Prospects for a Revival in U. S. Productivity Growth

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Abstract

The growth rate of total-economy U.S. labor productivity during the eight-year period between 2010:Q3 and 2018:Q3 was only 0.53 percent, lower by a large margin than any other eight-year interval in U.S. postwar quarterly data. This paper divides the question of a possible revival in productivity growth into two questions. The first is the possibility of a procyclical response in the gap between actual and trend productivity growth, and the second is a revival in the productivity growth trend itself. An econometric study of the procyclical gap response examines the sensitivity of that reaction to a higher output gap to alternative methods of detrending and to the choice between a level versus a change specification.

We conclude that there was a statistically significant downward shift from a productivity gap response of about 0.25 to a one-percentage point change in the output gap prior to 1986 to a response that is insignificantly different from zero since 1986. That result is qualified by the fact that the decline in the procyclical response is heavily influenced by the countercyclical behavior of productivity growth during the year 2009. In some specifications there is still a procyclical response of as much as 0.2 in data for 1986-2007.

The downward shift after 1985 in the response of the productivity gap implies an equal and opposite upward shift in the response of the hours gap to the output gap, and most of this emerges as a significant upward shift in the cyclical sensitivity of the employment rate. Our results contradict the recent finding of Laurence Ball and co-authors that in the context of Okun's Law the responsiveness of the unemployment rate to the output gap has been stable over the postwar period.

Because there is no post-1985 procyclicality in the productivity gap, in simulations of our equation estimated through 2015 we find that projections of the coefficients accurately track the failure of productivity growth to exhibit any revival during the three quarters of 2018 during which output growth has accelerated. Lacking a procyclical revival of the productivity gap, the chance of a revival rests with the productivity growth trend itself. An equation that estimates the responsiveness of that trend to labor market tightness and to capital deepening yields our final conclusion that, based on forecasts of the future trajectory of the unemployment rate and the capital-labor ratio, a revival in trend productivity growth of 0.4 percentage points may occur during 2019-21.

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1. Introduction

The low rate of U.S. productivity growth in the past eight years has been unprecedented. While most productivity research focuses on labor productivity in the nonfarm private business (NFPB) sector, this paper analyzes productivity data for the total economy, since that is the productivity concept relevant for determining the growth rate of potential output. In quarterly data for the total economy during 2010:Q3 to 2018:Q3 the growth rate of output per hour has been a mere 0.53 percent per year, compared to 1.73 percent per year during the 40 years between 1970:Q3 and 2010:Q3 and the even faster 2.80 percent per year between 1948:Q3 and 1970:Q3.[1]

In postwar data there has never been an eight-year period with productivity growth so low; the slowest previous eight-year interval was 1973:Q2-1981:Q2 with a total-economy growth rate of 0.94 percent per year.[2] In data going back to 1889 the only precedent for the slow pace of the last eight years was the eight-year interval extending from the peak of the 1920s boom to the trough of the Great Depression, 1925-33, with an annual growth rate in annual data of 0.53 percent.[3] But that episode was one in which productivity growth exhibited a strong procyclical component, as is evident in the contrasting annual growth rate of 4.44 percent per year during the economy's recovery during the eight-year interval between 1933 and 1941.

If it were to continue, the slow productivity growth registered in the past eight years would undermine the projection of the Congressional Budget Office that potential real GDP will grow in the next decade at 1.9 percent per year, which combines potential growth in the labor force of 0.5 percent per year with potential total-economy productivity growth of 1.4 percent per year. The outlook for productivity growth is also central to the boast by the Trump administration that its policies, particularly the recent tax rate reduction and tax reform, will be sufficient to boost the economy's long-run GDP growth rate from the 2.1 percent achieved during the Obama administration to a permanent rate of 3.0 percent or higher.[4] But since much of the Obama-era GDP growth was fueled by a reduction in the unemployment rate, a back-of-the-envelope calculation using Okun's Law suggests that the implied growth rate of Obama-era potential output since mid-2009 was not 2.1 percent per year but a much lower 0.9 percent per year.[5] With the same 0.5 percent potential labor force growth as projected by the CBO, to

[1] For the non-farm business sector the growth rates over these intervals are 3.15 percent for 1948-70, 2.12 percent for 1970-2010, and 0.76 percent for 2010-18.

[2] The fastest postwar eight-year growth rate for total-economy productivity growth was 3.11 percent during 1949:Q2-1957:Q2.

[3] Data for 1925 and 1933 come from Gordon (2016), Chapter 16, where productivity is GDP divided by total-economy hours of work from Kendrick (1961), Table A-X.

[4] Real GDP grew at 2.1 percent per year between 2009:Q1 and 2017:Q1.

[5] Using a conventional Okun's Law coefficient of 0.5, a reduction of one percent in the unemployment rate is accompanied by two percentage points closing of the gap between actual and potential output. The unemployment rate fell from 9.6 percent in 2009:Q3 to 4.7 percent in 2017:Q1, a decline of 4.9 percentage points, implying that the GDP gap closed by 9.8 points during that interval. The actual rise in GDP between those quarters was 16.2 log points, implying that only 6.4 points were contributed by potential output, or 6.4 points divided by 7.5 years, or 0.9 points per year.

achieve the Trump 3.0 percent potential GDP boast would require potential productivity growth of 2.5 percent, quintuple the achievement of the past eight years.

A revival in productivity growth could take two forms. First, a rise in output growth above its trend could pull up productivity growth above its trend if productivity growth is procyclical, that is, if the gap between actual and potential productivity growth is positively correlated with the output gap. A substantial procyclical productivity response was built into the original formulation of Okun's Law (1962), which posited that a one percentage point increase in actual output relative to potential output is accompanied by a decline of one-third percentage-point in the unemployment rate and an increase by one-third percent in productivity relative to its trend, with the remaining response divided between greater hours per employee and higher labor-force participation. Strongly procyclical productivity changes are central to the Real Business Cycle approach which in its extreme form makes productivity "shocks" the sole source of business fluctuations (see Basu-Fernald 2001 for a review of the role of procyclical productivity in macroeconomic analysis). If productivity growth is procylical, then we would expect to see it revive from its poor performance in response to the recent fiscal stimulus that has taken the form both of corporate and individual tax reductions and of substantial increases in discretionary federal government spending.

A second avenue for a revival in productivity growth could occur even if the procyclical response is weak or entirely absent. The underlying productivity growth trend could increase in response to higher investment that raises capital deepening, to an increased pace of innovation that raises total factor productivity (TFP) growth, and/or to a greater impact of ongoing innovation that boosts TFP growth. As one example, investment incentives such as the expensing of equipment investment could boost the pace of capital deepening. As another and possibly more potent example, ongoing innovation in areas like robotics, 3-D printing, artificial intelligence, and autonomous vehicles could begin to pull up trend productivity growth as these developments gain traction and spread from the laboratory into factories, warehouses, and offices. It is also possible that a sustained period of tight labor markets such as occurred in the late 1960s, late 1990s, or at the current time could generate an increase in the productivity growth trend either by stimulating labor-saving investment or by creating an incentive for firms to create changes in business methods and production techniques in ways that save labor.

This paper begins by examining alternative methods of decomposing productivity growth into trend and deviations from trend or "gaps." We study the cyclical responsiveness of the productivity gap to the output gap in the context of the output identity that divides up output changes by definition into changes in output per hour and in hours of work. The greater the cyclical responsiveness of the hours gap, the less is the responsiveness of the productivity gap, and vice versa. In turn, changes in the hours gap must by definition be divided up between changes in the gaps for the employment rate, hours per employee, and the labor-force participation rate. As noted above, Okun's original formulation of his law suggested that the procyclical response of the productivity gap was about one-third of the output gap, implying that the remaining two-thirds of the response occurred in the hours gap.

Recently a conflict has emerged regarding the cyclical responsiveness of components of the output identity. Several papers, including Stiroh (2009), Gali and Gambetti (2009), Gordon (2010), and Fernald and Wang (2014), find that the procyclical response of the productivity gap in U.S. data has disappeared since the mid-1980s. This implies that the procyclical response of the hours gap has increased to an elasticity of unity, which in turn implies a higher responsiveness of some combination of the three components of the hours gap – the employment or unemployment rate, hours per worker, and the labor-force participation rate. However, in research that does not mention productivity, notably Ball, Leigh, and Loungani (2013), the cyclical response of the unemployment gap to changes in the output gap is found to be stable throughout the postwar period, leading to the claim that Okun's Law is stable.

This paper applies a consistent econometric framework to examine the cyclical responsiveness of all of the components of the output identity, particularly productivity and the employment rate, to determine whether the reduced cyclical responsiveness of productivity is a robust finding and whether it implies that the cyclical responsiveness of the employment rate is stable or has risen *pari passu* as the productivity response has declined. We replicate the productivity results of Fernald and Wang and the employment results of Ball *et al.* and examine the sensitivity of cyclical responses to alternative methods of detrending and several different econometric specifications.

Then we use our preferred econometric specification to run post-sample simulations in which estimated coefficients are used to calculate the response of the productivity gap to actual and projected changes in the output gap. In one simulation we estimate our equation through 1995 and examine its performance in tracking the productivity growth revival of the late 1990s and early 2000s, showing how simulation errors gradually reveal the emergence of a faster productivity growth trend in that interval. Then we estimate our equation through 2015 and calculate its projected path of the productivity growth gap in response to data on the actual output gap through 2018:Q3 and to a hypothetical output path beyond 2018 through 2021.

The last section of the paper goes beyond the analysis of cyclical gaps and examines the behavior of the underlying trend in productivity growth. We examine the responsiveness of trend productivity growth to capital deepening and to labor-market tightness and ask whether there is an independent effect of tightness on the productivity trend when the contribution of capital deepening is taken into account. We find that the combination of capital deepening and tightness perform well in explaining the productivity growth trend between 1970 and 2007 but fail in opposite directions before and after that interval, explaining much too slow a pace of growth before 1970 and much too fast a pace after 2007.

We conclude that labor tightness has only a small direct impact on trend productivity growth while there is a likelihood of a small productivity trend revival in response to higher investment as it is stimulated by both tax incentives and the indirect effect of tight labor markets. The failure of capital deepening and labor market tightness to explain why productivity growth was so fast before 1970 reflects the strong growth of TFP and their inability to explain why productivity growth has been so slow since 2010 indicates slow TFP growth. In our interpretation the contrast between a low rate of TFP growth in recent data and the widespread evidence of multi-dimensional ongoing innovation in robotics, artificial intelligence, and other fields suggests that the current wave of innovation is having a less pervasive impact on business methods and techniques than earlier industrial revolutions.

2. Trends and Cycles in Output, Productivity, and Hours

The connection between the cyclical behavior of productivity and employment begins with the identity stating that total output *(Y)* is divided between output per hour *(Y/H)* and hours of work in the total economy *(H).* In all of our analysis total output is measured by the geometric average of GDP and gross domestic income (GDI), following the suggestion of Nalewaik (2011) that this average is more accurate than either GDP or GDI taken separately. Hours represented by *H* without a subscript refers to payroll hours, in contrast to hours as measured by the household survey (H_H), where the latter is a component in the identity linking payroll hours with household employment.

$$Y = \frac{Y}{H} \cdot H \tag{1}$$

Adopting the convention that lower case letters designate growth rates, we can write that the growth rate of output is equal to the growth rate of productivity plus the growth rate of hours

$$y = (y - h) + h \tag{2}$$

We can establish the link between productivity and household employment *(E)* by decomposing aggregate hours into its four constituent components. Using the notation that *L* represents the labor force and *N* the U.S. civilian, noninstitutional population, we have by definition:

$$Y = \frac{Y}{H} \cdot \frac{H}{H_H} \cdot \frac{H_H}{E} \cdot \frac{E}{L} \cdot \frac{L}{N} \cdot N \tag{3}$$

$\frac{H}{H_H}$ is the ratio of payroll survey hours to household survey hours; $\frac{H_H}{E}$ is the number of hours worked per employee; $\frac{E}{L}$ is the employment rate (or 100 minus the unemployment rate); and $\frac{L}{N}$ is the labor force participation rate. That is, the level of aggregate output can be decomposed into its basic components -- labor productivity, hours worked per employee, the employment rate, the labor force participation rate, and population. Again as in (2) letting lower-case letters represent growth rates, then the growth rate of output can be decomposed into its components as follows:

$$y = (y - h) + (h - h_h) + (h_h - e) + (e - l) + (l - n) + n \tag{4}$$

Table 1 displays average annual growth rates for the components of equation (5) during four key intervals in the postwar period, starting respectively at 1950:Q1, 1973:Q1, 1996:Q1, and 2005:Q1. The left three columns show growth rates for output, productivity, and hours, and the right section contains growth rates for the five remaining components of equation (5). Output growth slowed from 4.22 percent per year in the first period to 1.79 percent in the last period, while productivity growth zig-zagged from a high starting point of 2.85 percent, then down to 1.27 percent during 1973-95, back up to 2.62 percent in 1996-2004, and then down again to 1.04 percent in 2005-18. Payroll hours reached a peak during 1972-95 due to the entry into the labor force of women and baby-boom teenagers and then fell in two stages to just 0.74 percent per year during 2005-18.

Compared to the major changes in the three left columns of Table 1, changes over long intervals for the five components of hours growth were relatively minor. There were only minor changes over the four intervals in the payroll to household hours ratio, to household hours per employee, or to the employment rate. The labor-force participation rate increased in the second period, again due to the entry of women into the labor force, and then declined at about the same rate during the fourth period due to retirement of the baby-boom generation and a decline in prime-age participation. Population growth was steady in the first two periods and then slowed gradually in the final two periods.

Our subsequent analysis of the cyclical behavior of productivity and employment distinguishes between trends and deviations from trend, or "gaps". The top frame of Figure 1 illustrates the stark differences between the trend in output as measured by the Hodrick-Prescott (H-P) technique (using the conventional detrending parameter of 1600) and the Kalman technique, which filters out from the trend any correlation between deviations of output from trend and the unemployment gap. In estimating the Kalman trend, the unemployment gap is defined as the difference between the unemployment rate and the "long-run NAIRU" as estimated by the Congressional Budget Office. Note that the H-P methodology is univariate and smooths a series using only information on deviations from average growth of the series itself, without any "outside information" such as the behavior of unemployment or the presence of business cycles. In contrast the Kalman technique is bivariate, smoothing fluctuations in actual output growth by removing correlations between the output gap and the unemployment gap.

The behavior of the H-P trend in Figure 1 is highly implausible as an estimate of the underlying trend in output growth. For instance, it rises from 2.5 percent in 1957 to 5.3 percent in 1965 and then declines back to 2.9 percent in 1971. In contrast the Kalman trend series exhibits no response to the business cycle, with trend values of 3.7 percent in 1957, 4.0 percent in 1965, and 3.7 percent again in 1971. Note that there is a slow and steady decline in the Kalman trend output growth series from 4.0 percent in 1965 to 2.9 percent in 1993, with no response as in the H-P trend series to the recessions of 1970-71, 1973-75, 1980-82, 1990-91, 2001, or 2007-09. The Kalman trend displays a brief revival from 2.9 percent in 1993 to 3.4 percent in 1999, followed by a relatively steady and sharp decline down to 1.0 percent in 2015-2018.

The bottom frame of Figure 1 contrasts the H-P and Kalman trends for total-economy productivity growth. The differences between the two trend series for productivity are much smaller than for output, reflecting the fact that productivity has much smaller procyclical movements than output, and as we shall see from our subsequent results virtually no procyclical response after the mid-1980s. The H-P series does exhibit procyclical movements prior to 1990 and a stronger peak during the productivity growth revival of the late 1990s, but its values after 2003 are virtually identical to those of the Kalman trend and shows a similar collapse in trend productivity growth down to a low point of around 1.0 percent per year in 2015-2018.

Figure 2 compares the same Kalman trend for total-economy productivity growth from Figure 1b, the concept that we examine in this paper, to the Kalman trend for productivity growth in the nonfarm private business (NFPB) sector that is the focus of most research by others on productivity trends and cycles. We would expect that productivity growth in the NFPB sector would be consistently faster than in the total economy, as output growth in the government and household sectors is often measured by employment or hours growth, ensuring that measured productivity growth in those sectors is near zero. The NFPB trend in Figure 2 is a relatively constant 0.25 percent faster than the total-economy trend except during the productivity growth revival of the late 1990s and early 2000s when that difference expanded to bout 0.7 percent. Table 2 documents the respective growth rates of NFPB and total-economy productivity for the same intervals as in Table 1 and shows that the difference between them was between 0.2 and 0.3 percent per year except in the 1996-2004 interval when the difference was a much larger 0.7 percent per year.

Figure 3 repeats the Kalman trend for total-economy output from Figure 1a and juxtaposes it with the Kalman trend for growth in hours of work. By definition the distance between the red output line and blue hours line represents the Kalman productivity growth trend. The blue hours trend line has a characteristic "hump" between 1965 and 1995 representing the period of most rapid movement of women from home production to market work, and the supplementary peak in the late 1970s is caused by the entry of baby-boom teenagers into the labor force. Trend hours growth peaked at 2.0 percent per year in 1978, otherwise was roughly 1.5 percent per year between 1965 and 1995, slowed to about 0.7 percent per year during 2003-08, then was 0.4 to 0.5 percent per year after 2010. Those, for instance in the Trump administration, who forecast a return to the 3.0 percent growth rate that the economy achieved in the 1980s and 1990s often neglect the role of slower trend hours growth in subtracting a full percentage point from trend hours growth as the hours trend slowed from 1.5 percent per year before 1995 to only 0.5 percent for most of the past decade.

Is productivity growth procyclical or not? This question involves the behavior not of the output or productivity trend but of deviations from trend or "gaps," which can be expressed either in levels or growth rates. Using the notation * for trends and ' for gaps, the level and growth rate gaps of a variable like output can be written respectively as:

$$Y' = Y/Y^* \text{ and } y' = y - y^* \tag{5}$$

The postwar relationship of the level gaps for output and productivity is displayed in Figure 4, where the gaps are calculated as the logarithm of the ratio of the actual value to the trend value. The use of logarithms means that when the actual value is equal to the trend value the gap is zero rather 100 percent. The graph shows a marked change in behavior after the mid-1980s. Between the starting year of 1950 and 1985 a positive or negative output gap was accompanied by a movement of the productivity gap in the same direction with an elasticity of roughly 0.2 to 0.3. The time interval 1973-77 appears to be the only exception. In two episodes, the recession of 1960-61 and the expansion of 1971-73, the response of the productivity gap was greater than 0.5.

But after 1985 the procyclical relationship was muted or absent. There was a distinct procyclical response to the positive output gap of 2003-07, but the negative output gap of 1991-96 was accompanied by a negative productivity response that lagged two or three years behind. During the positive output gap period of the late 1990s the productivity gap never turned positive. Most notably the long slump in the output gap in 2009-15 was accompanied by a negative productivity gap only briefly in 2008, while in 2009 rapid productivity growth brought the gap back up sharply from negative to positive. After 2009 the productivity gap showed only small deviations from zero despite the large negative values of the output gap.

3. Regression Analysis of Cyclical Responses

To quantify the changes in cyclical behavior we turn to a regression analysis of the cyclical response of the gaps for productivity, hours, and the components of hours. By definition the diminution or disappearance of a procyclical response for productivity must be accompanied by an offsetting increase in the cyclical response of hours and of one or more of the components of hours, and so our regression analysis applies the same specification to productivity, hours worked, and the components of hours worked.

To determine the sensitivity of regression results to the form of the variables, we enter them as levels of gaps, expressed as above in logarithms, and alternatively as rates of change of gaps. Our initial specification lets the dependent variable be the gap X'_t of productivity, hours worked, or one of the components of hours worked as listed in equation (3) above. The explanatory variables are the current value of the output gap and four lagged values. As we shall see, an important aspect of the cyclical behavior of productivity is overshooting, with a high positive initial response to the output gap followed by negative responses that offset part or all of the initial positive response. This overshooting phenomenon reflects lags in the adjustment of hours to cyclical movements in the output gap.

$$X_t' = \sum_{i=0}^{4} \alpha_i Y_t' + \epsilon_t \tag{6}$$

The responses of each dependent variable to current and lagged values of the output gap are given by the α_i coefficients. Because output is defined as equal to the product of the separate components of the output identity, as in equation (3) above, its logarithm is equal to the *sum* of the logs of the separate components. Thus we should expect the α_i coefficients across all the component equations to sum to unity.

The sum of the α_i coefficients within each regression represents the long-run response of X' to the output gap. If the cyclicality of X' has changed over time, then this should be reflected in the sum of the α_is which would decrease over time to reflect a decrease in that variable's cyclicality. Alternatively an increase in the procyclical response would be reflected in an increase in the sum of the α_is. One way to provide a quantitative measure of the shift in the degree of procyclicality is to include a dummy "LATE" variable that is equal to 1 after a certain date and is multiplied by the explanatory Y' variables as in the following regression.

$$X_t' = \sum_{i=0}^{4} \alpha_i Y'_{t-i} + \sum_{i=0}^{4} \beta_i Y_{t-i}' LATE_{t-i} + \epsilon_t \tag{7}$$

On the basis of our visual inspection of Figure 4, we choose LATE to be equal to 1 starting in 1986 so that the sum of the α_is indicate the long run response of X' to the output gap before 1986, the sum of the β_is give the post 1985-shift of the long run response of X' to the output gap, and the sum of the α_is and β_is provides the long run response of x' to the output gap after 1986. A significant negative sum of β_is is associated with a decrease in cyclicality and a significant positive sum with a rise in cyclicality.

The results for the level of the gap for each of the component variables are shown in Table 3. The first two columns display results for the productivity and hours gaps, respectively. Displayed in the first row are the sums of the α_i coefficients and in the second row are the sums of the β_i coefficients. For the productivity gap the output response is 0.27, consistent with the response of one-quarter to one-third evident in Figure 4 for the years prior to 1986. The post-1985 dummy shift term is -0.22, so that the estimated post-1986 long-run ("LR") response is 0.27-0.22 or 0.04 after rounding. For hours the procyclical response is 0.73 which is shifted upward after 1985 by the same 0.22, resulting in a LR response for hours after 1985 of 0.73+0.22 or 0.96 after rounding. The sums of both sets of coefficients are highly significant at the 0.00 level of significance. The results have the important implication that since 1986, within four quarters the adjustment of the hours gap to movements in the output gap reaches nearly 100 percent, with virtually nothing left over for a response of the productivity gap. Below we consider several hypotheses to explain this shift in the behavior of hours and productivity.

The right section of Table 3 provides the same sums of coefficients for the four components of hours worked. Most important is a highly significant upward shift in the long-run response of the employment rate from 0.47 to 0.58. Hours per employee has a procyclical response of 0.24 with an insignificant upward shift of just 0.03. The "link" term, the ratio of payroll to household hours of work, had a strong procyclical response of 0.20 before 1986 that exhibits a significant downward shift of 0.15 to a post-1985 response of 0.05. Finally labor-force participation had a negligible and insignificant procyclical response before 1986 but a highly significant upward shift to a long-run post-1985 response of 0.06. In principle the sum of the long-run responses of the four components of total economy hours should be equal to the response of hours itself. For the pre-1986 long-run response this sum is 0.89, somewhat above the hours response of 0.78. The post-1985 long-run responses sum to 0.95, almost exactly the same as the long-run hours response of 0.96.

Subsequently we display the unusual behavior of the change in productivity during 2009, when there was a strong countercyclical effect as firms reduced hours by a greater percentage than the decline in output. At the bottom of Table 3 we display two additional rows showing alternative measures of the post-1985 LR response that illustrates the importance of the post-2007 behavior in reaching the conclusions that the procyclical response of productivity disappeared after 1986. When the sample period ends in 2017 as shown above the LR post-1985 productivity response is an insignificant 0.04, while an end point of 2007 yields a highly significant LR post-1985 response of 0.19. Notice that the removal of the 2008-18 data also creates changes in the LR post-1985 resonse for the components of hours, most notably a decline in the LR employment-rate response from 0.58 to 0.39. We conclude from the level gap results that the post-1985 procyclical productivity response weakened from 1986 to 2007 but did not disappear, and that the conclusion of its disappearance is due to behavior that occurred after 2007.

An alternative to expressing the dependent and explanatory variables as level of gaps is to enter them as rates of change of the gaps. Since the gaps as displayed in Figure 4 and entered in Table 3 are already expressed as logarithms, the rate of change of a gap is the first difference of the logarithm of the level of the gap, expressed in lower-case letters as in equation (5) above. The rate of change specification differs from the level treatment of equation (7) by including a series of four lagged dependent variables in addition to the set of current and lagged output gap changes entered by themselves and again entered when multiplied by the LATE dummy shift variable:

$$x_t' = \sum_{i=0}^{4} \alpha_i y'_{t-i} + \sum_{i=0}^{4} \beta_i y_{t-i}' LATE_{t-i} + \sum_{i=1}^{4} \gamma_i x_t' + \epsilon_t \qquad (8)$$

The long run response of x' to the change in the output gap pre-1986 is given by the sum of the α_i coefficients divided by unity minus the sum of the coefficients on the lagged dependent variable:

$$\frac{\sum_{i=0}^{4} \alpha_i}{1 - \sum_{i=1}^{4} \gamma_i} \tag{9}$$

The post-1985 shift is given by the sum of the β_i coefficients divided by the same denominator:

$$\frac{\sum_{i=0}^{4} \beta_i}{1 - \sum_{i=1}^{4} \gamma_i} \tag{10}$$

The long run response post-1985 is given by the sum of equations (9) and (10).

We supplement the specification in equation (8) by taking account of a phenomenon that has a significant impact when the variables are expressed as rates of change. There is a regular tendency in U.S. data, first identified and labelled the "end-of-expansion" (EOE) effect in Gordon (1979), for firms to boost the growth in hours of work relative to growth in output during the latter stages of the business expansion. One interpretation is that output growth slows in the year or two before the recession begins but that hours growth is maintained at a pace which does not reflect that slowdown in output growth, in part because firms make hiring decisions with a lag and are still reacting to the previous period of more rapid output growth. Then, realizing their mistake in "over-hiring", firms "under-hire" during the recession and early stages of the post-recession output recovery. Although the EOE effect was first apparent in data prior to 1979, it has strong explanatory power in each business cycle since then and helps, for instance, in explaining the slow pace of hiring in the post-recession "jobless recovery" of 1991-92 and the large decline of hours during the later stages of the 2007-09 recession and first few quarters of the recovery that began in mid-2009.

The EOE effect has an impact on hours growth only in displacing some growth that would have otherwise occurred from the recession and early post-recession recovery to the previous end-of-expansion interval, which is defined as the period between the peak in the output gap and the beginning of the recession. Reflecting the fact that the over-hiring is offset by under-hiring later, the EOE effect is measured by the fitted values on a set of 1, -1 dummy variables, not a set of 0, 1 dummy variables. The dummy variables have values that reflect the varying length of the EOE intervals. For instance if there are seven quarters between the peak of the output gap and the beginning of the recession, then the "on" dummy variable consists of seven successive values of 4/7 (summing to 4 rather than 1 to reflect the annualization of quarterly growth rates). Then the "off" dummy variable would be defined as a string of -4/5 values if the recession and post-recession rebound period is five quarters long. In between the "on" interval and "off" interval the dummy variable is set at zero, and between the end of the "off" interval and the subsequent "on" interval in the next business cycle the dummy variable is also set at zero. A single dummy variable is entered for the entire sample period and so its coefficient measures the average impact of the EOE effect across all business cycles. Its coefficient is expected to be positive in the hours equation and an equal negative value in the equation for productivity change. A listing of the EOE dummy variable is provided in the data appendix.[6]

The change-in-gap specification is now identical to (8) above with the addition of the EOE dummy variable:

$$x_t' = \sum_{i=0}^{4} \alpha_i {y'}_{t-i} + \sum_{i=0}^{4} \beta_i y_{t-i}' LATE_{t-i} + \sum_{i=1}^{4} \gamma_i x_t' + \varphi EOE_t + \epsilon_t \qquad (11)$$

The calculation of the long run responses is the same as in equations (9) and (10).

Table 4 for gap growth rates is set up in the same format as Table 3 for gap levels, with the addition of two additional rows displaying the sum of coefficients on the lagged dependent variables (LDV) and the single coefficient on the EOE effect. The productivity equation in the first column yields a LATE shift coefficient that is at the borderline of the 0.05 level of statistical significance. The LR effects are 0.22 before 1986 and 0.09 after 1985, respectively somewhat larger and smaller than those in the level gap productivity equation of Table 3. The EOE coefficient is a highly significant -1.57 percent in the productivity equation and +1.57 percent in the hours equation, indicating that productivity growth between the quarter in which the output gap reaches its maximum value and the quarter that ends the expansion cumulates to 1.57 percent slower than the rate predicted by the estimated output coefficient, and that this -1.57 percent shortfall of productivity is reversed in the later quarters of the recession and/or the early quarters of the post-recession recovery.

The LR responses in the equations for the components of hours change are roughly similar to those in Table 3. The LR employment-rate response is 0.45 for pre-1986 and 0.54 for post-1985, compared to 0.47 and 0.58 in the equivalent Table 3 results. The upward post-1985 LATE shift coefficient is significant at the 0.04 level. The pre-1986 LR responses are somewhat lower than in Table 3 for the employment rate and the payroll-to-household hours ratio and are somewhat higher for hours per employee and for the labor-force participation rate.

While Tables 3 and 4 only exhibit sums of coefficients, it is important to note the pattern of individual coefficients on the current and lagged output variables. The top five horizontal bars of Figure 5 show the individual current and lagged coefficients for the full-period impact of output gap changes on productivity gap changes. Note that the current-quarter impact effect of

[6] The only episode to be treated differently is 2000-2003, when the EOE effect was missing and productivity growth was strong in the final three quarters of the expansion between 2000:Q3 and 2001:Q1. Buoyant productivity growth during this interval continued through 2004, part of the puzzle of why productivity growth was so strong for four years after the collapse of the late 1990's "dot.com" investment and stock market bubble.

output is 0.45, considerably higher than the sum of coefficients of 0.33. This reflects the switch from a positive initial coefficient to mainly negative lag coefficients, and as shown by the top five blue bars for hours in the bottom of Figure 5, the negative lag coefficients for productivity are the counterpart of the pattern of gradually declining but positive lagged coefficients in hours equation that reflects the slow response of hiring to changes in output.

Because of the zig-zag pattern of coefficients in the productivity change equation, the conclusion that the sum of coefficients has an effect insignificantly greater than zero does *not* mean that there is no impact of output change on productivity change. This is shown by the second set of green bars in Figure 5 which are the full-period coefficients minus the LATE shift coefficients and thus represent the post-1985 responses. Even though the sum of coefficients is an insignificant 0.12, the impact effect in the current quarter is a substantial 0.53. Thus even after 1985 there is a short-run response of productivity change to output change that is gradually reversed over the subsequent four quarters.

We have previously noted the unusual behavior of productivity change in the 2007-09 recession and early stages of the recovery. This is illustrated in Figure 6, which plots the four-quarter growth rates of the output and productivity gaps between 1990:Q1 and 2018:Q3. The temporary bubble of productivity growth during 2009 is clearly visible, and the first two quarter of the positive hump in productivity growth overlaps with the two most negative quarters of output growth. This temporary phenomenon is the counterpart of the extremely rapid decline in hours growth, representing the panic phase of the recession following the global financial crisis. Looking at one-quarter changes rather than the four-quarter changes plotted in Figure 6, we see that for 2009:Q1 the one-quarter hours change was -8.33 percent at an annual rate, substantially greater than the -5.56 percent one-quarter output change, resulting in a one-quarter productivity growth rate of 2.77 percent points. In the subsequent quarter 2009:Q2 hours plummeted at a -6.47 percent rate even though output had turned around with a quarterly growth rate of 0.58 percent, resulting in a huge 7.05 percent growth bulge of productivity.

To gauge the impact of this unusual post-2007 behavior, as in Table 3, the two bottom rows of Table 4 show the difference in the post-1985 responses when the sample period ends in 2017 versus 2007. For productivity change the truncation of the sample period at 2007 raises the productivity response to output from 0.09 to 0.16, in contrast to larger increase from 0.04 to 0.19 in the Table 3 level equation. The 1986-2007 cyclical response of productivity has a significance value of 0.11 so is not statistically significant by standard criteria. This is not surprising as the change data are so much noisier than the gap levels data, and we note that all the LATE shift terms in Table 4 are less significant than they are in Table 3.

4. Comparison with Selected Recent Research

A conclusion from our previous regression analysis is that the decline in the procyclicality of productivity growth has been partially offset by an increased responsiveness of the employment rate to changes in output. This result conflicts with the finding by Ball *et al.* (2013), who claim in the context of Okun's Law that the response of the unemployment rate, and hence the employment rate, to output has remained stable over time. These authors do not comment on the conflict between their finding of stability in the unemployment-output relationship and a downward shift in the procyclicality of productivity growth, because their study is limited to the behavior of unemployment. Their findings stand in contrast to a body of literature that has examined the decay of Okun's law since the mid-1980s, including Meyer and Tasci (2012), Knotek (2007), and Owyang and Sekhposyan (2012).

This section revisits Ball *et al.*'s finding of stability to determine whether it is robust to alternative specifications and methods of detrending. We also compare our results with those of Fernald and Wang (2016), who use a different methodology but concur with our finding that the procyclical productivity response has disappeared. Fernald and Wang, however, do not link productivity behavior to that of hours and employment and so shed no light on the contrary results of the Ball *et al.* research.

Fernald and Wang were not the first to document the decline or disappearance of a procyclical productivity response. Earlier support for this finding was provided by Stiroh (2009) in an aggregate and industry-level investigation of decreased output volatility. Gali and Gambetti (2010) utilized a VAR framework to show a weakened response of productivity and heightened response of hours to non-technological shocks. Barnichon (2010) used a neo-Keynesian search and matching model to attribute productivity's weakening cyclicality to increased flexibility in labor markets beginning in the 1990s. Gordon (2010) documented the disappearance of the procyclical productivity response in the context of an increased cyclical response of hours and employment.

Papers supporting the procyclical productivity response tend to have been written earlier than those that find no effect, but several of them were written since the year 2000 by which time 15 years of evidence had accumulated covering years during which the procyclical effect had vanished. These include Basu and Fernald (2001) who titled their paper "Why Is Productivity Procyclical?" as well as a paper in the RBC tradition by Wen (2004), and a plant-level data study conducted by Baily *et al.* (2001).

Nevertheless, most recent literature supports the reduction or disappearance since the 1980s of the procyclical response of productivity. Daly *et al.* (2013) use both a "labor-market" model similar to ours by breaking hours growth into hours-per-employee, employment, and labor force participation, as well as a "capital" model that decomposes productivity into total factor productivity, capital deepening, labor quality, and utilization. While their "capital" model finds that most of productivity's newfound acyclicality is driven by a decrease in the role of procyclical utilization relative to countercyclical capital deepening and labor quality, their "labor market" model shows that most of the procyclical shift results from an increased response of the employment rate to the business cycle. Galí and Van Rens (2014) propose a model of the labor market where a fall in employment exit probability explains the increasing acyclicality of productivity and reduced volatility of output. Biddle (2014) suggests that a fall in firms' cost of adjusting employment means that labor-hoarding, once thought to be one of the potential drivers of procyclical productivity, has become less frequently practiced. Wang (2014) uses industry level data to show that much of the increased acyclicality of productivity can be attributed to the sectoral shift away from commodities production towards the more acyclical services sector as well as an increased sensitivity of TFP to persistent technological shocks that are negatively correlated with inputs.

Although the Ball *et al.* paper examines unemployment behavior while Fernald and Wang focus on productivity, the two studies share the reliance on the Hodrick-Prescott method of detrending and the transformation of unemployment and productivity data, respectively, into first-difference form. In this section we contrast results using Hodrick-Prescott (H-P) and Kalman as alternative detrending methods and also examine whether results differ when variables are expressed as levels or first differences.

Ball et al. on the Cyclical Response of Unemployment

We begin by replicating the equations displayed in Table 2 of Ball *et al.*, which display two types of regressions -- one of the level of the unemployment rate gap on the present and first two lags of the level of the log GDP gap (without a constant), and another of the first difference of the unemployment gap on three lags of the first difference of the log output gap (with a constant). As in equation (5) above, the first difference of the output gap is equivalent to the percentage change in output minus its trend growth rate. In our replication, we replace the unemployment rate (U) with the employment rate (100 – U), so our estimated coefficients have positive rather than negative signs.[7] Whereas Ball *et al.* estimate a single set of coefficients on current and lagged output variables, we also include as in Tables 3 and 4 above the same "LATE" dummy variable multiplied by the output term to provide an estimate of any post-1985 shift that may have occurred in the response of the employment rate to output. Their basic regression design is the same as our equation (7) plus a first-differencing variant indicated in equation (12) below. For consistency, we also include a "growth rate" version in equation (13).

$$\Delta \frac{E_t}{L}_t = \mu + \sum_{i=0}^{4} \alpha_i y_{t-i} + \sum_{i=0}^{4} \beta_i y_{t-i}\, LATE_{t-i} + \epsilon_t \tag{12}$$

$$(\mathrm{e_t} - l_t) = \mu + \sum_{i=0}^{4} \alpha_i y_{t-i} + \sum_{i=0}^{4} \beta_i y_{t-i}\, LATE_{t-i} + \epsilon_t \tag{13}$$

Equation (12) relates the first difference of the employment rate to the first difference of log output, which is simply the growth rate of output. Equation (13) has a similar interpretation, how a one percent increase in GDP growth affects the growth rate of the employment rate level.

[7] A minor difference is that we include four lags on the output terms instead of two lags as in the Ball *et al.* regressions.

Since equations (12) and (13) refer to variables that are not detrended, we add a constant, thereby remain consistent with the Ball *et al.* paper as well as previous literature.

The three left columns of Table 6 display results for our replication of the Ball et al. results, which shows the long run pre-1986 response of employment to output, the long run post-1985 response, and the significance of the post-1985 shift. While Ball *et al.* only perform regressions using the H-P level gap and first difference equations, we also perform robustness checks using our equation (11) and a quarterly growth[8] equation as in (13). Hence, the first two columns utilize equation (7) with the H-P and Kalman level gaps; the third uses (12), the fourth (13), and the final column equation (11). This final column corresponds precisely to column 5 of our Table 4 as discussed above.

For the H-P level filtering method in the first column, the sum of the coefficients of the employment rate on the output gap in the pre-1986 period is 0.50, similar to the 0.47 response shown in the second column for the Kalman detrending method. This is comparable to Ball et al.'s coefficient sum of -0.5 for the unemployment rate in their Table 2. However, there is a strongly positive and significant shift of the coefficient by 0.14 points after 1985, implying a post-1985 response of employment of 0.64. This contradicts the Ball *et al.* claim that the response of unemployment has remained *stable*. A highly significant positive late shift of 0.11 occurs when using the Kalman-filtered gaps in the second column. Sizeable and significant late shift responses are also obtained for the quarterly growth rate and first difference regressions with the non-detrended variables, as shown in the third and fourth columns. The result is more muted, but still significant at the 0.05 level for our Table 4 Kalman-detrended change equation. Thus all five of our alternative results contradict the Ball *et al.* conclusion that the Okun's Law response of unemployment to output has remained stable throughout the postwar period.

Fernald and Wang on the Procyclicality of Productivity

Table 1 of Fernald and Wang's paper displays correlations between both level gaps and growth rate gaps for output and productivity in the Nonfarm Private Business Sector. Our Table 7 adds an additional panel on the left side of this table that shows the results are similar using our aggregate economy data. We also add rows that show the robustness of their results to our Kalman detrending method. Finally, to establish consistency with our time periods, we set the start date as 1950:Q1, the "Late" break date as 1986:Q1 (rather than 1984), and the ending date as 2017:Q4. From top to bottom, we perform correlations using the Kalman level gaps, H-P filter level gaps, Kalman growth-rate gaps, and the H-P filter growth-rate gaps between output and productivity. The last row is presents a correlation between the quarterly growth rates of non-detrended productivity and output.

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[8] The difference is that in the first difference specification, the quarterly first difference of employment is used. In the quarterly growth rate version, we utilize the percentage growth rate of the employment rate, calculated using the natural log.

The first row of numbers in Table 7 shows that the Kalman log level productivity gap for the total economy experiences a massive shift in 1986, with the correlation with the aggregate output gap declining from a strong 0.74 from 1950-1986 to an insignificant 0.10 in 1986-2017. The Kalman results are equally pronounced for the NFPB sector Fernald and Wang use, falling from 0.83 to 0.19. Notably, the pre-1986 correlation with productivity is much higher with the Kalman filter for both sectors than with the H-P filter, although they fall to similar low levels of correlation. This occurs because the H-P technique, as shown in Figure 1, yields a trend series for output that has substantial remaining business cycle movements, removing those procyclical changes from the detrended output series. As we have seen, the two detrending techniques yield trends for productivity change that are much more similar than for output change.

The reduction in correlation after 1985 is less pronounced for all the first difference variants, with the correlation falling no more than 0.20 points for the first difference of the Kalman and HP gaps, as well as the non-detrended growth rates of productivity and output. Again, this reveals sensitivity in detecting structural shifts to the choice of levels or first differences. To explore this further, we perform an identical set of regressions to the ones we used to replicate Ball et al. (2017), using HP level gaps, Kalman level gaps, and quarterly growth rates. The results are displayed in Table 8. The regression equations are the same as those in Table 6 above, only replacing the employment rate dependent variable with labor productivity. In particular, the first two columns correspond to equation (7), the third to equation (13), and the final one to equation (11). The final column corresponds to column 1 of our Table 4.

The initial H-P level gap indicates a surprising result, that not only did labor productivity have almost no response to output growth pre-1986, but that productivity after 1985 turned weakly countercyclical with a significant negative shift coefficient. The Kalman level and change regressions show a positive response of labor productivity to output growth pre-1986 that has a statistically significant shift to zero for the post-1985 interval. The results are more muted but still significant at a 5% level in the final column that uses the Kalman growth rate version with the EOE effect as in equation (11).

In all cases, the replications confirm the Fernald and Wang finding that since 1985 productivity is no longer procyclical, the productivity gap has almost no response to the output gap, and therefore that the cyclicality of hours must have increased by a corresponding amount. These authors do not explore the role of the post-2007 interval in contributing to their finding, whereas in our analysis above the conclusion of a disappearing procyclical productivity response is considerably muted when the sample period ends in 2007 This raises the question as to whether the 1986-2007 or 2007-2018 interval is more relevant for the future cyclical behavior of productivity gap levels and changes.

5. Post-Sample Simulations to Detect a Productivity Growth Revival

All our results thus far refer to the output, hours, and productivity gaps, that is, the log ratio of actual to trend values. One way to detect a revival in trend productivity growth would be to estimate our gap change equation through a particular date and then simulate its predictions of a given output path holding constant the estimated cyclical coefficients and the assumed trend rate of productivity growth at the end of the sample period. If actual productivity growth consistently exceeds the prediction of the equation with the fixed assumption of trend productivity growth, then that autocorrelated series of errors would imply that the trend growth rate of productivity has risen relative to the assumed constant value.

Figure 7 illustrates how this procedure reveals the revival of productivity trend growth that we know occurred in the late 1990s. We estimate the growth gap version of our productivity equation (Table 4, col. 1) from 1950 to 1995 and calculate the predicted growth rates of productivity during 1996-2001, holding constant the value of the Kalman productivity growth trend of 1995:Q4 throughout the 1996-2001 interval. Figure 7 shows three four-quarter growth rates of values of output and productivity changes, which are the changes in the gaps plus the changes in the underlying output and productivity Kalman trends. Red represents the actual growth rate of output and green displays the actual growth rate of productivity. The black line through 1995:Q4 is the predicted value of the equation and the continuation of the black line to 2001:Q4 is the calculated prediction of the equation for that fixed trend growth rate. The graph shows that the actual value began in mid-1997 to exceed the predicted value and consistently did so by about one percentage point during late 1997 and 1998, then somewhat less in 1999 to early 2000, and then by even more than one percent as actual output growth decelerated and caused a decline in the predicted productivity growth series.

Does productivity behavior in 2017-18 display a similar response of the actual output relative to the prediction of the Table 4 equation? Figure 8 copies the same format and color scheme of Figure 7, except now the sample period ends in 2015:Q4 and the graph covers the interval 2010:Q1 to 2021:Q4. The red line depicts actual output growth through 2018:Q3 and a plausible projected path of output out to 2021:Q4. The assumption is that output grows at 2.5 percent from 2018:Q4 to 2019:Q4, then 1.0 percent during 2020 and 0 percent during 2021. This creates a growth bulge in 2018-2019.

The green line displays actual productivity growth, and the black line shows predicted productivity growth, consisting of the fitted value of the estimated equation through 2015:Q4 and then the projection to 2021:Q4 using the actual output values to 2018:Q3 and the assumed output values through 2021:Q4. As in Figure 7 the values of the lagged dependent variable in the projection interval are generated endogenously based on predicted productivity growth, not actual productivity growth. The forecast record of the equation through 2018:Q3 is remarkably good and there is no tendency of the equation to underpredict actual growth as occurred in 1997-2001. Thus, in contrast to 1997-98, there is no sign so far of a productivity growth revival. And, because of the low Table 4 post-1985 LR response of the productivity gap change to the output gap change, predicted productivity growth remains below 1.0 percent throughout the 2019-2021 interval.

Figure 9 is identical to Figure 8 but plots actual, fitted, and projected hours growth rather than productivity growth. The hours equation does quite well in tracking the actual bulge in hours growth in 2014-15 and the slump in hours growth in 2016 to early 2017. Quite noticeable is the accuracy with which the equation tracks the sharp increase in hours growth that has occurred in 2018. Hours growth is projected to continue at about 2.0 percent through late 2019 and then gradually to decline toward zero by late 2021, reflecting the assumed slowdown in output growth toward zero in 2021.

The continued growth of hours worked at a pace of 2 percent through 2019 implies continuing positive growth of the employment rate, i.e., a decline in the unemployment rate. Table 5 shows that the unemployment rate reacts to the assumed output growth path by declining to a minimum of 2.35 in 2020:Q4 before rising modestly to 2.67 in 2021:Q4. This continued multi-year interval of unemployment below 3.5 percent and even below 3.0 percent, lower even that the lowest rates reached in the 1960s, raises the possibility of accelerating inflation and an aggressive series of rate increases by the Fed that dampens the economic expansion sooner and by more than the assumed output growth path. Or, it could be that the productivity growth trend revives and makes it possible to achieve the assumed output path with less growth in hours and a smaller reduction in the unemployment rate.

6. Determinants of the Productivity Growth Trend

So far there is no evidence that the productivity growth trend has increased in 2017-2018, but that verdict could change in 2019 and 2020. What determines the trend growth of productivity? Traditionally the determinants of labor productivity growth are capital deepening (the growth of the capital-labor ratio times capital's income share), the contribution of changing labor quality, and the contribution of TFP growth which is calculated as a residual from data on the actual rates of change of labor productivity, capital deepening, and changes in labor quality. The determinants of TFP growth are innovation and technological change, as well as structural changes such as the growth or relaxation in productivity-curbing regulations.

The low level of current unemployment and the tightness of labor markets also raises the question as to whether trend productivity growth rises when labor markets are tight. The fact that the unemployment rate was low in the 1960s and late 1990s when the productivity growth trend was relatively high suggests that this relationship is worth investigating. This section examines the response of trend productivity growth to the unemployment rate as a measure of labor market tightness and to changes in the capital-labor ratio. A combination of tight labor markets and faster growth in the capital-labor ratio due to a revival of fixed investment are both factors that could yield an increase in trend productivity growth in 2019 and 2020. To estimate the likelihood of this outcome we need an equation with coefficients for the relationship between trend productivity growth and both the unemployment rate and the change in capital deepening.

The estimated equations are displayed in Table 9. The first set of columns refers to a sample period that runs from 1950:Q1 to 2007:Q4 – we reserve the years since 2007 to examine the ability of the equations to forecast what has happened to trend productivity growth since 2007. The equation includes the unemployment rate and the four-quarter change in the unemployment rate, as well as a constant and a constant shift term to allow for the slowing of trend productivity growth, and is displayed below as equation (14)

$$(y_t^* - h_t^*) = \alpha_0 + \alpha_1 LATE_t + \beta_1 U_t + \beta_2 (U_t - U_{t-4}) + \epsilon_t \qquad (14)$$

where U is the unemployment rate and y^*-h^* is the growth rate of trend labor productivity. The effect of the unemployment rate on trend productivity growth is highly significant with a coefficient of -0.27, meaning that over this 57-year sample period on average a one percentage point decline in the unemployment rate was associated with an increase in the trend productivity growth rate of 0.27 percentage points. This suggests that on balance tighter labor markets stimulate productivity growth. The four-quarter change in the unemployment rate has a highly significant coefficient of 0.13, indicating that at any given *level* of the unemployment rate, trend productivity growth is higher when unemployment is rising than when it is falling. The equation also includes a constant term reflecting the fact that the mean of the unemployment rate is not zero and a small but significant negative post-1986 constant shift term.

The predictions of the unemployment rate capture the fact that unemployment was relatively low in the 1950s, 1960s, and late 1990s while trend productivity growth in those periods was relatively high, while unemployment was relatively high during the 1970s and 1980s when productivity growth was relatively low. But the fit is relatively poor, as shown in Figure 10, reflecting the business cycles in the unemployment series that have been purged in the process of using the unemployment gap to create the Kalman productivity trend. A much more serious problem is the implied projection of trend productivity growth after 2007 that can be created by combining the estimated coefficients with the actual history of the unemployment rate. While the rising unemployment rate of 2009-10 tracks the decline in trend productivity growth, the projection is an utter failure after that, projecting a return of trend productivity growth above 2 percent instead of the decline to 0.5 percent that has actually occurred.

Why would trend productivity grow faster when unemployment is low? One possibility is that the unemployment rate is serving as a proxy for everything else that is different in an economy with tight labor markets, most notably a faster pace of investment and capital deepening. To untangle the separate effects of capital deepening and unemployment, we enter a capital-deepening term separately and then together with the unemployment rate. Our capital-deepening term is the growth rate of an index of capital services created by John Fernald at the San Francisco Federal Reserve divided by our trend hours series that is plotted above in Figure 3. To smooth the volatile movements in the capital series, the numerator of the change in the capital-labor ratio is defined as an eight-quarter moving average, and the resulting change in the capital-labor ratio term $(k_t - h^*_t)$ is entered as a current value and additionally as a four-quarter and eight-quarter lag. This is shown in equation (15).

$$(y_t^* - h_t^*) = \alpha_0 + \alpha_1 LATE_t + \gamma_1(k_t - h_t^*) + \gamma_2(k_{t-4} - h_{t-4}^*) + \gamma_3(k_{t-8} - h_{t-8}^*) + \epsilon_t \tag{15}$$

The capital-deepening term does not perform well in data prior to 1970 because capital deepening was substantially lower in the 1950s than the 1960s, while the productivity trend on average grows faster in the 1950s than the 1960s. But if we limit our sample period to 1970-2007, as in the middle section of Table 9, we obtain a highly significant sum of coefficients of 0.37 on the capital-deepening term. Does this eliminate the significance of the unemployment rate? We can combine both equations (14) and (15) to yield equation (16) below:

$$(y_t^* - h_t^*) = \alpha_0 + \alpha_1 LATE_t + \beta_1 U_t + \beta_2(U_t - U_{t-4}) + \gamma_1(k_t - h_t^*) + \gamma_2(k_{t-4} - h_{t-4}^*) + \gamma_3(k_{t-8} - h_{t-8}^*) + \epsilon_t \tag{16}$$

The third section of Table 9 shows that both the unemployment terms and the capital-deepening effect in equation (16) enter with a high level of significance and that the coefficients on both terms are reduced in comparison to the left sections of Table 9 where they are entered separately. The sum of coefficients on the capital deepening term is 0.27, which is not far from capital's income share – many studies of the sources of growth routinely use a capital share of 0.3.

Figure 11 shows the surprisingly good fit of the combined equation on the right side of Table 9. The decline in the productivity growth trend between 1970 and 1980 is tracked accurately, as is the plateau during 1980-95, the rise in the late 1990s, and the decline between 2003 and 2007. But notice in Figure 11 that the periods 1950-70 and 2007-2018 have been left blank. What are the implications of this set of coefficients for trend productivity growth when projected on the data for unemployment and capital-deepening for those two periods?

The answer is provided by Figure 12, and here we see that the equation is a dismal failure in explaining why trend productivity growth was so high before 1970 and so low after 2012. This failure helps us to remember that productivity growth reflects not only capital deepening but also the growth of TFP that introduces the role of innovation, technological change, and structural change. Clearly TFP growth during 1950-70 was much faster than on average during 1970-2007 and was much lower during 2012-2018. The pattern in Figure 12 suggests a slowing impact of innovation since 2012, particularly when compared with 1950-70.

Nevertheless the combined equation of Table 9 does provide coefficients that can help us to answer the question – even if we cannot forecast changes in TFP, what is the likely increase in the productivity growth trend that would occur in 2019-2021 given plausible forecasts for the behavior of the unemployment rate and capital deepening? We obtain projections of the unemployment rate from the post-2015 simulation experiment of Figure 9, which result in the unemployment rate series that we have already examined in Table 5 above. Forecasts of future changes in the capital-labor ratio have been kindly provided by Joel Praaken of Macro Advisers and yield an increase of roughly 0.7 percentage points of capital-labor growth between 2018;Q3 and 2021:Q4.

Figure 13 shows the resulting projection results for the period 2007-2021 while Figure 14 zooms in to show a magnified version of the same projections for 2018-2021. Four versions are provided. Version A assumes that both the unemployment rate and the capital-labor ratio growth rate are fixed during 2019-21 at the constant rate of 2018:Q3. Version B holds the capital-labor ratio constant while allowing the unemployment rate to decline as in Table 5. Version C holds the unemployment rate constant while allowing the capital-labor growth rate to rise as forecast by Macro Advisers. Finally, version D combines the forecasts of unemployment and the change of the capital-labor ratio. Comparing D with A, the difference made in trend productivity growth for 2021:Q4 is about 0.4 percentage points.

Note that these experiments are applied to the forecasts of the Table 9 equation which is highly inaccurate after 2012, because it fails to take account of the decline in TFP growth that has occurred in the last half-decade. If the Table 9 estimates of the effects of unemployment and capital-deepening are reasonably accurate, then when applied to the actual 2018:Q3 trend productivity growth rate of 0.5, the extra projected 0.4 points would cause trend productivity growth almost to double.

7. Conclusion

Productivity growth in the total U.S. economy has averaged only 0.5 percent over the eight years ending in 2018:Q3, slower than any eight-year period in postwar quarterly data and matched in the 20th century only by the 0.5 percent change of the peak-to-trough eight years between 1925 and 1933. But that 1925-33 slump in productivity growth reflected a strong procyclical component, as productivity grew at 4.1 percent in the subsequent eight years, 1933-41.

All the analysis in this paper refers to productivity growth in the total economy rather than the more frequently cited data on productivity growth in the nonfarm private business sector, and this reflects two overriding reasons to focus on the total economy. First, total-economy productivity growth is the concept needed to forecast future growth in potential real GDP. Second, total-economy productivity growth is linked by definition to growth in aggregate hours, which in turn can be decomposed into the sum of growth in the employment rate, hours per person, the labor-force participation rate, and the ratio of payroll to household hours.

What is the likelihood that aggregate productivity growth will revive from the dismal record of the past eight years? This paper divides that question into two parts by distinguishing between the growth in the productivity trend and changes in the difference or "gap" between actual and trend productivity growth. An econometric analysis revisits the magnitude of the procyclical response of the productivity gap to the output gap, one of the elements in Arthur

Okun's original 1962 Okun's Law. Since output growth in the U.S. economy has accelerated from 2.2 percent during 2010-17 to 3.1 percent in the first three quarters of 2018, productivity growth would be expected to have accelerated if the procyclical response remained positive as originally posited by Okun.

The creation of actual vs. trend gaps for productivity, hours, and output requires a detrending method. Results with the standard Hodrick-Prescott (H-P) univariate method are contrasted with an alternative bivariate method using the Kalman filter technique to extract from the time series on productivity and other variables the component that is correlated with the unemployment gap, which in turn is the unemployment rate minus the NAIRU published by the Congressional Budget Office (CBO). A comparison of output trend series shows that the H-P method yields an output trend that retains a sizeable business cycle component, in contrast to the Kalman output trend that is completely unresponsive to the alternation of postwar recessions and expansions. The H-P and Kalman trend series are much closer for productivity than for output, and both techniques agree that the productivity trend has slowed from about 1.7 percent per year in 2007 to a mere 0.5 percent in 2018. Since the Kalman hours trend also grows in 2018 at only around 0.5 percent per year, the Kalman output trend implies that potential real GDP is currently growing at only 1.0 percent per year, much less rapidly than the current 1.9 percent potential output growth estimate of the CBO.

Is productivity growth still procyclical. An econometric analysis reports on the response of the productivity gap to current and lagged values of the output gap. The analysis is carried out alternatively with variables expressed as level gaps and gap changes. An inspection of level gap data for productivity and output in Figure 4 reveals a shift toward acyclical behavior in the mid-1980s, and so a post-1985 shift term is introduced into both the level gap and gap change equations. The results for the level gaps have higher significance levels than for the gap changes, because the level data are smoother and less volatile, but both measures yield a highly significant post-1985 shift coefficient. In the level version the response of the productivity gap to a one-percentage-point change in the output gap declines from 0.27 pre-1986 to 0.04 post-1985. For the change version the decline is less sharp, from 0.22 to 0.09.

Even if the sum of current and lagged output terms is zero, however, this does not mean that output has no influence on productivity, because the current output term is always highly significant with a coefficient of around 0.5. The sum of coefficients is much less because the lagged coefficients in the productivity equations are negative. This pattern reflects the lagged adjustment of the hours gap to the level or change in the output gap. Thus in a period when output growth is accelerating as in 2017-18 we should observe a temporary boost to productivity growth even if the sum of coefficients is zero.

Our analysis points out that part of the downward post-1985 coefficient shift is due to the markedly countercyclical relationship between productivity and output growth during the most recent recession of 2007-09. During the year 2009 hours growth fell more drastically than output growth, resulting in an upward surge of productivity growth that reached 7 percent at an annual rate in 2009:Q2. To explore the role of the post-2007 data in the conclusion that the procyclical response of productivity has disappeared, we estimate our equations alternatively to end the sample period in 2007. For the level gap version the procyclical productivity response is still intact with a coefficient of 0.19, down somewhat from the pre-1986 coefficient of 0.27 but still highly significant.

Because the post-1985 coefficient shift downward is mirrored by an equal-sized upward coefficient shift in the response of the hours gap to the output gap, that increased hours response must correspond to an equal-sized shift in the components of hours. The upward shift is primarily reflected in a significantly more responsive employment rate, and there is also a smaller upward shift in the responsiveness of hours per employee and in the labor-force participation rate. In a literature review we contrast our results with those of Ball *et al.* (2017) who assert that the Okun's Law response of the unemployment rate to the level or change of the output gap is stable over the postwar period. We also compare our productivity shift conclusions to those of Fernald-Wang (2016), who also conclude that productivity is not procyclical but do not comment on the difference in pre-2007 and post-2007 behavior.

We assess the possibility of a productivity growth revival by examining both the change in the productivity gap and the productivity trend. Our proposed method to use our productivity growth equations is to stop the estimation several years before the period in question and calculate post-sample simulations of productivity growth in periods when output growth accelerated, holding constant the assumed productivity growth trend. In an experiment for the late 1990s, we estimate our equation through 1995:Q4 and then project the calculated values of the change in the productivity gap to the actual history of output, holding constant the productivity growth trend at its 1995:Q4 value. The equation goes off track after mid-1997, substantially underpredicting productivity growth for the rest of the 1990s, reaffirming what we already know, that the productivity growth trend accelerated markedly in the late 1990s.

The same experiment is carried out with an end-sample date of 2015:Q4. Assuming a fixed productivity growth trend, we compare the actual and projected values of productivity growth using the actual output outcome through 2018:Q3. In complete contrast to the 1990s our 2018 projects are right on track, providing no evidence that the productivity growth trend has begun a revival process.

A second approach is to examine the role of two determinants of the productivity growth trend, the tightness of labor markets and the contribution of capital deepening. A regression analysis shows that there is a highly significant response of the Kalman productivity growth trend to the unemployment rate with a response coefficient of -0.12 and to the change in the capital-labor ratio with a coefficient of 0.27, roughly the same size as the capital income share. While performing impressively in its fit to the 1970-2007 data, this equation does poorly in projections before the 1970 starting point of the sample period of after the 2007 termination point of the sample period. Compared to the predictions of the equation, actual trend productivity growth was much higher in 1950-70 and much lower in 2012-2018. These prediction errors reflect the role of total factor productivity (TFP) as an additional determinant of productivity growth.

Nevertheless the coefficients on unemployment and the capital-labor ratio provide a method to forecast a possible revival of trend productivity growth over the next three years. Using a forecast of the future unemployment rate from our simulation experiments and a forecast of capital-labor growth from Macro Advisers, we calculate that trend productivity growth could revive by about 0.4 percentage points between late 2018 and late 2021. This in turn would slightly moderate the unprecedented decline in the unemployment rate that is implied by our assumed output growth path.

The analysis yields several important conclusions. First, actual productivity growth during 2011-2018 has been low not because output growth has been relatively slow, because since 1985 there has been a negligible if any procyclical response of the change in the productivity gap to the change in the output gap. Rather, slow productivity growth in 2011-18 reflects the slow underlying trend of productivity growth, and this in turn has been caused by a marked decline in TFP growth rather than in the contribution of capital deepening. Given the slow 0.5 growth rate of trend hours, potential output growth has been running at about 1.0 percent per year rather than the 1.9 percent forecast of the CBO. The paper concludes that a further decline in the unemployment rate and increase in growth of the capital-labor ratio would yield a modest revival of trend productivity growth of 0.4 percentage points, enough to boost trend productivity growth from 0.5 to around 1.0 percent and potential output growth from 1.0 to around 1.4 percent per year.

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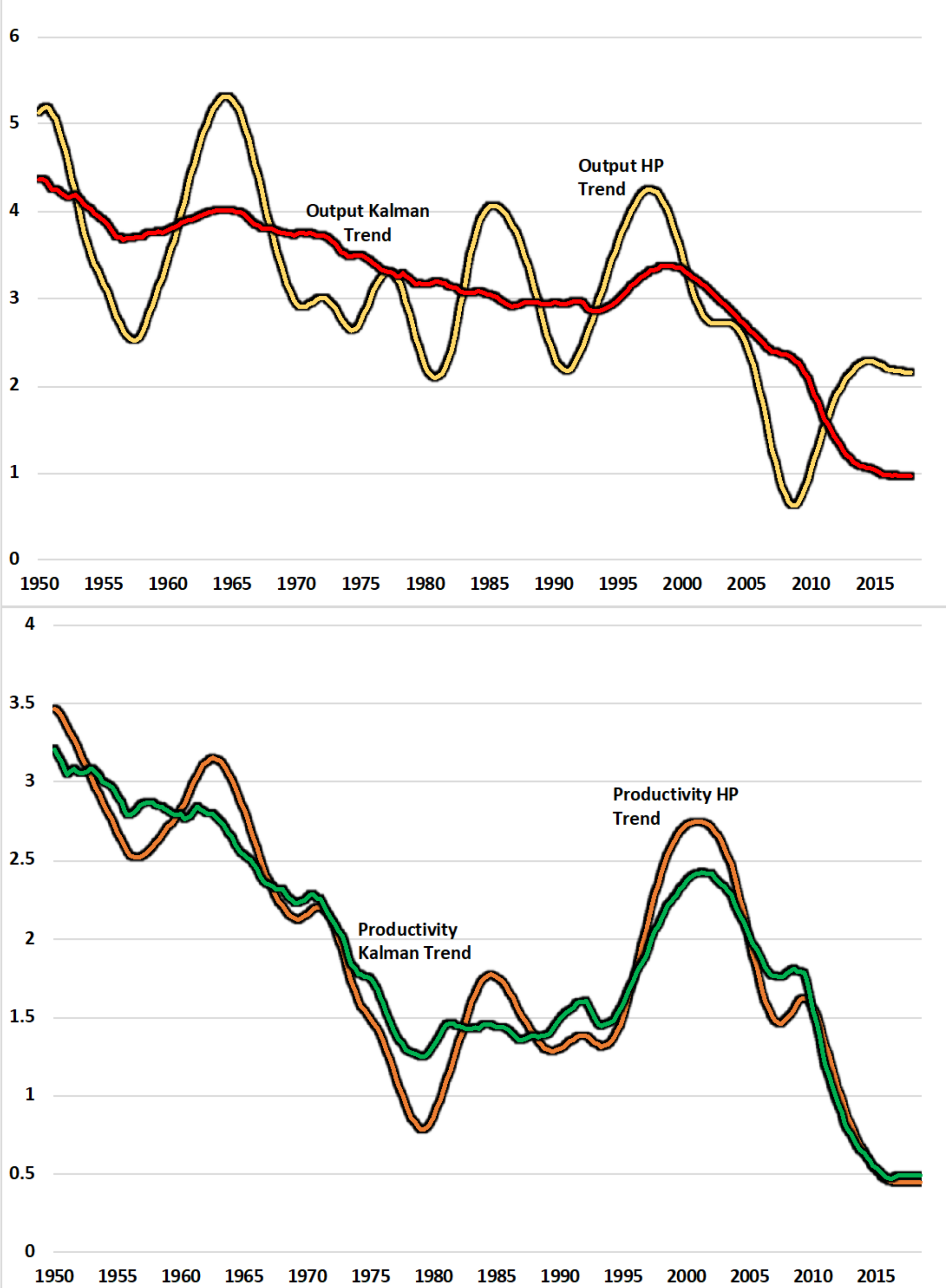
Figure 1. Output Trends for Total Economy, HP Filter vs. Kalman Filter, 1950:1-2018:3



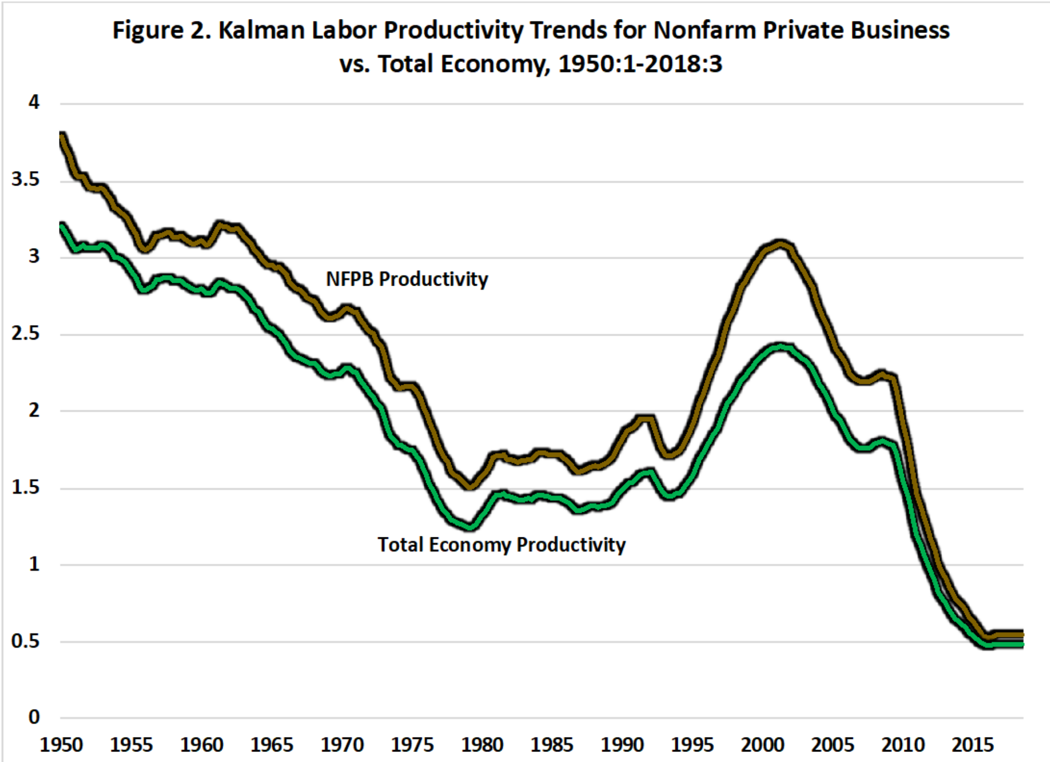


Figure 2. Kalman Labor Productivity Trends for Nonfarm Private Business
vs. Total Economy, 1950:1-2018:3
NFPB Productivity
Total Economy Productivity
4
3.5
3
2.5
2
1.5
1
0.5
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

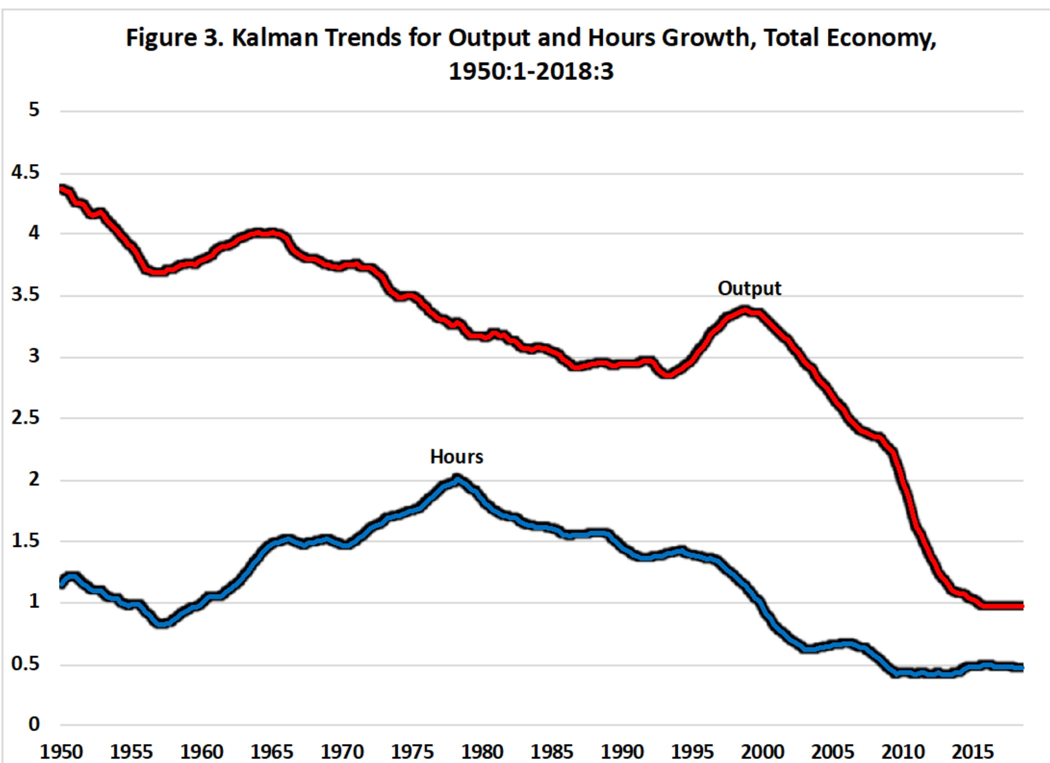


Figure 3. Kalman Trends for Output and Hours Growth, Total Economy,
1950:1-2018:3
Output
Hours
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Figure 4. Kalman Level Output and Productivity Gaps, Total Economy, 1950:1-2018:3

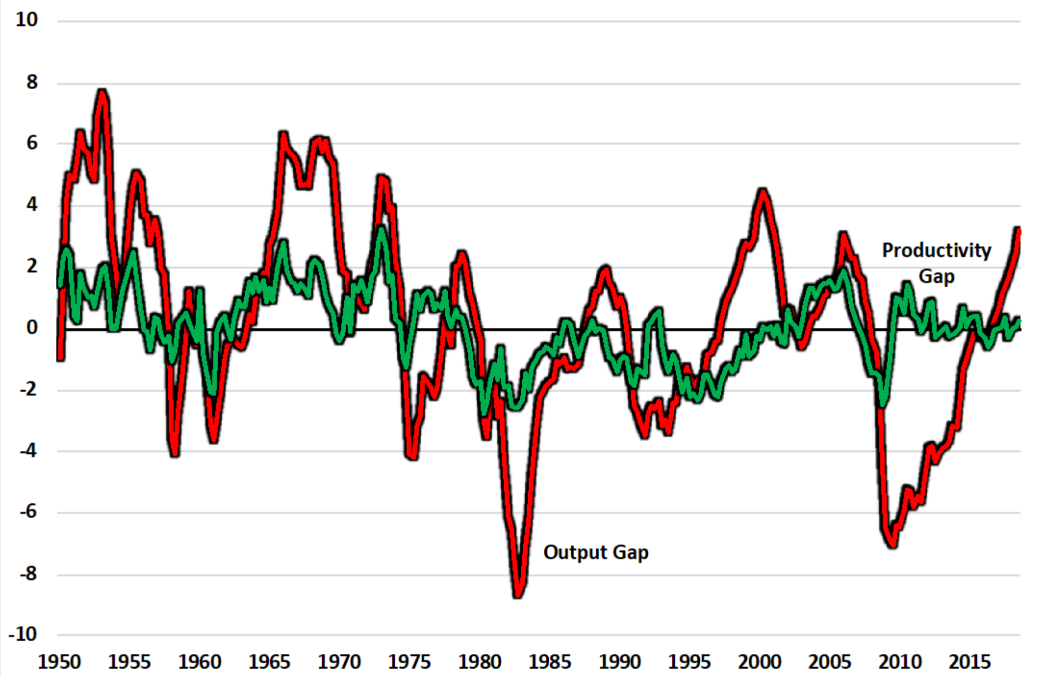


Figure 5a. Coefficients on Current and Lagged Output Gap Change from Productivity Regressions, Table 4, col. 1

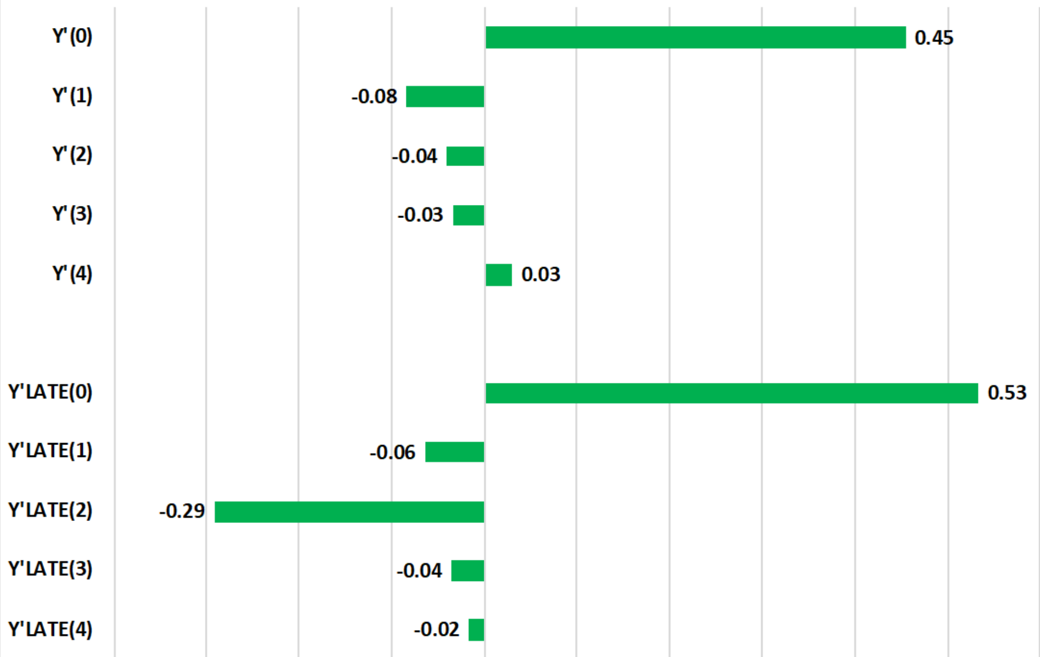
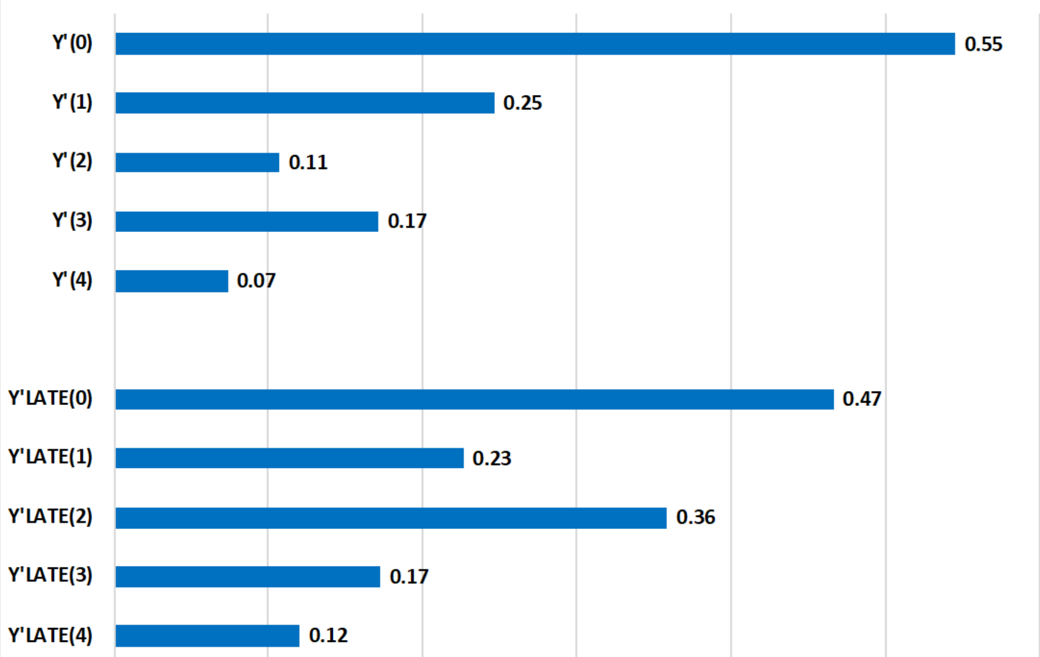


Figure 5b. Coefficients on Current and Lagged Output Gap Change from Hours Regressions, Table 4, col. 2



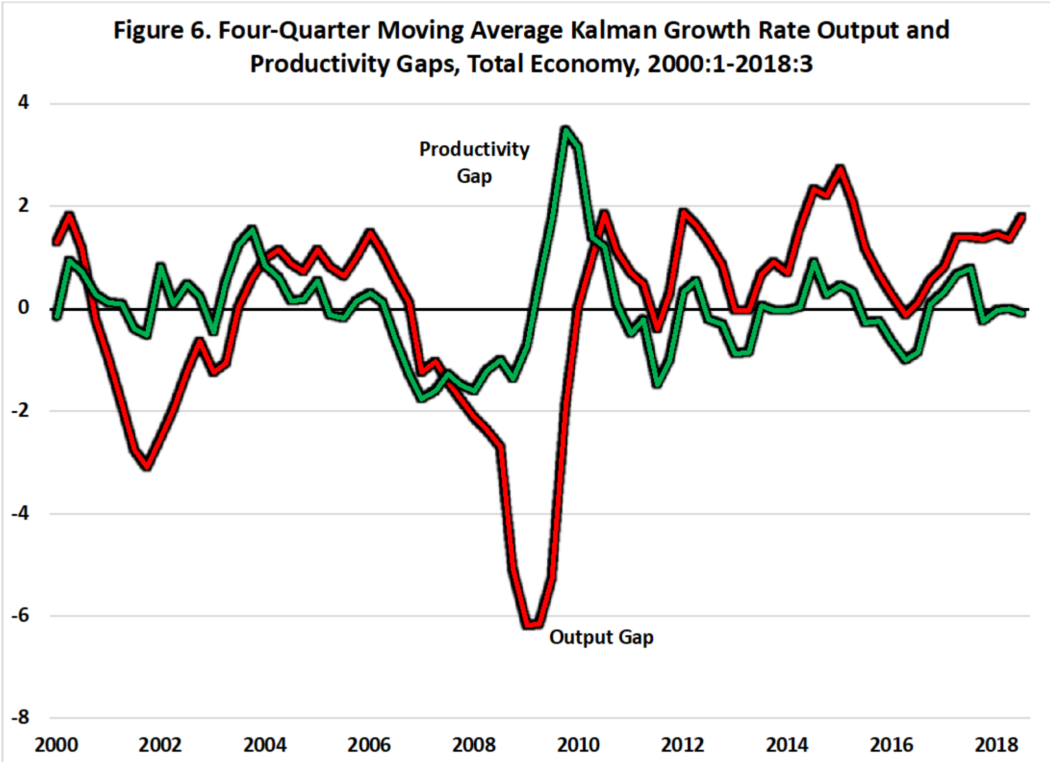


Figure 6. Four-Quarter Moving Average Kalman Growth Rate Output and Productivity Gaps, Total Economy, 2000:1-2018:3
4
2
0
-2
-4
-6
-8
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Productivity Gap
Output Gap

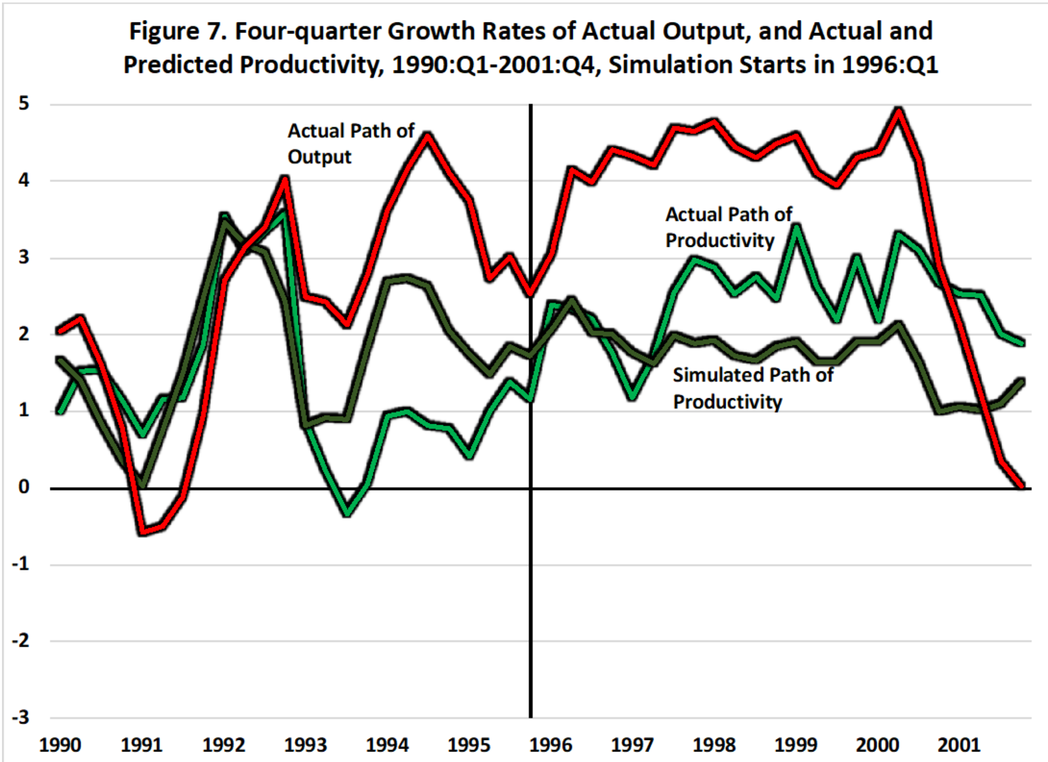


Figure 7. Four-quarter Growth Rates of Actual Output, and Actual and Predicted Productivity, 1990:Q1-2001:Q4, Simulation Starts in 1996:Q1
Actual Path of Output
Actual Path of Productivity
Simulated Path of Productivity
5
4
3
2
1
0
-1
-2
-3
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001

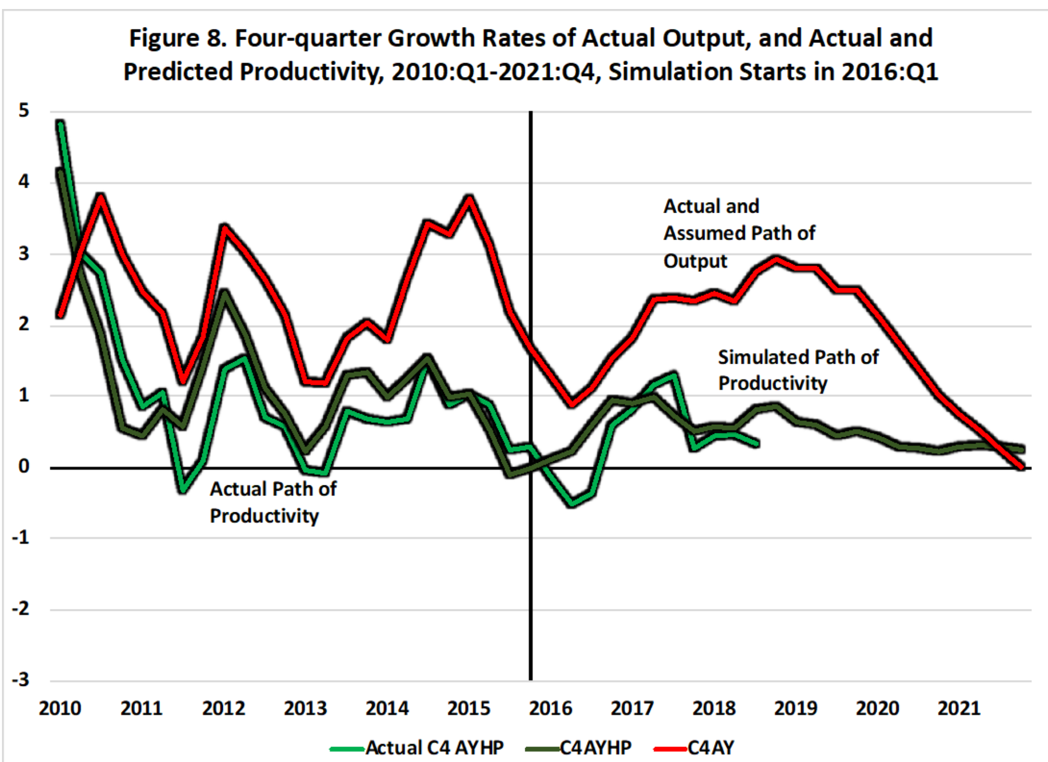


Figure 8. Four-quarter Growth Rates of Actual Output, and Actual and Predicted Productivity, 2010:Q1-2021:Q4, Simulation Starts in 2016:Q1
Actual and Assumed Path of Output
Simulated Path of Productivity
Actual Path of Productivity
5
4
3
2
1
0
-1
-2
-3
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Actual C4 AYHP
C4AYHP
C4AY

Figure 9. Four-quarter Growth Rates of Actual Output, and Actual and Predicted Hours, 2010:Q1-2021:Q4, Simulation Starts in 2016:Q1

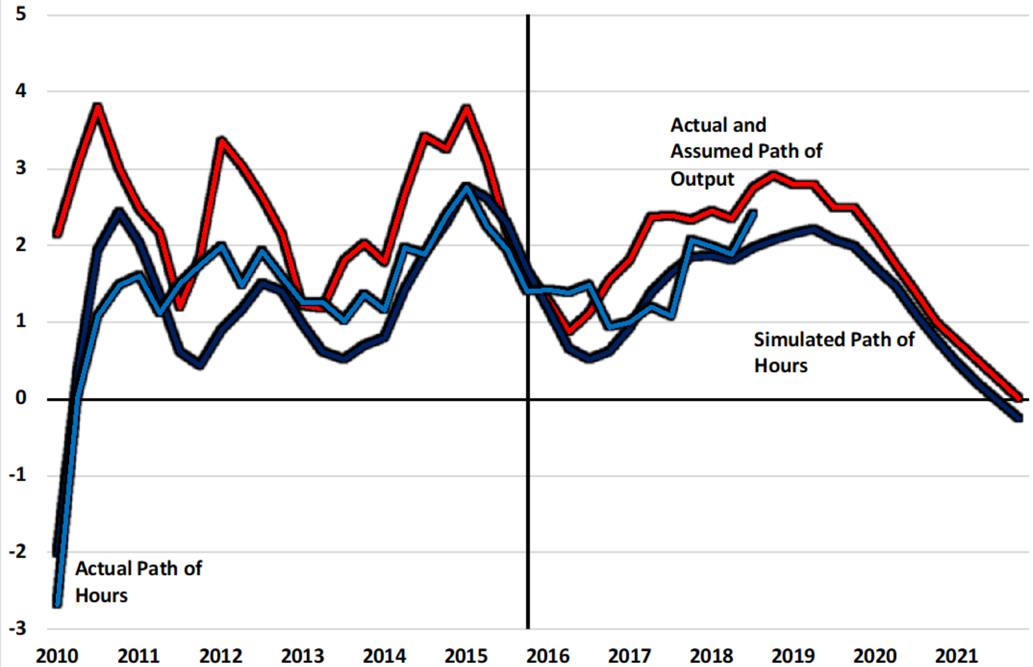


Figure 10. Fitted vs. Predicted vs. Actual Labor Productivity Trend, 1950:1-2007:4, Simulation 2008:1-2018:3 Based on Table 5 Col.1 with Unemployment Rate

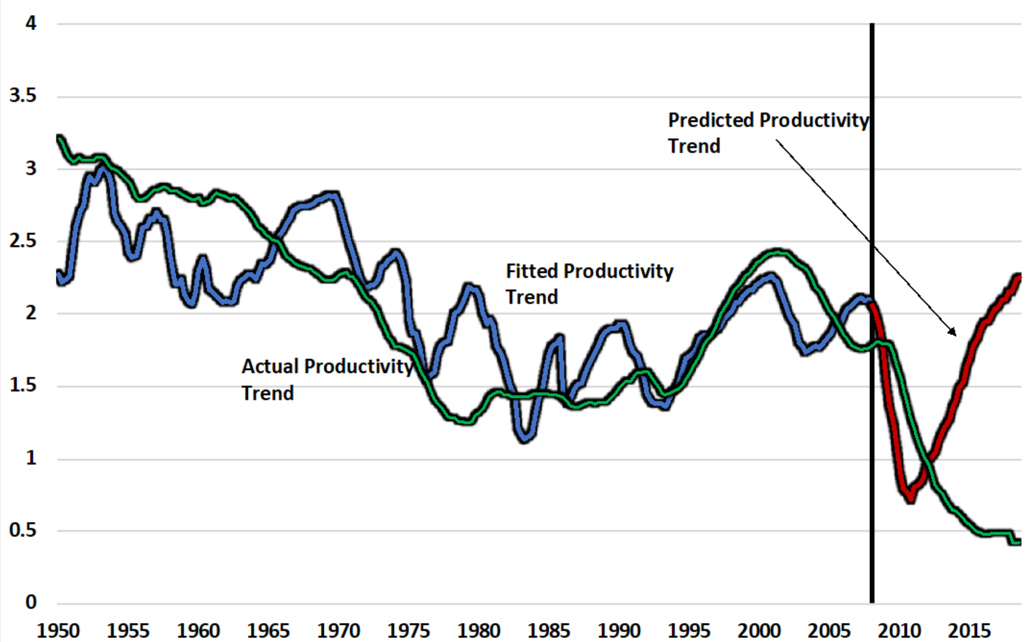



Figure 11. Fitted vs. Actual Labor Productivity Trend, 1950:1-2007:4, Based on Table 5 Col.3 with Unemployment Rate and Capital-Labor Ratio
Actual Productivity Trend
Fitted Productivity Trend
4
3.5
3
2.5
2
1.5
1
0.5
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

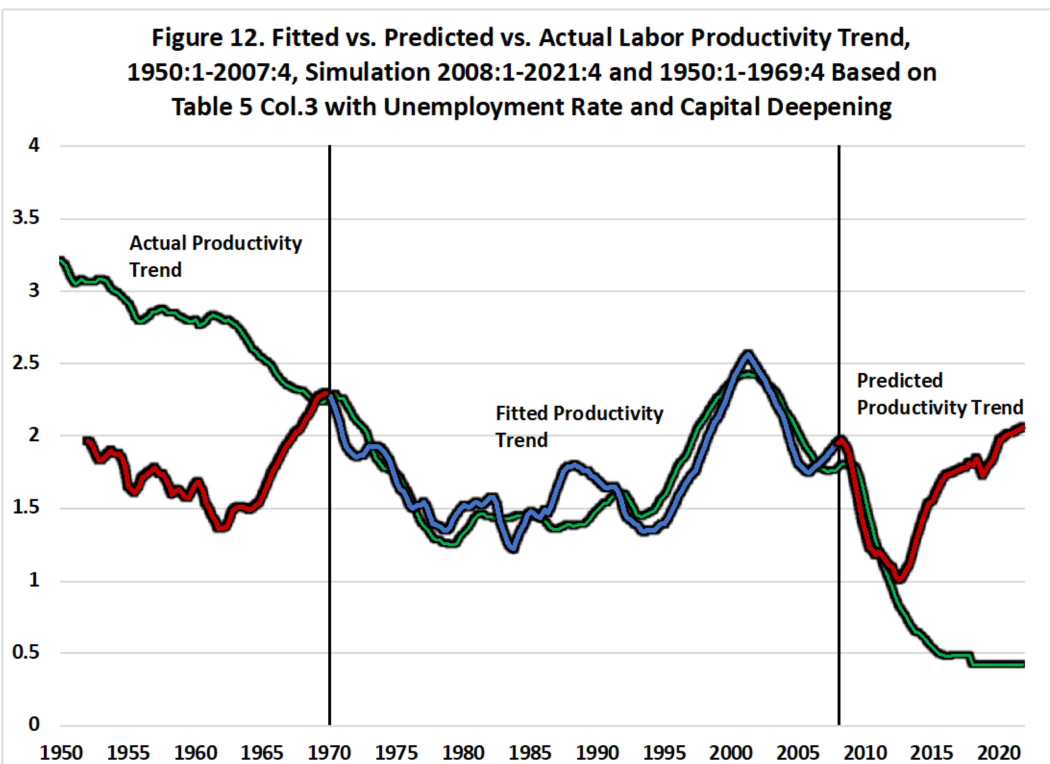


Figure 12. Fitted vs. Predicted vs. Actual Labor Productivity Trend, 1950:1-2007:4, Simulation 2008:1-2021:4 and 1950:1-1969:4 Based on Table 5 Col.3 with Unemployment Rate and Capital Deepening
Actual Productivity Trend
Fitted Productivity Trend
Predicted Productivity Trend
4
3.5
3
2.5
2
1.5
1
0.5
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

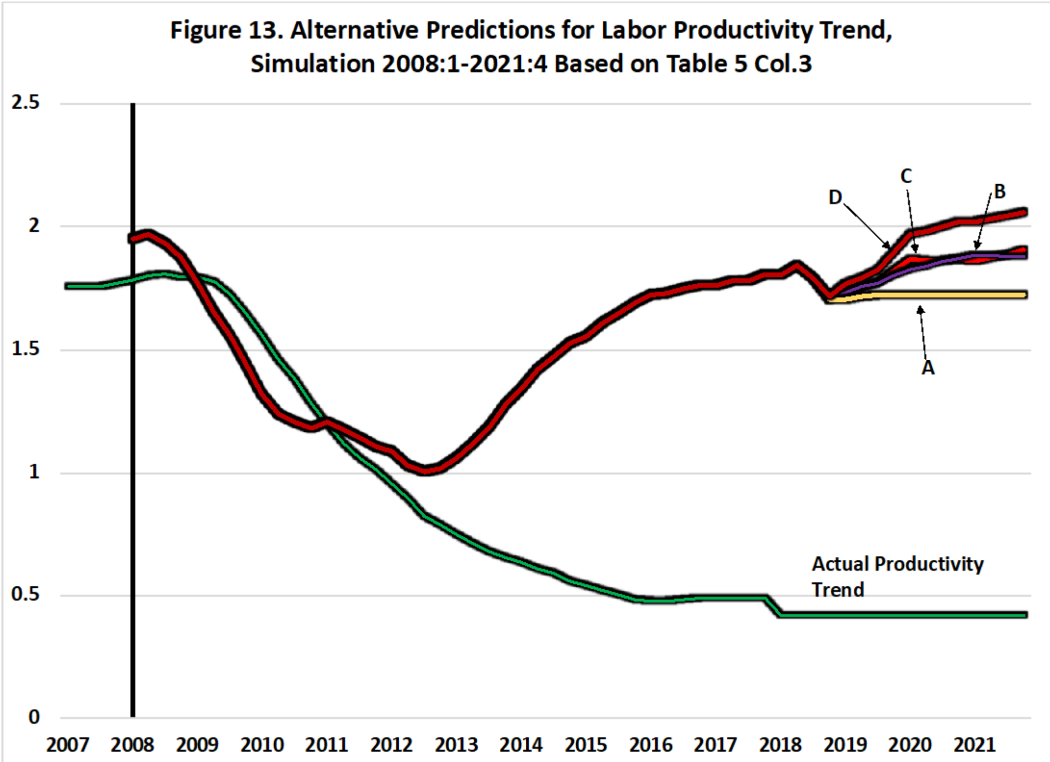


Figure 13. Alternative Predictions for Labor Productivity Trend,
Simulation 2008:1-2021:4 Based on Table 5 Col.3
2.5
2
1.5
1
0.5
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
D
C
B
A
Actual Productivity Trend

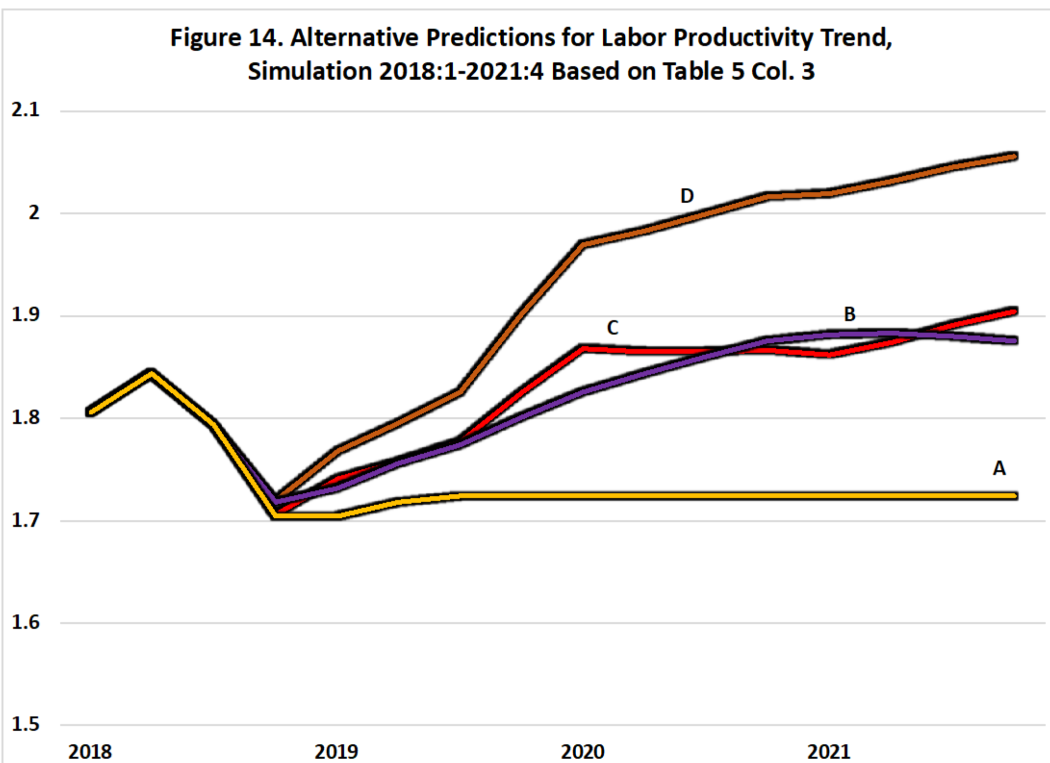


Figure 14. Alternative Predictions for Labor Productivity Trend,
Simulation 2018:1-2021:4 Based on Table 5 Col. 3
2.1
2
1.9
1.8
1.7
1.6
1.5
2018
2019
2020
2021
D
C
B
A

Table 1. Breakdown of Output Growth into its Components, 1950-2018								
Time Period	Output	Output per Hour	Payroll Hours	Payroll to Household Hours Ratio	Hours per Employee	Employment Rate	Labor Force Participation Rate	Population Growth
1950:1-1972:4	4.22	2.85	1.37	0.04	-0.25	0.05	0.11	1.42
1973:1-1995:4	2.88	1.27	1.60	-0.26	0.04	-0.01	0.42	1.41
1996:1-2004:4	3.48	2.62	0.86	-0.23	-0.08	0.02	-0.10	1.26
2005:1-2018:3	1.79	1.04	0.74	-0.04	-0.08	0.11	-0.35	1.11

Table 2. Labor Productivity Growth for NFPB vs. Total Economy, 1950-2018			
Time Period	NFPB Productivity	Total Economy Productivity	Difference
1950:1-1972:4	3.07	2.85	0.22
1973:1-1995:4	1.52	1.27	0.25
1996:1-2004:4	3.31	2.62	0.70
2005:1-2018:3	1.32	1.04	0.28

Table 3a. Regression Response to Changes in Output Gap for Hours and Labor Productivity, 1950:1-2017:4					Table 3b. Regression Response to Changes in Output Gap for Components of Hours, 1950:1-2017:4							
	Output per Hour		Payroll Hours		Payroll to Household Hours Ratio		Hours per Employee		Employ-ment Rate		Labor Force Partici-pation Rate	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Output Gap	0.27	0.00	0.73	0.00	0.20	0.00	0.24	0.00	0.47	0.00	-0.02	0.18
Output Gap Late Shift	-0.22	0.00	0.22	0.00	-0.15	0.00	0.03	0.55	0.11	0.00	0.08	0.00
LR Early Response	0.27	0.00	0.73	0.00	0.20	0.00	0.24	0.00	0.47	0.00	-0.02	0.18
LR Late Response	0.04		0.96		0.05		0.26		0.58		0.06	
Adj.R^2	0.48		0.90		0.16		0.41		0.92		0.09	
S.E.	0.88		0.88		1.11		0.99		0.48		0.54	
Alternative Post -1985 Long-Run Effects												
1986-2017	0.04	0.21	0.96	0.00	0.06	0.04	0.26	0.00	0.58	0.00	0.06	0.00
1986-2007	0.19	0.00	0.81	0.00	0.07	0.15	0.18	0.00	0.39	0.00	0.12	0.00

Table 4a. Regression Response to Changes in Output Growth Gap for Hours and Labor Productivity, Including Lagged Dependent Variable and End-of-Exp. Effect, 1950:1-2017:4					Table 4b. Regression Response to Changes in Output Growth Gap for Components of Hours, Including Lagged Dependent Variable and End-of-Exp. Effect, 1950:1-2017:4							
	Output per Hour		Payroll Hours		Payroll to Household Hours Ratio		Hours per Employee		Employ-ment Rate		Labor Force Partici-pation Rate	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
Output Gap	0.33	0.00	1.14	0.00	0.17	0.23	0.83	0.00	0.53	0.00	0.08	0.06
Output Gap Late Shift	-0.20	0.05	0.20	0.05	-0.17	0.51	0.18	0.48	0.11	0.04	0.04	0.64
Sum of LDV	-0.47	0.00	-0.47	0.00	-1.91	0.00	-2.19	0.00	-0.18	0.09	-0.39	0.01
End-of-Exp. Effect	-1.57	0.00	1.57	0.00	-0.07	0.91	0.82	0.19	0.61	0.00	0.07	0.09
LR Early Response	0.22	0.00	0.78	0.00	0.06	0.23	0.26	0.00	0.45	0.00	0.06	0.06
LR Late Response	0.09		0.91		0.00		0.32		0.54		0.08	
Adj.R^2	0.56		0.71		0.45		0.49		0.76		0.05	
S.E.E.	1.50		1.50		3.78		3.77		0.77		1.16	
Alternative Post -1985 Long-Run Effects												
1986-2017	0.09	0.22	0.91	0.00	0.02	0.78	0.29	0.00	0.52	0.00	0.11	0.01
1986-2007	0.16	0.11	0.84	0.00	0.03	0.70	0.23	0.00	0.45	0.00	0.16	0.00

Table 5. Projected Values of Unemployment Rate Based on Post-2018 Simulation		
Year	Actual Unemployment	Projected Unemployment
2018	3.90	
2018.25	3.8	
2018.5	3.8	
2018.75		3.54
2019		3.28
2019.25		3.06
2019.5		2.83
2019.75		2.62
2020		2.48
2020.25		2.41
2020.5		2.37
2020.75		2.35
2021		2.39
2021.25		2.47
2021.5		2.57
2021.75		2.67

Table 6. Results from Ball et. al Replication, Regressions of Employment on Output										
	HP Level Gap		Kalman Level Gap		First Difference		Quarterly Growth Rate		Table 4 Equation	
	Coefficient	Sig. of Shift	Coefficient	Sig. of Shift	Coefficient	Sig. of Shift	Coefficient	Sig. of Shift	Coefficient	Sig. of Shift
LR Early Response	0.50		0.47		0.40		0.42		0.45	
LR Late Response	0.64	0.00	0.58	0.00	0.53	0.00	0.57	0.00	0.54	

Table 7. Fernald and Wang Correlations Between Level and Growth Gaps for Productivity and Output, Total Economy vs. NFB Sector, 1950:1-2017:4						
	Total Economy			NFB Sector		
	1950:1-2017:4	1950:1-1985:4	1986:1-2017:4	1950:1-2017:4	1950:1-1985:4	1986:1-2017:4
Level						
Kalman Level Gap	0.56	0.74	0.10	0.63	0.83	0.19
HP Level Gap	0.32	0.43	0.09	0.42	0.58	0.09
Changes						
Kalman Growth-Rate Gap	0.57	0.61	0.44	0.64	0.68	0.52
HP Growth-Rate Gap	0.58	0.61	0.50	0.65	0.68	0.58
Growth-Rates	0.58	0.62	0.45	0.64	0.68	0.51

Table 8. Results from Fernald and Wang Using Regressions of Productivity on Output								
	HP Level Gap		Kalman Level Gap		Quarterly Growth Rate		Table 4 Equation	
	Coefficient	Sig. of Shift	Coefficient	Sig. of Shift	Coefficient	Sig. of Shift	Coefficient	Sig. of Shift
LR Early Response	0.06		0.27		0.18		0.22	
LR Late Response	-0.17	0.06	0.04	0.00	0.03	0.02	0.09	0.05

Table 9. Regressions of Long-Run Labor Productivity Trend on Total Unemployment and Capital-Labor Ratio						
	Productivity Trend on Unemployment Rate		Productivity Trend on Capital-Labor Ratio		Productivity Trend on Capital-Labor Ratio and Unemployment Rate	
	1950:1-2007:4		1970:1-2007:4		1970:1-2007:4	
	Coeff.	Sig.	Coeff.	Sig.	Coeff.	Sig.
U. Rate	-0.27	0.00	-	-	-0.12	0.00
4th Diff. of U. Rate	0.13	0.00	-	-	0.07	0.00
Capital-Labor Ratio	-	-	0.37	0.00	0.27	0.00
Constant	3.77	0.00	0.62	0.00	1.68	0.00
1986-2007 Dummy	-0.42	0.00	0.19	0.00	0.07	0.07
Adj.R^2	0.53		0.71		0.78	
S.E.E.	0.40		0.20		0.17	

Table A1. End-of-Expansion Dummy Variable Dates			
"On Date"	"On Value"	"Off Date"	"Off Value"
1955:4-1957:3	4/8	**1957:4-1958:3**	-4/4
1959:2-1960:2	4/5	1961:2-1962:4	-4/7
1968:4-1969:4	4/5	1970:2-1971:3	-4/6
1973:2-1973:4	4/3	1975:1-1976:2	-4/6
1979:1-1980:1	4/5	1980:4-1981:3	-4/4
1989:2-1990:3	4/6	1991:4-1992:3	-4/4
2006:2-2007:4	4/7	2009:1-2009:4	-4/4