The Slowest Potential Output Growth in U. S. History: Measurement and Interpretation*

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1. Introduction

Potential real GDP has experienced an average annual growth rate since 1875 of 3.4 percent, and in many long periods of U. S. history in excess of 3.7 percent. Only a few years ago, several of the more optimistic business economists assumed that future potential output would grow at a rate of 4 percent (Glassman, 2002). But in 2008 potential output was growing at only 2.5 percent per year, and only slightly faster at 2.7 percent per year on average during the decade 1998-2008.[1] The recent growth rate is substantially lower than the range of 3.0 to 3.5 percent that most business forecasters assumed only a few years ago and seems to be slowing toward the pessimistic 2.0 percent long-term future growth rate assumed by the Social Security Trustees for the years 2015-2085.[2] The title of this paper is suggested by the historical comparison (see Table 1 below) that potential real GDP growth has never grown as slowly during the history of the U. S. since 1875 as it is growing today.

This paper uses the adjectives "potential" and "trend" as synonyms to describe the long-run growth rate of real GDP, hours of work, and productivity at any given time after cyclical elements of the observed data are factored out by a statistical detrending procedure. Potential real GDP growth by definition equals the sum of the growth of total hours worked and productivity in the total economy. We make a careful distinction between total economy productivity and the quarterly official U. S. productivity data which refer not to the total economy but rather to the nonfarm

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1. The source is the Kalman trend line drawn in Figure XX below. Referenced in the text are the trend change for 2008:Q2 and the average of the trend change for 1998:Q3 to 2008:Q2.
2. See Board of Trustees (2007, Table VI.F6, p. 177), together with their assumption that the GDP deflator will grow during 2015-85 at 0.4 percent annually slower than the CPI.

private business (NFPB) sector, which excludes the agricultural and government sectors, as well as households and institutions.[3] This paper cuts through the complexity required to relate real GDP for the total economy to productivity for the NFPB sector by developing its entire analysis for the unpublished concept of total economy productivity.[4]

While most studies of long-run growth focus on productivity, potential output growth matters as well. Productivity is the chief driver of the standard of living, while potential output growth matters for the long-run solvency of the general government budget and of entitlement programs like Social Security, for the balance of world saving and investment, and for the role of the United States as an engine of growth for the rest of the world. Potential output growth also determines the long-run demand for residential housing and fixed investment more generally, as well as the long-run demand for infrastructure and government services.

While potential GDP growth has long been expected to slow as a result of the retirement of the baby-boom cohort of the labor force, the surprisingly low recent growth rates surprisingly do not reflect population growth, which has not exhibited a reduced growth rate, at least not yet. Rather, the culprits are slowdowns in the growth rates of productivity, hours per employee, and the labor force participation rate since the previous business cycle peak in early 2001. Much of this paper is devoted to documenting these slowdowns by separating trends from cyclical fluctuations and to examining the underlying reasons for the observed behavior.

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3. The BLS also publishes quarterly productivity data for the private business sector including farms and for durable and nondurable manufacturing and for nonfinancial corporations, but the data for the NFPB sector are the most widely cited.
4. Total economy productivity is defined as real GDP divided by total economy hours, an

1.1 The Three Goals

The ultimate goal of this paper is to provide a forecast of growth in U. S. potential real GDP for the next two decades, 2008-2028. The point of departure is the *output identity* that sets real GDP equal by definition to the product of five factors, total-economy productivity, hours per employee, the employment rate (that is, unity minus the unemployment rate), the labor force participation rate (LFPR), and the working-age population.[5] Any long-term forecast for real GDP growth must include a forecast over the same period of future growth in the five components of the output identity.

The second goal of the paper, connected closely with the first, is to provide an interpretation of changes over the past decade in the trends of the key components of the output identity, which are productivity, hours per employee, and the LFPR. The behavior of the other two components, the trend employment rate (or unity minus the natural rate of unemployment) and the trend growth of population have varied relatively little. We pay particular attention to the extraordinary productivity performance of the United States from 1995 to 2004 and the sharp slowdown in productivity growth in 2004-07 (with a bounce-back that may be temporary between mid-2007 and mid-2008). What weight should the 1995-2004 productivity growth explosion receive in a forecast looking out over the next 20 years? Similarly, how should we weight the post-2000 turnaround toward slower or more negative growth in hours per employee and the LFPR? Should a forecast of future growth, whether of

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unpublished series compiled quarterly by the Bureau of Labor Statistics (BLS).

5. As shown below in equations (1) and (2), the output identity contains five terms when the productivity concept refers to the total economy, but two extra terms for a total of seven are required when the productivity concept refers to the NFPB sector.

productivity, hours, or the LFPR, use as its precedent the average behavior of the past two years, past eight years, or a longer interval? Are there any reasons to qualify forecasts published by the BLS and other agencies of future growth in the working-age population and the labor force?

The third goal of this paper, related to the first two, is to provide a new breakdown of past U. S. economic growth between trend and cycle. In assessing long-term growth performance in the past, we would not want to include the portion of real GDP growth contributed by a sharp difference in cyclical conditions, for instance between the 7.5 percent unemployment rate of mid-1992 and the 3.9 percent unemployment rate of early 2000. This paper bases its cyclical analysis on the same output identity defined above that is also used to examine trends. This analysis uncovers important changes in cyclical behavior between earlier postwar downturns and the jobless recessions/recoveries of 1990-93 and 2000-03, in particular, the strength of productivity growth and the weakness of payroll employment growth in the early phases of the two most recent recoveries.

1.2 Long-Run Trends

To predict the future, naturally we start with the past. But how much of the past? This is not a question on which either economic or statistical theory provides much guidance. Sometimes we have good economic reasons for looking at only part of the past, believing strongly, for instance, that the economic dislocations of the Great Depression and World War II will not recur. When making demographic forecasts of future population growth, we may be quite sure that fertility rates will never return to the baby boom era of 1947 to 1963. But can we be so sure which decades into the past are relevant for predictions of productivity, mortality, or immigration?

This paper of necessity is limited to data for the United States. But we should keep in mind the dimension of "American Exceptionalism" that pervades international comparisons. In forecasting out over a period as long as two decades, we should at least consider the possibility that unusual aspects of American behavior could become more like other developed countries, instead of continuing to diverge. The most important aspects of American exceptionalism in the recent past have been the 1995-2004 productivity growth revival, which has not occurred in western Europe or Japan; the absence until recently of a decline in hours of work per employee; the relatively high level of fertility; and the important role of immigration in maintaining population growth.

1.3 Topical Issues in the Breakdown between Cycle and Trend

In examining our third topic, the separation of cycle and trend, we adopt a modern version of Okun's (1962) law and his original conception of potential output. In place of his description of potential output as representing a situation of "full employment," instead we apply the near-universal current definition of potential real GDP as the amount that the economy can produce at its natural rate of unemployment or NAIRU, which in turn is the unemployment rate consistent with steady non-accelerating inflation in the absence of supply shocks.[6] Our analysis of both trends and cycles uses the output identity that links potential output to the employment rate and other variables. By estimating regression equations which explain changes in the employment rate and the other variables by changes in detrended real GDP, we can achieve a complete decomposition of each component of

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6. The NAIRU is the Non-Accelerating Inflation Rate of Unemployment.

the identity into measures of trend, regular cyclical behavior, and residual terms that reveal unusual behavior not predicted by the regular cyclical patterns that have been observed in the past.

This three-way breakdown between trend, cycle, and residuals allows us to address a wide set of issues, including unusual aspects of the economic boom during 1995-2000, the 2001 recession, the recovery after late 2001, and the period of slower growth in 2006-08, viewed on their own and in comparison with past business cycles. For instance, why was payroll employment so much weaker in 2002-03 than in 1991-92, that episode which launched the term "jobless recovery," while the unemployment rate remained well below its 1992 peak? What are the roles in explaining these discrepancies of the major components of the output identity, productivity, hours per employee, and the LFPR?

1.4 Plan of the Paper

The paper begins by reviewing the record of potential output growth since 1875 to establish the point of departure that U. S. potential output is currently growing at the slowest rate in American history. For the period since 1954 we compute the trend growth rate of real GDP and the components of the output identity using a standard statistical technique, the Kalman filter.

Having established trends for each variable, then for each component of the identity we reassess the Okun's Law coefficient using both a nonstatistical examination of peak and trough ratios of output to trend, and also a regression analysis. The regression analysis yields a distinction between normal cyclical behavior and residual unexplained behavior that emphasizes the differences between the two jobless recoveries of 1991-92 and 2001-03 and previous cyclical episodes. We also ask whether the first half of 2008, which combined a decline in employment with a healthy rise in real GDP, is unprecedented in historical perspective. The econometric results, showing a substantial residual component in productivity and aggregate hours since 2001, raise both measurement and substantive issues, which we discuss in the context of recent research.

The final part of the paper discusses issues in projecting the components of the output identity out over the next 20 years, with an emphasis on productivity, population growth, hours per employee, and the LFPR. This section contains no econometrics, but rather an introduction to the kinds of decisions that must be made in carrying out such forecasts. In projecting the working-age population and the labor force, we assess alternative forecasts of the BLS and the Social Security Trustees, as viewed from the perspective of my two terms (2003 and 2007) on the quadrennial Technical Panel on Assumptions and Methods of the Social Security Advisory Board.

2. Growth in Potential Real GDP since 1875

There is no widely accepted time series of potential real GDP reaching back to World War II, much less to 1875. Here we take a different approach to the period before and after 1954. After that date we rely for our potential output measure on the statistical trends estimated and discussed below. However, before that date we do not believe that statistical trends are capable of identifying potential output in the sense of the economy's normal capacity to produce during peacetime. Any statistical trend has a tendency to "bend up" to respond to the super-normal production achieved during World War I and especially World War II, and to "bend down" in response to the catastrophic decline in output that occurred during the Great Depression. Only a few die-hard Real Business Cycle advocates deny that a collapse of aggregate demand pushed real GDP far below potential output during the 1930s.

To avoid distortion of potential output by the Great Depression and the two wars, we estimate potential output by the simple technique of calculating log-linear trends of actual real GDP between benchmark years when output is assumed to be roughly at the level of potential output, neither in a recession nor in an unsustainable peacetime or wartime boom. The top section of Table 1 shows the years chosen as benchmarks – 1875, 1891, 1901, 1913, 1928, 1950, and 1954, and the log-linear annual growth rates of real GDP between those benchmark years. While potential output growth was in the narrow range of 3.65 to 3.96 percent per annum in four of the six periods, growth was a much lower 2.88 percent during 1913-28 and a much higher 5.04 percent during 1928-1950. The fascinating questions raised by these variations in potential GDP growth are beyond the scope of this paper; see Gordon (2000, 2006).

After 1954 the annual growth rates of potential output shown in Table 1 are the growth rates of actual real GDP between particular benchmark quarters when the actual unemployment rate was roughly equal to the NAIRU (further details of the choice of benchmark quarters are presented in the next section).[7] These growth rates, also shown in Figure 1, display a steady decline from the initial 1954-64 interval. During 1954-72, potential output growth was roughly 3.75 percent per annum, about the same as between 1875 and 1913. But then growth slowed to 3.4 percent during 1972-77, then to 3.0 percent during 1977-97, and to 2.8 percent during 1997-2007. Since the slow observed growth has been experienced for more than a decade, it is puzzling that some business forecasters, including the previously quoted 4 percent estimate by Glassman (2002), could have overstated recent growth by so much.

2.1 The Output Identity: Notation and Definitions

We now turn to the separation of trend and cycle and to the components of the output identity that allow us to identify the factors that have contributed to slowing potential output growth. The output identity is equally useful for distinguishing the counterparts of long-run growth in potential GDP and in assessing the cyclical behavior of Okun's Law. We begin with a simple version of this 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).*[8]

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

At this stage we suppress time subscripts, since all of the variables in (1) and the subsequent versions of the output identity are contemporaneous. The right-hand side of (1) contains four elements that typically display procyclical behavior, albeit with different sets of leads and lags relative to total output *(Q)*, namely output per hour,

7. My latest estimates of the NAIRU are presented in Gordon (2008).

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

hours per employee, the employment rate, and the LFPR. We would expect no response of the working-age population *(N)* to the business cycle.

The identity (1) is requires that our concept of productivity refer to the total economy rather than the more widely cited published BLS series for the nonfarm private business (NFPB) sector. While it is possible to obtain unpublished data on total economy productivity, we need to be able to relate potential output growth to productivity growth in the NFPB sector. To relate potential and actual real GDP to the published productivity measure, we must expand identity (1), designating variables referring to the NFPB sector with the superscript *B*. Variables without superscripts refer to the total economy, except that total employment in the establishment or payroll survey is distinguished by a superscript *P* (i.e., E^P) to distinguish it from total employment as measured in the household survey *(E)*.

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

Identity (2) differs from (1) in the last two terms. The next to last term, which we can call the "mix effect", measures the ratio of output per payroll employee in the total economy relative to that in the NFPB sector. The final term measures the ratio of employment from payroll survey to that from the household survey.

Our previous study of the dynamics of the output identity used the seven-term version in equation (2) and discovered that considerable ambiguity is introduced by the need to interpret trends and cycles in the final two terms, the mix effect and the employment ratio. This paper takes the simpler approach of examining the five-term version in equation (1) and accepts the drawback that all comments in the paper refer to the less familiar concept of total economy productivity growth, not NFPB sectoral productivity growth. Productivity growth for the total economy is almost always slower than for the NFPB sector, albeit by different amounts.

To simplify the notation and allow for the subsequent treatment of growth rates and ratios of actual to trend, we take logs of (1) and choose a single letter for each term. This relationship states that by definition the log of real GDP (y) is equal to the sum of the logs of the following: output per hour (p), hours per employee in the NFPB sector (h), the employment ratio (e), the labor-force participation rate (l), and the working-age population (n).:

(3)	$y \equiv p + h + e + l + n$

We are interested in growth rates of the components of (3) over longer or shorter intervals, in estimated trends of the components, and in log ratios of actual to trend.

Using the same notation, we identify trends, ratios of actual to trend, and growth rates in the simplest possible way. The trend of the log of real GDP (y^*) is the sum of the same five components as in (3) when each of the components, say x, is designated with an asterisk, i.e., x^*. The log-ratio of actual to trend also observes the identity (3) when the components are designated with a prime, and $x' = x - x^*$. In our regression analysis we will be studying rates of change in quarterly data. Adding time subscripts, a rate of change is $\Delta x_t = x_t - x_{t-1}$. The dependent variable in our regressions is the rate of change of the deviation of a variable from trend, $\Delta x'_t = \Delta x_t - \Delta x^*_t$. Rates of change in logs of actual values, of trend values, and of deviations from trend all obey identity (3).

Okun's law can be expressed in this notation either as a relationship among deviations from trend or a relationship among rates of change. We can define k as the response of the deviations from trend of the employment rate relative to total output:

(4)	$k = \frac{e'}{y'}$

The coefficient k was one-third in Okun's original (1962) analysis. However, it has long been recognized that unemployment is a lagging indicator, and including both the current and lagged reaction of unemployment and the employment rate brings the coefficient k up to a value between 0.4 and 0.5.

2.2 Growth Rates between Benchmark Quarters

Our first use of the output identity is to see which components account for differences between the growth rates of output per capita and productivity over time. As in the bottom section of Table 1 above, we choose to calculate growth rates over intervals between "benchmark" quarters which represent roughly the same stage of the business cycle. These quarters are those when the actual unemployment rate is equal to the NAIRU, where the latter is estimated in Gordon (2008). In each business cycle, starting at the cyclical trough, the unemployment rate declines through the NAIRU and in the next recession rises through the NAIRU; our benchmark quarters occur at the first of these events, the quarter when the actual unemployment rate first declines below the NAIRU. The benchmark quarters are those that appear in Tables 1 and 2; their selection is discussed in the Data Appendix.

Table 2 presents the annual growth rates of real GDP and the five other components of the identity from equation (1) for six intervals between benchmark quarters; thus each of the numbers in Table 2 is interpreted as a “trend growth rate”.

Also shown are growth rates for the four final quarters after the final benchmark in 2007:2. By definition, as in identity (3), the growth rates of the five components on the right side of the identity must sum to the growth rate of real GDP in the first column.

In the six periods between 1954 and 2007, the first and second (1954-64 and 1964-72) stand out as having the highest growth in trend real GDP, propelled by rapid productivity and population growth, only partly offset in 1964-72 by a relatively rapid decline in hours per employee. The third period (1972-77) had much slower productivity growth but was notable for the fastest growth in the LFPR and in population of any period but the fastest decline in hours per employee. The negative correlation between the growth rates of hours and the LFPR reflect the role of women who entered the labor force disproportionately in part-time jobs. After 1977 there was slower growth in productivity, the LFPR, and the population, causing output growth to fall to 2.99 percent in 1977-87 and 2.96 percent in 1987-97. Real GDP growth decelerated by 0.14 percentage points between 1987-97 and 1997-2007, despite the 0.88 percentage point acceleration in productivity growth, indicating that the other components of the identity taken together acted as a drag on potential real GDP growth. The most important of these were hours per employee and the LFPR, with a partial offset from the rate of population growth.

The bottom line of Table 2 shows actual growth rates in the final four quarters between 2007:2 and 2008:2, when real GDP was growing slower than potential, as seen from the sharp drop in the employment rate (and its counterpart, a sharp increase in the unemployment rate). Notable during the most recent year were strong productivity growth and the first evidence of the long-predicted decline in the growth rate of the working population (from 1.24 percent per year in 1997-2007 to 0.82

percent in 2007-08).

These points are made with a different arrangement of the same data in Table 3 and in the bar chart of Figure 2. Here the annual growth rates of real GDP per capita and productivity are shown in the first two columns and their difference in the third.[9] By definition, this difference must be equal to the sum of the contribution of the three labor-market variables (employment rate, LFPR, and hours per employee). For the first three intervals between benchmark quarters, per-capita real GDP (shown by the black bars in Figure 2) grows substantially slower than productivity (shown by the dark gray bars), and this can be traced mainly to the decline in hours per employee and to a lesser extent in the employment rate, partially offset by an increase in the LFPR.

For the next two periods, 1977-87 and 1987-97, real GDP per capita grew more rapidly than NFPB productivity growth. This turnaround was due to a slower rate of decline in hours per employee and an increase in the employment rate (decline in the unemployment rate). The final period 1997-2007 witnessed the largest shortfall of real GDP per capita growth relative to NFPB productivity growth since 1954-64. This was accounted for by a turnaround from positive to negative growth of hours per employee and of the LFPR.

2.3 Establishing Trends

To examine the cyclical behavior of components of the output identity, we need

9. Here "per capita" means "per member of the working age population," not the usual "per member of the total population."

to divide actual changes into cyclical and trend elements. And to project the components out over the next two decades, we need the best possible measures of trend behavior, especially in the recent past. The growth rates in Tables 2 and 3 are not based on statistical methodology; they are simply log-linear growth rates over intervals between "benchmark" quarters that are chosen on the basis of an outside criterion, the closeness of the actual unemployment rate to the NAIRU. These trends represent the "trends through benchmarks" or TTB method of detrending. While useful in providing summary information about the growth rate of the eight components over a uniform set of historical intervals, these trends are less useful for our subsequent analysis. When the primary variable of interest is the rate of change of a trend, the TTB method generates instantaneous jumps up or down in the rate of change in the trend at the benchmark quarters, as in Table 2 and as shown graphically in Figure 1 below. As a consequence of these jumps, the TTB method understates trend growth before a positive jump in a trend rate of change and overstates it after such a jump. To create trends that exhibit smooth rather than jumpy behavior in their rates of change, we consider a statistical technique, the Kalman filter.

While previous versions of this research (e.g., Gordon, 2003) based its trends on an average of the Kalman method with the Hodrick-Prescott (H-P) technique, in this paper we rely on the Kalman method alone. The Hodrick-Prescott filter is the most commonly used detrending method in macroeconomics, presumably because it allows the trend to move continuously and because it is easy to understand and to estimate. Its primary flaw is that the estimated trends from any given time series can exhibit wildly different behavior, depending on the smoothness parameter that is chosen by the user, and that choice of parameter is entirely arbitrary. At one extreme, the choice of a parameter of unity yields a trend that exactly tracks every value of the series being detrended. At the other extreme, a parameter of infinity yields a single straight loglinear trend over the full period of the data, e.g., 1954-2008. Between zero and infinity, a relatively low value for the smoothness parameter creates a trend series that "bends" frequently in response to changes in the actual series and hence implies relatively small deviations of the actual values from trend; a high parameter value creates a relatively smooth trend and relatively larger deviations from trend.

The parameter endorsed by Hodrick and Prescott for quarterly data is a relatively low value (1600) that implies implausibly large accelerations and decelerations of the trend within each business cycle.[10] 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 capacity utilization rate was unusually high.

Our preferred technique is the Kalman filter.[11] This can be used to estimate

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

11. 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

time-varying coefficients in any type of time-series model, whether a complex multi-equation model or a single equation. Our application is even simpler, the estimation of a single time-varying coefficient in a single equation, without allowing the other coefficients in that single equation to change. Detrending methods make little difference for most of the components of the output identity, which tend to evolve smoothly over time, but detrending methods and parameter choices are crucial for productivity growth. The estimation of time-varying coefficients with the Kalman filter explains the change in productivity growth (Δp_t) by a time-varying constant (a_t) and any set of other explanatory variables (βX_t):

(5) $\Delta p_t = a_t + \beta X_t + \omega_t$

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

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

The error terms of this two-equation system are:

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

In the estimation of this system a smoothness parameter must be specified to control the variance of the random walk process (τ^2), and this then allows a range of trend rates of change to be obtained, ranging from very jumpy to very smooth, just as in the case of the H-P filter.[12]

The advantage of the Kalman filter over the H-P filter is that any additional

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Kalman filter has many uses beyond the estimation of time-varying coefficients.

12. 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. Hamilton cites Doan, Litterman, and Sims (1984) as an early example of the use of the adaptive

number of variables *(X_t)* in (5) may be specified to control for determinants of actual productivity changes that do not represent fundamental causes of changes in the trend, for example the *X* variables could include changes in unemployment or the output gap, or dislocations caused by short-run dislocations such as strikes or temporary changes in oil prices. In contrast the H-P filter cannot by its design use any outside information, e.g., that slow and even negative productivity growth in the early 1980s occurred at a time when the output gap was at a record negative level.

2.4 Trend Growth and Actual/Trend Ratios for Output Identity Components

Figure 3 compares two trend series for the growth rate of total-economy productivity, the Kalman trend and the TTB trend as is shown by the set of growth rates between benchmark quarters in the second column of Table 2. The TTB trend grows at 2.85 percent during 1954-64, then slows in three steps to 1.2 percent in 1977-87 and 1.3 percent in 1987-97, and finally rises to 2.0 percent in 1997-2007.[13] The Kalman trend displayed in Figure 3 is based on a time-varying coefficient, as in equations (5) and (6) above. As the additional explanatory variable *(X_t)* we use the current and four leading values of the change in the output gap, which in turn is defined as the log ratio of real GDP to its TTB-based trend. We use leads rather than lags because a consistent feature of the data is that productivity leads output, which in turn leads aggregate hours of work; in Table 5 below we regress changes in hours on *lagged* changes in output, and regress productivity on *leading* changes in output.

The top frame of Figure 4 repeats from Figure 3 the Kalman trend based on feedback from detrended real GDP and compares this trend to an eight-quarter annual

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formulation.
13 Figure 1 extrapolates the 1994-2001 trend to 2003:Q2, thus ignoring any information on

rate of change of actual total-economy productivity. We note that actual productivity growth was slower than trend during most of the period between 1987 and 1997 and then faster than trend during most of the period 1997-2004. Accordingly, the log ratio of *the level* of actual to trend productivity fell from 1987 to 1997 and rose from 1997 to 2004. After 2004 actual growth was slower than trend and the ratio of the level of actual to trend declined.

The standard view of cyclical productivity behavior is that the ratio of the level of actual to trend productivity is positive when the log output ratio is positive and negative when the log output ratio is negative. The bottom frame of Figure 4 contradicts this view. The actual-trend ratio for productivity was negative in the late 1960s and 1972-73 when the output ratio was high. The actual-trend ratio for productivity exhibits three spikes, one during the 1980-82 pair of recessions, the second during the 1990-91 recession and its "jobless recovery" aftermath, and the third during 2001-02. This positive response of the actual-trend ratio during and after recessions is consistent with the "early-recovery productivity bubble" interpretation developed below in connection with Table 7.

Three of the other four components of the output identity in equation (3) above are detrended by the same Kalman methodology; the exception is the employment rate which is discussed separately in the context of Figure 6 below. Figure 5 displays in the upper frame the actual eight-quarter change in hours per employee and the Kalman trend. Trend growth is negative from 1955 to 1990, with the trend reachest is maximum negative growth rate in the early 1970s, presumably related to the influence of labor-force entry by women. In addition the early 1970s marks the maximum rate

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rapid productivity growth actually achieved between 2001:Q2 and 2003:Q2.

of growth of the working-age population, and many labor-force entrants were teenagers in part-time jobs. After hovering around zero from 19888 to 1998, the trend declined into negative territory over the past decade, and this helps to explain why trend GDP growth has been so much slower than productivity growth.

The log ratio of the level of hours per employee to trend is shown in the bottom frame of Figure 6 and displays a more consistent procyclical pattern than productivity. The ratio reached its largest positive values during the economic expansions of the late 1960s and late 1990s, and its longest string of negative values in the late 1970s and early 1980s. Much of the slow growth in actual hours evident in the top frame of Figure 6 could be interpreted as mean reversion of the actual-trend level ratio back toward normal from its unusual cyclical peak of 1999-2000.

The single exception to using the Kalman trend technique involves the employment rate. We want our trend to reflect what we mean by changes in potential output, the amount that the economy can produce when operating at the natural rate of unemployment or NAIRU. The NAIRU changes slowly in response to structural changes in labor-market behavior and does not suddenly jump up or down in response to business booms or slumps. The counterpart of the NAIRU in our analysis is the trend employment rate, which is simply unity minus the NAIRU. This should evolve independently of business cycles, and no smoothing parameter for the Kalman filter achieves the desired degree of stability. The desired stable behavior of the trend employment rate is achieved when the TTB method is used, yielding the changes in the trend employment rate illustrated in Table 2 and the top frame of Figure 7.[14] The

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14. The TTB method yields a trend employment rate series that is very close to the alternative of using a NAIRU series like that estimated by Gordon (2008).

TTB trend is almost flat (the unemployment rates in each benchmark quarter are listed in the first table in the data appendix); it exhibits a slight decline in the trend employment ratio between 1955 and 1978 that is the counterpart of the gradual upcreep of the NAIRU in that era, then a stable trend employment ratio of 94.1 percent through 1987 (the counterpart of a 5.9 percent NAIRU), and then a gradual increase to 95 percent by 1995, the counterpart of the decline of the NAIRU in the 1990s that was evident in the early analyses of the time-varying NAIRU and has been ratified since then.[15]

The bottom frame of Figure 7 displayes the log ratio of the actual employment rate to its TTB trend value. This series is simply the inverse of the actual unemployment rate with a slight adjustment to detrend part of the bulge in the unemployment rate in the 1970s and early 1980s. A notable feature of this series is the long lag of the employment ratio, which remains in negative territory for several years after the trough date of the NBER-defined business cycle.

Actual and trend values of growth in the labor-force participation rate (LFPR) are displayed in the top frame of Figure 7. The long period of a positive trend in LFPR growth extends from 1965 to 1995 and corresponds roughly, but not entirely, to the period of a negative trend in growth of hours per employee as illustrated in the top frame of Figure 5. The peak in trend LFPR growth was reached in 1978, six years after the trough in trend growth of hours per employee, and trend LFPR growth continued for about five years after the trend decline in hours per employee came to an end in 1990. The period of slight negative growth in the LFPR trend earlier in this decade

15. Early estimates of the time-varying NAIRU appeared in the same issue of the *Journal of Economic Perspectives,* see Staiger-Stock-Watson (1997) and Gordon (1997). Updated estimates

was the first sign of a negative trend since the early 1960s.

The log ratio of the actual LFPR to its trend is shown in the bottom frame of Figure 7. The procyclical pattern is not as uniform as that for hours per employee or the employment rate. While the LFPR ratio was solidly positive in the late 1970s, late 1980s, and late 1990s, it was negative during the business expansions of the 1960s and early 1970s. Also, with the exception of 1975, there is little tendency of the LFPR ratio to exhibit a sharp decline during and after a recession, as does the employment rate.

The eight-quarter actual and Kalman trend growth rates of the working-age population are shown in Figure 8. Peak trend population growth occurred in 1972-73, roughly 16 years after the peak number of births reached in 1956-57. Then trend growth declined until 1990, after which it has been remarkably steady at a rate of about 1.25 percent per year. Standard predictions of a decline in population growth to below one percent per year have been premature, largely because immigration (both legal and illegal) has exceeded predictions made five or ten years ago. We do not plot the log level ratio of actual population to trend, as this would have no interpretation relevant to business-cycle behavior.

When the Kalman trend growth rates of the five components of the output identity are added together, we get the "sum-of-components" trend growth rate of real GDP shown in the top frame of Figure 9. Separately we have calculated a Kalman trend directly from the real GDP data, and this lies on top of the sum-of-components series so that no difference between them is visible. Note in comparison with the top frame of Figure 4 that the historical evolution of the real GDP trend is much smoother

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of the NAIRU are presented by Gordon (2008).

than the productivity trend. As shown in Table 3 and Figure 2, labor-market variables have offset some of the movements in the productivity trend, leading to smaller changes in the real GDP trend. This raises an interesting question as to whether there is a long-term tradeoff between productivity growth and hours growth, an interesting subject that is beyond the scope of the current paper. However, part of the smooth appearance of the trend in Figure 9 compared to the productivity trend in Figure 4 is an optical illusion due to the greater span of the vertical scale in Figure 9, due to much larger cyclical variations in output growth than in productivity growth.

The bottom frame of Figure 9 shows the log level ratio of actual to trend real GDP. The output ratio corresponds closely to the employment ratio in the bottom frame of Figure 6 but exhibits a greater variance. Also, the employment ratio tends to lag the output ratio, as we would expect if employment responds with a lag to changes in output. We now turn to a study of a modern version of Okun's Law, a decomposition of cyclical output changes into the separate contributions of the components of the output identity.

3. A New Decomposition of Okun's Law

3.1 An Examination of Ratios of Actual to Trend

Before turning to regression analysis that takes account of lagged reactions, we can employ a crude but revealing technique to determine the contribution of the components of the output identity to cyclical fluctuations in output. For each of the periods between benchmark quarters we determine the quarter when the log level ratio of actual to trend real GDP reached its highest value, and the quarter when that ratio was the lowest. The dates of these peak and trough quarters are listed in Table 4 along with the log ratios of actual to trend in those quarters for real GDP and the five right-side components of the output identity (equation 3 above).

Does the actual/trend ratio for the employment rate equal roughly one-third of the actual/trend ratio for real GDP, as Okun's original (1962) analysis would suggest? The third section of Table 4 shows the average values of the ratios at peaks and at troughs. For peaks the average value of the actual/trend ratio for the employment rate is 0.99 percent, which is 28 percent of the 3.53 peak actual/trend ratio for real GDP. The response of the employment rate in troughs is a much greater 50 percent, the

-2.06 percent ratio for the employment rate divided by the 4.11 percent ratio for real GDP. For the average of peaks and troughs the employment response of 1.52 percent is 40 percent of the real GDP response of 3.82 percent. The larger relative employment response of in troughs relative to peaks may reflect shorter adjustment lags in short-lived recessions than in longer-lasting expansions.

Which other components of the output identity are most important in accounting for output fluctuations, besides the 50 percent average contribution of the employment ratio? The bottom line shows that output per hour has a response of 31 percent, hours per employee of 25 percent, and the LFPR of only 5 percent. These averages disguise varying contributions in particular episodes. In about half of the peak and trough episodes, the LFPR contribution has the wrong sign, helping to account for its small response in the overall average. In the last 1989 peak episode, the productivity contribution has the wrong sign, as also occurs in the trough episodes of 1975 and 2003.

3.2 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 54 years of history. This will be the perspective then for assessing unusual aspects of the expansion of the late 1990s, the period of recession and recovery after the year 2000, and the prelude to the recession that appears to have started sometime in late 2007 or early 2008.

The point of departure for the dynamic specification used here is Sims (1974) and my earlier work on cyclical productivity issues (Gordon, 1979, 1993, 2003). We examine the dynamic response to output changes of each of the five components of the right-hand side of the log version of the output identity (equation 3 above). Each of these dependent variables is expressed as the first difference of the log of the variable, say x, minus the log of its trend x^*, and in the notation introduced above, this is $\Delta x'_t$. This is regressed on a series of lagged dependent variable terms and on the first differences of deviations of the log of real GDP from its trend ($\Delta y'_t$). The output deviation variable in principle can enter with leads, the current value, and lags. The lags can be interpereted as reflecting adjustment costs and, for such components as the employment rate and the LFPR, delays in hiring and firing. The use of leads was introduced by Sims 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 alternatively as a regression with hours lagging behind output, as in Gordon (1993), or as 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.[16] 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.[17] 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, the employment rate, or the other components of the identity. In summary, our specification explains the rate of change of a deviation from trend by the rates of change of the deviation from trend of the lagged dependent variable and of output, and the *level* of the deviation of the dependent variable from its own trend.

3.3 The End-of-Expansion Effect

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

17. 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, 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.[18] 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. Although originally developed in my previous studies of cyclical productivity behavior, the same phenomenon should show up in equations for some or all of the labor-market variables in the output identity. 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. It is particularly interesting to reassess the EOE effect now, in light of the apparent change in cyclical behavior of productivity since the mid-1980s evident above in the bottom frame of Figure 4 and also in Table 4.

The EOE effect is introduced into the dynamic specification through a set of seven dummy variables, corresponding to seven end-of-expansion episodes since 1955. 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

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18. Gordon (1979, 1993).

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 output reaches its highest level relative to trend or potential output. 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 is determined by examining residuals in equations that omit the dummies entirely. The amplitude of the EOE effect is allowed to differ across business cycles by allowing the dummy variable for each cycle to have its own coefficient; subsequently we test whether these coefficients can be pooled into a single coefficient.[19]

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

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

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

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

dummies. The γ_k coefficients are interpreted according to which dependent variable is being explained; labor-market variables like hours of labor input in a productivity equation, 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.

3.4 Estimation for Components of the Output Identity

Our results in estimating equation (7) are presented in Table 5. Regressions for population are omitted because there is no reason to expect the working-age population to have a cyclical response to changes in output. Table 5 has five columns corresponding to the five alternative dependent variables, each expressed as in equation (7) as the first difference of a log ratio of the actual value to the Kalman trend value. The coefficients are presented in rows corresponding to their order in equation (7), and the bottom of the table provides alternative estimates of the γ_k coefficient for the EOE effect that imposes the constraint that all these coefficients are equal.

Let us first examine the employment-rate results in the second column of Table 5. The sum of coefficients on the output deviation is 0.51, somewhat above the 0.40 response (that ignores lags) in the bottom row of Table 4. The error-correction term has the expected negative sign, indicating that a high value of the lagged ratio of the employment rate to its trend tends to push down subsequently on the growth rate of the employment rate relative to its trend. All of the EOE coefficients (except 1958-62)

1980s are identical to the "early" EOE dummy discussed by Gordon (1993, p. 300).

have the expected positive sign and most are highly significant, indicating that the employment rate was pushed up by overhiring in the late stages of expansions in 1955-57, 1968-69, 1973-74, 1978-79, 1988-90, and 2000-01.

Turning now to the first and third columns of Table 5, there is a strong positive response of hours per employee to cyclical output movements but no significant response of the LFPR. All the error-correction terms in these columns are significant with the expected negative sign. Almost none of the EOE coefficients are significant, indicating that the entire EOE effect occurs through the employment rate, not through hours per employee or the LFPR. However, in the bottom section of Table 5 we report the results of alternative equations that enter all the EOE dummies as a single variable, rather than seven separate variables, and this coefficients is significantly positive for the LFPR in column 3.

One of the components of the output identity is total-economy output per hour. We choose to supplement the equation explaining changes in the deviation of productivity from trend with an alternative equation which explains the quarterly change in the log ratio of actual to trend aggregate hours of work. Why do we need an equation for aggregate hours to supplement that for productivity? A familiar aspect of productivity dynamics is that aggregate hours of work responds 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 it prevents us from estimating the equation or providing residuals that cover a period of great interest, namely the final four quarters of the sample period that ends in 2008:2. In order to estimate residuals that can be discussed in the context of the 2007-2008 period, our basic results for productivity in column 4 of Table 5 use as the dependent variable the first difference in the log ratio of actual to trend of aggregate hours.

The hours results change remarkably little from previous estimates of this equation in previous papers (Gordon 1979, 1993, 2003). However for the first time in this paper we have switched from hours in the NFPB sector to hours in the total economy, and this demotes three of the EOE dummies (for 1958-62, 1978-83, and 2000-03) to statistical insignficance, albeit they have the correct positive coefficients. We cannot reject the hypothesis that the EOE dummy coefficients are an identical 1.89, implying that the EOE effect raises aggregate hours cumulatively by 1.89 percentage points during the EOE period, followed by an unwinding of this effect, with the opposite impact on productivity growth. Subsequently we turn to an interpretation of the coefficient on output deviations in the hours equation.

The fifth column of Table 5 switches the dependent (and lagged dependent) variable from hours to productivity itself. The four lags on the output deviation are replaced with four leads, and the sample period ends one year early (in 2007:2) to provide the required data for the leads. The productivity version has similar implications to the hours version, and the variant shown at the bottom of column five implies that the EOE coefficients are not statistically different from one another, and that on average the EOE effect creates a cumulative reduction in output per hour of -2.33 percentage points in the EOE period, followed by an unwinding of this effect.

How should the coefficients on the output deviation be interpreted between the hours and productivity versions? The short-run response of hours to output is 1.09 in column 4, and this translates into a long-run response of 0.77 when divided through by unity minus the sum of coefficients on the lagged dependent variable. This, in turn becomes a response of productivity change to output change of 1-0.77, or 0.23. The same arithmetic implies an almost identical long-term response in column 5 of 0.20.

How do the long-run responses of the components of the output identity to cyclical movements in output compare between Table 5 and the crude results of Table 4? These results are brought together in Table 6, which reports the share of any change in the output deviation contributed by each of the components of the output identity. The shares are also illustrated by bar charts in Figure 10. The first column copies the shares of total responses based on peak and trough quarters from the bottom row of Table 4. These are compared with the shares of long-run regression responses from the components of the output identity in Table 5, the the productivity response based on column 5 rather than column 4. In each case the long-run regression responses are calculated as the sum of the coefficients on the output ratio divided by unity minus the sum of coefficients on the lagged dependent variable. The response shares are somewhat different between the crude peak and trough responses in the first column and the more sophisticated regression responses in the second column. The productivity shares are 31 and 20 percent, respectively, while the hours per employee shares are 25 and 30 percent, and the employment rate shares are 40 and 39 percent. The columns agree that the LFPR effect is unimportant.

4. Interpreting Trends and Cycles in Productivity Growth, 1985-2008

We now have the tools to determine how much of productivity growth since the mid 1980s was predicted by the equation and how much emerges in the unexplained residual of the equation. In Figure 11 the solid black line plots a four-quarter moving average of the residual from the hours equation (Table 5, column 4), with its sign changed to convert it from an hours residual to a productivity residual. That is, the equation cannot explain why hours changes were so low (i.e., so negative) in 1990-93 and 2000-2004, and that translates into its inability to explain why productivity changes were so rapid.

We note that the productivity residual was somewhat smaller during the jobless recovery of 1991-92 than in 2001-04. The counterpart of the 1991-92 bulge in the productivity residual was an unexplained decline in the employment rate, so the high unemployment rate that peaked at 7.7 percent in mid-1992 is at least partly unexplained by the employment rate equation. The fact that the productivity residual was negative during almost the entire period between 1993 and late 2000, then persistently positive between 2001 and 2005, and then negative in 2005-07 is intriguing, and it is consistent with the intangible capital hypothesis of Yang and Brynjolfsson that we discuss below. We also need to notice the revival from a negative to a positive residual in 2007-08 and to ask whether this was permanent or temporary.

The dashed grey line in Figure 11 represents the residuals of the productivity equation (Table 5, column 5) as contrasted to the hours equation (Table 5, column 4). Since these two equations are based on the same data and a symmetric specification, it is not surprising that the residuals are almost identical. The productivity equation residual is a larger negative number in 1994-95, a smaller negative number in 1998-2000, and a larger positive number in 2000-2004. Overall the smaller plotted residuals of the hours equation suggest that it is a preferable specification to capture the cyclical behavior of productivity over the last two decades.

4.1 The Early-Recovery Productivity Growth "Bubble"

Productivity growth was extremely rapid in the initial quarters after the trough of real GDP in 2001. But this is nothing new. A similar period of rapid productivity growth has been observed in the first few quarters of almost every postwar recovery, and in every case it has been followed by a return of productivity growth back to trend growth or even below trend growth in the subsequent phase of the expansion. This "early-recovery productivity growth bubble" is consistent with the EOE effect, for in the first few quarters of the recovery profits are still squeezed, and business firms are aggressively attempting to cut costs by reducing labor input.

Table 7 summarizes this little-noted cyclical phenomenon. The top panel reports, in the first column, the average growth rate of actual productivity relative to trend in the first four recovery quarters after each NBER trough quarter for real GDP in seven cyclical recoveries going back to 1958. The bottom panel reports the same measure for the eight quarters following the first four quarters of the recovery. At the bottom of each panel is the average over the seven cyclical episodes. The remaining columns report averages over each interval of the predicted value from the productivity regression in table 5, column 5; the statistical contribution of the EOE dummy variables to that prediction; the prediction minus the EOE contribution; and finally the statistical residual.

The bottom line in each panel of table 7 shows the averages over the seven episodes in that panel and reveals a striking difference between the first four, "bubble" quarters of the average recovery and the following eight quarters. Productivity grows, on average, 1.59 percentage points a year faster than trend in the first four quarters but 0.11 percentage point *slower* than trend over the next eight quarters. This difference is almost entirely captured by our dynamic model of cyclical productivity behavior, with an average residual of only 0.27 percentage point in the first four quarters and an even smaller 0.23 percentage point in the subsequent eight quarters. The predicted change in the first four quarters is 1.31 percentage point compared with -0.34 percentage point in the subsequent eight quarters.

How does the model explain the early-recovery bubble? As shown for the average of the first four quarters, about two-thirds of the predicted 1.31-percentage-point early-recovery productivity growth is attributable to the EOE reversal effect and the remaining one-third to the other variables, mainly the role of unusually rapid output growth in the first four quarters in stimulating rapid productivity growth. In the subsequent eight quarters, the EOE effect (which by then equals zero in most episodes) diminishes to zero while the remaining variables, slower output growth and the error correction term, both hold down productivity growth relative to trend.

This history of cyclical recoveries puts the 2001-03 productivity performance into perspective. Relative to trend, the early take-off of actual productivity growth in the first four quarters after the GDP trough in 2001:Q4 was not unusual, although it was somewhat smaller than the average in the previous six episodes. The productivity equation can explain most of this growth (0.81 out of 1.06 points) while the residual explains the rest (0.25 points). The estimated EOE effect was smaller than average, and the other variables predicted a small 0.14 point growth above trend.

The post-2001 episode is distinguished by the subsequent 8 quarters, when the actual productivity growth deviation was positive, with a relatively large 0.93 point residual relative to the -0.29 point predicted value. Thus if anything was unusual about 2001-04 was not only that trend growth was so high but that actual growth remained above trend during the eight quarters after the usual initial four-quarter bubble period. Combining these effects, the positive growth deviation of productivity in the twelve quarters of 2001-04 taken together were sufficient to pull up the actual *level* of productivity 2.34 points relative to its rapidly growing trend, as was shown above in the top frame of Figure 4.

4.2 Labor Market Counterparts of Rapid Productivity Growth

The counterpart of rapid productivity growth in 2001-04 was weak growth of several of the components of the output identity originally introduced as equations (1) and (3) above. Table 8 carries out this task for four subperiods: early 1987 to late 1995, late 1995 to mid-2000, mid-2000 to mid-2003, and from then until the final data point in 2008:2. All elements of the identity are listed in the same order as in Table 2, and the final column sums the components of the output identity.

The first panel for 1987-95 suggests that actual was close to trend growth for all variables, and that the shortfall of real GDP growth below trend was roughly equal to the shortfall of productivity growth below trend. The second panel for 1995-2000 reveals an annual growth of actual real GDP of 1.44 percentage points above trend, as compared to a surplus of just 0.52 for productivity. The remaining rapid growth of actual real GDP is explained (in the third row of the second panel) by positive growth rates of hours per employee, and the employment rate, as we would expect during a business cycle expansion, but this procyclical response did not include the LFPR.

The unusual features of the 2000-03 period are set out in the third panel. While real GDP grew at an annual rate fully 1.56 percent slower than trend, productivity actually grew 0.32 points *faster* than trend. How does the output identity explain this discrepancy? There were unusual declines in two components of the output identity that were more rapid than the underlying equations of Table 5 can explain – these are hours per employee and the employment rate.

The period after 2003:2 was characterized by both real GDP and total-economy productivity growing roughly at trend, with relatively small residuals in all equations. The actual-trend ratio recovered for hours per employee and the employment rate, but declined further for the LFPR.

5. Explanations of Rapid Productivity Growth in 2000-04 and the Subsequent Slowdown

We now turn to an explanation of productivity growth behavior since 1995, an important prerequisite for any attempt to project future productivity growth. Beginning at the peak of the economic expansion of the 1990s a series of papers used growth accounting techniques to isolate the role of growth in information and communication technology (ICT) in the post-1995 productivity growth revival (see Jorgenson and Stiroh (2000), Jorgenson, Ho, and Stiroh (2008), Oliner and Sichyel (2000, 2002), and Oliner, Sichel, and Stiroh (2007). There is a general consensus now that accelerated growth of ICT investment explains most of the productivity growth revival during 1995-2000. But a significant problem emerged after 2000 when ICT investment collapsed as a share of GDP while productivity growth accelerated further rather than decelerating. The growth accounting verdict is that ICT investment makes a *negative* contribution to productivity growth in 2000-04.

Thus we must look elsewhere to find an explanation of the 2000-04 upsurge. I have previously suggested (2003, pp. 247-56) that a key role was played by "savage corporate cost cutting" which is complementary to the second hypothesis of intangible capital developed separately by Basu *et al.* (2004) and by Yang and Brynjolfsson (2001). The first of these holds that an unusual degree of downward pressure on profits led to unusually aggressive cost cutting by firms. The second helps to explain how firms were able to produce so much output after reducing their labor forces by so much. The intangible capital hypothesis is a necessary complement to the savage cost-cutting hypothesis.

5.1 Cost Cutting and Intangible Capital

Both productivity and profits are leading indicators. Because of lags in hiring and firing, productivity growth leads output, surging when output is growing rapidly and then slowing down as labor input catches up to output in the typical expansion. Late in the expansion, output growth slows, but overly optimistic expectations may lead firms to continue adding to labor input during this late-expansion slow-growth period, thus reducing productivity growth to a smaller positive or even a negative rate. This tendency to overhire in the last stages of the expansion goes beyond the simple dynamics of lagged coefficients on output changes, and this is what is captured by the EOE dummy variables discussed above in the context of Table 5.

Profits are related to productivity through the income shares of labor and capital. The cyclical expansion of the 1990s exhibited behavior typical of corporate profits as measured in the national income and product accounts (NIPA), which registered a near doubling of nominal profits between 1992 and 1997 followed by a decline between mid-1997 and early 2000, a slight further decline into 2001, and then a recovery in 2002 and beyond.

William Nordhaus (2002) contrasts the behavior of NIPA profits with that of S&P reported profits, which show a very different timing pattern, growing by 70 percent between early 1998 and early 2000 and then declining by more than half between early 2000 and early 2001.[i] He 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." A further unusual aspect of 2001-02 was the extremely low ratio of S&P reported earnings to S&P operating earnings, primarily due to the one-time charges that firms take to correct for previous business or accounting mistakes. Overall, Nordhaus estimates that reported S&P earnings for 2001 were held down by about 30 percent by a combination of normal cyclical and extraordinary accounting impacts.

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

A plausible interpretation of the unusual upsurge of productivity growth in 2002-03, then, is that it was the counterpart of an unusual degree of pressure for corporate cost cutting, in turn caused by the role of accounting scandals and corporate write-offs that led to the unusual trajectory of reported S&P profits relative to NIPA profits. This interpretation is supported by the cross-industry regressions of Oliner, Sichel, and Stiroh (2007, pp. 121-27) who show that during the period 1997-2001 there is a strong positive correlation between the change in profits and growth in hours of work and a strong negative correlation between the change in profits and the growth in output per hour.

This chain of causation from the profits "debacle" to the 2002-03 productivity surge seems plausible as the leading explanation of the unusual productivity behavior documented in previous sections. But it raises a central question: How were corporate managers able to maintain output growth while cutting costs so savagely? Why didn't the massive layoffs cause output to fall, as it would have if productivity growth had stagnated? This brings us to the central role of ICT investment in the post-1995 productivity growth revival and to the puzzle of explaining how productivity growth surged after 2000 even as ICT investment growth was collapsing along with corporate profits and the stock market.

The intangible capital hypothesis is intriguing, because it offers a possible explanation of the puzzling second acceleration of productivity growth after 2000, in the wake of the collapse in the ICT investment boom. Intangible capital is complementary to ICT and contributes to measured output. However, net intangible investment, which builds intangible capital, leads to an understatement of current-period output, because it is not counted in measured output even though the factor inputs required to produce it are counted. When the share of intangible investment is constant, this means that the amount of output credited to other, tangible factors and to total factor productivity is overstated by the percentage of output devoted to intangible investment, but there is little effect on growth rates or on the allocation of growth between factor inputs and TFP. However, when the share of output devoted to intangible investment is changing, the effect on measured productivity and its growth rate can be dramatic. A 1-percentage-point increase in the share of output devoted to intangible investment, say, from 3 to 4 percent, reduces measured output relative to total output almost point for point. If this increase takes one year, measured output growth is biased downward by 1 percentage point for one year; if it takes five years, the growth rate bias is one-fifth as large, or 0.2 percent a year.

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

At least one obvious question is raised by the Y-B analysis, and this is why intangible capital did not produce a productivity growth upsurge during previous periods when the share of spending on computer hardware was growing rapidly, particularly 1972-87, the interval that led Robert Solow to utter his famous quip that later became known as the Solow "computer paradox," that "we see the computer age everywhere except in the productivity statistics". One possible answer is that the 1972-87 increase in the share of computer spending in GDP was slow and gradual, while the post-1995 upsurge was sudden and hence created a greater imbalance between measured and unmeasured ICT investment. A second possibility is that the nature of ICT innovation in the 1990s was more disruptive and required a more substantial investment in intangible capital than did earlier waves of computer innovation.

5.2 Productivity Growth, 2004-08

The most straightforward explanation of the sharp slowdown in actual productivity growth after 2004 was that the delayed impact of the ICT investment boom of the late 1990s, working through the intangible capital hypothesis, had run its course. Further, profits rebounded and in 2006-07 reached record levels expressed as a share of GDP, eliminating the previous pressure for cost cutting. The main source of the 1995-2000 productivity revival had disappeared, as the share of ICT investment in GDP had crashed in 2000-02 and then remained at a plateau during 2002-08 roughly equal to its average of 1985-95.

In this pessimistic interpretation, nothing remained of the three one-shot sources of the post-1995 productivity growth revival. The initial source of the revival, a sharp jump in the GDP share of ICT investment, had disappeared. Savage cost cutting during and after the 2001 recession was inherently temporary and vanished after profits began their steep ascent, although the financial crisis of 2007-09 may be in the process of bringing with it another cost-cutting episode. The intangible capital hypothesis can best be thought of as a sophisticated version of the “delay” hypothesis that the fruits of important innovations can be spread out over many years. While it is plausible that it took three to five years for firms and workers to learn how to use the ICT equipment invented during the late 1990s, it is hard to believe that these delayed benefits remain today.

As shown in Figure 4, by 2007-08 the Kalman trend for total-economy output per hour had declined to 1.6 percent, lower than in any year since 1997 but still higher than the 1.3 percent average trend that occurred between 1978 and 1995. In the next section we will assess the implications of the recent record for projections of future growth in productivity and potential real GDP.

6. Projections for 2008-28

The third goal of this paper is to forecast growth in potential real GDP over the next two decades through 2028. This requires that we provide forecasts not only for total-economy productivity but also for the other components of the output identity.

6.1 Future Productivity Growth

What growth rate of productivity should be projected out over the next 20 years? A natural place to start would be the actual growth rate over the previous 20 years. The column of Table 9 shows that growth in total-economy productivity averaged 1.70 percent per year between 1987:2 and 2008:2. This combines a period of slower growth of 1.31 percent per year between 1987:2 and 1997:2, much faster growth of 2.43 percent per year between 1997:2 and 2004:2, and a return to slow growth of 1.34 percent per year between 2004:2 and 2008:2. What weight should be given to these different intervals in making forecasts?

Slow growth between 1987 and 1997 remains a puzzle. By 1987 the economy had moved past the dislocations caused by oil shocks, high inflation and unemployment, and high and volatile interest rates. Much attention has been devoted to explaining the macroeconomic "Great Moderation" that began in the mid-1980s, with shorter recessions, longer expansions, and a much reduced variance of real GDP changes. The 1987-97 period remains the core interval to which the Solow productivity puzzle applies. But it happened, and we must pay attention to it.

There are several reasons to believe that the rapid productivity growth recorded during 1997-2004 was temporary and unsustainable. The share of ICT investment in GDP responded to a major game-changing industrial revolution, the marriage of the computer and communications in the form of the internet and world wide web. But the dot.com boom and bust has not been followed by a recovery of the share of ICT investment in GDP. This suggests that the most fruitful applications of the ICT industrial revolution have already been implemented.

Optimists like Dale Jorgenson have been quoted (in *Time* magazine) as suggesting that there is still ample room for productivity growth to occur in sectors that have been slow to implement information technology, namely medical care, universities, and the government. While individual doctors have been reluctant to adopt ICT in the form of computerized medical records, adoption has been quick in group health organizations employing more than 50 doctors. I obtain medical services from a medium-sized medical provider called Northshore University Healthcare System, which includes three hospitals and employees roughly 500 doctors. This group was early to computerize all its operations, won a national prize for its implementation in 2003, and has been paperless ever since. But computers cannot and do not replace hospital nurses and assistants, and the tedious tasks of patient care and management.

It is more obvious that the low-hanging fruit of computerization has already been plucked by universities. Library card catalogues have been replaced by banks of computers and flat-screen monitors. Professors have new forms of two-way communication with their students and can show colorful Powerpoint illustrations that expand and amplify their textbook lecture material. Research assistants on papers like this one can provide all the required tables and charts, with no need ever to see the professor in person, relying on software packages and instant web access to data. But all this does not change the inexorable productivity arithmetic of universities – the only way to raise the productivity of a professor is to raise the student-teacher ratio. Yes secretaries are gone but have been replaced by legions of IT specialists needed to maintain and install the vast numbers of computers available in a typical university for faculty, staff, and students.

Just as the "low-hanging fruit" explanation predicts that the share of ICT investment in GDP will not return over the next 20 years to the levels of the late 1990s, so the other one-shot hypotheses of savage cost-cutting and intangible capital are unlikely to recur as well. In particular, the delay aspect of intangible capital requires that there be "something to be delayed." Without a repeat of the late 1990s ICT investment boom, there will be no burst of new equipment about which firms and workers have to learn in a lagged process. Miniaturization of computer equipment continues to occur, and functions are gradually migrating from desktop computers to laptop computers to smart phones and other small devices, but these are a second-order improvement in comparison to the invention of the internet itself.

We should not forget the work of Jorgenson, Ho, and Stiroh (2008) that emphasizes the plateau reached by U. S. educational attainment. Their calculations show that the contribution of changes in labor quality to TFP growth will taper down gradually to zero over the next two decades from its average over 1973-2003. This by itself would result in a reduction of trend productivity growth by 0.19 percent 2001-21 is compared with 1995-2001.

Overall, I expect productivity growth over the next twenty years to be closer to the 1.3 percent annual rate of 1987-97 and 2004-08 than to the elevated 2.4 percent rate of 1997-2004. An optimistic view, in light of the one-time nature of the sources of the 1997-2004 revival, would be that productivity growth in 2008-28 would equal the 1987-2008 average of 1.7 percent. The plateau of educational attainment leads me to nudge that number down from 1.7 to 1.6 percent, as shown in the bottom section of Table 9.

6.2 Labor Market Variables

In this version of the paper I base my projection of 2008-28 growth in the working-age population on the BLS employment and population projections available on the BLS web site for 2006-16. They project that the working-age population will grow at 0.9 percent per year and that the LFPR will decline at 0.1 percent per year, mainly due to the effects of baby boom retirements in pushing a greater share of the population into low-participation retirement years. Separately, I project that hours per employee will decline at 0.05 percent per year, half the rate of decline experienced in 1987-2008, largely as a result in the turnaround of the LFPR from growth to decline.

7. Conclusion

The conclusions of the third task of this paper are summarized in the right-hand column of Table 9. Taken together the projections of the components of the output identity imply a slowdown in potential GDP growth from 2.86 percent in 1987-2008 to 2.35 percent in 2008-28. Real GDP per capita will grow at 1.45 percent in the next two decades as compared to 1.71 percent in the past two decades. The next two decades will see, as summarized in the title of this paper, "The Slowest Potential Output Growth in U. S. History."

There is obviously a range of uncertainty to these forecasts. At the moment population projections are particularly uncertain due to the murky political status of illegal immigration. Clearly the weight of optimistic and pessimistic arguments for faster or slower future productivity growth will vary across observers. However, a framework such as Table 9 limits the room for argument and casts serious doubt on any projection that claims that the U. S. can grow at 3 percent or faster over the next two decades.

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Table 1. Annual Growth Rate of Real GDP between Benchmark Years and Quarters, 1875-2008:2

Period	
Growth between Benchmark Years	
1875-1891	3.96
1891-1901	3.73
1901-1913	3.81
1913-1928	2.88
1928-1950	5.04
1950-1954	3.65
Growth Between Selected Quarters	
1954:1-1964:3	3.74
1964:3-1972:1	3.72
1972:1-1977:3	3.39
1977:3-1987:3	2.99
1987:3-1997:2	2.96
1997:2-2007:2	2.82
Memo Items	
1875-2008:2	3.42
2007:2-2008:2	2.03

Sources:
1875-1929. Robert J. Gordon, *Macroeconomics,* 11th edition, Table A-1.
1929-2008. NIPA, www.bea.gov

Table 2. Annual Percent Growth Rate of Real GDP and Components of the Output Identity, 1954:1 - 2008:2

Period	Real GDP	Five Output Identity Components				
		Output per Hour[a]	Hours per Employee[a]	Employment Rate	LFPR	Working-age Population
Between benchmark quarters						
1954:1-1964:3	3.74	2.85	-0.49	0.06	-0.12	1.44
1964:3-1972:1	3.72	2.18	-0.59	-0.11	0.42	1.81
1972:1-1977:3	3.39	1.85	-0.80	-0.19	0.54	1.97
1977:3-1987:3	2.99	1.22	-0.21	0.09	0.47	1.41
1987:3-1997:2	2.96	1.28	0.28	0.10	0.21	1.09
1997:2-2007:2	2.82	2.04	-0.43	0.04	-0.08	1.24
Final quarters after last benchmark						
2007:2-2008:2	2.03	2.21	-0.04	-0.98	0.03	0.82

Source: See appendix A

a. Data are for the total economy, not the nonfarm private business sector.

Table 3. Annual Percent Growth Rate of Real GDP and Components of the Output Identity, Alternative Decomposition, 1954:1 - 2008:2

Period	**Real GDP per capita**[a]	**Output per hour**[b]	**Difference: Attributable to Labor Market Variables**[c]
Between benchmark quarters			
1954:1-1964:3	2.30	2.85	-0.55
1964:3-1972:1	1.91	2.18	-0.28
1972:1-1977:3	1.41	1.85	-0.44
1977:3-1987:3	1.58	1.22	0.35
1987:3-1997:2	1.87	1.28	0.58
1997:2-2007:2	1.58	2.04	-0.46
Final quarters after last benchmark			
2007:2-2008:2	1.21	2.21	-1.00

Sources: See appendix A.

a. Per member of the working-age population.

b. Data are for the total economy, not the nonfarm private busness sector

c. Difference between the first and second data columns, the contribution of hours per employee, the employment rate, and LFPR.

Table 4. Peak and Trough Values of Annual Growth Rate of Ratio of Actual to Trend, Selected Quarters, 1954:1 - 2008:2

Quarter	Real GDP	Output per hour[a]	Hours per employee[a]	Employment rate	LFPR	Working-age population
Peak quarters						
1955:3	5.48	2.04	1.33	1.72	0.96	-0.56
1966:1	5.97	3.26	2.25	1.80	-1.02	-0.32
1973:2	4.48	2.80	0.07	1.41	-0.02	0.23
1978:4	1.89	0.21	-0.07	0.01	1.06	0.68
1989:1	1.36	-0.86	0.45	0.96	0.57	0.24
2000:2	4.15	0.27	1.76	1.12	1.01	-0.01
2007:3	1.38	1.32	0.14	-0.10	-0.02	0.04
Trough quarters						
1961:1	-4.93	-2.68	-1.21	-1.55	0.91	-0.39
1970:4	-1.08	-0.33	-0.17	-0.03	-0.22	-0.33
1975:2	-4.37	0.15	-1.84	-2.41	-0.67	0.41
1982:4	-9.88	-3.00	-1.86	-5.66	0.02	0.62
1991:4	-3.52	-0.92	-0.74	-1.69	-0.13	-0.04
2003:1	-0.91	0.52	-0.59	-1.02	0.04	0.14
Average at peaks	3.53	1.29	0.85	0.99	0.36	0.04
Average at troughs	-4.11	-1.05	-1.07	-2.06	-0.01	0.07
Average, peaks and troughs (absolute value)	3.82	1.17	0.96	1.52	0.18	-0.01
Average Absolute Value, Share of Real GDP in Percent	100.0	30.6	25.1	39.9	4.8	-0.3

Source: Author's calculations, using trend values from Table 2

Table 5. Regressions Explaining Cyclical Deviations from Trend in Components of the Output Identity, 1955:1 - 2008:2[a]

	Dependent variable				
Independent Variable	Hours per employee[b]	Employ-ment rate	LFPR	Total Hours[b]	Output per hour[b]
Lagged dependent variable[c]	-0.89 **	-0.32 *	-0.26	-0.42 **	-0.67 **
Output deviation from trend[d]	0.57 **	0.51 **	0.03	1.09 **	0.33 **
Error correction term[e]	-0.30 *	-0.45 **	-1.03 **	-0.25 **	-0.12
End-of-expansion (EOE) dummy variables[f]					
1955-58	0.29	1.38 **	0.95	2.26 **	-3.10 **
1958-62	-0.35	0.26	1.08	1.09	-2.03 *
1968-71	1.72 *	1.26 **	1.16	2.86 **	-3.23 **
1973-76	0.43	1.83 **	0.97	2.60 **	-3.16 **
1978-83	-0.12	1.42 **	0.37	0.99	-1.41
1988-92	1.42	1.39 **	0.97	2.93 **	-2.93 **
2000-03	-0.52	0.85 *	0.37	1.29	-1.17
Summary Statistics:					
Adjusted R^2	0.29	0.62	0.22	0.64	0.61
Standard error of estimate	1.80	0.93	1.35	1.66	1.65
Sum of squared residuals	629.19	166.44	352.47	536	514
***Addendum:* all EOEs are constrained to be equal**					
EOE	0.35	1.12 **	0.83 **	1.89 **	-2.33 **
Standard error of estimate	1.80	0.93	1.33	1.67	1.66
Sum of squared residuals	648.50	172.45	355.56	555	537

Source : Author's regresions using equation 7 in the text and data from cources 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

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.

Table 6. Responses to Output Changes of Output Identity Components, 1954:4-2008:2

Component		
Output per Hour	30.6	19.8
Hours per Employee	25.1	30.2
Employment Rate	39.9	38.6
LFPR	4.8	2.0
Population	-0.3	N.A.
Sum of Coefficients	100.1	90.6

Source: Author's calculations

Note: Long-run response for output per hour is calculated from Table 6, column 2.

Table 7. The Early-Recovery Productivity Growth Bubble across Seven Cyclical Episodes, 1958:2 - 2004:3

Episode	*Change in Productivity Deviation from Trend*	*Predicted Value*	*Contribution of EOE Effect to Predicted Value*	*Predicted without EOE Effect*	*Residual*
First four quarters after real GDP trough					
1958:2-1959:1	1.52	0.43	0.01	0.42	1.08
1961:1-1961:4	2.66	1.59	1.01	0.57	1.07
1971:1-1971:4	1.18	2.31	1.61	0.70	-1.13
1975:2-1976:2	1.02	1.12	1.80	-0.68	-0.10
1983:1-1983:4	1.87	0.97	0.70	0.26	0.90
1991:2-1992:1	1.80	1.96	1.47	0.50	-0.16
2001:4-2002:3	1.06	0.81	0.67	0.14	0.25
Average	1.59	1.31	1.04	0.27	0.27
Next eight quarters					
1959:2-1961:1	-1.39	-0.32	-0.51	0.19	-1.07
1962:1-1963:4	0.54	0.12	0.51	-0.39	0.42
1972:1-1973:4	0.25	-2.74	-0.90	-1.84	2.99
1976:2-1978:1	-1.02	0.74	0.00	0.74	-1.76
1984:1-1985:4	0.40	-0.47	. . .	. . .	0.87
1992:2-1994:1	-0.19	0.55	1.02	-0.47	-0.74
2002:4-2004:3	0.64	-0.29	-0.30	0.00	0.93
Average	-0.11	-0.34	-0.03	-0.29	0.23

Source : Regression estimates in table 5, column 5-5

a. EOE dummy is not in effect for these quarters

Table 8. Annual Growth Rates of Actual and Trend Real GDP and Its Components, Selected Intervals, 1987-2008

	Real GDP	Output per hour[a]	Hours per employee	Employment rate	LFPR	Working-age population	Sum of last five columns
1987:1-1995:4							
Actual	2.77	1.24	0.21	0.12	0.14	1.07	2.77
Trend	2.92	1.39	0.07	0.00	0.20	1.14	2.80
Ratio of actual to trend	-0.15	-0.15	0.14	0.12	-0.06	-0.08	-0.03
Predicted Ratio	. . .	0.24	-0.20	-0.09	-0.11	. . .	-0.15
Residual	. . .	-0.39	0.34	0.21	0.05	. . .	0.20
1995:4-2000:2							
Actual	4.31	2.20	0.10	0.38	0.36	1.27	4.31
Trend	2.87	1.67	-0.11	0.06	0.04	1.22	2.89
Ratio of actual to trend	1.44	0.52	0.21	0.32	0.31	0.05	1.42
Predicted Ratio	. . .	0.56	-0.27	0.29	-0.33	. . .	0.25
Residual	. . .	-0.03	0.48	0.03	0.64	. . .	1.12
2000:2-2003:2							
Actual	1.21	2.44	-1.43	-0.82	-0.27	1.30	1.21
Trend	2.77	2.12	-0.48	0.04	-0.08	1.24	2.84
Ratio of actual to trend	-1.56	0.32	-0.95	-0.87	-0.18	0.05	-1.63
Predicted Ratio	. . .	-0.56	-0.11	-0.54	-0.17	. . .	-1.38
Residual	. . .	0.88	-0.84	-0.33	-0.01	. . .	-0.30
2003:2-2008:2							
Actual	2.72	1.65	-0.07	0.17	-0.14	1.11	2.72
Trend	2.58	1.71	-0.40	0.04	-0.06	1.21	2.51
Ratio of actual to trend	0.14	-0.07	0.33	0.12	-0.07	-0.10	0.21
Predicted Ratio	. . .	0.02	0.13	0.02	0.15	. . .	0.31
Residual	. . .	-0.08	0.20	0.11	-0.22	. . .	0.00

Source: Author's calculations, see appendix A

a. Predicted values and residuals are from regressions reported in table 5, column 5, with four lags on the output deviation variable substituted for four leads.

Output per hour data are for the total economy. Predicted values and residuals for other columns (except working-age population) are from the regressions reported in table 5

Table 9. Actual and Predicted Annual Growth Rates of Components of Real GDP, 1987-2008 and 2008-2028

	Actual 1987:2 - 2008:2	Projected 2008 - 2028
Component		
Real GDP	2.86	2.35
Aggregate Hours	1.16	0.75
Household Employment	1.26	0.80
Labor Force	1.21	0.80
Working-Age Population	1.15	0.90
Related Ratios		
Real GDP per Capita	1.71	1.45
Total Economy Output per Hour	1.70	1.60
Total Economy Hours per Employee	-0.10	-0.05
Employment Rate	0.05	0.00
Labor-Force Participation Rate	0.06	-0.10

Figure 1. Annual Growth Rate of Real GDP between Benchmark Years and Quarters, 1875-2008:Q2

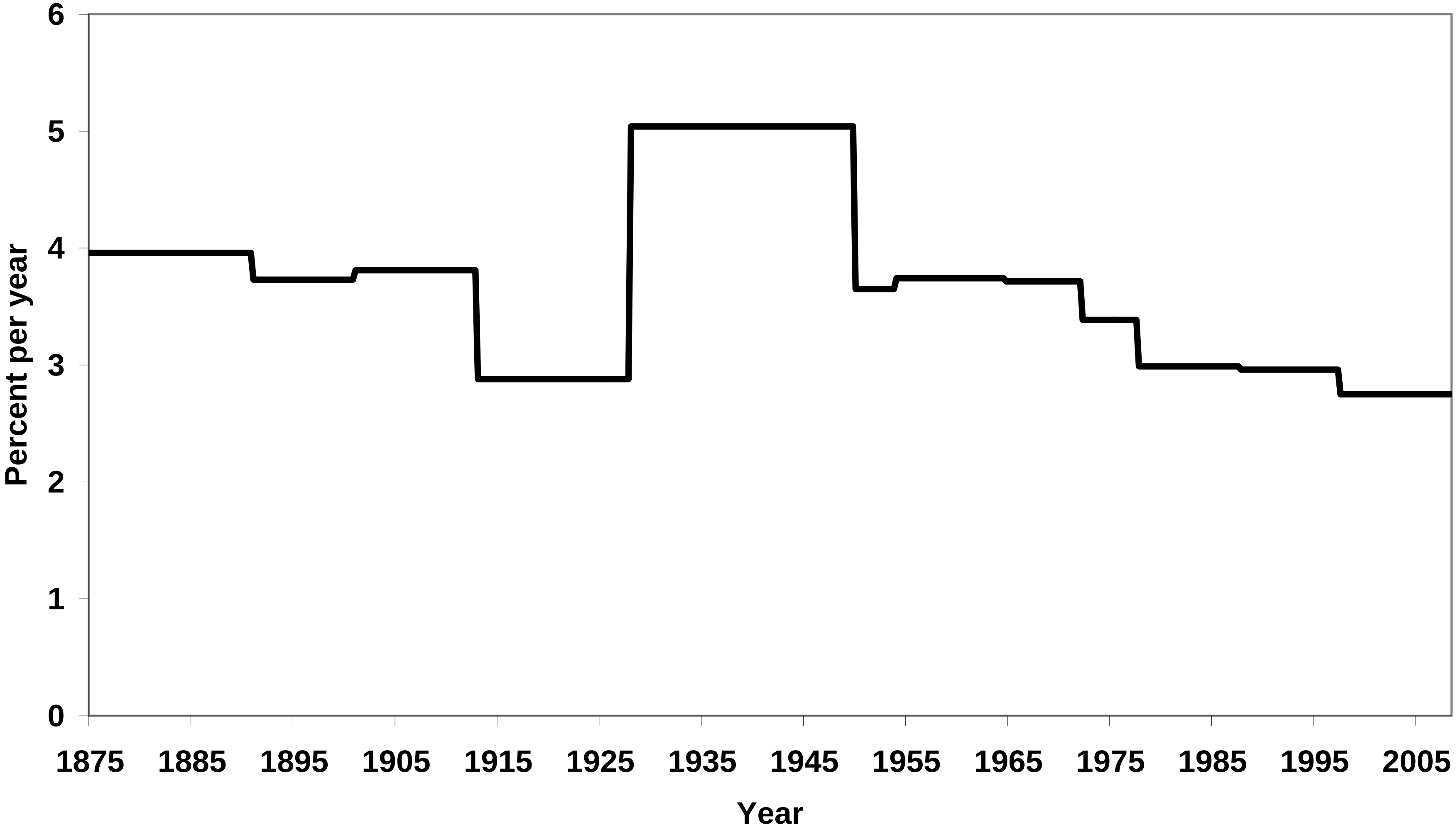


Figure 2. Annual Percent Growth Rates of Real GDP per Capita, Total Economy Productivity, and Labor Market Variables, 1954:1 - 2008:2.

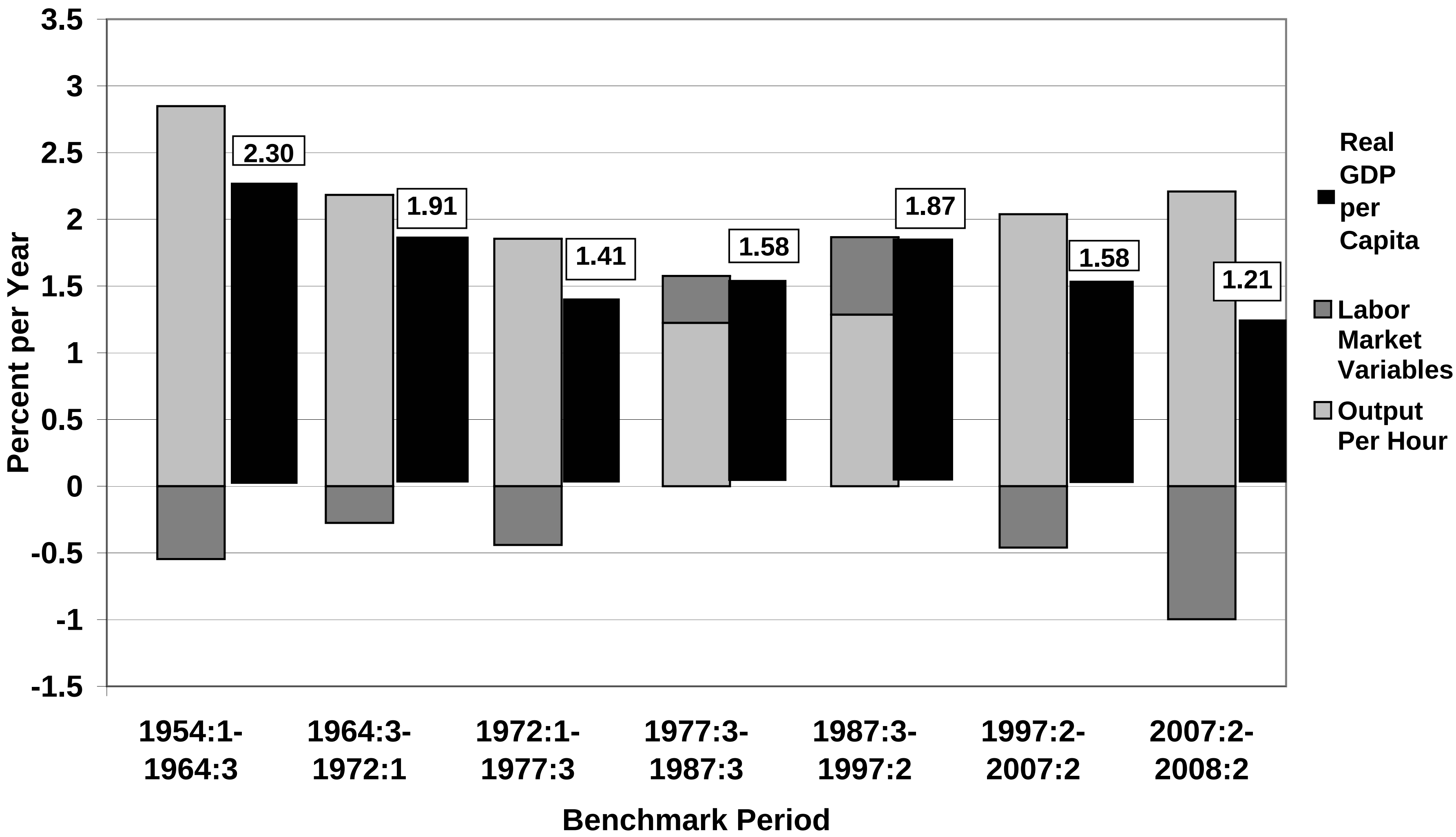


Figure 3. Annual Growth Rate of Real GDP between Benchmark Years and Quarters Compared with Kalman Trend, 1954 - 2008:Q2

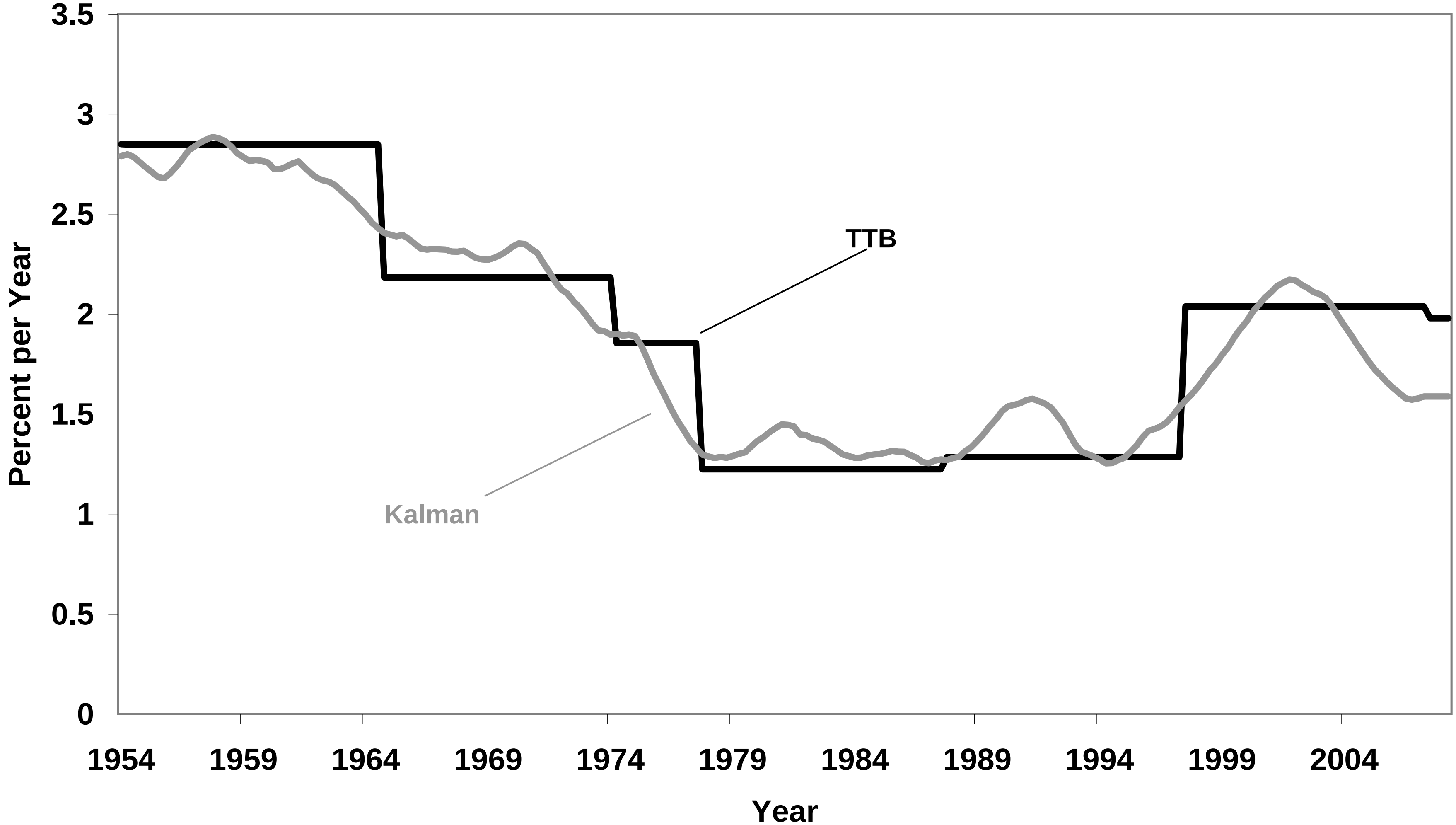


Figure 4a. Eight Quarter Rate of Growth at an Annual Rate of Total Economy Productivity and its Kalman Trend, 1955 - 2008

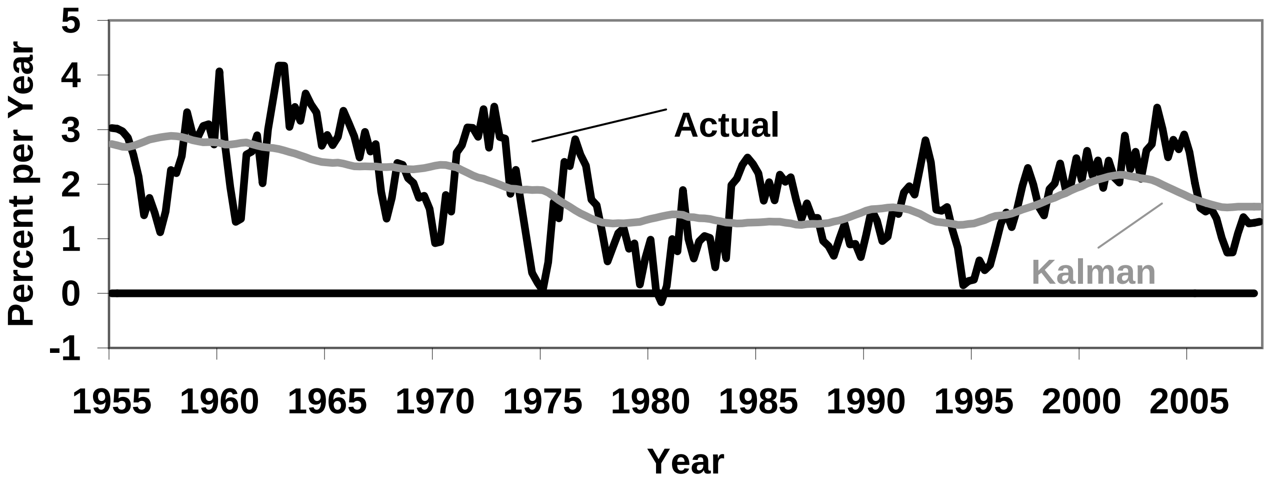
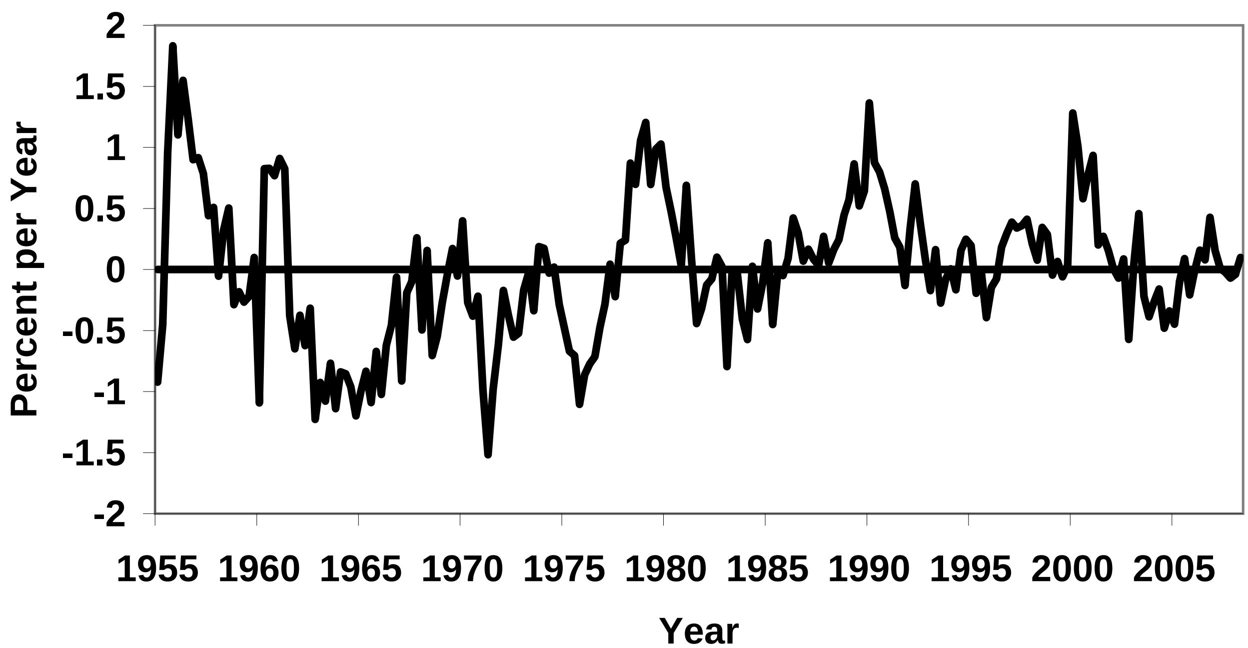
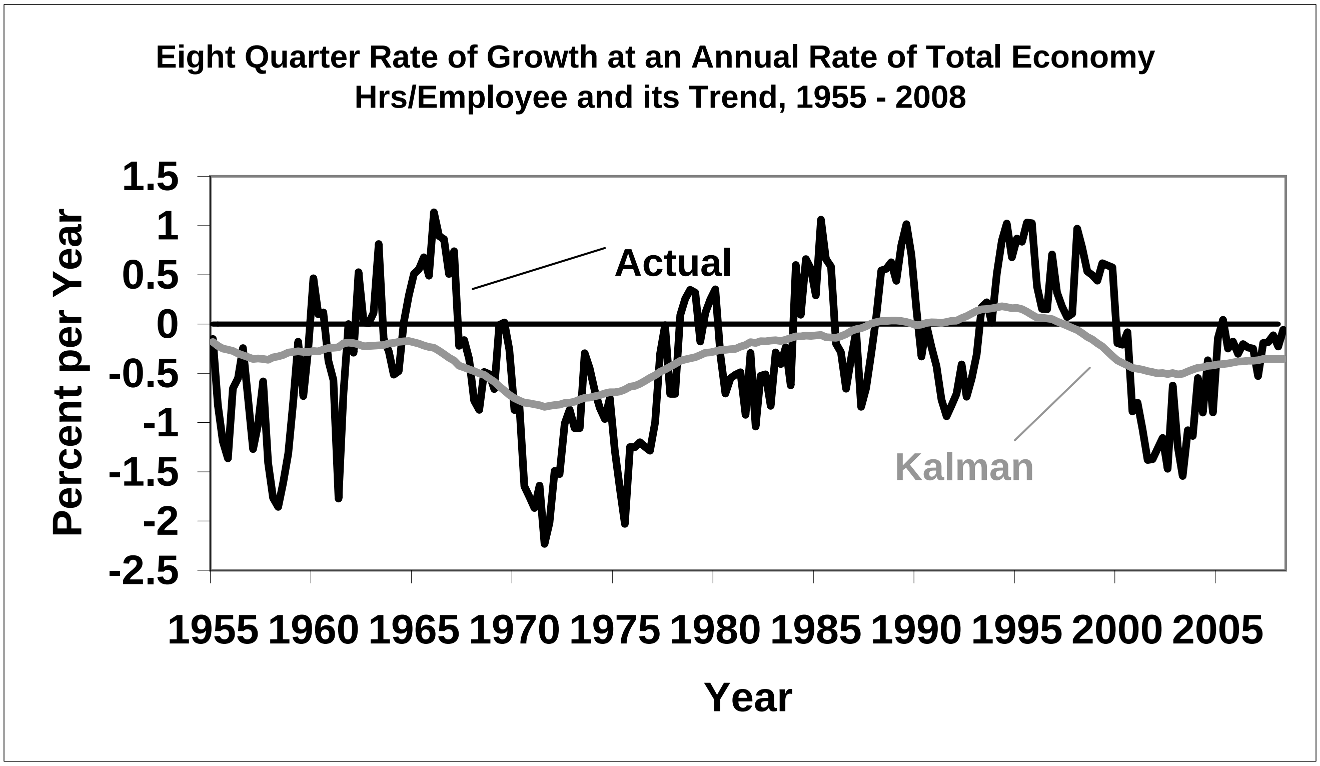


Figure 4b. Ratio of Actual to Trend of Total Economy Productivity, 1955 - 2008




Eight Quarter Rate of Growth at an Annual Rate of Total Economy Hrs/Employee and its Trend, 1955 - 2008
Percent per Year
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
Actual
Kalman
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year

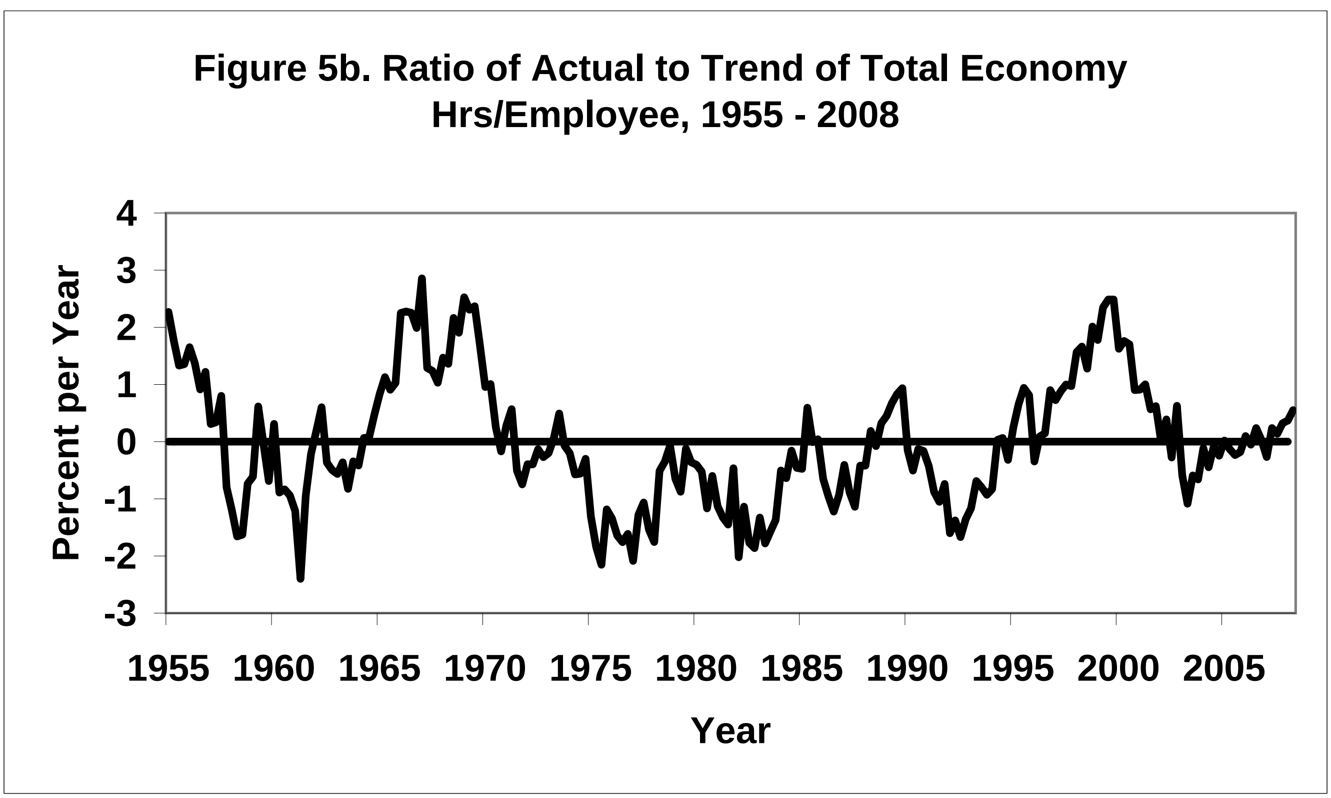


Figure 5b. Ratio of Actual to Trend of Total Economy Hrs/Employee, 1955 - 2008
Percent per Year
4
3
2
1
0
-1
-2
-3
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year

Figure 6a. 8-Quarter Rate of Growth at an Annual Rate of Employment Rate and its Trend, 1955 - 2008

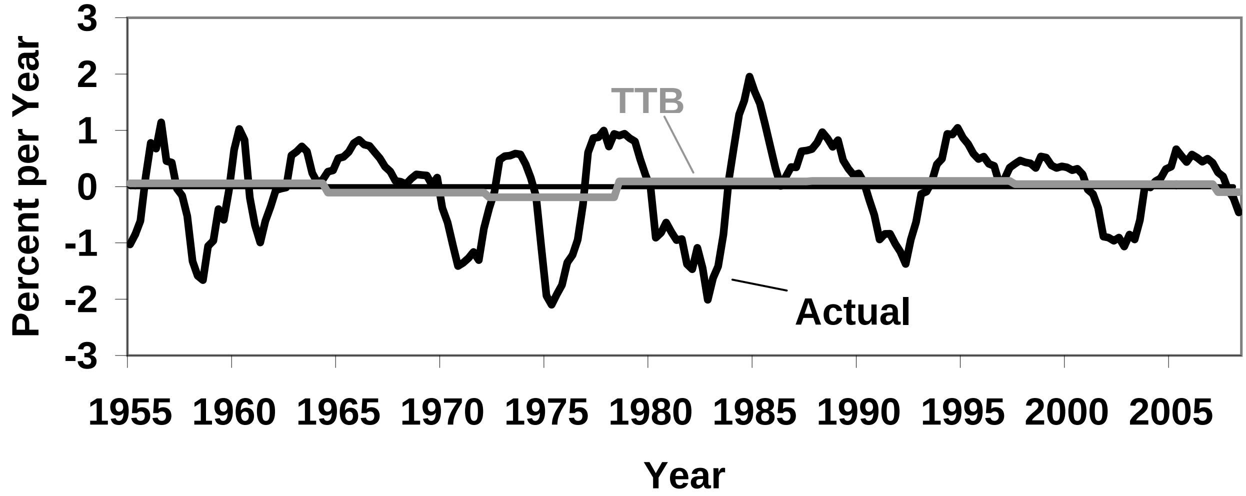


Figure 6b. Ratio of Actual to Trend of Employment Rate, 1955 - 2008

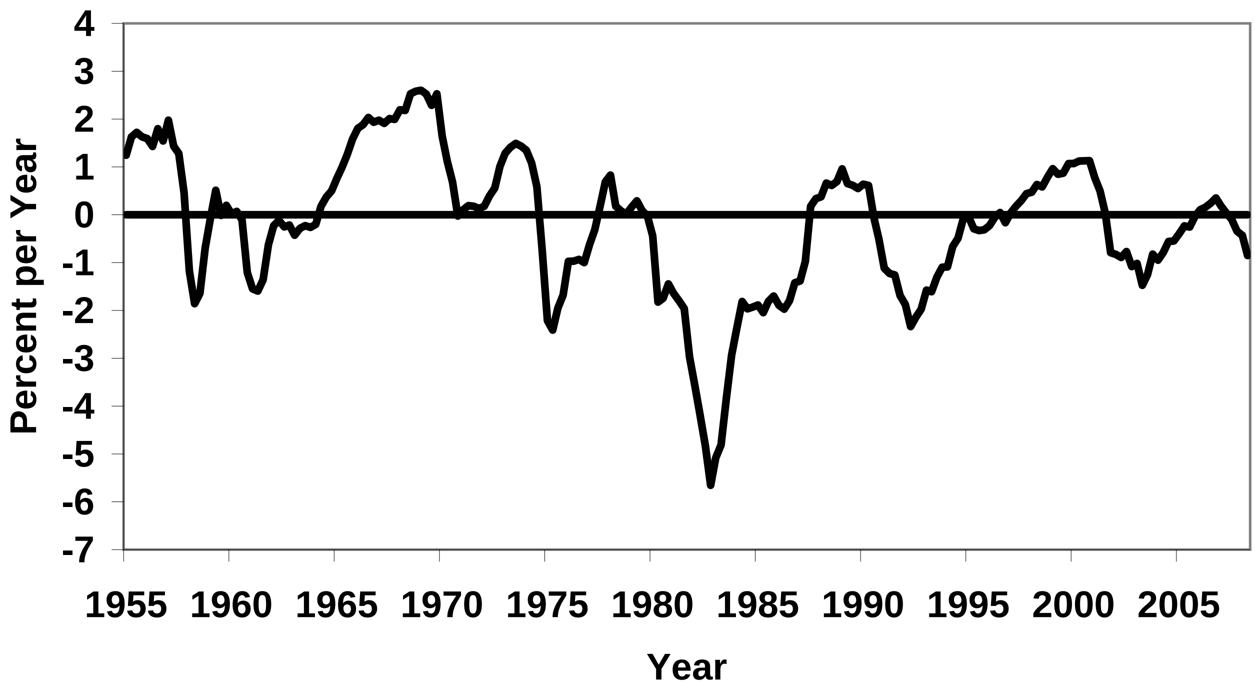


Figure 7a. Eight Quarter Rate of Growth at an Annual Rate of LFPR and its Trend, 1955 - 2008

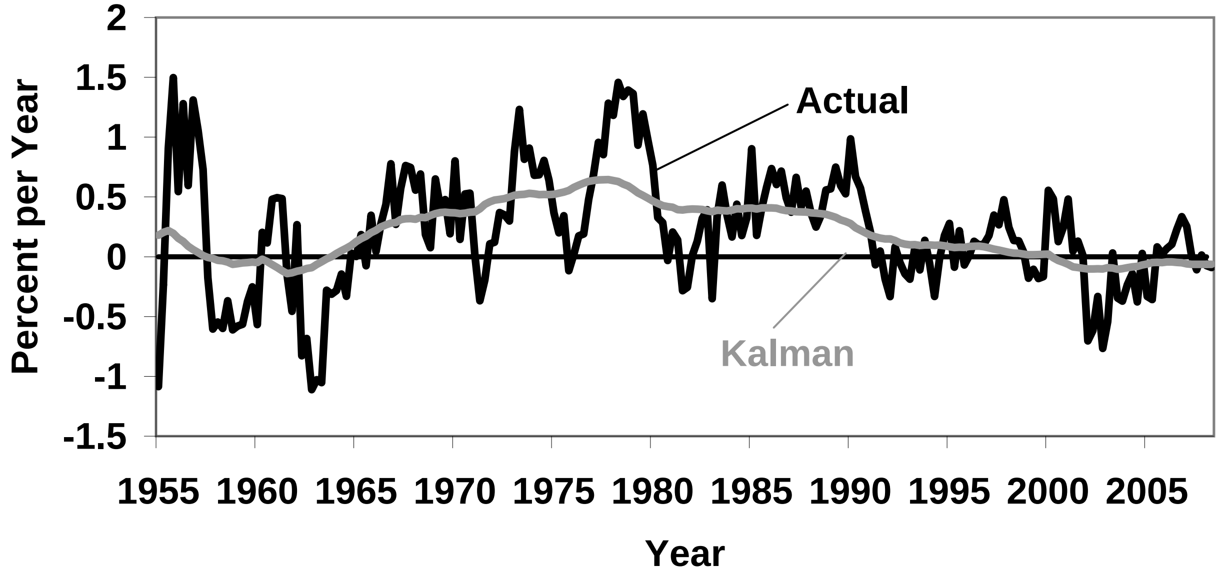


Figure 7b. Ratio of Actual to Trend of Employment Rate, 1955 - 2008

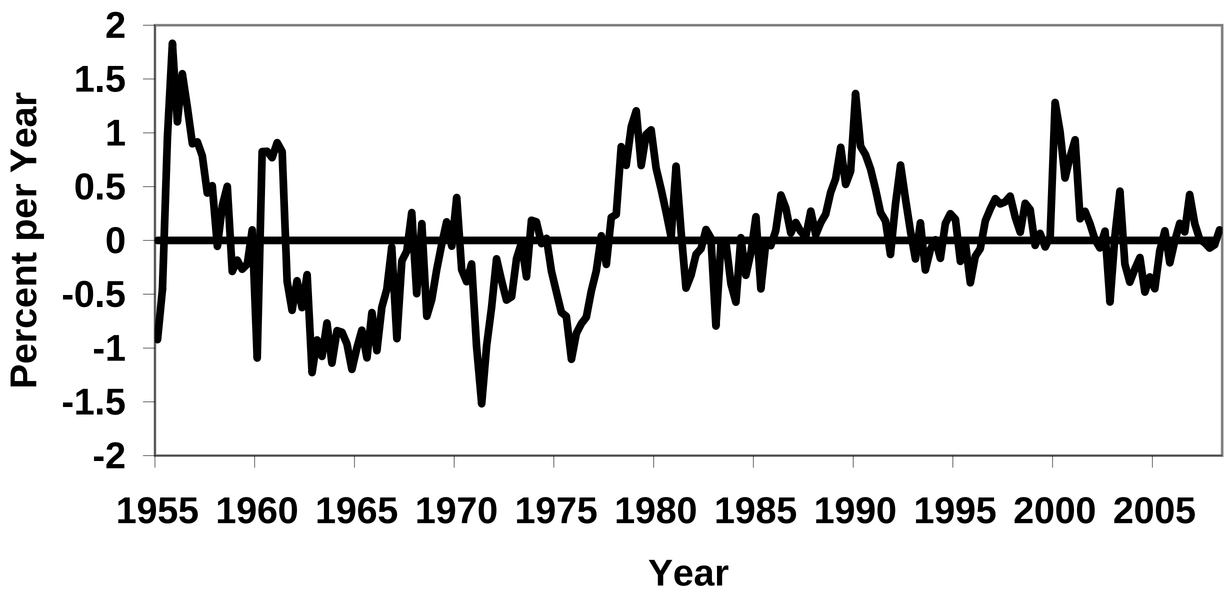
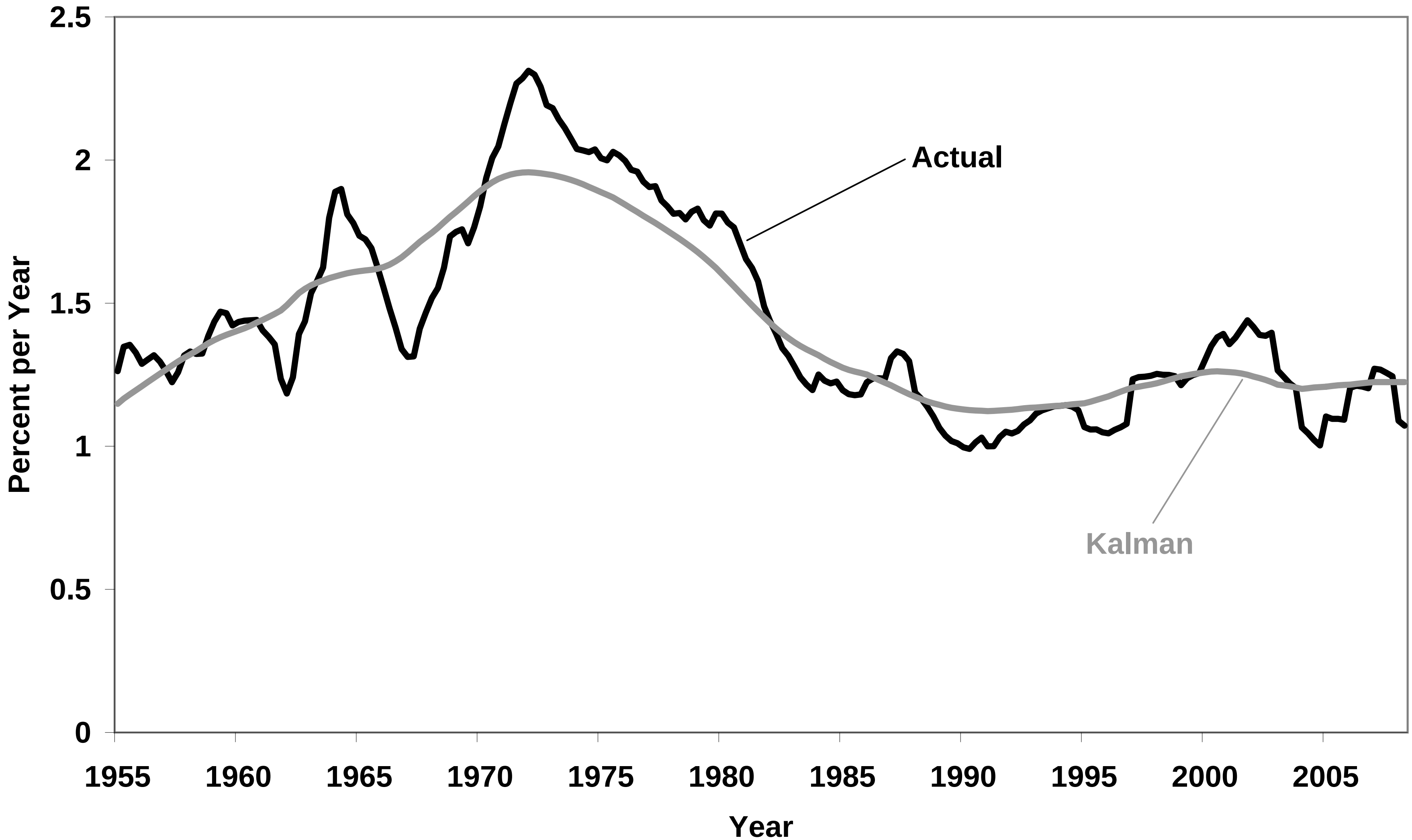


Figure 8



2.5
2
1.5
1
0.5
0
Percent per Year
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Actual
Kalman

Figure 9a. Eight Quarter Rate of Growth at an Annual Rate of Real GDP, Kalman Trend, and Trend as a Sum of Output Components

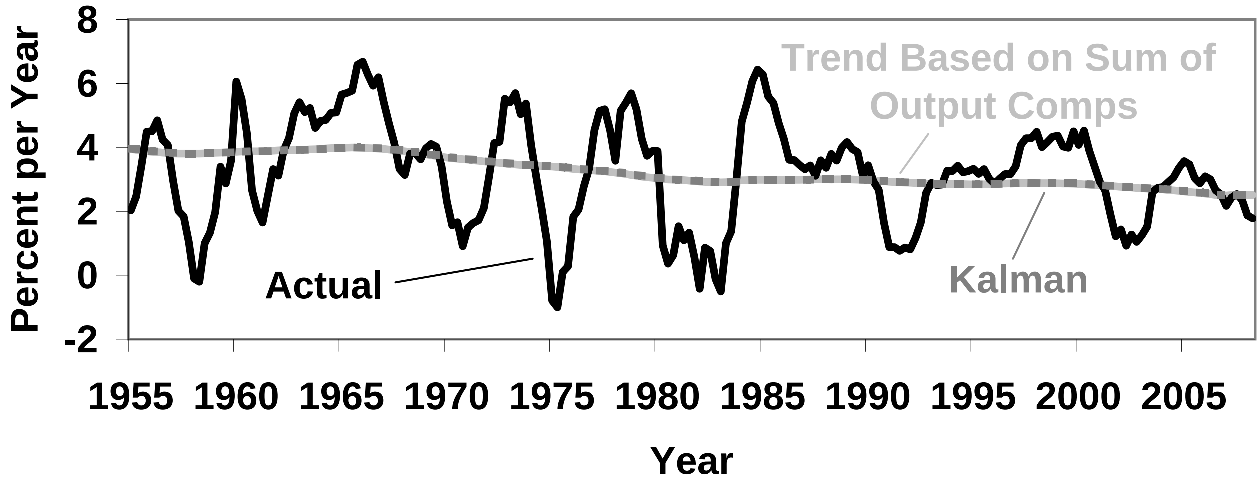


Figure 9b. Actual to Trend Ratio of Real GDP

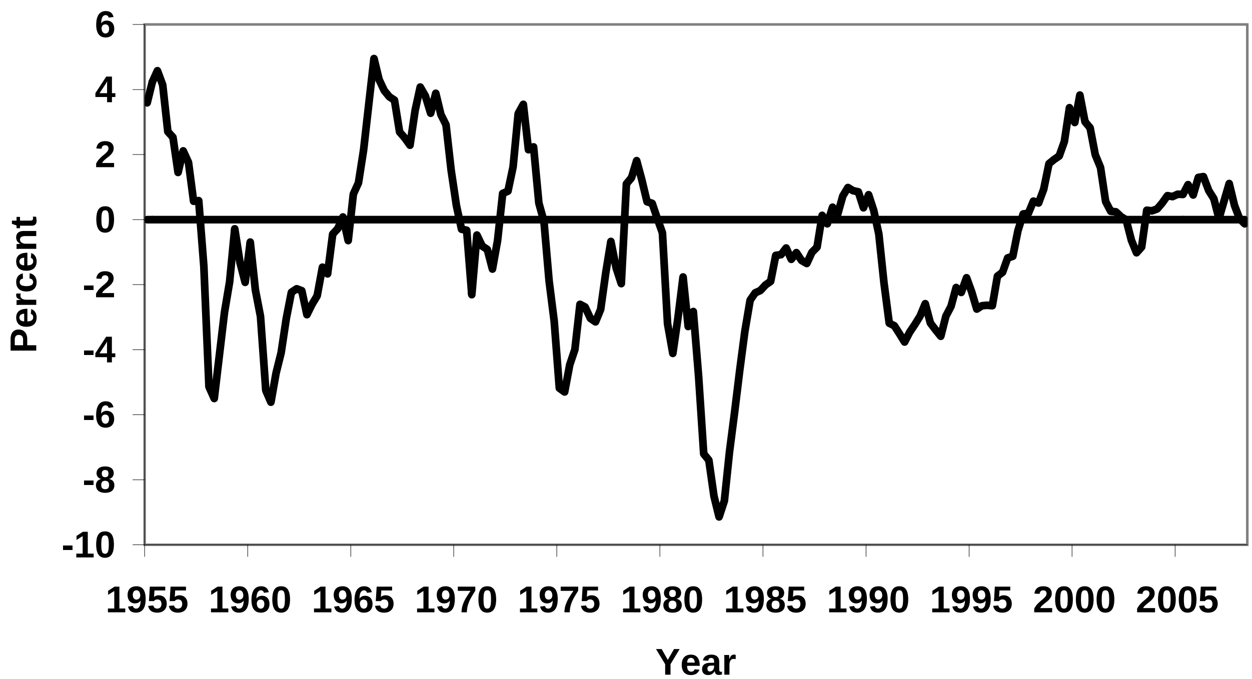


Figure 10. Responses to Output Changes of Components of the Output Identity, 1954:4-2008:2

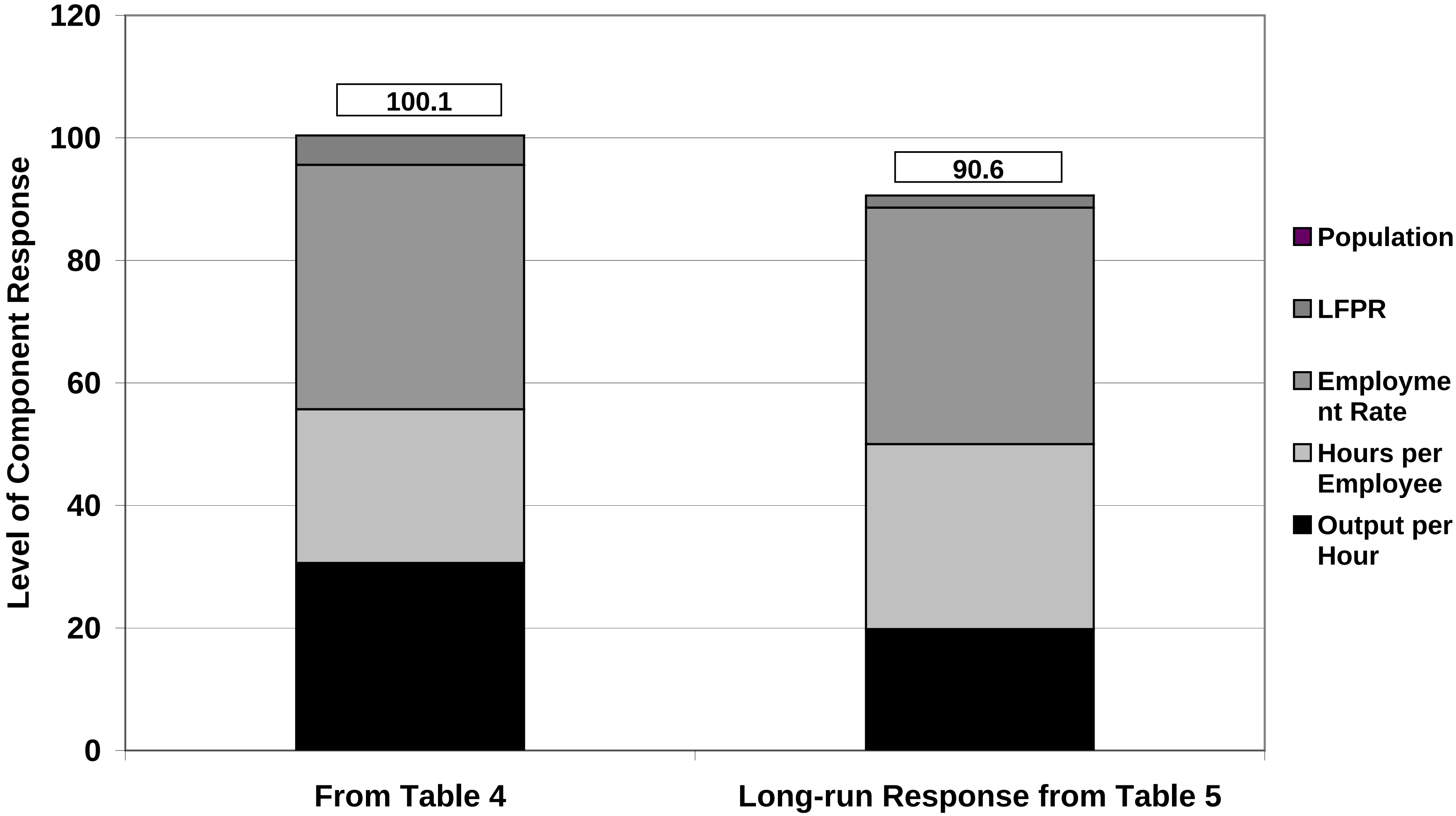


Figure 11. Residuals from Productivity Growth Equations, 1985:1-2008:2