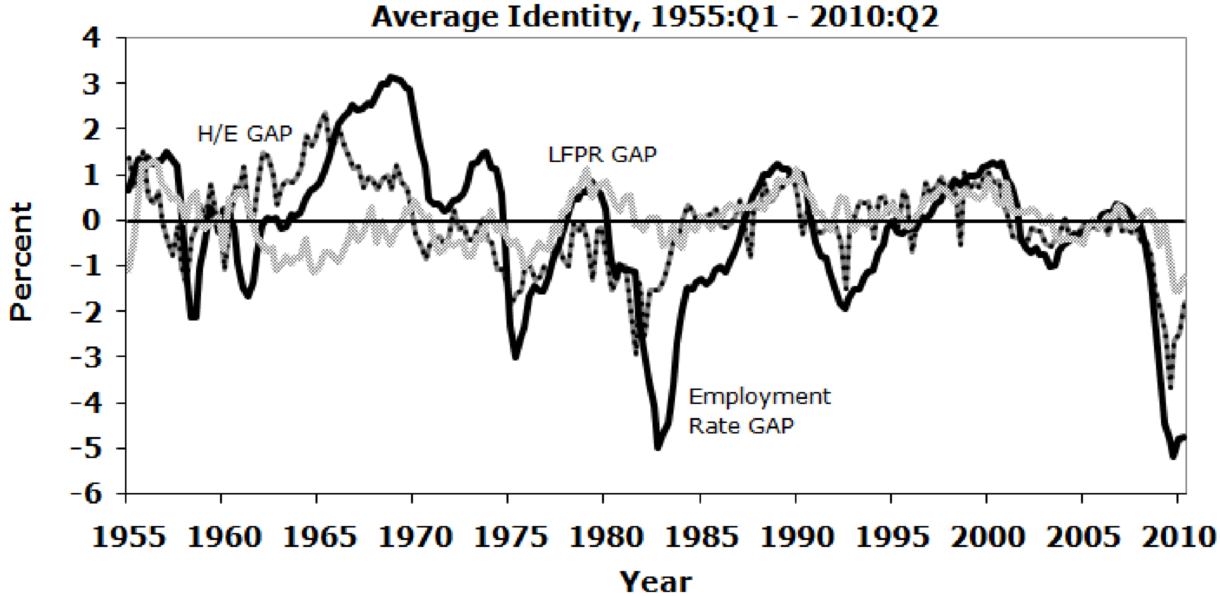


Figure 6. Long Run Response of Labor Productivity and Aggregate Hours by Conventional Definitions using 1954:Q1 - 1986:Q1 vs 1986:Q1 - 2010:Q2 Coefficients

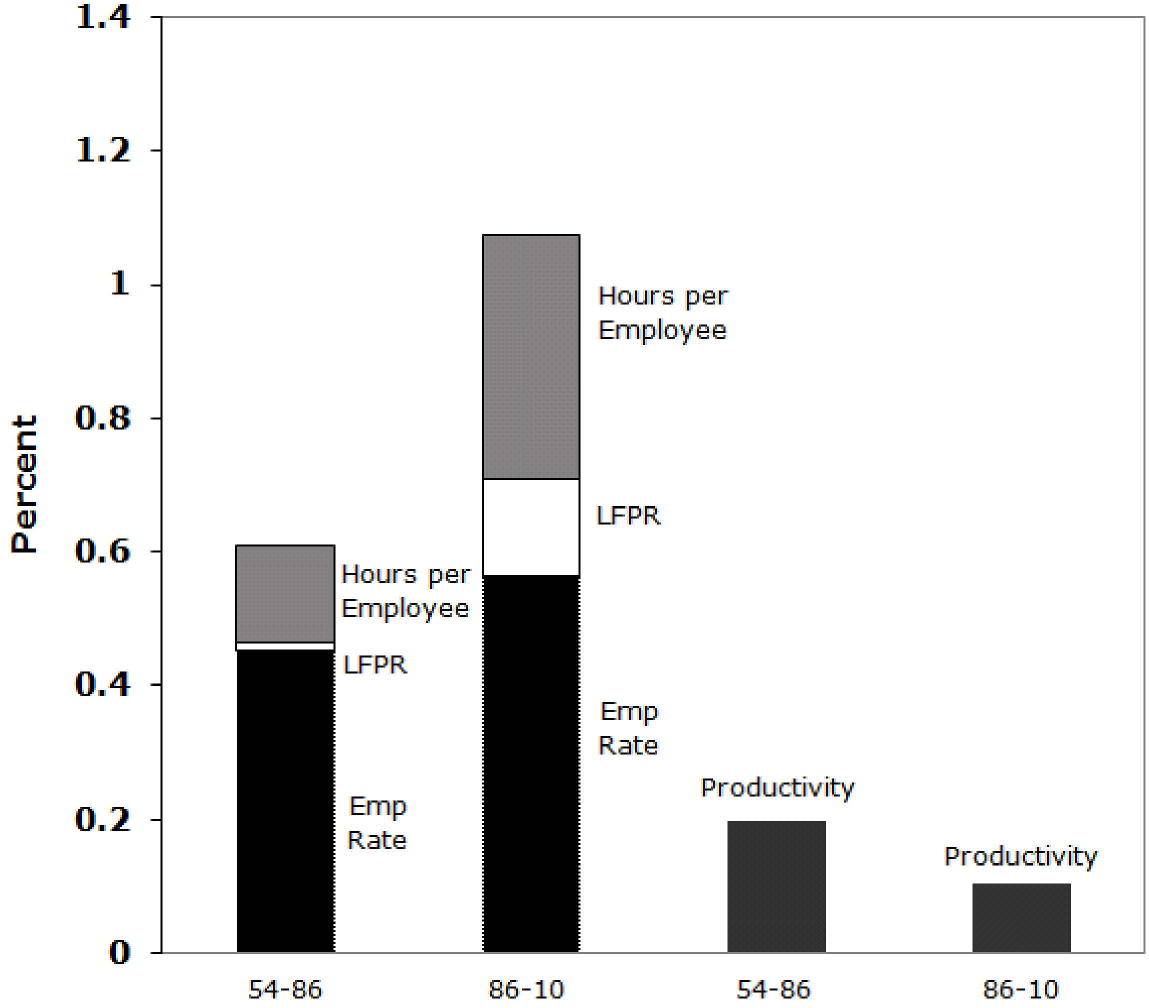


Figure 7a. Annual Growth Rates of Actual, Fitted, and Trend Aggregate Hours, Early and Late Coefficients, Conventional Identity

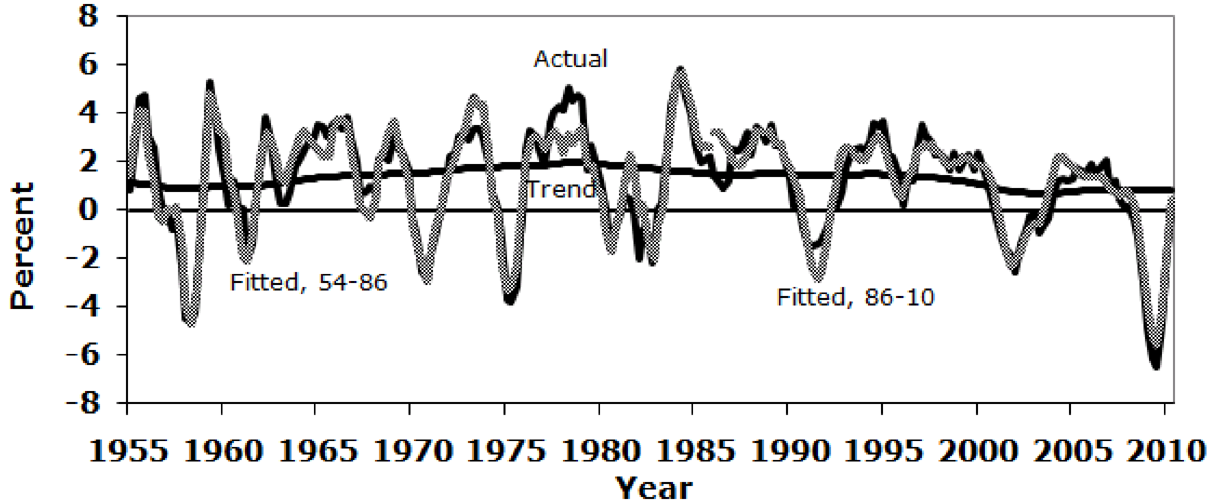


Figure 7b. Hours Residuals using Early and Late Coefficients, Conventional Identity

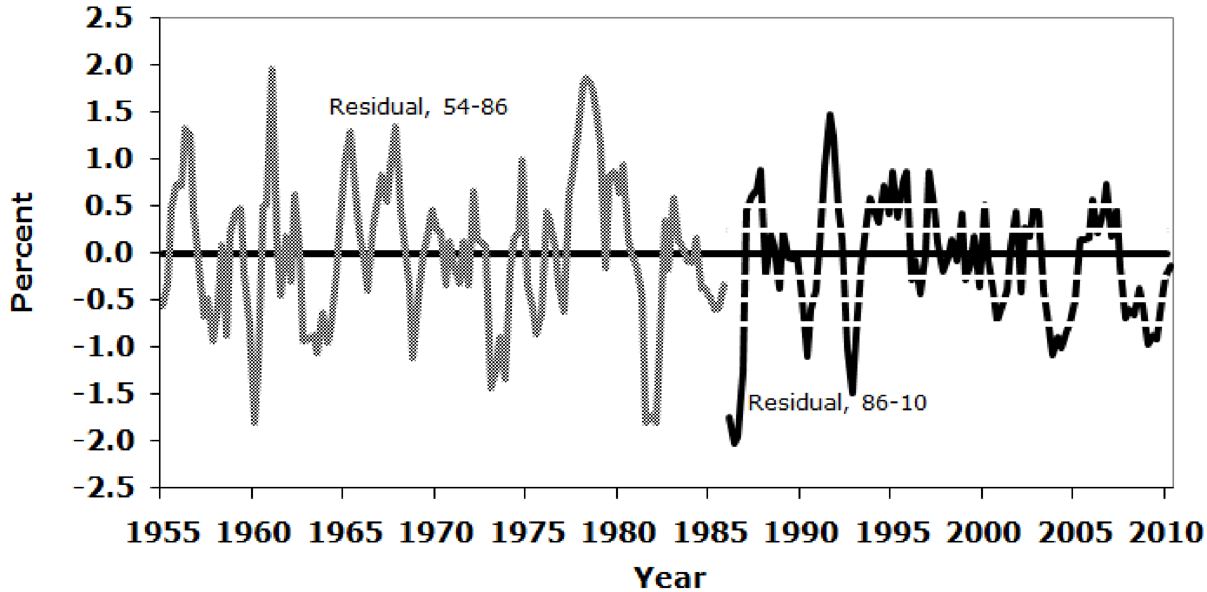


Figure 8a. Actual, Fitted, and Trend Growth Rates for Labor Productivity, Early and Late Coefficients, Conventional Identity, 1955:Q1 - 2010:Q2

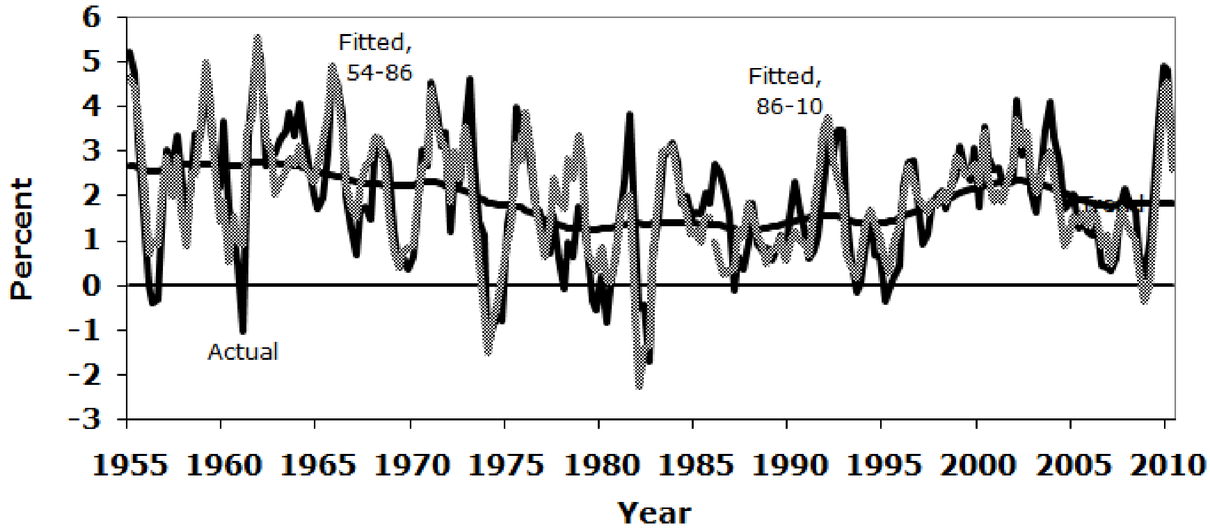
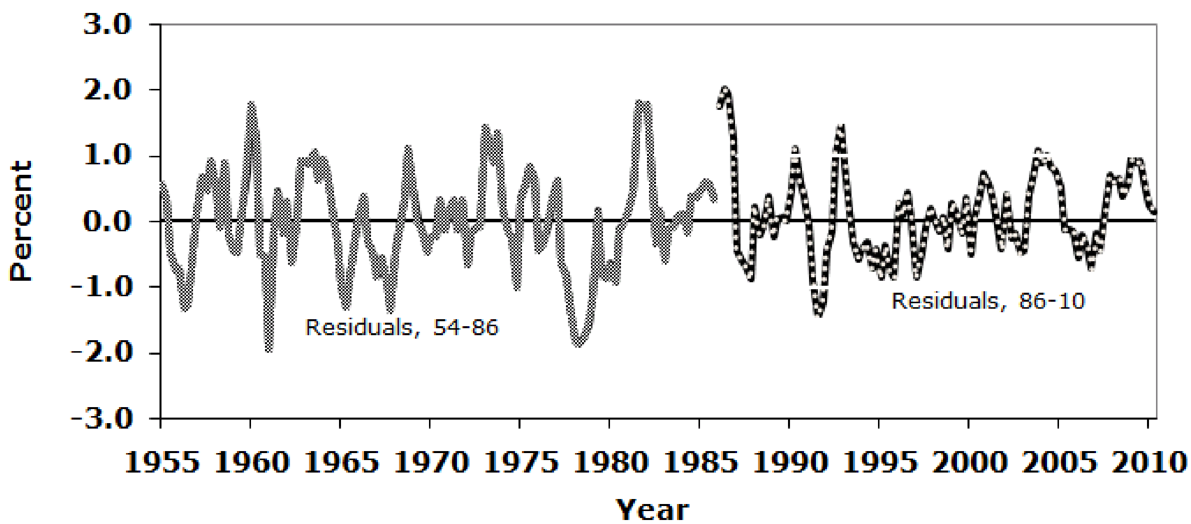


Figure 8b. Labor Productivity Residuals using Early and Late Coefficients, Conventional Identity



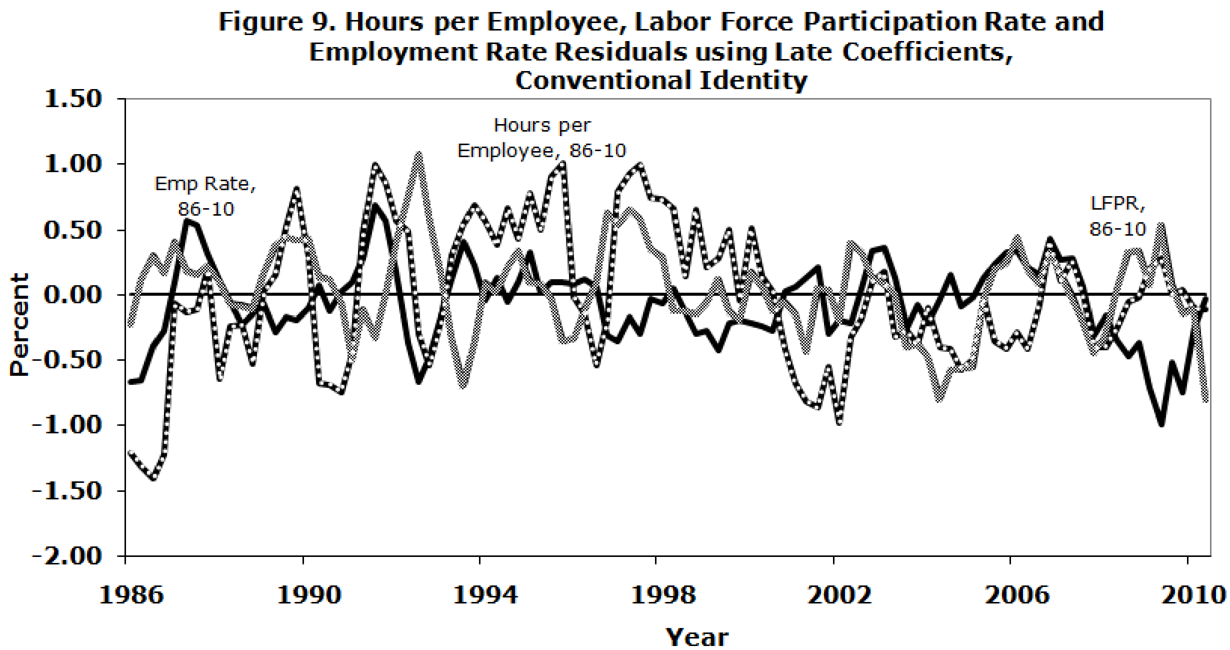


Figure 9. Hours per Employee, Labor Force Participation Rate and Employment Rate Residuals using Late Coefficients, Conventional Identity
Hours per Employee, 86-10
Emp Rate, 86-10
LFPR, 86-10
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
Percent
1986
1990
1994
1998
2002
2006
2010
Year

Table 1. Growth Rates of Various Components (AAGR)

	1954:Q4-1987:Q4	1987:Q4-2010:Q2		1954:Q4-1972:Q2	1972:Q2-1987:Q4		1987:Q4-1996:Q1	1996:Q1-2001:Q1	2001:Q1-2007:Q4	2007:Q4 - 2010:Q2
Conv Output	3.46	2.54		3.80	3.07		2.61	4.00	2.49	-0.51
Unconv Output	3.47	2.50		3.76	3.14		2.63	4.48	2.04	-0.63
Difference	**-0.01**	**0.03**		**0.05**	**-0.07**		**-0.02**	**-0.47**	**0.44**	**0.12**
Average	3.46	2.52		3.78	3.11		2.62	4.24	2.27	-0.57
Conv Hours	1.49	0.73		1.25	1.75		1.31	1.89	0.36	-2.50
Unconv Hours	1.27	0.79		0.71	1.92		1.10	2.13	0.82	-2.96
Difference	**0.21**	**-0.06**		**0.54**	**-0.16**		**0.21**	**-0.24**	**-0.46**	**0.47**
Average	1.38	0.76		0.98	1.83		1.20	2.01	0.59	-2.73
Conv Hours per Employee	-0.77	-0.30		-1.04	-0.45		-0.36	-0.33	-0.23	-0.27
Unconv Hours per Employee	-0.64	-0.12		-1.04	-0.19		-0.12	0.28	-0.07	-1.04
Difference	**-0.12**	**-0.19**		**0.00**	**-0.26**		**-0.24**	**-0.61**	**-0.16**	**0.77**
Average	-0.71	-0.21		-1.04	-0.32		-0.24	-0.02	-0.15	-0.66
Conv Output per Hour	1.97	1.81		2.49	1.32		1.30	2.11	2.13	1.99
Unconv Output per Hour	2.19	1.71		3.05	1.23		1.53	2.34	1.23	2.33
Difference	**-0.22**	**0.10**		**-0.56**	**0.09**		**-0.23**	**-0.23**	**0.90**	**-0.34**
Average	2.08	1.76		2.77	1.27		1.42	2.23	1.68	2.16

Table 2. Regressions Explaining Cyclical Deviations from Trend in Conventional Output Identity Components[a], 2007:4 Trend End

	Dependent variable, 1954:1 - 1986:1		Dependent variable, 1986:1 - 2010:2	
Independent Variable	Hours	Output per Hour[b,g]	Hours	Output per Hour[b,g]
Lagged dependent variable[c]	-0.55 **	-0.72 **	0.02	-0.54 **
Output deviation from trend[d]	1.18 **	0.37 **	1.18 **	0.13
Error correction term[e]	-0.12	-0.18	-0.25 **	-0.40 *
End-of-expansion (EOE) dummy variable[f]	1.88 **	-2.16 **	0.67	-2.49 **
Adjusted R^2	0.71	0.65	0.66	0.41
Standard error of estimate	1.81	1.76	1.45	1.62
Sum of squared residuals	388.34	367.52	182.18	228.93
Chow Test[h]			1.50	0.38
Mean Lag/Lead Response to Output Changes	0.90	-2.19	1.40	-1.70
Long Run Response to Output Changes[i]	0.76	0.21	1.20	0.09

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 616.75 for Hours and 608.79 for LP.

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

Table 3. Regressions Explaining Cyclical Deviations from Trend in Conventional Output Identity Components[a], 2007:4 Trend End

Independent Variable	Dependent variable, 1954:1 - 1986:1 Emp Rate	LFPR	Hours per Employee[b]	Dependent variable, 1986:1 - 2010:2 Emp Rate	LFPR	Hours per Employee[b]
Lagged dependent variable[c]	-0.31	-0.04	-0.56 *	0.29	-0.46	-0.32
Output deviation from trend[d]	0.58 **	0.02	0.19 *	0.45 **	0.22 **	0.51 **
Error correction term[e]	-0.07	-0.76 **	-0.46 *	-0.17	-0.36	-1.43 **
End-of-expansion (EOE) dummy variable[f]	0.86 **	0.55 *	-0.44	0.13	0.29	0.08
Adjusted R^2	0.75	0.15	0.19	0.73	0.22	0.29
Standard error of estimate	0.95	1.22	1.77	0.62	0.79	1.16
Sum of squared residuals	106.37	176.84	370.63	33.16	54.30	117.07
Chow Test[h]				1.49	0.81	1.04
Mean Lag/Lead Response to Output Changes	0.71	11.96	-0.97	1.48	2.59	1.38
Long Run Response to Output Changes[i]	0.44	0.02	0.12	0.63	0.15	0.39

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 150.75 for Employment Rate, 241.21 for LFPR, and 515.07 for Hours per employee.

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

Table 4. Long Run Responses, 2007:4 Kalman Trend End, Conventional, Unconventional, and Average Identities

Dependent Variable	1954:1 - 1986:1			1986:1 - 2010:2		
Identity	Conventional	Unconventional	Average	Conventional	Unconventional	Average
Hours	0.76	0.65	0.71	1.20	0.92	1.06
Output per Hour	0.21	0.21	0.20	0.09	0.16	0.10
Employment Rate	0.44	0.45	0.45	0.63	0.50	0.57
LFPR	0.02	0.02	0.01	0.15	0.13	0.14
Hours per Employee	0.12	0.15	0.14	0.39	0.34	0.37

Table 5. Mean Actual, Predicted, and Residuals, Conventional Identity

Range	Hours Actual	Hours Predicted	Hours Residual	Productivity Actual	Productivity Predicted	Productivity Residual
	Dependent variable, 1986:1 - 2010:2					
1986:1 - 2001:1	1.62	1.61	0.01	1.56	1.57	-0.01
2001:1 - 2004:2	-0.55	-0.32	-0.22	2.68	2.46	0.22
2004:2 - 2007:4	1.18	1.27	-0.10	1.41	1.31	0.10
2007:4 - 2010:2	-2.21	-1.77	-0.44	2.00	1.56	0.44
1986:1 - 2010:2	0.85	0.93	-0.08	1.76	1.68	0.08

Table 6. Mean Residuals, 2007:4 Kalman Trend End, Conventional Identity

Range	Dependent variable, 1954:1 - 1986:1					Dependent variable, 1986:1 - 2010:2				
	Hours	Output per Hour	Employment Rate	LFPR	Hours per Employee	Hours	Output per Hour	Employment Rate	LFPR	Hours per Employee
1986:1 - 2001:1	0.15	-0.15	0.04	0.29	0.03	0.01	-0.01	-0.02	0.12	0.12
2001:1 - 2004:2	-1.19	1.19	-0.17	-0.16	-0.23	-0.22	0.22	0.03	-0.15	-0.38
2004:2 - 2007:4	0.62	-0.62	0.28	-0.03	-0.06	-0.10	0.10	0.00	-0.07	-0.26
2007:4 - 2010:2	-2.16	2.16	-0.89	-0.69	-0.32	-0.44	0.44	-0.25	0.00	0.04
1986:1 - 2010:2	-0.21	0.21	-0.05	0.06	-0.04	-0.08	0.08	-0.03	0.04	0.01

Table 7. The Early-Recovery Productivity Growth Bubble across Seven Cyclical Episodes, 1971-2010, Conventional Identity

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 Output trough					
1971:1-1971:4	1.17	0.40	1.22	-0.83	0.77
1975:2-1976:2	1.74	2.04	1.49	0.55	-0.29
1983:1-1983:4	1.80	2.13	-0.53	2.66	-0.33
1991:2-1992:1	1.73	1.78	1.50	0.28	-0.05
2001:4-2002:3	0.92	0.16	0.45	-0.29	0.76
2009:3-2010:2	0.89	1.32	1.14	0.18	-0.42
Average	1.37	1.30	0.88	0.42	0.07
Next eight quarters					
1972:1-1973:4	0.29	-0.55	-0.04	-0.51	0.84
1976:2-1978:1	-0.81	-0.25	0.01	-0.25	-0.56
1984:1-1985:4	0.31	0.35	-0.33	0.67	-0.04
1992:2-1994:1	-0.15	0.34	0.37	-0.03	-0.50
2002:4-2004:3	0.44	-0.59	-0.14	-0.46	1.03
Average	0.02	-0.14	-0.02	-0.12	0.16

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