

The Evolution of Okun's Law and of Cyclical Productivity Fluctuations in the United States and in the EU-15

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**For Presentation at EES/IAB Workshop,
Labor Market Institutions and the Macroeconomy
Nuremberg, June 17-18, 2011**

*I am grateful to Marco Corrao for outstanding research assistance on previous versions of this paper and for creating the new EU-15 quarterly data set and to Jon Barber for taking over from Marco and providing comparative charts and regression results for the EU vs. the US. For reactions over several versions of this project I am grateful to John Bishop, Roger Brinner, Martin Feldstein, John Fernald, James Stock, Mark Watson and other participants for helpful comments at presentations at the Federal Reserve Bank of San Francisco, the Atlanta AEA meetings in January 2010, the NBER Summer Institute in July 2010, and at a CREI-CEPR conference in Barcelona in November 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 The main conclusion of the paper is that the procyclical productivity response of Okun's Law is obsolete in U. S. data since the mid-1980s.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.

The results are strengthened by a parallel econometric analysis of the EU-15, which shows that over time the cyclical response has shifted toward a greater response of productivity in Europe and a smaller response of labor input, the opposite of the shift in the U. S. response. Hypotheses are developed to explain this disparity, based on a range of differences in institutional arrangements and customs across the Atlantic, sometimes summarized as "American Exceptionalism." Some of these are the much greater increase of income inequality in the U. S. than in the EU-15 since the 1970s, the related shift of power to management from labor as the influence of U. S. labor unions has waned.

The explanation of why European responses have moved in the opposite direction begin with the difference of the time-series behavior of income inequality in the U. S. as compared to Europe. There has been no parallel shift in Europe towards maximizing shareholder value as the prime decision criterion of European executives. Perhaps more important is a large set of employment protection legislation that raises the cost of layoffs and firing of workers (which is essentially costless in the U. S.), and a complex set of work-sharing institutions involving both government subsidies and union-firm negotiations that have created an explicit attempt to minimize employment responses to output fluctuations.

Perhaps the most important implication of this paper is for the evolution of modern macroeconomics, which since the initial invention of the real-business cycle model has treated productivity fluctuations as exogeneous processes that implicitly and vaguely reflect random technological changes. This paper shows that cyclical productivity fluctuations have little to do with technology, and a lot to do with the evolution of labor-market institutions, customs, and practices.

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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 a one-percent decline in output relative to trend during a recession is 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 Okun response is 2/3 in aggregate labor hours and 1/3 in productivity. The procyclical 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. This in turn suggested that long-run production functions are not a good point of departure for understanding cyclical fluctuations in productivity.

This paper revives the Okun-Oi tradition by demonstrating that procyclical productivity fluctuations are not autonomous developments that have anything to do with technology, but rather are statistical residuals resulting from different responses of labor input to cyclical fluctuations in output. These labor responses vary according to institutional changes over time and across countries. The paper shows that the procyclical fluctuations of labor productivity have almost disappeared in the U. S. since 1986 yet are alive and well in Europe. Institutions matter, and technology-based procyclical productivity fluctuations are dead as a fundamental source of macro business cycles.

This paper provides new econometric estimates for both the U. S. and the EU-15. The first part of the paper develops an econometric model that takes advantage of all the data richness in the U. S., which allows estimates for several measures of labor input over a time period extending from 2010 back to 1954. The basic result for the U. S. is that Okun's original adjustment parameters conceived in 1962 were prophetic and characterized with relative accuracy the division between changes in labor hours and in productivity in response to changes in the output gap, but only through the mid-1980s. After the mid-1980s responses changed towards a greater response of labor hours and a smaller response of productivity to changes in the output gap.

Is this shift toward larger labor input responses an American phenomenon, another example of "American exceptionalism," or has it occurred as well in western Europe? Is there an Okun's Law in Europe and has it changed? Have responses changed towards a greater elasticity of labor input responses to output fluctuations in Europe as they have the U. S.? There are two main reasons for the lack of parallel research on European labor markets to match that carried out for the U. S. The first is that the required data exist at the level of individual

countries, and a compendium of regression coefficients for 10 or 15 separate nations are hard to interpret. The American economist's immediate instinct is to defer an analysis of individual countries, just as American labor economists pay little attention to differences in macro time-series behavior among states of the union, and focus on the EU-15 aggregate that is similar in size to the United States.

Yet, surprisingly, the econometrician cannot download quarterly data on output and on labor input for the EU-15 that are comparable to those readily available with a few clicks for the US aggregate. If we want to avoid the complexity of analyzing data for separate countries, and thus if we want to study the EU-15 aggregate, the lack of quarterly data creates a roadblock. Nevertheless, we have pieced together a new quarterly data set on employment and output for the EU-15, and our preliminary results of analyzing these data constitute a new contribution of this paper.¹

Most of the paper is devoted to the U. S., where a wealth of data provides considerable latitude for alternative specifications and explanations. The availability of EU-15 quarterly data only for real GDP and employment, but not for aggregate hours or the labor force, forces us to compare the U. S. and Europe in a stripped-down, simplified version of the U. S. model. We find some evidence that the EU-15 employment elasticity to cyclical output changes has become smaller and is thus the opposite of the shift in the U. S. response. Our tentative explanation builds on differences between the U. S. and Europe that have been discussed earlier for rising inequality and now appear to be relevant for macro labor market dynamics.

The last part of the paper attempts to explain this difference between the U. S. and Europe, which may seem surprising to some macroeconomists who work with models devoid of institutional idiosyncracies. Yet institutions matter. The paper links the disparate changes in labor-market responses in the U. S. vs. the EU-15 to a long list of institutional differences, including the move to maximization of shareholder value in the U. S., greater rise of inequality of the U. S. compared to the EU, the decline in the importance of unions in the U. S. in part because of its unique institution of right-to-work states that allow firms to set up new establishments outside of the purview of labor unions. Unique features of Europe that help to explain these differing shifts of coefficients are explicit government-sponsored (but firm-union negotiated) reductions of hours per worker in order to preserve employment.

1. *Annual* data for the EU-15 aggregate are easily available at the annual frequency; the problem lies in the previous absence of consistent aggregation to the EU-15 level of *quarterly* data. Upon request Bart van Ark of the Conference Board supplied his quarterly series on EU-15 output and employment, but these extended back from 2010 only to 1995 and contained several errors due to the failure to link out jumps of output and employment as the membership of the EU-15 changed, particularly in 2001 with the entry of Greece. The newly developed quarterly data for EU-15 real GDP and employment used in this paper extend back to 1975 and link out any changes due to the changing membership of the EU-15.

1.1 The Demise of Okun's Law and of Procyclical Productivity Fluctuations in the U. S.

The Okun/Oi tradition was almost forgotten over the past three 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 in U. S. data.² 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. If we define the "hours gap" as the log ratio of actual to trend hours and if we set the gap equal to zero in 2007:Q4, then the hours gap declined to negative 9.2 percent between 2007:Q4 and 2009:Q3 and as of 2010:Q4 had recovered by only 0.6 percent, leaving the hours gap a negative 8.6 percent.

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 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 has almost disappeared in U. S. data even as it remains evident in data for the EU-15. The concept of a procyclical "productivity shock" and "technology shock" is no longer relevant to the analysis of American business cycles, except in reference to sharp swings in the relative price of oil or other commodities. The question of why

2. Notable exception are Gali and Gambetti (2009) and Gali and van Rens (2010). See also Van Zandweghe (2010).

procyclical productivity responses remain evident in EU-15 data is deferred to the final section of this paper.

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. 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. Accordingly all the data for the U. S. examined in this paper refer to the total economy, not the NFPB sector, and this choice also facilitates comparison with Europe.

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 cyclical 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 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 . 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). This is done only for the United States; the comparison of the U. S. and EU-15 comes at the end of the paper and is based only on the conventional productivity concept.

1.3 Plan of the Paper

Parts 2 through 5 of the paper are entirely devoted to an analysis of U. S. quarterly data, and then part 6 provides a comparison between the U. S. and EU-15 based on a shorter list of variables and a simplified version of the econometric approach.

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. We propose an improved method of generating statistical trends which are a necessary prerequisite to calculating "gaps," that is, log deviations of a variable from its trend. After we arrive at plausible trends for the conventional measure of U. S. output, hours, and productivity in Part 2, then in Part 3 we contrast these with similarly constructed trends for the unconventional concepts of U. S. 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 regression analysis for the U. S. extends over the period 1954-2010 and examines shifts in coefficients across the 1955-86 and 1986-2010 sub-periods. The cyclical analysis 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. 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?

2. The Decomposition between Cycle and Trend in the United States

Was the decline of U. S. 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 U. S. business cycles 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

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

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

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

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:

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

The bridge term E^P/E^H 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.

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

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 designate 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:

$$(4) \quad y \equiv y-h + h-e + r + e-l + l-n + n$$

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 $\Delta x'$.

Subsequently at the beginning of Part 7 we will display the simplified version of the conventional identity (equation 2 above) that is used when we have data only on output, employment, and population, as is the case for quarterly data for the EU-15 aggregate over the 1975-2010 interval.

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. We consider 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 are 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 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

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

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 ($\Delta(h-e)$), the employment rate ($\Delta(e-l)$), and the labor-force participation rate ($\Delta(l-n)$), 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 creates a trend series that 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 These large negative trends of -1.1 to -1.7 percent for hours are particularly implausible in the context of a working-age population that is growing at about +1.0 percent per year.

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:Q2. It exhibits a cyclical downturn to 0.6 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

5. The recent study by Van Zandweghe (2010) bases its analysis entirely on H-P trends of output, hours, and productivity.

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 real GDP 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:Q2 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 Kalman 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,

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

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.

The Kalman trends displayed in Figure 1 are based on a time-varying coefficient, as in

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. .

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 Federal Reserve’s 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 analysis of U. S. data in Parts 3 through 6, 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. Trends in Part 7, where we compare the EU-15 with the United States, are based on the H-P filter (due to absence of an unemployment gap variable for Europe).

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 (2011).

3. Conventional versus Unconventional Measures of Trends and Gaps for the United States

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 C 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 1960s.

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

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

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.

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 in the United States: 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. We do not carry out a symmetric regression analysis of the unconventional output identity, both to limit the length of the paper and because the measure of household hours H^H is relatively noisy at high frequencies.

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 current value and a series of lags of 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 interpreted 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 cointegration, 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

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).

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 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

12. Gordon (1979, 1993, 2003).

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.

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

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

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.

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 aggregate hours, namely 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 1954-86 early 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. Figure 6 shows 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, at least for the United States (below we compare the responses in the EU-15).

Table 4 displays the long-run responses implied by the regression estimates of the output identity components for the conventional productivity definition taken from Tables 2 and 3 and also for the unconventional definition when the same regressions are rerun with the alternative left-hand and right-hand variables. 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.

4.5 Plots of residuals

We now have the tools to determine how much of U. S. 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.

The top frame of Figure 7 displays four-quarter moving averages of the hours residuals. 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

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.

in the top frame of Figure 5, generates a residual that is surprisingly small.

The bottom frame of Figure 7 presents a parallel plot of the four-quarter moving average of the productivity growth residuals. 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 7). 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.

It is evident from the bottom frame of Figure 7 that the productivity residuals show a pronounced tendency to be positive after 2003. 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 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.

5. A Parallel Analysis of Changes in Labor Market Dynamics for the U. S. and EU-15

Before turning to possible hypotheses that might explain changes in labor-market dynamics in the United States, we provide a comparison with the EU-15, that is, the 15 members of the Common Market prior to its enlargement of May 1, 2004. The EU-15 is the most appropriate entity for a comparison of Europe with the United States, as it is at a similar level of economic development and of similar magnitude, having 125 percent of the population of the

U. S. and 87 percent of its GDP (expressed in PPP-adjusted dollars).¹⁵

5.1 Data Limitations Constrain the Direct Comparison of U. S. and EU-15 responses

Data limitations prevent an analysis of EU-15 output and labor-market data that replicates the U. S. study carried out above. While quarterly data on hours and employment exist for some countries, they have not previously been combined into a consistent EU-15 aggregate.¹⁶ The analysis in this section is based on a consistently aggregated quarterly data series for EU-15 real GDP and employment covering the period 1975:Q1 to 2010:Q4. Details of the aggregation are provided in the Data Appendix.

Use of the new data requires a stripped down analysis. Because we do not have data series on aggregate hours or labor-force participation, we cannot examine hours per employee (H/E), the employment rate (E/N), or the labor-force participation rate (L/N), as in Table 3 above. We are limited to a simplified version of the initial output identity (equation 1 above) which examines the cyclical behavior of real GDP (Y), productivity expressed as output per employee (Y/E), and the labor-market response of the employment-population ratio (E/N):

$$(8) \quad Y \equiv \frac{Y}{E} \cdot \frac{E}{N} \cdot N$$

Going beyond data limitations, other changes must be made to allow an identical treatment of the U. S. and EU-15 data. Allowing two years for lags, the sample period begins in 1977:Q1 rather than 1954:Q1 as in the preceding study of the U. S.¹⁷ The separation of actual values into

15. The projected 2010 population of the EU-15 from www.demographia.com is compared to the 2010 U. S. Census total. EU-15 real GDP per capita is 70 percent of the U. S., using an average of "G-K" (Geary-Khamis) weights calculated in 1990 dollars and the "E-K-S" (Eltető, Köves, and Szulc) weights calculated in 2008 dollars. See the Groningen economywide data base at <http://www.conference-board.org/economics/database.cfm>.

16. Bart van Ark of the Conference Board sent us the only quarterly he had, for real GDP and employment going back from 2010 to 1995 and for aggregate hours going back only to 2000. However, is data turned out to contain errors due to a failure to properly link out changes in the composition of the countries summed into the EU-15 aggregate. We have created the missing EU-15 quarterly data aggregate for real GDP and employment going back to 1975:Q1, but so far have been unable to do so for aggregate hours.

17. Initially two years were allowed for lags in order to experiment with lags 0-8 on the output gap explanatory variable rather than lags 0-4 as in Tables 2 and 3. However, the addition of lags 5-8 did not survive tests of statistical significance, and so the results presented here use only lags 0-4 as in Tables 2 and 3 above.

trends and gaps is carried out with the Hodrick-Prescott filter rather than the Kalman filter, since for Europe we have no available outside cyclical variable to use as the feedback variable in the Kalman process (for the Hodrick-Prescott filter we use the quarterly parameter of 6400 and constrain the trends of all variables to be constant in 2008-10 at the value reached in 2007:Q4). Finally, we drop the end-of-expansion dummy variables.

5.2 Key Features of the EU vs. U. S. Data for 1976-2010: A Graphical Tour

Figure 8 is the first of three charts which examine the comparative data on the U. S. and EU-15, with variables defined in the same way and covering the same interval of 1976:Q1 to 2010:Q4. Three charts are stacked within Figure 8; each frame shows the four-quarter moving average log rate of change of a variable. This is output per capita in the top frame, employment per capita in the middle frame, and productivity (i.e., output per employee) in the bottom frame. Each frame plots two lines, a solid line for Europe and a dotted line for the U. S.

The most striking aspect of the top frame of Figure 8 is the nearly identical U. S. and EU decline in output growth in 2008-09 and the nearly identical recovery in 2010. Between 1986 and 2006 the volatility of EU and U. S. output cycles was about the same, with different timing in that the U. S. had a significant recession in which the output change was negative in early 1991 while in EU-15 the trough of the output change was 10 quarters later, i.e., in mid-1993. This European recession reflected a combination of the end of the European boom associated with German reunification together with the output declines that occurred in the nations that dropped out of the ERM in mid-1992. Between 1976 and 1986 the U. S. business cycle was much more volatile and was punctuated by the back-to-back recessions of 1980 and 1981-82. The much discussed U. S. "Great Moderation" of 1985-2007 appears to be a return to normalcy as represented by typical EU volatility during the entire period prior to the Global Economic Crisis.

The middle frame of Figure 8 displays the four-quarter change in the employment-to-population (E/N) ratio in the EU and U. S. Prior to 1997 the patterns shown in the middle frame are similar to those in the top frame, namely the much more volatile U. S. business cycles of 1980 and 1981-82, together with the similar magnitudes of the EU employment response in 1992-94 displaced about ten quarters later than the U. S. response, the same as for the output response in the top frame. But after 1997 two differences stand out. First, the average growth rate of the E/N ratio was substantially faster than in the U. S., and second, the decline in the European E/N ratio in 2008-09 was only about half that of the U. S. decline.

If output responses were similar yet after 1997 E/N grew faster on average in Europe and exhibited a smaller cyclical decline during 2008-09 in Europe, then by definition it follows that labor productivity (Y/E) in Europe must both have grown more slowly than in the U. S. and exhibited a larger cyclical decline. This is shown quite clearly in the top frame of Figure 8, where EU productivity growth is slower than in the U. S. in almost every quarter after 1996 and

EU productivity growth is much more negative in the 2008-09 crisis period than in the U. S.

Some of the differences in these growth rates reflect differences in trend and others reflect differences in cyclical responses. The trends are plotted in the three frames of Figure 9; these are Hodrick-Prescott trends using an intermediate smoothness parameter of 6400. The story told by Figure 9 is quite simple – after 1995 the EU had roughly the same trend in output per capita as in the U. S., had a substantially faster trend in the employment-population ratio, and thus by definition a slower rate of growth of productivity (output per employee, Y/E).¹⁸ Several of these trends may seem surprising, but the counterpart of the rough equality of growth in income per capita (Y/N) in the EU and U. S. is the stagnation of the *level* of EU-15 per capita income at 70 percent of the U. S. level (a level that has been sustained for the last four decades). The more rapid growth of EU productivity before 1995 and the slower growth after 1995 also has its counterpart in levels. The level of PPP-adjusted productivity in the EU-15 relative to the U. S. reached about 92 percent in 1995 before slipping back to about 83 percent.

When the levels of the actual values and trends are combined, we can calculate the “gaps” between actual and trend for a given variable, i.e., the percent log ratio between actual and trend. These gaps are displayed in Figure 10, where the top frame restates the verdict that the depth of the Global economic crisis recession of 2008-09 was virtually identical. The average and standard deviation of the output gap are roughly similar between the EU and U. S. during the two decades between 1987 and 2007, while the U. S. displays its characteristic volatility in 1976-2006 due to the oil shocks, the Volcker disinflation, and the appreciation of the dollar in 1980-85.

The middle frame of Figure 10 displays the gap for the employment-population ratio (E/N), which declines less in 2008-09 than in the U. S. However the difference between the EU and the U. S. is smaller than in the middle frame of Figure 8, because the faster E/N trend of Europe has been subtracted out in calculating the gaps. Thus we must keep straight two facts that are both true, that EU employment growth dropped in 2008-09 only about half as much as in the U. S., but this was from a higher pre-2007 trend growth rate. Relative to trend, the decline in European employment was only modestly less severe than in the U. S.

The most striking difference between the U. S. and EU-15 is apparent in the labor productivity gap, as plotted in the bottom frame of Figure 10. For the recent recession we see that the U. S. had an earlier and shorter-lived drop in productivity. The trough productivity gap for the U. S. was -3.4 in 2008:Q4 and was -5.3 for Europe in 2009:Q1. But the recovery from that gap was much faster and more complete in the U. S., with the productivity gap reaching -0.1 percent in 2010:Q4 as compared to a dismal -3.4 percent for Europe, and this is a gap relative

18. The case that Europe experienced a productivity-employment tradeoff in the 1983-2007 period is made in Dew-Becker and Gordon (2008).

to a long-run European productivity trend that in 2007-10 was growing at only 0.8 percent per annum. The same frame of Figure 10 also shows that the productivity gap in the U. S. fell by almost as much in 1982 but soared in a temporary recovery in 1984-86 far above what has yet been observed in 2010.

Overall we find a tendency of EU employment to respond less than in the U. S. to output fluctuations in the last half of our sample period, that is, 1993-2010. Any differences in response prior to 1993 are harder to detect, because both output and employment were more volatile in the U. S. than in the EU during the first 10 years of our data (1976-86).

5.3 Regression Results for the U. S. Compared to the EU-15, 1977-2010

As stated above, data limitations prevent us from replicating the full set of regression results that are displayed for the U. S. over the 1954-2010 sample period in Tables 2 and 3 above. Instead we present results for the sample period 1977-2010 and compare them to results for the U. S. that apply the identical specification to the longer 1954-2010 interval. As before, we compare coefficients and responses for the "early" interval (now 1977-1993) and the "late" interval (now 1994-2010). The explanatory variables are four lags of the dependent variable and the error-correction term defined as before, and the quarterly change in the output gap, entered as before with the current value and four lags.

Before we examine the results, we should step back and consider an important aspect of the results in Tables 6 and 7 compared to Tables 2 and 3. In the previous analysis the concept of labor input was aggregate hours per capita and of productivity was output per hour. Now we are constrained by data limitations to measure labor input by employment per capita and productivity as output per employee. To the extent that there are systematic procyclical fluctuations in hours per employee, as is strongly supported in Table 3 (especially for the late-interval 1986-2010 results), then we would expect that the long-run responses of employment to output changes would be lower in Table 6 than the hours responses of Table 2, and correspondingly that the productivity responses in Table 7 would be larger than the productivity responses of Table 2. Indeed, this turns out to be the case.

Results are displayed in Table 6 with the quarterly change in the employment gap as the dependent variable and in Table 7 where the dependent variable is the quarterly change in the productivity gap. In Table 6 the first two columns compare sums of coefficients for the U. S. and EU-15 in the early period and the next two columns refer to the late period. The final two columns show for comparison the U. S. results for the longer 1954-2010 period divided into early and late intervals at 1986:Q1.

The most interesting aspect of the results is shown in the bottom line, where the estimated coefficients are used to calculate the long-run response of the employment gap to a

change in the output gap.¹⁹ The early-interval long-run response for the U. S. is 0.63, quite close to the 0.55 estimate when the longer 1954-86 period is used. These responses are larger than the 0.47 early-interval response of the E/N gap when the equation is estimated as in Table 3 above, and this is entirely due to the omission of the end-of-expansion dummy variables that appear to soak up some of the long-run response of employment to output changes.

In contrast the early-interval long-run response for the EU-15 is 1.07. Other differences in the EU-15 early-interval results include a much better fit, a positive rather than negative sum of coefficients on the lagged dependent variable (indicating positive rather than negative serial correlation), and a substantially longer mean lag of 1.66 months in the employment response to output changes as compared to 1.13 months for the U. S.

The most important result is that in the late interval the long-run responses shift in the opposite direction, rising from 0.63 to 0.90 for the U. S. and declining from 1.07 to 0.65 for Europe. The increase in the U. S. over the longer data interval starting in 1954 is from 0.55 in the early interval to 0.87 in the late interval. Other results in the late-interval equations in Table 6 include a substantially improved fit, and mean lags of 1.5 months for the U. S. and 1.3 months for Europe.

We next turn to Table 7, which is the "dual" to Table 6 by changing the dependent variable to the quarterly change in the productivity gap and leaving unchanged the other details. Recall that we would expect the long-run responses of productivity to output to be higher in Table 7 than in Table 2, because we are now measuring productivity as output per employee rather than output per hour. We focus first on the long-run response, which declines for the U. S. from the early-interval 0.42 to the late interval 0.08, reinforcing our conclusion from Table 2 that procyclical productivity fluctuations are obsolete for the U. S. For the full period 1954-86 shown on the right side of Table 7, the long-run response declines from 0.52 in the early interval to 0.13 in the late interval. As expected these responses in the early interval are much higher than in Table 2 (0.20 in Table 2 vs. 0.52 in Table 7); this is due both to the different definition of productivity and also to the deletion of the end-of-expansion dummy variable in Table 7. In contrast the late-interval responses for 1986-2010 are virtually identical (0.10 in Table 2 and 0.13 in Table 7), which is not surprising since the end-of-expansion dummy coefficient is small and insignificant in Table 2.

Just as we found in Table 6 that in the late interval the European employment response declines, i.e., shifts in the opposite direction as in the U. S., here in Table 7 we also find that the European long-run productivity response declines, thus shifting in the opposite direction as in the U. S. The European long-run productivity response increases from 0.35 in the early interval

19. The long-run response is the sum of coefficients on the output gap divided by unity minus the sum of coefficients on the lagged dependent variable.

to 0.56 in the late interval. Other aspects of the Table 7 results include a better fit for the European equations, and a lead of productivity ahead of output of about one quarter.²⁰

A puzzling aspect of the European results refers to the sum of the long-run responses in Tables 6 and 7. The sum of the employment and productivity response to changes in the output gap should be roughly unity, as the variables obey the identity $Y/N \equiv Y/E * E/N$. The sums of long-run responses of Table 6 plus Table 7 across the six columns are, respectively, 1.05, 1.42, 0.98, 1.21, 1.07, and 1.00. The European sum of 1.42 for the early interval is too high and we are checking for a possible error in those long-run responses (by contrast the sums of the hours and productivity responses for the U. S. in Table 2 above are 0.91 for the early interval and 1.16 for the late interval).

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

We are confronted with the need to explain why the responses of labor input and of productivity to output fluctuations moved in the opposite direction in the United States and in Europe. Defining the early interval as 1977-1993 and the late interval as 1994-2010, in the United States there was a distinct shift toward a unitary elasticity of the response of cyclical hours movements to cyclical fluctuations in output, together with a corresponding shift toward a zero response of productivity. Thus for the U. S. the challenge is to find an explanation for a higher labor input responsiveness and for the disappearance of procyclical productivity fluctuations.

For the EU-15 we face the opposite challenge, which is to explain why the response of employment declined while the response of productivity increased. Results for the late interval (1994-2010) are dominated by the behavior of output and employment in the Global Crisis recession and early recovery of 2008-10. Many observers have previously noted that the 2009-10 output gaps in the U. S. and Europe were similar (as shown above in the top frame of Figure 10), yet the unemployment rate in the United States increased by at least twice as much as in any country of Western Europe besides Spain. Why was the employment response in Europe so muted and the productivity response so large?

This section proposes a joint explanation of changing U. S. and European behavior based on American exceptionalism. The shifts in the U. S. toward greater responses of labor input are explained by the "disposable worker hypothesis" based on a significant shift in market power from labor to management. The causes are the same as those of the increase of income

20. The lead in the late-interval U. S. results of -7 quarters for 1994-2010 and -5 quarters for 1986-2010 is spurious, due to the small and insignificant sum of coefficients on the output deviation variable.

inequality in the United States since the late 1970s. The basic answer to the opposite shift over time in labor input and productivity responses in Europe is that Europe has not experienced a similar change in market power between labor and management. Further, while the EU-15 are far from uniform in their labor-market institutions, several important European countries have developed explicit work-sharing policies that reduce the reliance of European firms on layoffs and firings that reduce employment. The counterpart of these policies is that more of the impact of output fluctuations falls on reduced hours per employee (for which we lack data in the quarterly study carried out above) and on output per employee.

We begin our discussion of substantive explanations with the proposed disposable worker hypothesis for the U. S. Then we turn to Europe, where an ample literature documents both the differing behavior of inequality and the development of work-sharing institutions that involve cooperation among firms, labor unions, and the government.

6.1 Explaining the Sharp Decline of U. S. Employment in 2001-03 and 2008-09

I have suggested (Gordon, 2003), that both the weakness of hours growth and strength of productivity growth in 2001-03 were the result of savage corporate cost cutting that caused labor input to be reduced more (relative to the output gap) than in previous recessions and recoveries. The same pressure for cost-cutting was even greater in 2008-09, leading to a parallel jettisoning of workers and an unprecedented decline in business investment. A complementary factor relevant for 2001-03 (but not for 2008-09) was the delayed lagged benefits for productivity growth of the late 1990s boom of investment in information and communication technology (ICT) investment.

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."

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 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 proposed 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? The basic answer is that an industrial revolution occurred between 1995 and 2000 with the invention of the internet and all of its complementary inventions, and the process of learning how to use these new inventions to raise productivity spilled over from the high investment period of 1995-2000 into the years after 2000 when measured hardware investment collapsed.

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 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 processes, retraining, and general acquisition of human capital. The direction of mismeasurement is to overstate the extent of the productivity growth revival between 1995 and 2000 but to understate it in the first few years afterward. 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.²¹

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 U. S. 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.

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

21. 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.

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.

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 developed above that a fundamental underlying cause was the 1990s shift of executive compensation toward 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.

6.4 Aspects of European Labor Markets that Protect Employment at the Cost of Procyclical Productivity Fluctuations

The most striking aspect of the results in Tables 6 and 7 is a shift in Europe towards a decline in the cyclical responsiveness of employment to cyclical output fluctuations, and a corresponding increase in the procyclical responsiveness of productivity. These are the opposite of the shifts over the same time interval in the United States. The natural place to look for an explanation is to examine about a broader set of differences between economic behavior and institutions in the U. S. vs. the EU-15. Three differences stand out as offering a starting

place to discuss the transatlantic contrast in labor-market responses, (1) the different evolution of inequality, (2) longstanding European regulations that protect employment, and (3) explicit European institutions that encourage work-sharing and hours shedding, both over the long run and during a cyclical downturn.

6.4.1 Transatlantic Differences in Changes of Inequality

The previous analysis of the shift toward more elastic U. S. labor input responses emphasizes increased managerial attention to maximizing shareholder value, which translates into greater emphasis on drastic cost cutting when profits and the stock market experience a cyclical decline. The sources of this change in U. S. management strategy are the same as those that have contributed to a significant increase of income inequality in the U. S. since the late 1970s. There is a large literature on differences between the U. S. and Europe that attempts to explain the much smaller secular rise in European inequality, and some of these differences are relevant to understanding the smaller response of European employment to output fluctuations in data for the 1994-2010 period, as documented above. These include the smaller role of short-run profit maximization as a guiding principle for management, a greater power of unions in Europe, and the corporatist tradition in several countries in which unions and join with management in making joint decisions about the response of labor input to cyclical fluctuations.

Standard measures of inequality have risen much more in the U. S. than in the EU-15 or in most EU countries. The stark facts about differences across countries originate in the raw data on inequality at the top as summarized by Piketty-Saez (2006) and analyzed by Atkinson (2007).²² Piketty and Saez (2006) show that the income share of the top 0.1 percent almost quadrupled from 2 to 8 percent of total income (excluding capital gains) between 1975 and 2000. But the top share in France has remained amazingly stable, while the share in the U. K has increased but much less than in the U. S. Other data applying to the entire distribution, not just the top one percent, support the view that inequality in the US is high and growing. The 2007 Gini coefficient averaged 0.31 in the EU-15, with a range between 0.23 in Sweden to 0.34 in the U. K. This is contrasted with a Gini coefficient of 0.45 for the U. S. in the same year.²³

What hypotheses have been proposed to explain the high level and growth of inequality in the US as compared with other OECD countries? One approach taken by Mishel *et al.* (2007, p. 357) and others, is to cite a difference in the socio-political-economic "system" that differentiates the US from other developed countries, so-called "American exceptionalism" that

22. A variety of papers containing cross-country comparisons of top incomes is in the volume edited by Atkinson and Piketty (2007). A list of citations to ten different countries is contained in Roine *et al.* (2007, footnote 11).

23. http://en.wikipedia.org/wiki/List_of_countries_by_income_equality

dates back to the nineteenth century. In the view of Mishel *et al.* (2007), the market-driven "US Model" leads to more inequality, higher poverty rates, an "expensive-yet-underperforming" health care system, and jobs that require more work hours per year and fewer paid days off. This view is consistent with a view that culture and social norms matter in explaining numerous dimensions of American exceptionalism, of which income inequality is only one.

Harjes (2007) emphasizes the contrast between the U. K. and continental countries. The U. K. pursued de-unionization in the 1980s as government policy along with privatization, helping to explain the relatively high U. K. ranking in measures of inequality and its change. In contrast the "consensus model" adopted in the Netherlands and to a lesser extent in Sweden, Ireland, and Germany obtained moderation in wage demands by labor in return in some cases for reduced income taxes and in other cases with the expectations that managers would avoid excess compensation increases for themselves. In Germany excessive executive compensation is mitigated by such institutional features as the two-tier company board with strong labor representation, "legal co-determination rights," and a high tax rate on capital gains from stock options" (Ponssard, 2001).

There is ample support in the literature on transatlantic inequality to support the view that managements in Europe operate under constraints that limit both their own compensation and the extent to which they can alter labor input at will without consultation. Different customs (the role of labor on corporate boards in Germany), and different institutions (consensual bargaining in the Netherlands and other countries) all play a role in explaining why corporations outside the US have been constrained from offering to their top officers the types of pay packages typical in the U. S. and why they do not resort to the same degree of massive layoffs and employment reduction as in the U. S.

Perhaps the most important difference between the U. S. and Europe is the near-total disappearance of union power as a constraint on the choices of management, in contrast to the corporatist collaboration of management and unions in some European countries, particularly Germany and the Netherlands. A unique aspect of U. S. labor law originates with the Taft-Hartley legislation of 1947 that allows states at their own will to restrict the ability of unions to organize workers. Under that legislation's "open shop" section, an employee cannot be compelled to join a union. This "right to work" without the need to join a union creates a sharp contrast with Europe where in most countries unions and firms conduct bargaining that applies to the entire nation. The ability of firms to establish non-union plants in "right-to-work states," particularly those in the American south (the "Old Confederacy") is the single biggest reason for the hollowing out of the city of Detroit. Virtually all auto plants established in the U. S. during the past three decades by foreign auto firms from Japan, Korea, and Germany have been located in right-to-work states and have so far avoided union representation.

6.4.2 Employment Protection Legislation and Work-Sharing Practices

Before 1980 the unemployment rate in the EU-15 was consistently lower than in the United States. But from 1985 until recently the average EU-15 unemployment rate was higher, fluctuating in a range between 8 and 10 percent for more than two decades. Governments in most of the EU-15 (but not in the U. K.) reacted by instituting policies that reduced employment per capita (see Nickell *et al.* 2005). To deal with the individual hardship caused by higher unemployment, governments increased the generosity and duration of unemployment benefits. To limit the increase in unemployment itself, they attempted to regulate layoffs through employment protection legislation (EPL). To spread the available jobs across the population, they resorted to legislation favoring early retirement and shorter hours of work, so-called "work sharing" (Alesina, Glaeser, and Sacerdote, 2006).

EPL includes measures that limit the ability of firms to layoff and fire employees, both by outright prohibition and by requirements for substantial severance pay. This alone would help to explain the European responses in Tables 6 and 7 above, with a shift toward a less elastic response of employment to cyclical changes in output. A question remains as to the timing of this effect, as OECD measures of the severity of employment protection legislation tend to reach their peak in the early 1990s (Bassanini and Duval, 2006), while our regressions show lower employment responses in Europe after 1993 as compared to before 1993.

EPL has been blamed for exacerbating the EU unemployment problem that persisted after the mid-1980s by raising employer costs and making employers reluctant to hire permanent employees. A partial solution was instituted after 1995 in several countries by introducing a second tier of flexible employment exempt from the EPL legislation. This has given European employers more flexibility to hire and fire at will and is generally viewed as a move toward American-style flexible labor markets, albeit at the cost of a two-tier labor market and increased inequality both of incomes and job security. The increase in flexible employment in the past decade raises a question as to whether EPL is a convincing explanation of the shift in the EU-15 labor input response toward lower elasticity in response to cyclical output fluctuations.

A more convincing set of causes originates in the effort since 1985 or 1990 in several major EU-15 countries to raise employment by cutting work hours. The comprehensive analysis of work-sharing by Boeri *et al.* (2008) is entirely devoted to secular changes in hours of work that have occurred in France, Germany, the Netherlands, and Sweden as a result of various combinations of management-labor collaboration and government compulsion. These long-term changes toward fewer work hours per year help to explain why annual hours of market work in the EU-15 have continued to decline relative to the United States. But they are only indirectly related to the changes in cyclical responses reported in Tables 6 and 7 above.

Nevertheless the Boeri *et al.* (2008) study provides new insight on the various forms that

work-sharing takes across the four case studies of individual countries. In Sweden reductions in work hours primarily are dedicated to allowing extensive subsidized parental leave to both females and males with newly born children. In the Netherlands there has been a massive shift to part-time work to accommodate an apparent cultural norm that mothers should be at home raising children rather than in market work. In Germany reductions in hours were accomplished through a corporatist set of negotiations between employer associations and unions (from a U. S. perspective it is unthinkable that any multi-firm industry-wide negotiation could occur as in Germany). In France the Boeri *et al.* (2008) authors emphasize the contrast with Germany; instead of a consensus emerging through collaboration between unions and management, France achieved its reduction to a 35-hour week through government compulsion.

These secular moves to try to raise employment by work-sharing (which economic theory rightly argues is futile) do not necessarily provide an explanation of the reduced elasticity of European employment to cyclical output fluctuations. However, there is a link. The common thread is that European managements, unions, and governments view work hours explicitly as an adjustment mechanism, while in the United States corporate cost cutting usually takes the form of job loss and layoffs with little if any cooperative attempt to preserve jobs with lower hours. Much of the cyclical sensitivity of U. S. hours per employee evident in Table 3 above stems from occupational shifts, e.g., from full-time work in construction or manufacturing to part-time work in retailing or other services. The U. S. media have recently reported on workers at Wal-Mart and Target being allowed to work only two or three days a week while the help-wanted sign is up for new workers, implying that the companies are consciously pursuing a process of reducing employees from relatively secure full-time status to relatively insecure part-time status.

Burda and Hunt (2011) have provided perhaps the most relevant analysis that helps to inform the results reported in Tables 6 and 7 above. A feature of German labor markets, also discussed by Boeri *et al.* (2008), are "working-time accounts" which are reported to apply to 33 percent of German workers in 1998 and to 48 percent in 2005 (Burda-Hunt, p. 22). These accounts base worker pay on an average over time of hours worked, thus allowing firms to avoid overtime pay if hours per worker average to some standard over a time window. Burda and Hunt (2011) find that this provided strong disincentives for employers to reduce employment during the 2008-09 recession.

Formal cyclical work-sharing (or *kurzarbeit*) programs exist in the Netherlands, Germany, and Austria. These provide an additional reason why European firms are less obsessed with layoffs and more concerned with maintenance of a permanent employee base which works shorter hours when demand declines. Formal programs involving government intervention provide partial government subsidies to workers whose hours have been cut, thus encouraging employers to keep the employee group intact while everyone works shorter hours

with a partial government subsidy to maintain incomes. This short-hours government subsidy in part represents a replacement for traditional unemployment compensation.

7. Conclusions

This paper develops an econometric analysis of the response of changes in labor input and of productivity to cyclical changes in output in both the U. S. and in the EU-15. Its point of departure 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 for the United States 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 form of a unitary elasticity of the hours response and a near-zero response productivity to cyclical fluctuations in real GDP.

Comparisons of responses in the U. S. and in the EU-15 are tentative, because thus far quarterly data are available for the EU-15 only for real GDP and employment, and not for aggregate hours or the labor force. And the European data allow an exact comparison of the responses in the U. S. with those in the EU-15 only for the period dating back from 2010 to 1975, in contrast to the core U. S. analysis of the paper which extends back to 1954. This comparison shows that the EU-15 cyclical employment response has become smaller in the last half of the post-1977 sample period while the U. S. response has become bigger.

These results provide the two major conclusions of the paper. First, the shift toward a greater labor input elasticity in the United States and a smaller elasticity in Europe can be traced to institutional changes. These include in the U. S. the shift in power from labor to management, the greater emphasis in management decisions on maximizing shareholder value, and the increase of income inequality which reflects numerous shifts since the 1970s of which the decline in union presence and power may be the most important. Europe has moved in the opposite direction in many dimensions, including a smaller level and increase of inequality, a continued corporatist tradition in which decisions on labor adjustment are made cooperatively between firms and unions, and explicit subsidies to encourage firms to react to output fluctuations by shortening hours rather than layoffs which disconnect the previous employee from the firm.

The second major conclusion is a direct implication of the first. If institutions cause procyclical productivity fluctuations to disappear in the U. S. after 1986, and if institutions better insulate European employment from cyclical fluctuations after 1993 than before, then the entire concept of procyclical productivity fluctuations – the core of Real Business Cycle models and still at the heart of modern DSGE models -- becomes dubious and questionable. Productivity fluctuations are not a macro phenomenon that is an autonomous representation of the randomness of technological change. Rather these fluctuations are a residual artifact of the

fact that the denominator of labor productivity, whether employment or hours, responds with a different elasticity and timing to changes in the numerator, which is real output.

The paper suggests a set of complementary hypotheses to explain these changes in behavior. We begin with a set of explanations of the substantial increase in the U. S. responsiveness of labor input to cyclical changes in output. 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 explanations for the diminished European elasticity of labor input to cyclical output fluctuations after 1993 are in part the complement of the U. S. explanations. Inequality rose in the U. S. in part as a side-effect of the growing relative power of managers relative to workers. This did not happen nearly to the same extent in the EU-15, especially in the continental EU-15 countries that exclude the U. K. and Ireland. In Europe there was not the parallel shift of executive compensation to bonuses and stock options that made compensation dependent on stock market valuations. And in Europe there was an independent impulse that barely existed in the U. S. to reduce worker hours over the 1985-2005 period in a vain attempt to boost unemployment. The many institutional developments in Europe, including employment protection legislation, forced reduction to a 35 hour work week in France, movement toward part-time work in the Netherlands, and corporative negotiations in Germany, all created a paradigm in which hours reductions would be considered as an alternative to connection-breaking layoffs as occurred in the U. S.

Much remains to be accomplished in this line of research. A time series on aggregate hours needs to be compiled for the EU-15. Recognition is required of differences in the time series behavior of the major EU-15 members, that is, France, Germany, Italy, Spain, and the U. K. The hypotheses need to reflect the fact that German-like *kurzarbeit* and working time accounts are duplicated in few if any other EU-15 countries.

Nevertheless, this paper makes a start to broadening the literature on the shift in

responses between the U. S. and EU-15 to cyclical fluctuations between labor market and productivity responses. If anything is learned from this research, it is that productivity fluctuations are a residual depending on the response of labor input to output and do not reflect autonomous changes in technology.

DATA APPENDIX

Data Sources

All data, with the exception of payroll and CPS (Current Population Survey) 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

<i>Dummy Variable (k)</i>	M	<i>D(k) = 1/M during</i>	N	<i>D(k) = -1/N during</i>
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

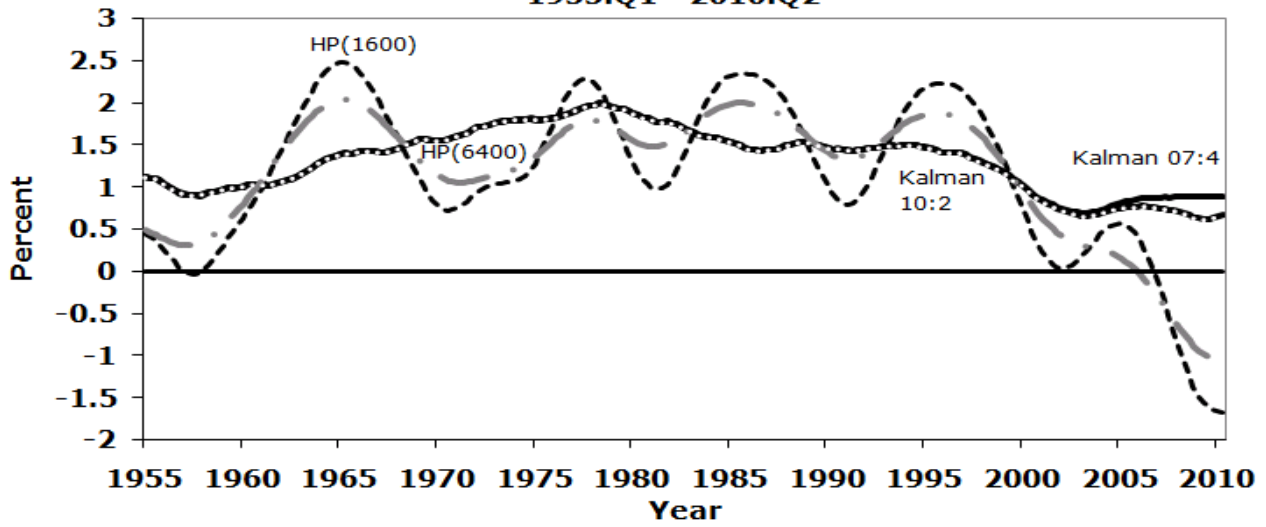


Figure 1b. Annualized Trend Growth Rate of Output, Alternative Methods, Conventional Identity, 1955:Q1 - 2010:Q2

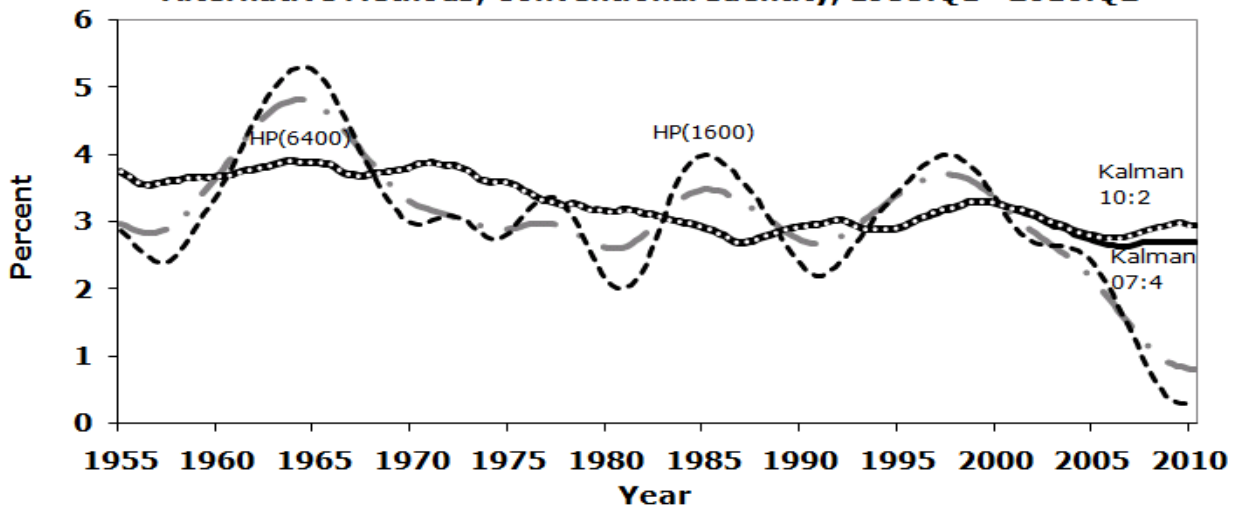


Figure 2. Actual Unemployment Rate, Time-Varying NAIRU, and Implied Unemployment Gap, 1955:Q1 - 2010:Q2

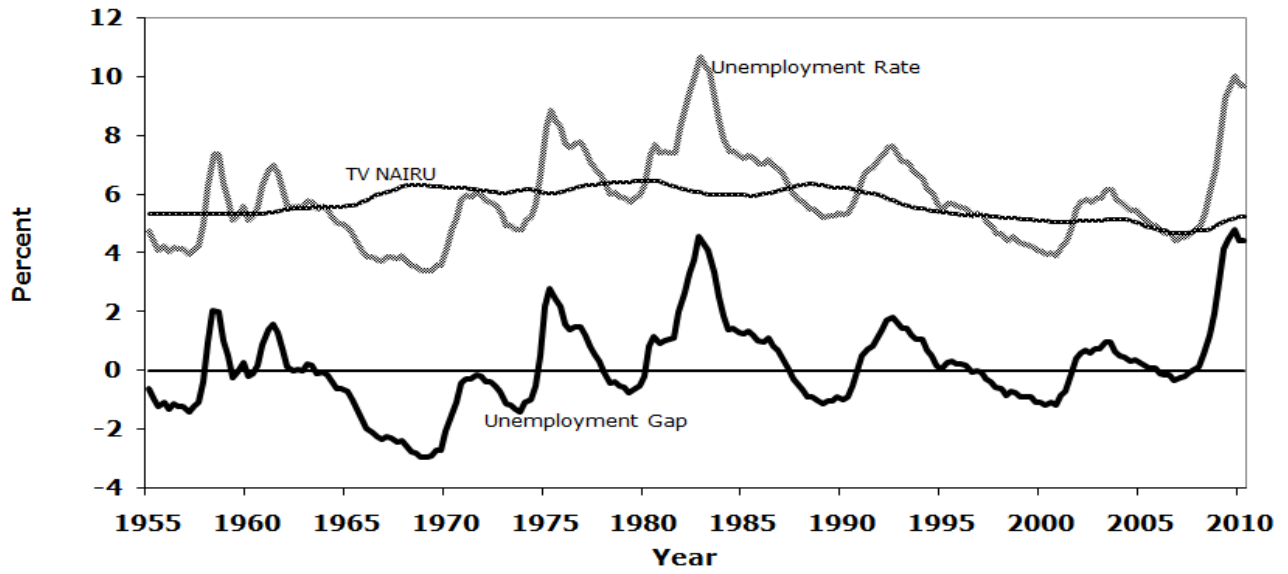


Figure 3a. Annualized Quarterly Growth of Output and Aggregate Hours Trends, Conventional vs. Unconventional Measures, 1955:Q1 - 2010:Q2

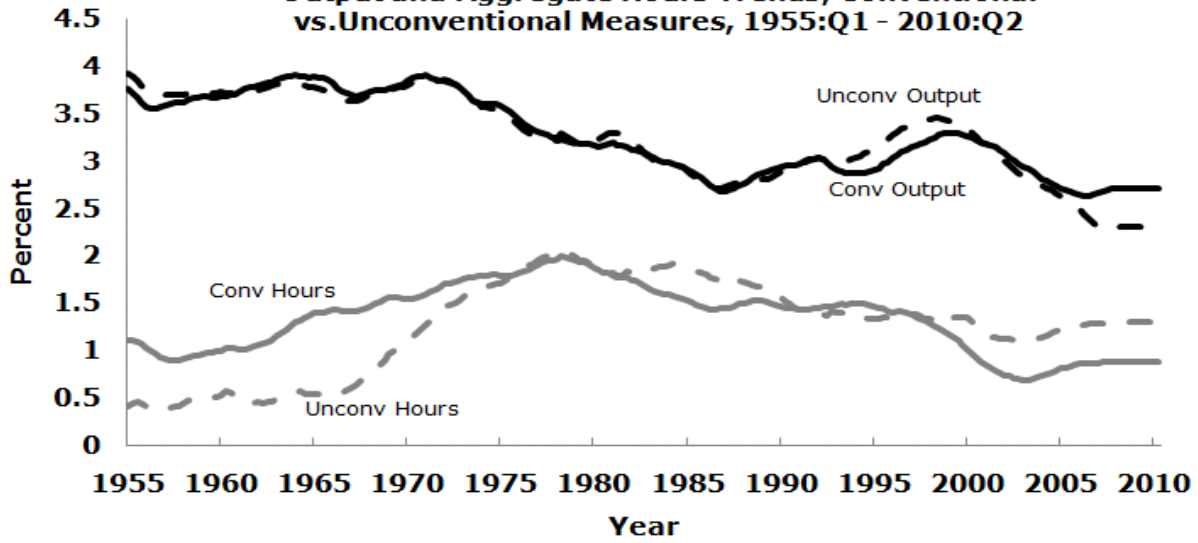


Figure 3b. Annualized Quarterly Growth of Labor Productivity, Conventional vs. Unconventional Measures, 1955:Q1 - 2010:Q2

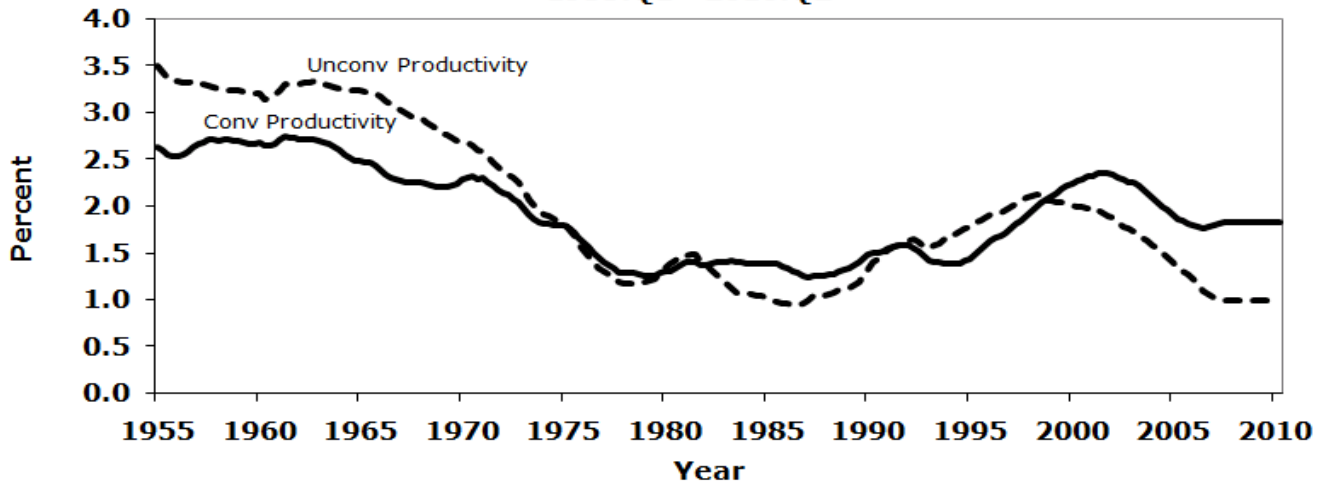


Figure 4a. Annualized Trend Growth of Labor Productivity, Hours, and Output, Estimated through 2007:Q4 and then Held Constant, Average Identity, 1955:Q1 - 2010:Q2

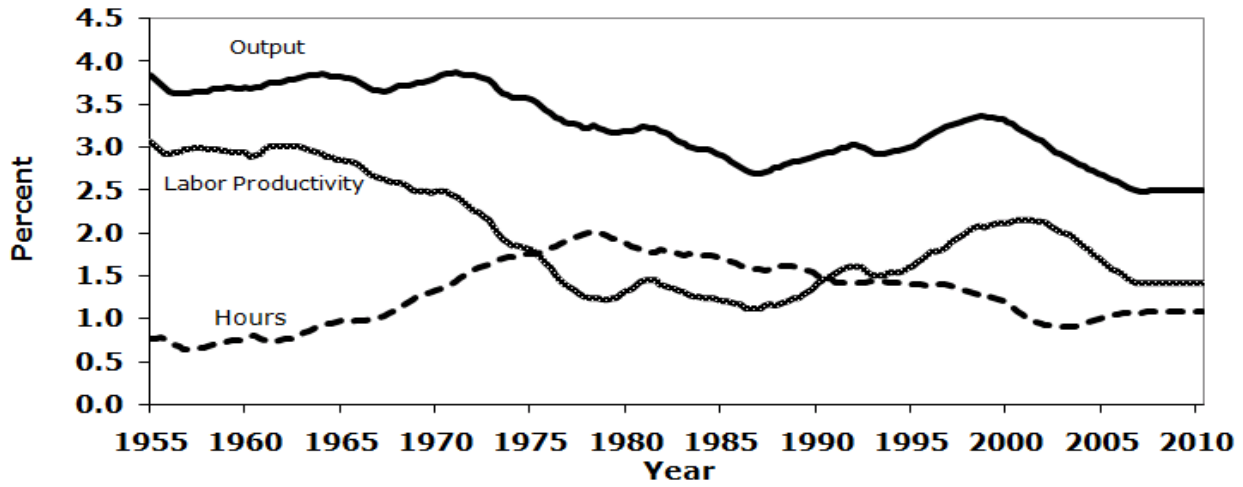


Figure 4b. Annualized Trend Growth of Hours per Employee, the Employment Rate, the Labor Force Participation Rate, and Working-Age Population, Average Identity, 1955:Q1 - 2010:Q2

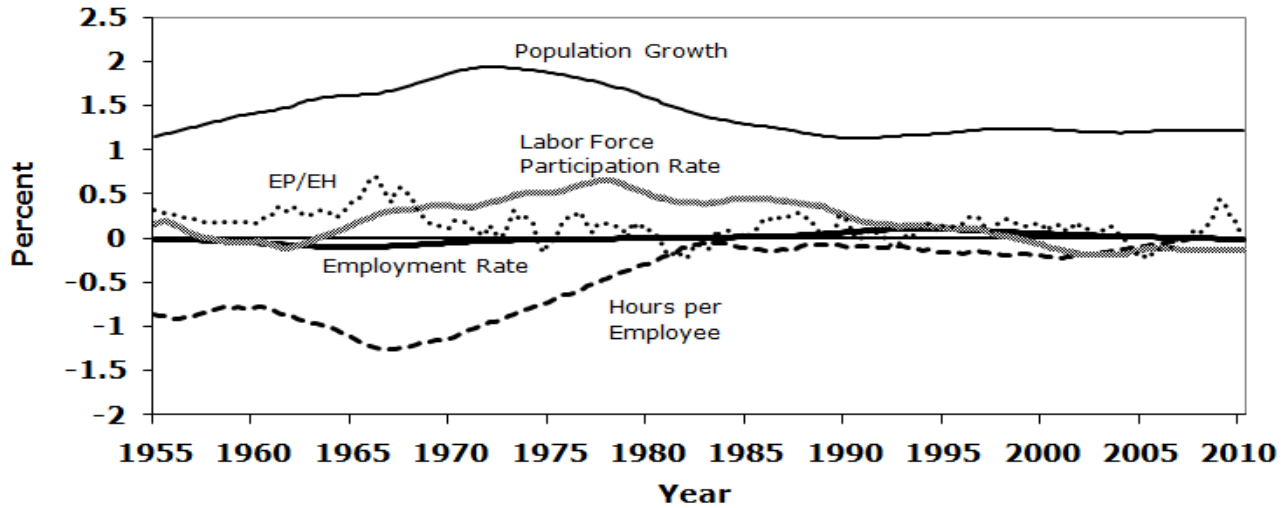


Figure 5a. Log Percent Gaps of Actual Relative to Trend for Output, Aggregate Hours, and Labor Productivity, Average Identity, 1955:Q1 - 2010:Q2

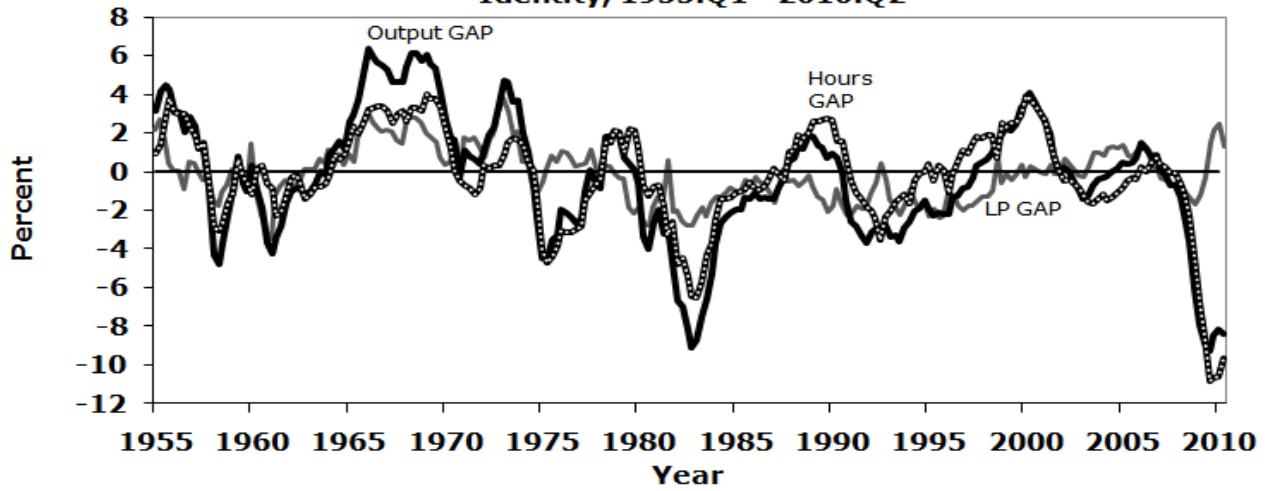


Figure 5b. Log Percent Gaps of Actual Relative to Trend for Hours per Employee, the Employment Rate, and the Labor Force Participation Rate, Average Identity, 1955:Q1 - 2010:Q2

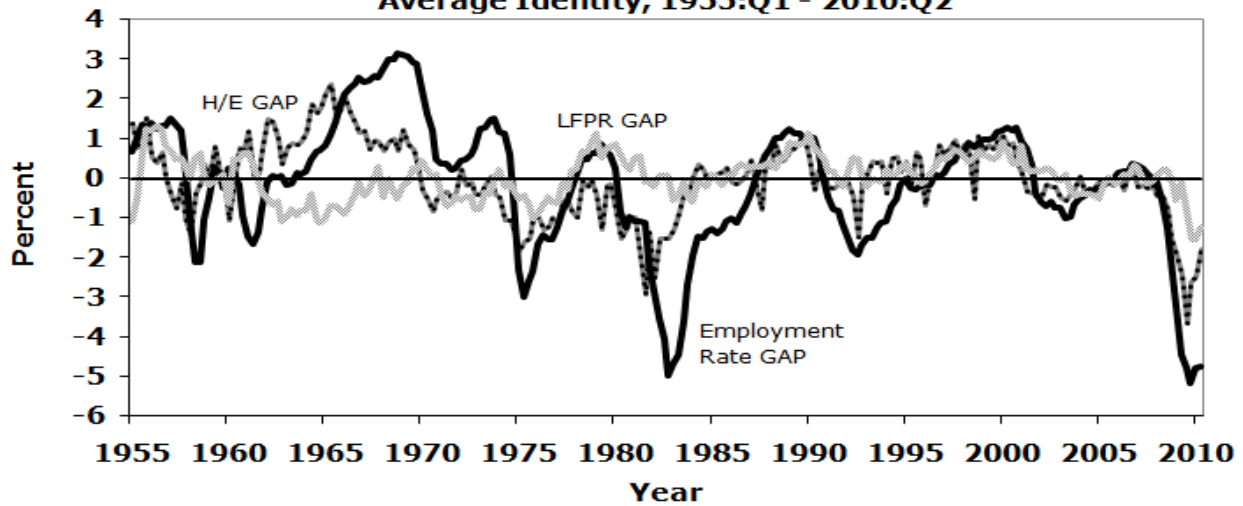


Figure 6. Long Run Response of Labor Productivity and Aggregate Hours by Conventional Definitions using 1954:Q1 - 1986:Q1 vs 1986:Q1 - 2010:Q2 Coefficients

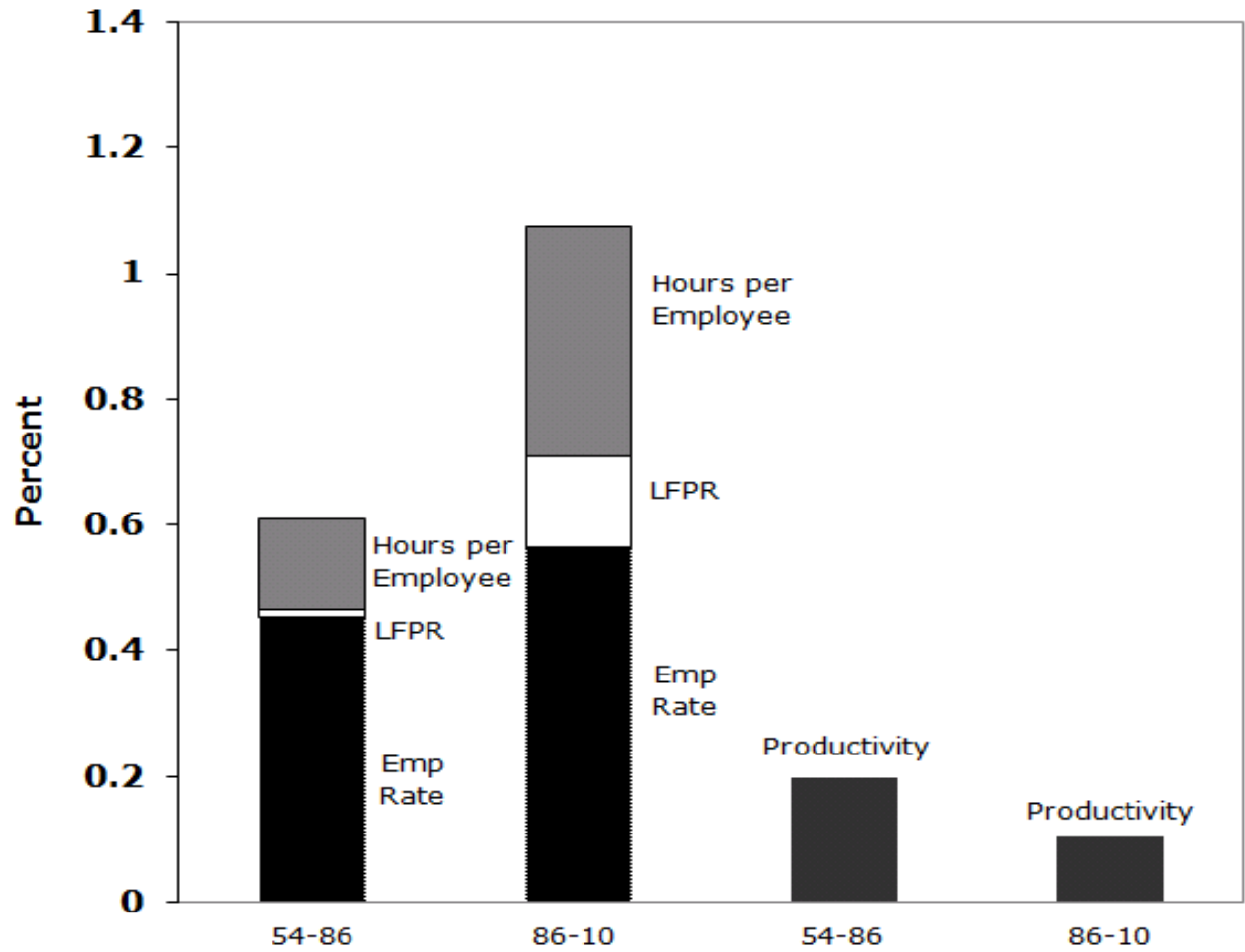


Figure 7a. Hours Residuals using Early and Late Coefficients, Average Identity

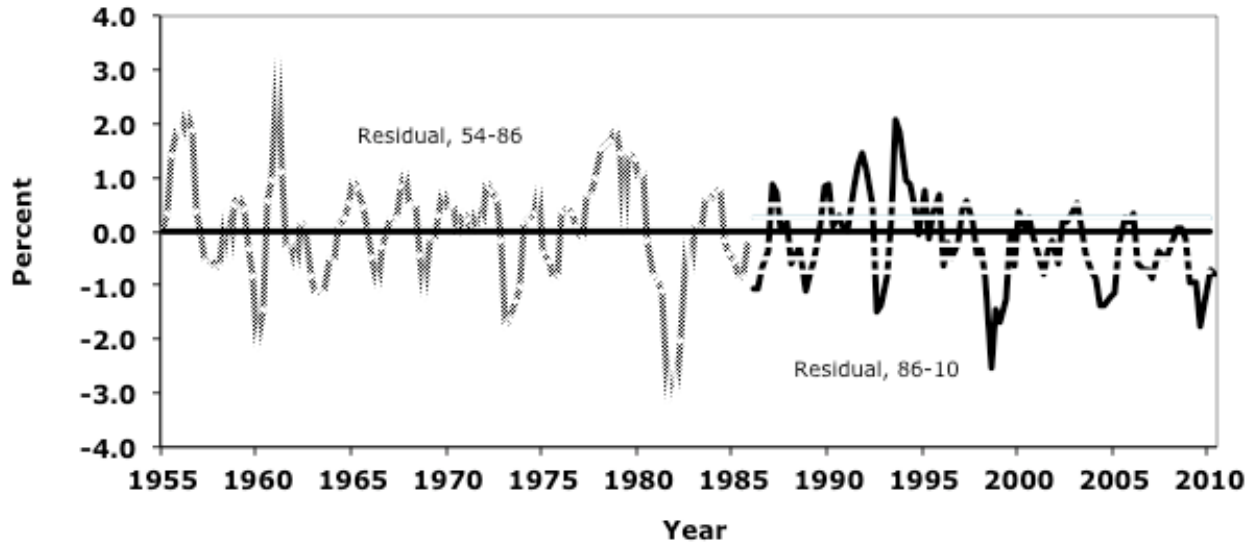
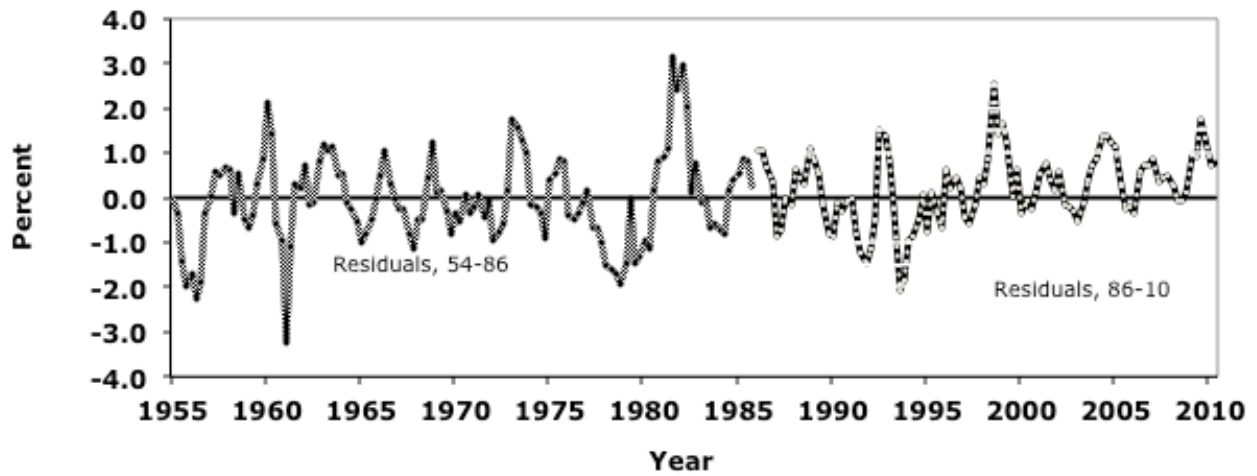
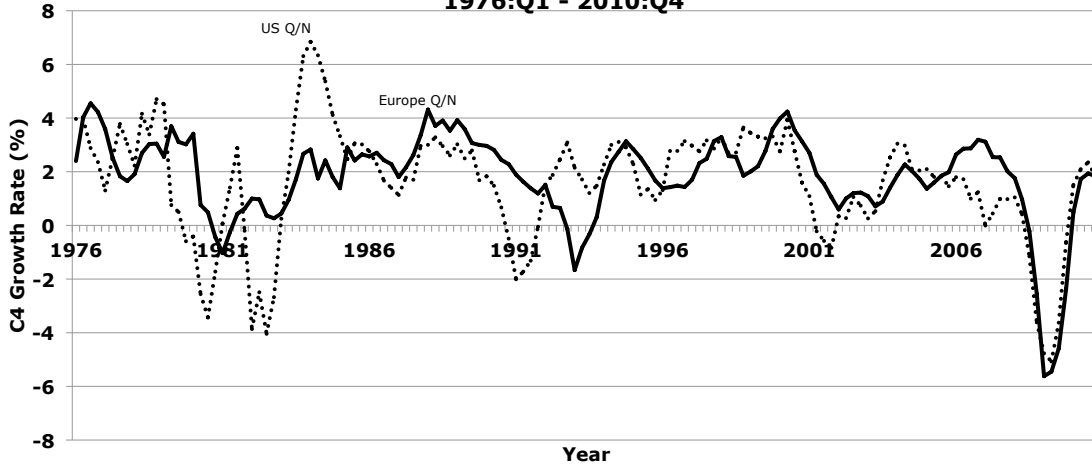


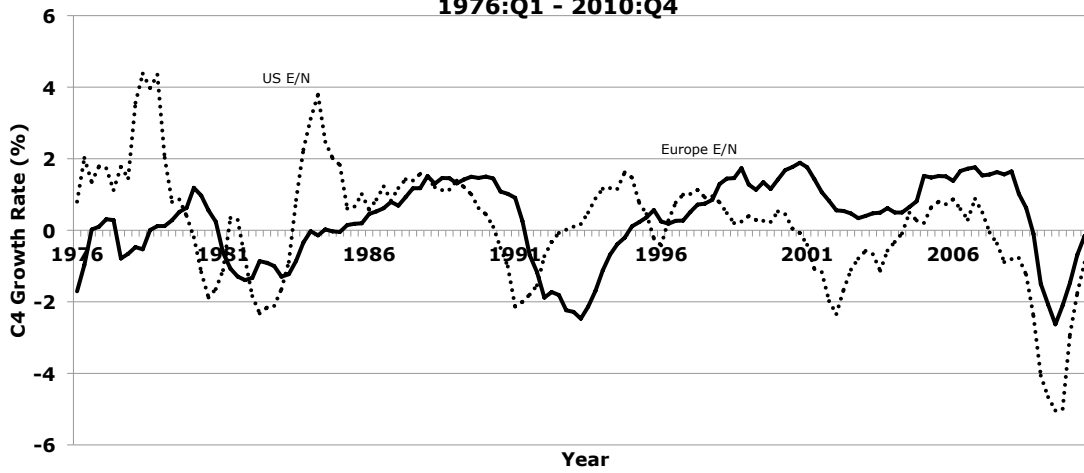
Figure 7b. Labor Productivity Residuals using Early and Late Coefficients, Average Identity



**Figure 8a. US vs. Europe Four-Quarter Actual Growth Rates of Output per Capita
1976:Q1 - 2010:Q4**



**Figure 8b. US vs. Europe Four-Quarter Actual Growth Rates of Employment over Population
1976:Q1 - 2010:Q4**



**Figure 8c. US vs. Europe Four-Quarter Actual Growth Rates of Output per Employee
1976:Q1 - 2010:Q4**

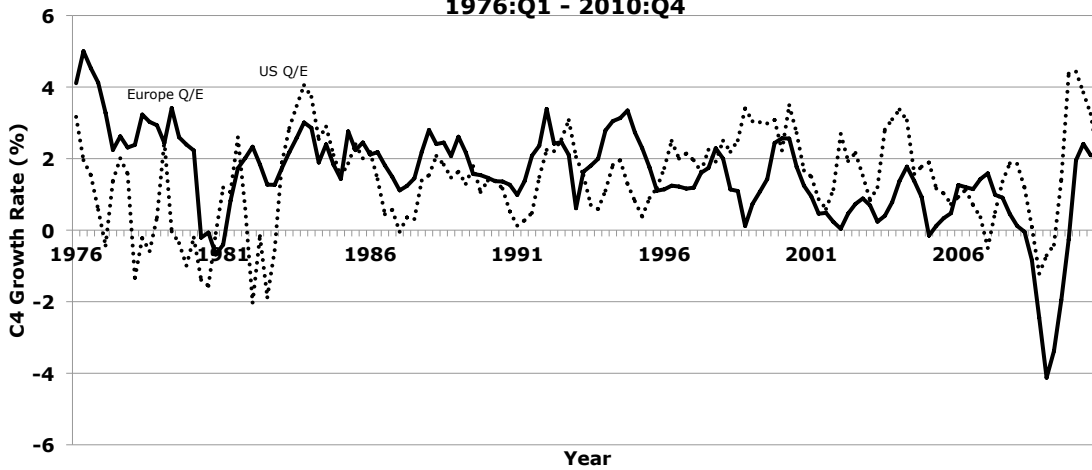


Figure 9a. US vs. Europe Four-Quarter Trend (HP 6400) Growth Rates of Output per Capita 1976:Q1 - 2010:Q4

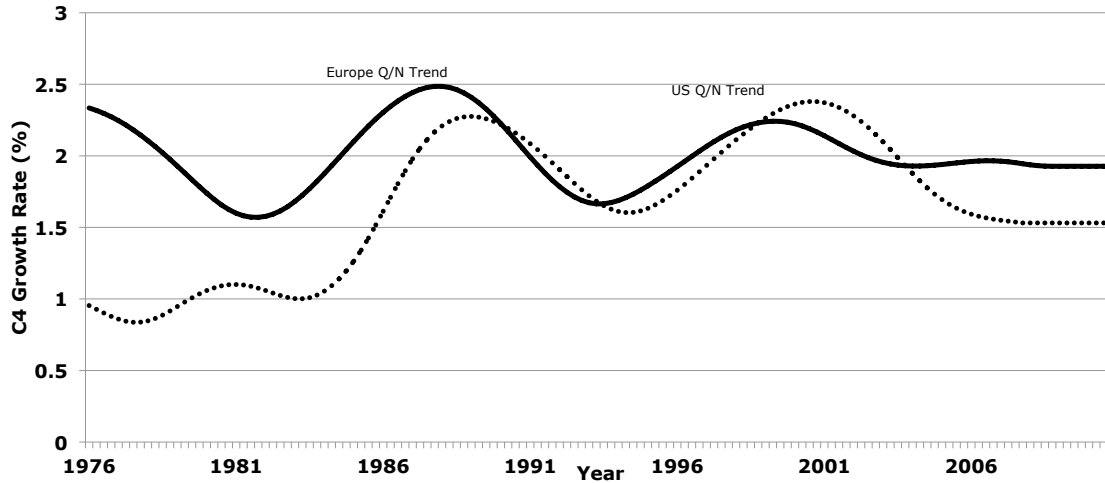


Figure 9b. US vs. Europe Four-Quarter Trend (HP 6400) Growth Rates of Employment over Population 1976:Q1 - 2010:Q4

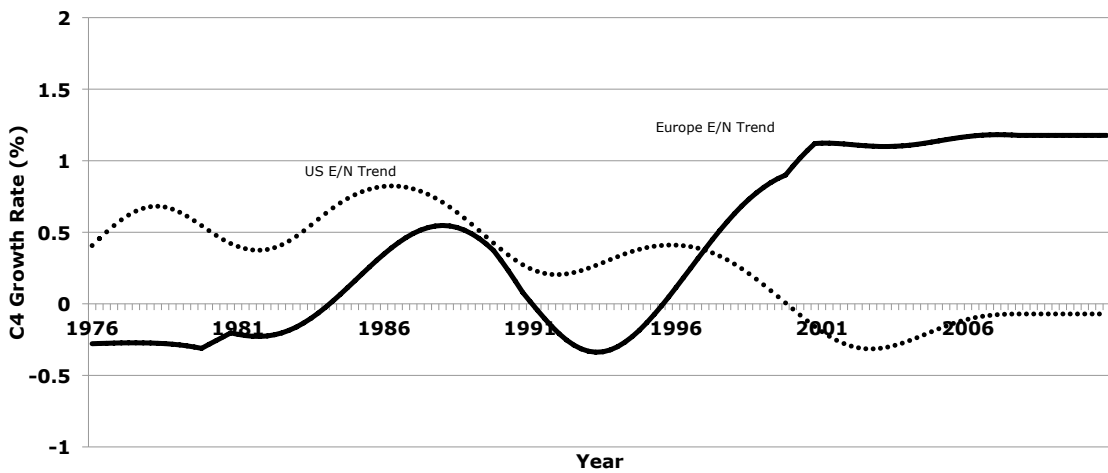


Figure 9c. US vs. Europe Four-Quarter Trend (HP 6400) Growth Rates of Output per Employee 1976:Q1 - 2010:Q4

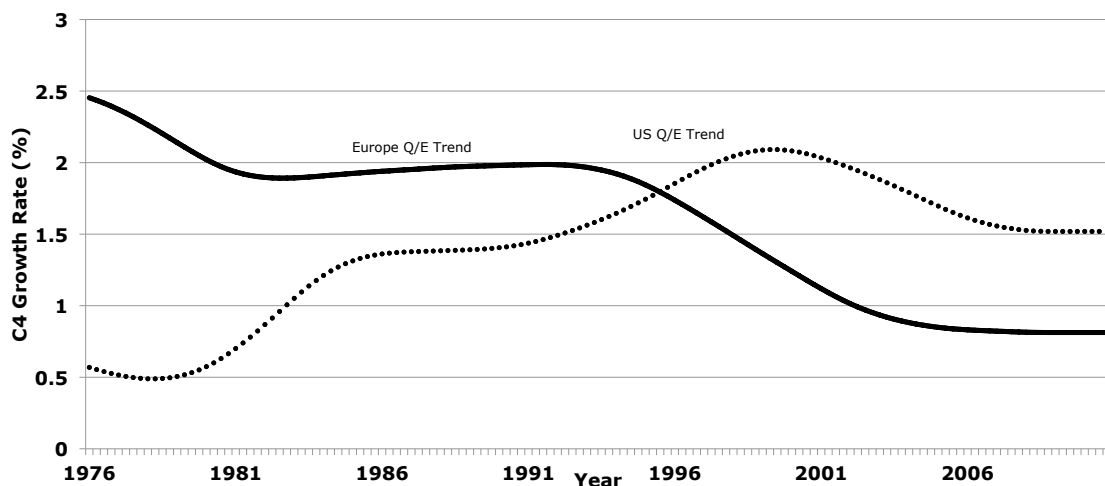


Figure 10a. Europe vs US GDP Gap (HP 6400) 1976:Q1 to 2010:Q4

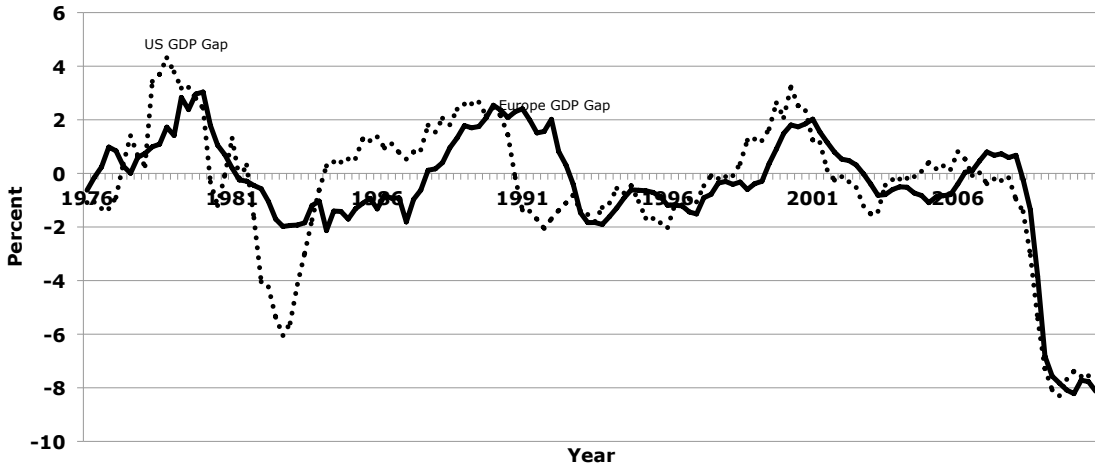


Figure 10b. Europe vs US Employment over Population Gap (HP 6400) 1976:Q1 to 2010:Q4

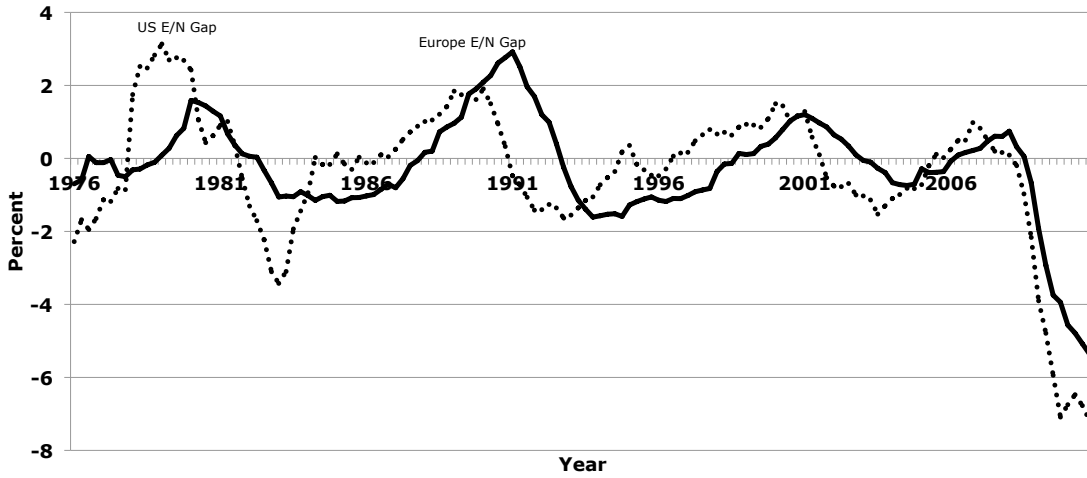


Figure 10c. Europe vs US Output per Employee Gap (HP 6400) 1976:Q1 to 2010:Q4

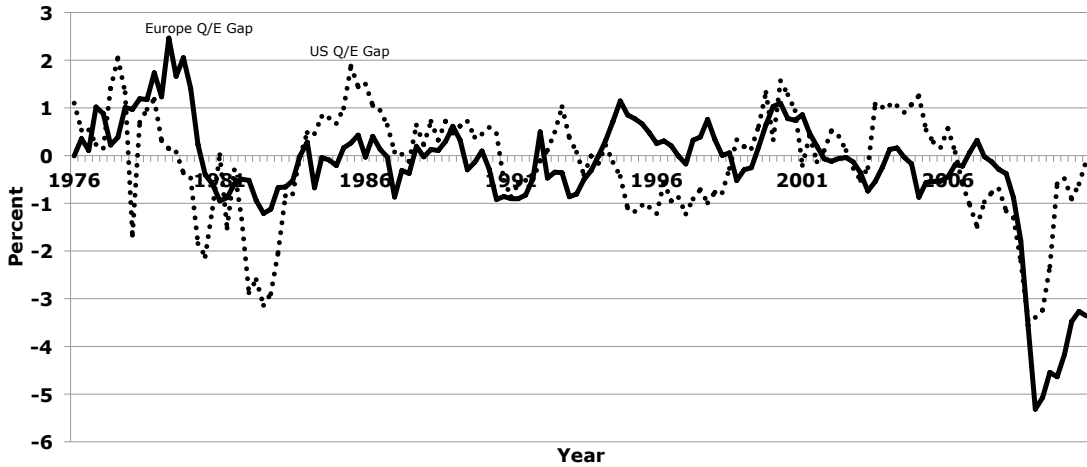


Table 1. Growth Rates of Various Components (AAGR)

	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 Average Output Identity Components^a, 2007:4 Trend End

<i>Independent Variable</i>	<u>Dependent variable, 1954:1 - 1986:1</u>		<u>Dependent variable, 1986:1 - 2010:2</u>	
	Hours	Output per Hour ^{b,g}	Hours	Output per Hour ^{b,g}
Lagged dependent variable ^c	-0.61 **	-0.76 **	-0.50	-0.72 **
Output deviation from trend ^d	1.15 **	0.35 **	1.59 **	0.18
Error correction term ^e Engel-Granger expansion (EGE)	-0.19	-0.14	-0.13	-0.24
dummy variable ^f	1.54 **	-1.91 **	1.12	-2.60 **
Adjusted R ²	0.58	0.55	0.56	0.28
Standard error of estimate	2.13	2.08	1.90	1.92
Sum of squared residuals	537.52	509.02	312.48	320.93
Chow Test ^h			1.58	1.01
Mean Lag/Lead Response to Output Changes	0.92	-1.90	1.17	-13.66
Long Run Response to Output Changes ⁱ	0.71	0.20	1.06	0.10

Source: Author's regressions 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 868.11 for Hours and 823.02 for LP when there are varying coefficients on EOE, and 922.41 for Hours and 875.11 for LP when coefficients on EOE are constrained to be equal

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

Table 3. Regressions Explaining Cyclical Deviations from Trend in Average Output Identity Components^a, 2007:4 Trend End

<i>Independent Variable</i>	Dependent variable, 1954:1 - 1986:1			Dependent variable, 1986:1 - 2010:2		
	Employment Rate	LFPR	Hours per Employee ^b	Employment Rate	LFPR	Hours per Employee ^b
Lagged dependent variable ^c	-0.26	-0.06	-0.77 **	0.15	-0.42	-1.02 **
Output deviation from trend ^d	0.57 **	0.02	0.25 **	0.48 **	0.20 **	0.74 **
Error correction term ^e	-0.06	-0.78 **	-0.41 *	-0.13	-0.36	-1.00 **
End-of-expansion (EOE) dummy variable ^f	0.72 **	0.57 *	-0.46	0.17	0.35	0.37
Adjusted R ²	0.78	0.15	0.19	0.73	0.19	0.34
Standard error of estimate	0.91	1.22	1.80	0.61	0.80	1.58
Sum of squared residuals	97.35	176.92	383.24	32.72	55.83	217.84
Chow Test ^h				1.23	0.82	1.86 *
Mean Lag/Lead Response to Output Changes	0.59	15.38	-0.39	1.44	2.53	1.20
Long Run Response to Output Changes ⁱ	0.45	0.01	0.14	0.57	0.14	0.37

Source: Author's regressions 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 132.20 for Employment Rate, 240.63 for LFPR, and 610.89 for Hours per Employee when there are varying coefficients on EOE, and 138.68 for Employment Rate, 243.01 for LFPR, and 661.20 for Hours per employee when coefficients on EOE are constrained to be equal

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

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

Dependent Variable Identity	1954:1 - 1986:1			1986:1 - 2010:2		
	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	Dependent variable, 1986:1 - 2010:2					
	Hours Actual	Hours Predicted	Hours Residual	Productivity Actual	Productivity Predicted	Productivity Residual
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. Regressions Explaining Cyclical Deviations from Trend in Employment over Population^a, 2007:4 Trend End

<i>Independent Variable</i>	<u>1977:2 - 1993:4</u>		<u>1994:1 - 2010:4</u>		<u>1955:2 - 1986:1</u>	<u>1986:1 - 2010:4</u>
	E/N US	E/N EU	E/N US	E/N EU	E/N US	E/N US
Lagged dependent variable^b	-0.16	0.59 **	0.08	0.25	-0.14	0.17
Output deviation from trend^c	0.73 **	0.44 **	0.83 **	0.49 **	0.63 **	0.72 **
Error correction term^d	-0.19	-0.18	-0.02	0.00	-0.27	-0.03
Adjusted R²	0.36	0.59	0.68	0.74	0.40	0.62
Standard error of estimate	1.73	0.73	0.99	0.61	1.94	0.97
Sum of squared residuals	170.13	30.40	56.36	21.26	430.00	84.26
Chow Test^e			0.91	0.44		1.37
Mean Lag/Lead Response to Output Changes	1.13	1.66	1.48	1.29	0.72	1.50
Long Run Response to Output Changes^f	0.63	1.07	0.90	0.65	0.55	0.87

Source: Author's regressions 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. Four lags are used

c Current value and four lags are used

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

e. The value of SSR for the whole sample (1977-2010) is 253.46 for US and 54.63 for EU. The SSR for the expanded US sample (1955-2010) is 564.81

f. The long-run response is the sum of coefficients on the change in the output deviation from trend divided by unity minus the sum of coefficients on the lagged dependent variable.

Table 7. Regressions Explaining Cyclical Deviations from Trend in Output Per Employee^a, 2007:4 Trend End

<i>Independent Variable</i>	1977:2 - 1993:4		1994:1 - 2010:4		1955:2 - 1986:1	1986:1 - 2010:4
	Y/E US	Y/E EU	Y/E US	Y/E EU	Y/E US	Y/E US
Lagged dependent variable^b	-0.21	0.52 **	0.19	0.09	-0.15	0.24 *
Output deviation from trend^c	0.50 **	0.17	0.07	0.51 **	0.59 **	0.10 *
Error correction term^d	-0.11	-0.34 *	-0.03	-0.20	-0.10	-0.06 *
Adjusted R²	0.68	0.84	0.79	0.89	0.70	0.76
Standard error of estimate	1.75	0.73	0.99	0.58	1.99	0.97
Sum of squared residuals	174.82	30.33	57.38	19.65	449.94	84.56
Chow Test^e			0.80	0.81		1.07
Mean Lag/Lead Response to Output Changes	-1.37	-1.25	-7.09	-0.89	-0.31	-5.50
Long Run Response to Output Changes^f	0.42	0.35	0.08	0.56	0.52	0.13

Source: Author's regressions using equation 7 in the text and data from sources and

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

b. Four lags are used

c Current value and four lags are used

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

e. The value of SSR for the whole sample (1977-2010) is 256.61 for US and 55.28 for EU. The SSR for the expanded US sample (1955-2010) is 575.56

f. The long-run response is the sum of coefficients on the change in the output deviation from trend divided by unity minus the sum of coefficients on the lagged dependent variable.