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REVISITING U. S. PRODUCTIVITY GROWTH OVER THE PAST CENTURY WITH A VIEW OF THE FUTURE

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This paper is dedicated not only to the 80th birthday of Angus Maddison but also to the memory of Robert McGuckin of the Conference Board. The 2006 conference version of this paper was made possible by the creative research assistance of Robert Krenn. Jesse Wiener brought new insights to this revision and extension of the data. The views expressed herein are those of the author and do not necessarily reflect the views of the National Bureau of Economic Research.

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ABSTRACT

This paper provides three perspectives on long-run growth rates of labor productivity (LP) and of multi-factor productivity (MFP) for the U. S. economy. It extracts statistical growth trends for labor productivity from quarterly data for the total economy going back to 1952, provides new estimates of MFP growth extending back to 1891, and tackles the problem of forecasting LP and MFP twenty years into the future.

The statistical trend for growth in total economy LP ranged from 2.75 percent in early 1962 down to 1.25 percent in late 1979 and recovered to 2.45 percent in 2002. Our results on productivity trends identify a problem in the interpretation of the 2008-09 recession and conclude that at present statistical trends cannot be extended past 2007.

For the longer stretch of history back to 1891, the paper provides numerous corrections to the growth of labor quality and to capital quantity and quality, leading to significant rearrangements of the growth pattern of MFP, generally lowering the unadjusted MFP growth rates during 1928-50 and raising them after 1950. Nevertheless, by far the most rapid MFP growth in U. S. history occurred in 1928-50, a phenomenon that I have previously dubbed the “one big wave.”

The paper approaches the task of forecasting 20 years into the future by extracting relevant precedents from the growth in labor productivity and in MFP over the last seven years, the last 20 years, and the last 116 years. Its conclusion is that over the next 20 years (2007-2027) growth in real potential GDP will be 2.4 percent (the same as in 2000-07), growth in total economy labor productivity will be 1.7 percent, and growth in the more familiar concept of NFPB sector labor productivity will be 2.05 percent. The implied forecast 1.50 percent growth rate of per-capita real GDP falls far short of the historical achievement of 2.17 percent between 1929 and 2007 and represents the slowest growth of the measured American standard of living over any two-decade interval recorded since the inauguration of George Washington.

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1.1 Introduction

This paper looks ahead 20 years and predicts future growth rates of U. S. labor productivity and potential real GDP. Yet we know nothing about the future unless we understand the past, and this paper provides a new interpretation of the growth of labor productivity and of multi-factor productivity (MFP) since 1891. Everything in this paper refers to the U. S. and the reader is referred elsewhere for an interpretation of the divergence of productivity growth in the U. S. and Europe in the postwar period, with a European catching up process through 1995 and a falling back since then (see Dew-Becker and Gordon 2008 and Timmer *et al.* 2010).

The paper begins with the short-run facts by providing up-to-date productivity and potential GDP trends based on US quarterly data through the fourth quarter of 2009 (henceforth 2009:Q4). The trends and deviations from trends (i.e., "gaps") are new and constitute an update with improved methodology of my paper (Gordon, 2003) on the 2001-04 "explosion" in U.S. productivity growth. We learn that the productivity explosion in 2001-04 unraveled rapidly in 2004-07 prior to another explosion in 2009. Both the 2004-07 slowdown and the 2009 explosion reinforce themes long emphasized in my research going back more than three decades (see Gordon 1979), that productivity growth is weakest in the final stages of the business cycle expansion ("the end-of-expansion slowdown") and is most rapid in the early stages of the economic recovery ("the early recovery productivity bubble").

Next, we turn to a medium-term horizon. Relying entirely on the work of others, especially that of Steve Oliner and Dan Sichel, and of Dale Jorgenson, Mun Ho, and Kevin Stiroh, we summarize what is known about the contribution of ICT (Information-Communication-Technology) investment to the post-1995 revival of U. S. productivity growth. These authors find that, while ICT was central in the 1995-2000 revival, in contrast ICT investment plays a much smaller role in the volatile ups and downs of productivity growth between 2000 and 2008. In most of this literature the sources of the 2001-04 explosion remain mysterious and unexplained. In this section we revisit our own previous suggestions (Gordon, 2003) centering on profit pressure and intangible capital and expand these ideas to apply to the 2008-09 recession.

When forecasting the future over 20 years, a longer time horizon is necessary than just the most recent five or ten years. The core sections of this paper revisit growth in labor productivity and MFP over the entire 20th century. In the decade since my "One Big Wave" paper (Gordon, 2000a) on U.S. twentieth century economic growth, two events have occurred that warrant a reassessment. First, another decade of data has emerged in which U. S. productivity growth has revived and, at least for a few years has surged ahead of any similar period in recorded history. Second, and perhaps more important, the 1999 conversion of the U. S. National Accounts to chain-weighted price and quantity indexes resulted in a major upward revision in U. S. real GDP growth during 1929-48, and this adds further support to the previous "big wave" hypothesis that productivity growth during the middle of the twentieth century was historically unique. The analysis of long-term labor productivity and MFP growthbegins with BLS estimates of MFP for the period since 1948 and extends those back to 1891, developing adjustments for labor and capital composition and for changes in the quantity of capital. The capital quantity adjustments are also extended into the post-1948 era.

The last section of the paper develops the implications of the historical analysis for future forecasts. What span of history is relevant for a 20-year forecast, just the past 20 years or a longer horizon? How can we take advantage of forecastable components of future economic growth, such as the plateau of educational attainment that already has occurred? Jorgenson and colleagues, as well as economists at the U. S. Congressional Budget Office (CBO) have provided forecasts going out at least over the next ten years, and we attempt to learn from their forecasts in developing our own.

The paper develops an internally consistent set of forecasts for output, output per capita, labor productivity, the capital deepening effect, labor quality, and MFP growth. The outcome is a projected annual growth rate for 2007-2027 for total-economy labor productivity of 1.7 percent per year, slower than the actual 2.02 percent for 2000-2007 or the actual 1.79 percent for 1987-2007, but faster than the 1.36 percent for 2004-07 or the 1.25 percent for 1972-95. The implied growth rate of 2007-2027 real GDP is 2.4 percent, slightly slower than the 2.5 percent consensus in several recent projections. However, the implied 1.5 percent growth rate of real GDP per capita represents a significant slowing in the projected advance in the American standard of living from the 2.16 percent annual growth rate achieved over 1929-2007.

2. Trend Productivity and GDP Growth in Quarterly Data, 1954-2007

Distinguishing features of the U. S. quarterly postwar growth performance are relatively rapid growth in labor productivity from the late 1940s through 1973, much slower growth through 1995, and a revival after 1995 that further accelerated in 2001-04. As many had predicted, productivity growth slowed in 2004-07 to be followed by an unexpected resurgence during the recession and early recovery of 2008-09. This section disentangles trend from cycle in the U. S. data for aggregate output, labor productivity, and aggregate hours of work.

The U. S. performance contrasts starkly with that in Europe, particularly the original 15 members of the EU prior to the 2004 enlargement (the "EU-15"). After growing more rapidly than the U. S. throughout the postwar period and almost catching up to the level of U. S. labor productivity, Europe stalled after 1995; its productivity growth rate declined while that in the United States revived. By one set of PPP weights, the ratio of labor productivity in the EU-15 relative to the US was 77 percent in 1979, reached 91 percent in 1995, and by 2008 had slipped back to 83 percent.[1] To limit its scope, this paper has no further discussion of European performance regarding productivity or per-capita income. Readers are referred to parallel

1. Details are provided in Gordon (2010a), which in turn is based on data from the Groningen web site.

papers by Dew-Becker and Gordon (2008), Gordon (2010a), and the book by Timmer *et al.* (2010). However, hypotheses suggested to explain the long-period fluctuations in U. S. productivity growth should always refer to the quite opposite European experience; for instance slow productivity growth in the U. S. during the 1973-95 period can hardly be blamed on high oil prices when Europe's productivity continued to grow rapidly despite experiencing the same oil prices.

2.1 The Output Identity

In this section we examine the dimensions of postwar growth in U. S. output, productivity, and aggregate hours. We develop statistical elements of trend growth in these three variables that help us to illuminate changes over time in cyclical and long-run behavior. The output identity 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)*.[2]

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

The identity in equation (1) requires that we define labor productivity using not the standard published measures of output per hour in the private nonfarm business sector (NFPB), but rather output per hour in the total economy. This shift in definition requires use of unpublished BLS data on aggregate hours of work in the total U. S. economy *(H).* Most work on productivity growth refers only to the NFPB sector and cannot be compared to economywide trends in employment, the labor force, and the working-age population without the introduction of cumbersome identical terms in (1), as has been previously analyzed in Gordon (2003). Here we limit the analysis of short-term behavior to equation (1), in which output per hour *(Y/H)* is defined as real GDP divided by aggregate hours of work for the total U. S. economy.

2.2 Actual and Trend Growth in Output, Hours, and Productivity, 1952-2009

To distinguish long-run trends from cyclical movements, we develop trends based on the Kalman filter method. Unlike the more frequently used method of Hodrick and Prescott, which produces trends that are excessively sensitive to business cycle movements, the Kalman technique allows the cycle to be purged from the trend growth estimates through the use of a cyclical feedback variable (See Hamilton 1994). The particular technique of developing the cyclical feedback variable for our trend estimates is based on separate research on the relationship between U. S. inflation and the gap between the actual and natural rates of unemployment, as summarized in Gordon (2010b). Here we skip over the details and present the results, which reveal a problem in extending trend estimates past the U. S. business cycle peak of 2007:Q4 to the most recent data in 2009:Q4.

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

Our examination of trends and cycles begins in Figure 1, which displays the eight-quarter change of real GDP and its Kalman filtered trend growth rate. The eight-quarter actual changes capture the magnitude and timing of the major and minor business cycles over the postwar period. The depth and duration of the 2007-09 recession are comparable to the previous 1980-82 double recession episode. Because the Kalman filter uses the estimated unemployment gap (backed out of the inflation equation) to control for the business cycle, the trend displayed in Figure 1 flattens out the variability at the business cycle frequency and reveals almost no response of the trend to the marked business cycles of 1974-75, 1980-82, or other recession episodes.

Notice that after 2002 the trend estimates diverge. The line that surges up after 2005 is an unconstrained estimate based on the data estimated through 2009:Q4. To obtain some perspective on the role of the 2008-09 recession in creating this trend output growth resurgence, the dashed line shows the growth rate of trend GDP estimated freely through 2007:Q4 and then forced to remain constant after that quarter.

Why do the trend estimates diverge as they do in the 2008-09 period? The key to understanding this phenomenon is the shift in labor-market behavior documented by Gordon (2010b). During the 2008-09 recession employment and unemployment responded with a much higher elasticity to the output cycle than in earlier cyclical downturns. As a result, the use of the unemployment gap as a cyclical feedback variable in the Kalman detrending technique leads the trend estimation procedure to conclude that the output gap in 2008-09 was much larger than actually occurred. To explain actual real GDP behavior in light of this large (but exaggerated) output gap based on the unemployment gap, the Kalman estimation technique translates this large assumed output gap into an increase in the trend growth rate of output as required to make the trend compatible with the exaggerated output gap and the actual data on real output growth. For 2009:Q4 the freely estimated Kalman trend growth rate is 3.7 percent per year, much higher than the constrained 2.8 percent per year, and we reject the higher rate as an implausible byproduct of the structural change discussed above.

Because all trends estimated from data after 2007 are contaminated by structural change in the relationship between output and labor markets, the analysis of this paper sets the end of the relevant sample period in 2007:Q4 rather than 2009:Q4. The resulting trend growth series for real GDP is quite stable over the entire postwar period, ranging between 3.5 and 4.0 percent from 1952 to 1974, and then in the range between 2.7 and 3.5 percent from 1975 to 2007.

Figure 2 displays the actual and trend behavior of aggregate hours in the same format as Figure 1, and Figure 3 does the same for total-economy productivity growth. Figure 2 for aggregate hours displays a peak in the growth trend in 1978 of 1.9 percent per year as a result of the rise in labor force participation of females (and also the peak entry of baby-boom teenagers). There is little difference in the trend estimates for 2008-09 based on free estimation and a constrained extrapolation of the estimates through 2007:Q4; the former is 0.90 percent per year and the latter 0.96 percent per year. What remains unexplained and quite unique in the history of aggregate hours growth is the marked decline in both hours per employee and in labor-force participation in the 2001-05 period. This weakness in the position of labor relative to management that was evident in the aggregate hours data for 2001-03 also may have an impact on the economic recovery of 2010 and beyond (see Gordon 2010b).

Figure 3 provides a parallel presentation of output per hour in the total economy, not the standard published data for the NFPB sector. The growth trend for productivity varies substantially more than the output trend in Figure 1. The trend declines from a peak of 2.8 percent per year in 1961 to 1.2 percent in 1979. The influx of inexperienced females and teens is often cited as a factor for slow trend productivity growth in the late 1970s. Then the trend fluctuated in a narrow range between 1.4 and 1.6 percent per year between 1980 and 1995, before surging up to its unconstrained peak of 2.4 percent in 2002.

In parallel with Figure 1, an alternative estimate of trend productivity growth is presented in Figure 3 that estimates the Kalman trend procedure freely through 2007:Q4, the end of the previous 2001-07 business expansion, and assumes that the 2008-09 productivity growth trend persists at the trend growth rate observed for 2007:Q4. The 2009:Q4 trend growth is 2.9 percent for the unconstrained trend and 1.9 percent for the constrained trend. While rejecting the unconstrained trend as an artifact of the above-discussed structural change in labor market behavior in 2008-09, we admit that this poses a dilemma in making future forecasts. What will be the path by which the unexplained "excess productivity" of 2009 will be eliminated? We return to that question in the final section of the paper.

2.3 Components of the Output Identity Between Benchmark Quarters, 1954 to 2007

We can now look more closely at the growth rates of components of the output identity over the period from 1954 to 2007. The benchmark quarters are chosen to be those in each business cycle recovery when the unemployment rate first declines below the natural rate of unemployment (or time-varying NAIRU) as identified in my ongoing research on the U. S. inflation process. In the final quarter (2007:Q4) the actual unemployment rate was roughly equal to the natural rate of unemployment.

The rows of Table 1 display the growth rate of real GDP, real GDP per capita, and hours per capita, and then the five components of the output identity in the same order as in equation (1). We know by definition that output per capita (line 2) grows more slowly than productivity (line 4) whenever there is a decline in hours per capita (line 3). This happened in Table 1 in the two intervals 1954-72 and 1996-2007, while the opposite occurred in 1972-96, especially during 1987-96 when there was a temporary reversal from the normal historical decline in hours per employee (line 5). Note especially that the decline in H/N pulled down 1996-2007 U. S. growth in output per capita to 1.74 percent, as compared to the relatively healthy 2.16 percent growth rate of total-economy productivity. The decline in hours per capita, in turn, reflected both a return to the normal historical decline in hours per employee, and an unprecedented decline in labor-force participation, particularly among young people.

The resumption of the decline in hours per employee, especially after 2001, has been partly blamed on pressure from employers for employees to work on a part-time basis which deprives employees of expensive pensions and health-care benefits. The 2001-06 decline in the LFPR has been the subject of much discussion, see especially Aaronson *et al.* (2006), and is now thought to be a structural rather than cyclical phenomenon.

3. Interpretations of the Post-1995 U. S. Productivity Growth Revival

Thus far we have looked only at labor productivity and have not yet examined the decomposition of trend growth in labor productivity between capital deepening and MFP growth. Using lower-case letters to represent growth rates, the trend growth in multifactor productivity *(m)* equals output growth minus input growth, which in turn equals the income share of each input times its trend growth rate. Distinguishing only the growth rates of capital *(k)* and labor *(n)* as inputs, and using the notation b for the income share of capital, we obtain the standard relationship between MFP growth, labor productivity growth, and the contribution of capital deepening.

$$m = y - bk - (1-b)n = y-n - b(k-n) \qquad (2)$$

Thus MFP growth can be written either as the growth rate of output minus the weighted growth rate of the two inputs, labor and capital, or alternatively as the growth rate of labor productivity *(y-n)* minus the growth rate of the capital-deepening effect *(b(k-n)).*

3.1 Growth Accounting for the 1995-2000 Revival and the Post-2000 Aftermath

The literature on the post-1995 productivity growth revival goes beyond equation (2) by distinguishing between the contribution of capital deepening in ICT and non-ICT capital, and MFP growth in ICT and non-ICT capital. It is also conventional to estimate the component of MFP growth due to higher labor quality and to list that contribution separately. An important recent contribution is the November, 2008, update by Oliner and Sichel of their 2000 and 2002 papers (see reference list).[3]

These authors devote careful attention to the contribution of the several important categories of ICT capital. They divide up the different contributions of capital deepening by type of capital and as well subdivide the growth of MFP between the contributions of the ICT-producing sectors and the rest of the economy. Their latest calculation is displayed in Table 2 for three periods, the slow productivity growth period of 1973-95, the initial revival period of 1995-2000, and the subsequent interval that started with the 2001-04 productivity "explosion" but then was followed by very slow productivity growth between 2004 and 2007. All data in

3. Table 2 was provided to me by Dan Sichel on February 12, 2010.

both Tables 2 and 3 refer to the NFPB sector, in contrast to Table 1 which covers the entire economy.

Starting at the top of Table 2, we first observe on line 1 the upsurge of US productivity growth from 1.47 percent in 1973-95 to 2.51 percent in the initial "revival" in 1995-2000 and then back down only slightly to 2.48 percent in 2000-07. The next section of the Oliner-Sichel table subdivides the total contribution of capital deepening in the three periods (that is, the *b(k-n)* term in equation 2 above) into the contributions of ICT and non-ICT capital. The 1995-2000 period was remarkable in that ICT capital contributed *almost all* of the capital-deepening effect, whereas ICT capital contributed about two-thirds of the capital-deepening effect prior to 1995 and after 2000. The absolute contribution of ICT capital deepening after 2000 (0.87 percent per year on line 2) was only slightly higher than before 1995 (0.77 percent).

The contribution of ICT to overall productivity growth also includes the contribution of growth of MFP in the ICT industries. This also surged after 1995 and after 2000 remained substantially higher than before 1995. In particular the contribution of semiconductors and of software to overall MFP growth was substantially higher after 2000 than before 1995, while communications was the same and the contribution of computer hardware actually lower.

Oliner and Sichel's headline result is that the sum of the ICT contribution to overall productivity growth fell from 74 percent in 1995-2000 to 43 percent during 2000-07, a lower percentage contribution than before 1995 (see line 17). However, the absolute contribution of ICT for 2000-07 on line 16 was substantially greater than in the pre-1995 interval. The total contribution of the ICT sector to explaining the post-2000 productivity growth was *negative* in the sense that the ICT contribution both to capital deepening and to MFP growth declined substantially while the overall growth rate of productivity, the phenomenon to be explained, was basically flat. By definition, this implies that the continuing rapid rate of labor productivity growth after 2000 resulted from a combination of faster growth in labor quality (line 8), of capital deepening in non-ICT capital (line 7), and especially in MFP growth in the non-ICT industries.

Dale Jorgenson and co-authors (2008) arrive at similar conclusions using similar techniques. Table 3 displays their results in a format that is as close as possible to that of Table 2. Their share of ICT in explaining growth in average labor productivity is less than that of Oliner-Sichel in each period, but they concur that the share of ICT was lower after 2000 than before 1995. Their results extend back from 1973 to 1959 and show that ICT capital made virtually no contribution to economic growth before 1973, but made a greater relative contribution during 1973-95 than during 2000-06, although the absolute contribution was higher in the later period.

The most important difference between Tables 2 and 3 is that the Jorgenson team estimates the total effect of capital deepening to have been much higher in 1995-2000 (their 1.51 percent vs. 1.09 percent in Table 2) and also after 2000 (their 1.26 percent vs. 0.87 percent in

Table 2). *All* of this difference is attributed to the non-ICT part of the economy, with post-2000 non-ICT capital deepening 0.90 percent in Table 3 vs. 0.28 percent in Table 2. Offsetting the higher estimate of the capital deepening effect are lower estimates of MFP growth especially after 2000 (0.92 percent in Table 3 vs. 1.26 percent in Table 2).

Whatever the reason for Oliner and Sichel's larger estimates of MFP growth and the Jorgenson *et al.* larger estimates of the capital-deepening effect outside of the ICT sector, there remains the task of explaining why productivity growth remained robust after 2000 despite the collapse of the ICT investment boom. What caused MFP growth in the non-ICT part of the economy to grow so rapidly in 2000-2006/7 relative to its much slower growth prior to 1995?

3.2 Substantive Explanations of What Happened after 2000

The upsurge of productivity growth between late 2001 and mid-2004, and its much more moderate growth rate during 2004-07, supports the interpretation offered in Gordon (2003). This explanation had two key components. First, I argued that the most important cause of the productivity growth upsurge in 2001-03 was an unusual degree of downward pressure on profits that led to aggressive cost cutting by business firms. A second explanation was the role of intangible capital that contributed a source of lagged response of productivity growth to the ICT boom of the late 1990s.

The first explanation (see Gordon, 2003, pp. 247-49) relies on the unusual trajectory of corporate profits in 1992-2003 that was initially examined by Nordhaus (2002). While National Income (NIPA) profits peaked in 1997 and declined after that as a share of national income, the stock market focused on the measure of profits compiled by the Standard and Poors (S&P) corporation as part of their compilation of the S&P 500 stock market average. S&P profits grew by 70 percent between early 1998 and early 2000 and then declined by more than half between early 2000 and early 2001. Nordhaus 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' words, these tricks led to the "enrichment of the few and depleted pension plans of the many." The stock market bubble between 1997-2000 can be explained in part by the divergence between NIPA and S&P profits.

The unusual trajectory of S&P reported profits in 1998-2001 placed unusual pressure on corporate managers to cut costs and reduce employment after 2000. 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 effect 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 2001-03, 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. The unprecedented nature of corporate cost cutting was widely recognized at the time. As the *Wall Street Journal* put it:

> The mildness of the recession masked a ferocious corporate profits crunch that has many chief executives still slashing jobs and other costs . . . Many CEOs were so traumatized by last year's profits debacle that they are paring costs rather than planning plant expansions (Hilsenrath, 2002).

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

This chain of causation from the profits debacle to the 2002-03 productivity surge seems plausible as the leading explanation of the unusual productivity behavior that cannot, as we have seen in Tables 2 and 3, be explained by ICT investment. But it raises a central question: How were corporate managers able to maintain output growth while cutting input costs so aggressively? One explanation is that the heady atmosphere of overstated profits and an accompanying stock market boom in the late 1990s caused corporations to become overstaffed with layers of unproductive employees. A complementary explanation is that some of the productivity benefits of the ICT investments of the late 1990s had delayed effects that lasted into the years (2001-03) after ICT investment itself collapsed.

The idea that some of the benefits of ICT investment were delayed is compatible with the influential Paul David (1990) "delay" hypothesis that he applied in parallel to the development of electricity generating (when the payoff in manufacturing productivity in the 1920s was delayed 40 or more years after the invention) and to the development of the computer. The Oliner-Sichel and Jorgenson *et al.* estimates in Tables 2 and 3 require that the full productivity payoff from the use of ICT capital occurs at the exact moment that the computer is produced. Assuming no delay between production and installation, the computer produces its ultimate productivity benefit on the first day of use.

Subsequent research after David's insightful paper has suggested that the full impacts of great inventions like electricity, the internal combustion engine, and in this case the marriage of personal computers with the internet, may take a substantial time to come to fruition (see Gordon 2000b). The full impact of electricity took more than 50 years to occur, waiting on the complementary inventions of consumer appliances, radio, TV, and air conditioning. The full impact of the internal combustion engine required the complementary inventions of supermarkets and superhighways. Similarly, many of the complementary innovations made possible by the invention of the internet came to fruition in 2001-04 after the investment boom had collapsed, including the notable example of the airport lobby electronic check-in kiosk that barely existed in 2000 but by 2005 was universal. Several authors have gone further than David's "delay" hypothesis by modeling the role of business learning, that they call "intangible capital," in shifting the time path of the investment and the payoff of those investments.[4]

3.3 Implications of Explanations for Future Growth

To speculate in 2003 about the causes of the then-evolving productivity growth explosion was risky, but as the data evolved between 2003 and 2007 those hypotheses seem more plausible. The pressure on costs and to layoff workers reached a peak in 2001-2002, and productivity growth exploded. After 2003 profits have increased rapidly and productivity growth slowed dramatically. The "intangible capital" hypothesis is also inherently temporary unless a second era of rapid increases in ICT investment occurs, but that did not happen after 2001.

Viewed in retrospect the 2001-04 productivity growth explosion increasingly looks like a one-off, unique, temporary phenomenon. In particular, I find ever less plausible the view, common in the late 1990s, that ICT investment had a magic quality that would break through all previous boundaries set by the scarcity of economic resources. Doubtless the invention of the internet has revolutionized industries ranging from university libraries to bookshops, but that revolution is over. University libraries have already replaced card catalogues by computer terminals, and Amazon (together with Barnes and Noble and Borders) has already achieved its goal of pushing independent bookshops out of business. In turn, Amazon has come close to pushing Borders out of business.

My interpretation of the ICT revolution is that it is increasingly burdened by diminishing returns. The push to ever-smaller devices runs up against the fixed size of the human finger that must enter information on the device. Most of the innovations since 2000 have been directed to consumer enjoyment rather than business productivity, including video games, DVD players, and I-pods. I-phones are nice, but the ability to reschedule business meetings and look up corporate documents while on the road already existed by 2003. Readers of this paper who actively create economic research might ask themselves what has happened to improve their productivity since the invention of "Office 97" (including MS Word and Excel), other than the arrival in their home offices of broadband internet in contrast to the feeble dial-up connections of the late 1990s?

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4. See Basu, Fernald, Oulton, and Srinivasan (2003) and Yang and Brynjolfsson (2001).

And what about Europe? Europeans use cell phones and web connections as much or more than Americans (admittedly with substantial variation between Scandinavia and the Olive Belt). But what good has this done? As they have adopted their desktops and laptops equipped with Intel processors and Microsoft software, Europeans have experienced a steady slowing in the growth rate of their output per hour, and indeed of their output per capita. The failure of Europeans to achieve accelerated growth in productivity after 1995, as occurred in the U. S., shifts the focus of causal explanations away from universal technological advances such as the internet, to country-specific environmental factors that encourage or discourage growth. The Groningen research (see especially Timmer *et al.* 2010) that has made us aware of the enormous difference between productivity growth in US vs. EU retailing, despite the universal adoption of bar-code scanning, has pointed to non-electronic sources of cross-country differences, starting with land-use restrictions and planning.[5] This author walks around the central cities of Europe and notices many things, but particularly the protection of ancient inner-city shopping districts in which basic commodities are sold in cramped aisles and with less self-service than in the median American retailer.

The goal of this paper is to make forecasts 20 years ahead of growth in US output per hour and potential GDP. So far interesting issues have been identified without resolution. The first section devoted to the quarterly data and output identity leaves open whether the unique 2008-09 gap between a repeat explosion of actual productivity growth and the constrained trend growth in productivity will be followed by a subsequent radical slowdown, just as the 2001-04 explosion was followed by the subsequent 2004-07 slowdown. The second section which identified the disconnect between ICT investment and the post-2000 U. S. productivity growth experience makes the 2001-04 "explosion" look temporary rather than permanent and adds urgency to our need to determine which part of pre-1995 history is relevant to forecasting productivity growth into the future. This suggests a strong motivation to re-examine the 20th century history of growth in output, labor productivity, and MFP.

4. A Re-Examination of 20th Century History

We now turn to a longer-term perspective on economic growth since the late nineteenth century. We begin with a simple calculation of output, conventional inputs, and MFP growth for 1891-2007, dividing up those 115 years into nine subintervals between benchmark years that are chosen to be cyclically neutral and thus to skip over years influenced by war, recessions, or depressions. These data are then compared for the postwar period with the BLS computations of MFP growth that implement adjustments for capital composition, the so-called "capital quality" correction that has long been advocated by Dale Jorgenson and his co-authors. Building on earlier research in Gordon (2000a), we attempt to extend adjustments for capital

5. The first policy recommendation in Baily and Kirkegaard (2004, p. 7-8) is to reform land-use planning in Europe.

and labor quality back before 1948 and in addition to make additional adjustments to the quantity of capital input.

4.1 BEA and Kendrick Data for MFP since 1891

The results of our initial data exercise are displayed in Table 4 for the nonfarm private nonhousing economy. The concept of labor is total hours and for capital is the total capital stock, with structures and equipment weighted equally using inflation-adjusted dollar weights. There are no adjustments for changes in labor or capital quality. Benchmark years are chosen to be 1891, 1913, 1928, 1950, 1964, 1972, 1979, 1988, 1996, and 2007. Current NIPA data are linked to Kendrick's (1961) data in 1929 for output, in 1948 for labor input, and in 1925 for capital input.

The top section of Table 4 exhibits our newly calculated results with NIPA data current as of February, 2010. The middle section displays results for the same concepts and time intervals in the "old" (pre-1999) data used by Gordon (2000a, Table 1), and the bottom section displays the difference between the growth rates based respectively on the new and old data. The theme of the earlier paper was the "one big wave" of US MFP growth that began around the time of World War I, peaked in the 1928-50 interval, and then ebbed after 1972. One notes in the old data that MFP growth increased after 1913 and again after 1928 and then slowed successively after 1950, 1964, and 1972.

There are three important differences in the new data. First, the crescendo in 1928-50 is substantially stronger than before, with MFP growth in that interval 1.85 points higher than in 1913-28 (compared with 0.48 points in the old data) and 1.61 points higher than in 1950-64 (compared with 0.43 points in the old data). In the bottom section we note that data revisions have increased the growth rates for the 1928-50 interval by 1.33, -0.24, 1.26, and 1.46 for output, labor, capital, and MFP, respectively.[6] Second, for the period after 1964 output growth has been revised upwards more than the data on labor and capital, implying substantial upward revisions of MFP growth. Third, and most obviously, we now have eleven more years of data after the previous terminal year of 1996, and the resulting rate of MFP growth in 1996-2007 is faster than in any other interval shown but the 1928-50 "big wave" period, although MFP growth in 1996-2007 is only moderately faster than the third-place interval 1950-64.

4.2 BEA Data Compared with BLS MFP Data, with and without Composition Adjustments

If we were interested only in the growth of labor productivity and of MFP for the postwar years, we would not need to put together data series from the BEA and Kendrick sources, because the BLS has already done the job for us for the years since 1948. Our

6. The NIPA revisions for 1929-48 were introduced in the benchmark revision of August, 1999. They combine the influence of chain-weighted deflators that increase more slowly than the previous fixed-weight deflators, and in addition the growth rate of nominal GDP was revised upwards.

previous examination of the BEA-Kendrick series originates in our interest in what happened to growth in labor productivity and in MFP for the years before 1948.

The BLS calculates MFP by subtracting from output growth not only the growth of labor hours and growth in the capital stock, but it also subtracts the contribution of changes in labor and capital composition. Its labor composition adjustment is based on subdividing the labor force into cells by age, gender, and educational attainment, and then weighting by the labor compensation earned in each cell. Thus a shift in composition toward more educated workers yields a positive labor composition adjustment, while the increase in the share of teenagers in the 1960s and 1970s caused by the baby boom creates a negative labor composition adjustment. The BLS capital composition adjustment results from aggregating different components of the capital stock (structures, ICT equipment, non-ICT equipment, inventories, and land) using weights based on the user cost of capital. Because of rapid depreciation, one dollar of ICT equipment receives a higher weight than one dollar of non-ICT equipment, which in turn receives a higher weight than one dollar of structures.

The basic series released by the BLS contain data only on their composition-adjusted "labor input" (as contrasted to labor hours) and "capital services" (as contrasted to the capital stock). However, the BLS web site has extensive information that allows us to create Table 5 and to compare BLS series with their BEA counterparts used in Table 4. The middle section of Table 5 simply copies the BEA post-1950 growth rates of output, inputs, and MFP from the top section of Table 4. Then the top section of Table 5 reports BLS growth rates for output and for labor and capital inputs *without composition adjustments.* Except for measurement and definitional issues, these should be the same as their BEA counterparts in the middle section. Also reported is the growth rate of BLS "non-adjusted MFP", using the BLS income shares to calculate MFP growth by subtracting growth in unadjusted labor hours and the unadjusted capital stock.

The three right-hand columns of the top section report the contributions to output growth of the labor and capital composition adjustments. Note that the labor composition adjustment is essentially zero during 1964-79, when the baby-boomers entered the labor force as inexperienced teenagers. The labor composition adjustment was also held down between 1964 and 1988 by the entry of females into the labor force. Given the increasing importance of computers in recent years, it is somewhat surprising that the capital composition contribution was roughly similar in each of the six periods.[7] Presumably the shift from structures to equipment in the early part of the postwar years was as important as the shift from long-lived non-ICT equipment to short-lived ICT equipment in the period since 1988.

The final column in the top section reports the "adjusted" growth rate of MFP, that is, the officially reported BLS series on MFP growth that incorporates the composition

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7. The numbers shown in the top right section of Table 5 are not the composition adjustments themselves but rather their contributions, calculated by multiplying the labor and capital composition adjustments by the income shares of labor and capital, respectively.

adjustments. Because the composition adjustments sum to a positive number ranging between 0.52 percentage points to 0.93 percent, the adjusted MFP growth rate is always lower than the unadjusted MFP growth rate.

The bottom section of Table 5 subtracts the BEA-based numbers from the unadjusted BLS numbers, and we find differences that are surprisingly large. While differences for output and labor hours are quite small, differences for growth in the capital stock are relatively large and always negative, while differences for MFP are always positive and relatively large in the first two periods, 1950-64 and 1964-72, albeit nearly zero in the intervals 1979-88 and 1996-2007. Some part of the differences may be due to a differing treatment of residential capital, since our BEA series exclude all residential capital while the BLS includes residential income-generating rental property.

4.3 Adjustments for Labor Composition Prior to 1950

This section develops composition adjustments for labor and capital in the period prior to 1950 and also calculates additional adjustments to the quantity of capital. Each of the adjustments made in this section is based on the analysis of Gordon (2000a, pp. 61-73), and there is no new research here other than to apply the previous research to the revised data summarized above in Table 4.

The first adjustment is for labor quality and is based on the extensive analysis carried out by Edward F. Denison in his well-known books on the sources of US economic growth. We reject two of Denison's (1962) controversial assumptions, first that effort per hour increased as hours per week decreased between 1909 and 1957, and second that part of the reward to educational attainment reflects innate ability rather than the contribution of education itself. While either assumption is debatable, neither is adopted by the BLS in their postwar data on MFP growth, and we want to adhere as closely as possible to the BLS approach.

The first line in Table 6 shows the Denison hours adjustment, based on the assumption that the elasticity of productivity (i.e., the effectiveness of an hour of work) to declining labor hours declined steadily from a negative unity in 1913-28 to about -0.2 in 1972-79. The second line shows his adjustment for educational attainment which includes two components that are not part of current BLS practice. First, he adjusts for increasing educational attainment using earnings weights but then multiplies the result by 0.6, assuming that the remaining 0.4 of earnings differences reflects innate ability rather than the contribution of education. Second, he assumes that any percentage increase in the number of school days per year has the same effect on productivity as a similar percentage increase in the number of school years per person. Our alternative education adjustment displayed on line 4 eliminates Denison's adjustments for the length of the school year and for ability. [8]

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8. Eliminating the ability adjustment for 1913-28 in Denison (1962) requires dividing his adjustment for increasing school years by 0.6, whereas after 1928 the correction is applied to another book, Denison (1979), and involves dividing through by 0.8.

Our alternative labor composition adjustment includes the alternative education component and Denison's age-gender effect, that is, line 5 is the sum of lines 3 and line 4. For comparison we show the BLS labor composition adjustments for the post-1950 and note that they are uniformly lower, perhaps because their data (obviously more recent than Denison's) places more importance on the negative age-sex adjustment and less importance on the positive correction for educational attainment.[9]

4.4 Adjustments for Capital Composition before 1950

The BLS makes adjustments for the composition of capital in its postwar MFP data by weighting each type of capital by its user cost. Pending further research on the user cost of capital prior to 1950, we calculate a capital composition adjustment in this section by a rough approximation. The BLS capital composition effect reflects both the rising share of short-lived equipment to structures, and the rising share of short-lived ICT equipment within the total of capital equipment. To determine the relative importance of the composition effect before 1950, we have recalculated our BEA capital stocks alternatively with equal dollar weights and with a weight of three dollars on each dollar of equipment and one dollar for each dollar of structures.

In Table 7 the first column shows that the growth rate of capital with the 3:1 recalculation in 1928-50 is 0.27 percent faster than with the basic 1:1 calculation. Comparing the average growth rate of the 3:1 effect in the 1950-2007 interval with the BLS capital composition effect, we find that the average growth rate of the 3:1 correction in Table 7 is 0.50 percent per year, much lower than the BLS capital composition adjustment that averages 1.57 percent per year over the same 1950-2007 period. Accordingly, we backcast the BLS capital composition adjustment from 1950 back to 1891 by multiplying column (1) for that period by 1.57/0.50. The result is shown on the first three lines of column (2) in Table 7.

4.5 Revising the Quantity of Capital

An important error in standard measures of capital input is the assumption that service lifetimes are fixed. Yet Feldstein and Rothschild (1974) have argued from a theoretical perspective that a fixed retirement pattern is not optimal, and Feldstein and Foot (1971) showed on the basis of firm-level data that retirement patterns are variable and depend on firm cash flow and on the state of the economy-wide business cycle. The issue of variable retirement was mainly important between 1930 and 1950 when gross fixed investment was very low. Standard capital measures assume that structures and equipment were being retired during 1930-50 on a fixed schedule even though nothing was being built or purchased to replace the capital that was allegedly being retired. Yet Chicago's Loop and Manhattan's Midtown were not littered with vacant lots during the 1930s and 1940s; the old buildings were still there, and so was the old

9. A labor composition effect of 0.5 is applied to the pre-1913 period to reflect increasing educational attainment, particularly at the elementary school level, as explained in Gordon (2003), pp. 65-66.

equipment which made such a contribution to America's production achievement during World War II.

The method developed in Gordon (2000a) is to make the ratio of retirements to capital, relative to its historic mean, depend on the ratio of gross investment to capital, also relative to its historic mean. This procedure implies that retirements are reshuffled among the years between 1925 and 1996, but that the average retirement rate over the entire period is maintained at the same level as in the BEA data. The effect as shown in column (4) of Table 7 is substantially to raise the growth rate of capital in the 1928-50 period and to reduce it thereafter. The data for this adjustment are taken from Gordon (2000a) and no further calculations have been made for the period since 1996.

Two types of capital financed by the government enter the production function of the private business economy and should be included in private capital input. Part of the sharp rise in US output during World War II was made possible by government-owned privately-operated (GOPO) capital. Initially the government did not keep track of this stock of capital, but after I studied this phenomenon and estimated its magnitude (Gordon, 1969), the BEA began to keep track of GOPO capital and provides estimates that we can use in this historical retrospective (see Wasson, Musgrave, and Harkins, 1970). GOPO capital makes a small addition to the growth of capital input in 1928-50 and then reduces it after 1950 as the wartime plants (many of which were converted to civilian use in the late 1940s) were eventually retired.

A related problem is that a substantial part of government-owned infrastructure serves as an unmeasured input to production in the private sector. Over the twentieth century there was a gradual shift over time in the transportation sector from privately-owned railroad capital to government-owned highways, airports, and air-traffic control facilities. We rely on Fraumeni's (2007) estimates of highway capital. As shown in column (5) of Table 7, highway capital added to the growth rate of capital input in each period before 1972 and reduced capital input growth thereafter.

The total adjustment to capital input varies over time but reaches by far its highest impact in the "big wave" period of 1928-50, due to the combined effects of capital composition, variable retirement, GOPO capital, and highway capital. The effect was smallest in 1950-64 when the variable retirement effect was being reversed. The capital adjustment was substantially higher in 1988-2007 than in 1950-88, mainly because the negative impact of variable retirement and GOPO capital by then had faded away.

4.6 Alternative Measures of MFP Growth

The end result of the research in this section has been to develop several adjustments to the growth of labor and capital input. For the period since 1950 the labor and capital composition effects are taken from the BLS, and we develop composition effects by similar methods that are applied to the period 1891-1950. In addition we make three adjustments to the growth of capital input that go beyond the BLS methodology by adjusting for variable retirement, GOPO capital, and highway capital.

Table 8 displays the results. Column (1) shows the same unadjusted growth in MFP as was displayed in the top section of Table 4. Column 2 incorporates the labor composition adjustments from Table 6, line 5 for 1913-50, with the average of 1913-50 backcast to 1891. For 1950-2007 the contribution of the labor composition adjustment is taken directly from the top section of Table 5, where the BLS source has already multiplied by labor's income share. Columns 3-5 further adjust for the corrections in capital input growth from Table 7, multiplied by a capital income share of 0.32.

Column (5) shows the growth in MFP with the full set of adjustments, and column (6) shows the difference made by the full set of adjustments. The largest downward adjustments are in the "big wave" period when unadjusted MFP growth was the highest, but there is no consistent tendency for the adjustments to be negatively correlated with unadjusted MFP growth. The "big wave" period 1928-50 retains its first place in column (5) by a substantial margin. The adjustments tend to create a rough uniformity in MFP growth across five of the remaining periods including 1891-1928, 1950-72, and 1996-2007, with an average adjusted MFP growth rate in these intervals of 1.12 percent per year.

These successful periods for adjusted MFP growth contrast with the dismal slowdown years of 1972-96 when adjusted MFP growth was only 0.33 percent per year. A difficult problem in forecasting into the next decade or two is to determine which of the previous time intervals are relevant.

What do these results for MFP growth imply for labor productivity growth? A glance back at the BLS data in Table 5 show that the difference between unadjusted growth in output per hour and BLS-adjusted MFP growth over the full 1950-2005 period is 1.07 percent with relatively little variation across periods. Over the past 116 years the adjusted growth rate of MFP from Table 8, column 5, has been 1.19 percent per year, which added to the 1.07 would yield a "normal" growth rate in unadjusted labor productivity of 1.07+1.19 or about 2.26 percent per year. By coincidence this is very close to the actual growth rate of NFPB output per hour of 2.23 percent between 1997 and 2007.

The results on adjusted MFP growth raise numerous questions about which vast amounts have been written. Why was adjusted MFP growth so low between 1972 and 1996 and so high between 1928 and 1950? Should we accept a "normal rate" of adjusted MFP growth of 1.12 percent as occurred in five of our nine intervals? These issues are discussed in the next section as we attempt to forecast the main magnitudes for the next 20 years.

How does the adjusted BLS growth rate of MFP for the post-1972 period in Table 8 compare for similar time intervals with the Oliner-Sichel estimates reported in Table 2 and the Jorgenson *et al.* estimates reported in Table 3? Table 9 has four lines reporting in order: the official BLS estimates from Table 5, the Oliner-Sichel estimates from Table 2, the Jorgenson *et al.* estimates from Table 3, and our adjusted estimates from Table 8. The exact years covered by each source are shown in the row labels. The range of estimates for 1972/73 to 1995/96 is quite narrow between 0.33 percent and 0.46 percent. The range of estimates for 1995/96 to 2006/07 is wider, but if the low Jorgenson numbers are excluded the range between 1.19 and 1.25 percent is very narrow. Table 9 serves as background to our attempt to pull hints from historical data that are relevant to our task of creating forecasts for 2007-27.

5. Learning from the Past to Forecast the Future: Productivity and Real GDP Growth 2007-2027

One stands on relatively solid ground when talking about the past, but at least initially feels as if floating in a haze when looking out 20 years into the future. But an examination of data in this paper going back to 1891 yields several possible criteria to bound the likely growth rates of labor productivity and of MFP in the future.

5.1 Aspects of the Record, 1987-2007 as Contrasted with 2000-2007

Our forecasts are developed in steps within the format of Table 10. The left two columns record annual growth rates of the central variables for 1987:Q4 to 2007:Q4, and the two middle columns record growth rates for 2000:Q4 to 2007:Q4. Two columns are shown for each time interval, the first reporting data on the total economy as displayed in Table 1, and the second reporting current BLS data for the NFPB sector. We are particularly interested in any similarities or differences between the two overlapping intervals, and we will make use both of the total-economy data and of the NFPB data in arriving at our future forecasts. The longer 20-year period has contained many surprises up and down in the history of growth in labor productivity and in MFP. The 20-year average of these surprises should be highly relevant to what happens over the next 20 years.

Interest in the seven-year interval 2000:Q4 to 2007:Q4 originates in the fact that both quarters were at or near business cycle peaks. This interval can be viewed as more "normal" than 1987-2000, which combined a period when total-economy productivity growth was slower than anyone could explain (1.19 percent for the total economy), and then productivity revived more rapidly than anyone had predicted (2.42 percent). The 1987-95 interval was best described by Solow's famous paradox that "we can see the computers everywhere but in the productivity statistics." But the 1995-2000 revival period was unusual as well. This was the famous "dot.com" era, when by general consensus there was too much investment in computers and communication infrastructure, and this five-year interval may also have been unique in that one could only invent the internet once.

The 20-year period 1987-2007 combines the inexplicably slow productivity growth of 1987-95, the temporarily ebullient period 1995-2000, and the interesting 2000-07 period that in some dimensions looks like more normal behavior. The seven years between 2000:Q4 and 2007:Q4 were neatly divided in half, with extremely rapid productivity growth between 2000:Q4 and 2004:Q2 (2.68 percent), and much slower growth from 2004:Q2 to 2007:Q4 (1.36 percent), averaging out to 2.02 percent for the seven-year interval. As argued above the productivity growth "explosion" of 2001-04 rested on a combination of savage corporate cost cutting and delayed learning from the internet revolution. Once profits had recovered the pressure for cost cutting disappeared, and eventually the delayed learning subsided as well.

Unfortunately, the relevance of the 2000-07 period is tainted by the bizarre behavior of the labor-market variables. Given that the unemployment rates were similar at the beginning and end, there was an unprecedented drop in hours per capita, with aggregate hours *(H)* growing at only 0.36 percent per year while the working-age population grew at 1.24 percent per year. Hours per capita fell by 0.88 percent per year, or a cumulative exponential 6.4 percent decline between 2000 and 2007.

The sharp decline in hours per capita in 2007 to some extent reduced output growth but it also raised productivity growth, in that some of the reduction of labor hours represented a permanent transition to a more aggressive stance of management against labor (Gordon, 2010b). To this extent that 2.02 percent growth in total-economy output per hour in 2000-07 may be misleading as an indicator for future forecasts. Since forecasts of future growth of aggregate hours are bunched together at 0.7 percent (see for instance Jorgensen *et al.* 2008, Table 2), we anticipate that at least half of the return from 0.38 in 2000-07 to 0.70 on average after 2007 will be offset by slower productivity growth.

This argument that the 2000-07 growth rate of total economy labor productivity was unsustainably high, due to the role of cost-cutting in boosting productivity at as offset to a sharp decline in labor hours, suggests that the long-run growth rate of productivity in the total economy is likely to be closer to the 1.79 percent of 1987-2007 than the 2.02 percent of 2000-07. By the same reasoning, the growth rate of NFPB sector productivity, shown in Table 10 to be 2.48 percent in 2000-07, is more likely to be closer to the 2.23 percent of 1987-2007.

5.2 Reconciling Labor Productivity and MFP in the Forecasts

One possible criterion lies in a coincidence that two key numbers are the same. As shown in Table 10, the average annual growth rate of NFPB labor productivity between 1987:Q4 and 2007:Q4 was 2.23 percent per year, The coincidence comes from the historical analysis in this paper. The average growth rate of adjusted MFP over the past 116 years (Table 8, column 5) has been 1.19 percent. Add to this the average excess of actual (unadjusted) labor productivity growth over adjusted MFP growth in the BLS postwar data from 1950 to 2007, which is 1.07 percent. Lo and behold, these two numbers add up to 2.26, almost identical to the actual rate of productivity growth for 1987-2007.

Do we have any good reasons to suspect that the next 20 years will deliver a significantly faster growth rate of unadjusted labor productivity than the last 20 years? Similarly, is there any good reason to think that adjusted MFP growth will exceed the rates that were achieved over the past 116 years? When we add those realized adjusted MFP growth rates to the recorded relationship since 1950 of average labor productivity to adjusted MFP growth, we keep coming back to a NFPB productivity growth rate of roughly 2.25 percent per year.

The lower section of Table 10 reports the decomposition of labor productivity growth into capital deepening, the labor quality effect, and the growth rate of MFP. This is shown both for 2000-07 using the Oliner-Sichel data reported in Table 2, and also for 1987-2007 creating weighted averages of the Oliner-Sichel data and assuming that growth rates observed in Table 2 over 1973-95 apply for 1987-95 as well. Note that the capital-deepening effect declined from 1987-2007 to 2000-07 by about 0.10 percentage points and that all of this decline was in the ICT sector. Growth in labor quality stayed roughly constant, while MFP growth outside of the ICT sector increased markedly.

Our forecasts for the capital-deepening effect are almost identical to the actual record of 2000-07, and we expect the share of ICT investment in GDP to be roughly stable. This share, displayed in Figure 4, shows that during 2001-07 the share of neither ICT investment or PDE investment ever came close to reaching the levels achieved in the temporary investment bubble of 1998-2000. With no reason to expect this bubble to happen again, there is no reason why the rapid growth rate of the capital-deepening effect in 1995-2000 should be relevant to forecasts.

The next line in the bottom section of Table 10 shows that we expect the contribution of labor quality growth to fall by roughly half over the next 20 years. Jorgenson, Ho, and Stiroh (2006), show that educational attainment has reached a plateau in the US, in their estimates implying that the improvement in labor quality (the BLS labor composition effect) will gradually decline toward zero over the next 10 to 15 years. Similarly, Goldin and Katz (2008) both lament and explain the plateau in U. S. educational attainment. They point out (2008, Figure 9.1, p. 327) that unlike most European nations, where a catching-up process has made the 25-34 age group much better educated than the 55-64 age group, in the U. S. the educational attainment of both age groups is the same, the very definition of a plateau.

Since the continuation of the labor quality adjustment depends largely on increasing educational attainment, yet this increase seems to have disappeared, Table 10 cuts in half the labor quality adjustment for 2007-2027 as compared to its average value of 1987-2007. The difficulties of further increasing U. S. educational attainment are well documented by Goldin and Katz, including a rapidly increased relative price of higher education and a paucity of opportunities for less privileged students to gain fellowship support.

What growth rate should we choose for MFP? This is the wild card in any forecast of future productivity behavior. As summarized above, the average growth rate of adjusted MFP for the U. S. economy since 1891 has been 1.19 percent. The respective figures for 1987-2007 and 2000-07 from Table 10 are 0.96 and 1.26 percent respectively. My inclination is to lean toward a number closer to the 1987-2007 experience than the unusual 2000-07 period. The fundamental driver of adjusted MFP growth is innovation, which exhibits ebbs and flows over time. The "Great Inventions" of the late nineteenth century, especially electricity and the internal combustion engine, propelled MFP growth through most of the 20th century until those inventions had been exploited, at least in the US, around 1970. By the early 1970s the country was electrified, air conditioning had allowed manufacturing and service industries to spread across the south and southwest, consumer appliances had liberated women, radio and TV had ended isolation and brought the world into the living room, the interstate highway system was largely built, and the population had moved to the suburbs.

Perhaps it is not so surprising that the opportunities to exploit technology were limited between 1972 and 1995. Then came the upsurge of the contribution of ICT capital to economic growth, and according to the results in Tables 2 and 3 from Oliner-Sichel and Jorgenson-Ho-Stiroh, the duration of the contribution of this invention was surprisingly short-lived, leading to the skepticism I have previously expressed (Gordon 2000b) as to whether the invention of the PC and internet deserves to be called a "Great Invention" of the magnitude of electricity and the internal combustion engine, or something in the next category of greatness.

The MFP forecast for 2007-27 in Table 10 of 1.05 percent is relatively optimistic. It is faster than the 0.96 for 1987-2007 and much faster than the lamentable growth rates of 0.33 to 0.46 percent recorded for 1972-2005 in the four estimates summarized in Table 9. In 1972-95 the subsidiary innovations from the Great Inventions of the late nineteenth century were depleted. The same could happen again over the next twenty years. ICT technology in the last ten years has mainly taken the form of miniaturization, not a true transformation of function as occurred in the 1990s. Without a set of new and transforming inventions, there is more likelihood that MFP growth may drift below the projected 1.05 percent than rise above it.

5.3 Implications for Future Growth in Real GDP and Output per Hour for the Total Economy

When the components of NFPB labor productivity growth in the lower right section of Table 10 are summed, we arrive at a projected growth rate of 2.05 percent, slower than the 2.48 percent of 2000-07 and even slower than the 2.23 percent of 1987-2007. Nevertheless this relatively pessimistic estimate is much more rapid than the 1.47 percent for 1973-95 in Table 2.

Once the future growth rate of NFPB labor productivity is established, it becomes relatively easy to set out the future growth rates of the other components of the output identity. We take our forecasts of future growth in population and the other labor variables from recent articles projecting to the period 2008-18 by Toossi (2009) and Wyatt and Byun (2009). The projected growth rate of aggregate hours is 0.7 percent, the same as forecast by Jorgenson *et al.*

(2008). Projected growth in total economy labor productivity of 1.70 is slower than the 2.05 percent estimate for the NFPB sector – as usual, the gap between productivity growth in those two sectors is positively correlated with NFPB productivity growth (the slower the NFPB growth, the smaller the gap between NFPB growth and total economy growth). The implied growth rate for GDP is 2.40 percent, almost exactly the same as for 2000-07 and the slowest growth in potential real GDP of any period in recorded American history since at least 1870.

Does the explosion of labor productivity growth in 2009 require a significant qualification of these projected growth rates for 2007-27? While total-economy growth in output per hour between 2008:Q4 and 2009:Q4 was a robust 3.78 percent, growth in the preceding four quarters was a minimal 0.8 percent. The annual growth rate over the eight quarters between 2007:Q4 and 2009:Q4 was 2.29 percent, and this implies that for total-economy productivity growth to average 1.7 percent per year for 2007-27, given what has already occurred, productivity growth for 2009-2027 will be only slightly slower at 1.63 percent per year. The productivity growth explosion of 2009 has been impressive (at least in part a consequence of panicked cost cutting in late 2008 and early 2009) and reinforces the view of Gordon (2010b) that labor hours are now more responsive to output fluctuations than before the 1990s, while productivity no long exhibits procyclical fluctuations at all. However, the overall magnitude of the 2007-09 productivity growth achievement is not large enough to require any qualifications to the growth rate forecasts of Table 10. The implied growth rate for 2009-2027 of 1.63 percent is still higher than the 1.36 percent actual growth rate between 2004:Q2 and 2007:Q4 and even higher than the 1.25 percent actual growth rate between 1972:Q4 and 1995:Q4.

6. Conclusion

This paper provides a novel combination of perspectives on the behavior of growth in both output per hour and of MFP at high frequencies for the past 50 years, at low frequencies dating back to 1891, and in forecasts of the likely outcome over the twenty-year period 2007-2027. The history of U. S. productivity behavior in the past 116 years is characterized by significant upward and downward shifts in growth rates. To make sensible forecasts, we must understand the past.

This paper contributes to that understanding initially by decomposing the growth of total-economy output, aggregate hours, and labor productivity from 1952-2007 into actual changes, changes in a statistical trend that is defined to exclude business-cycle movements, and the residual or deviation from trend growth. The growth rate of trend real GDP has fluctuated in a narrow range between 3 and 4 percent since 1952, while the trend in aggregate hours for the total economy has ranged from 0.7 to 1.9 percent. The peak period for output growth was in the 1950s and 1960s, while the peak period for hours growth was in the late 1970s as teenagers and females entered the labor force at a rapid rate. The low 0.7 trend growth rate of hours reached in 2002-03 reflected an unprecedented reduction in work hours that was the counterpart of superheated productivity growth in this interval. This paper interprets both as inherently temporary.

The statistical trend for growth in total economy labor productivity ranged from 2.75 percent in early 1962 down to 1.25 percent in late 1979 and recovered to 2.45 percent in 2002. Our results on productivity trends identify a problem in the interpretation of the 2008-09 recession. The unprecedented decline in labor hours, employment, and labor-force participation in 2008-09 lead the statistical detrending technique to the conclusion that productivity was doing quite well, given the historical weakness of productivity in recessions. As discussed in Gordon (2010b) this represents a shift in labor-market behavior rather than an unexplained upsurge in the productivity growth trend, and for the discussion of short-term responses we hold constant the trend of real GDP, aggregate hours, and total economy labor productivity after 2007 at the trend growth rate reached in 2007:Q4.

The medium-term analysis of changes in U. S. labor productivity and MFP begins with the familiar decompositions of labor productivity growth into the contributions of capital-deepening, labor quality, and MFP, further divided into the contributions of ICT and non-ICT investment. These results show that the 1995-2000 productivity growth revival was primarily driven by ICT investment, while the subsequent relatively rapid growth in productivity during 2000-07 was primarily driven by an upsurge of MFP growth in non-ICT industries. We have provided an interpretation of the temporary productivity growth explosion of 2001-04 based on Gordon (2003, 2010b): a sharp decline in profits and in the stock market in 2000-01 motivated firms to cut all costs, and particularly labor costs, more deeply than had previously occurred for a given change in the output gap. Employment continued to decline while output rose in 2001-04 not only because the pace of the output recovery was weak, but because delayed learning how to use the late-1990s invention of the internet caused some of the benefits of that invention to spill over from the 1990s to the 2001-04 interval. Once the cost-cutting had been digested and the delayed benefits from the internet invention had been realized, productivity growth slowed in 2004-07 to a pace little faster than in 1972-95.

An important contribution of the paper is to provide an updated decomposition of productivity growth over the "long century" extending between 1891 and 2007. By far the most rapid MFP growth in U. S. history occurred in 1928-50, a phenomenon that I have previously dubbed the "one big wave." This paper presents numerous corrections to the growth of labor quality and to capital quantity and quality, leading to significant rearrangements of the growth pattern of MFP, generally lowering the unadjusted MFP growth rates during 1928-50 and raising them after 1950.

The paper approaches the task of forecasting 20 years into the future by extracting relevant precedents from the growth in labor productivity and in MFP over the last seven years, the last 20 years, and the last 116 years. Its conclusion is that over the next 20 years (2007-2027) growth in real GDP will be 2.4 percent (the same as in 2000-07), growth in total economy labor productivity will be 1.7 percent, and growth in the more familiar concept of NFPB sector labor productivity will be 2.05 percent. The implied forecast 1.50 percent growth rate of per-capita real GDP falls far short of the historical achievement of 2.17 percent between 1929 and 2007 and represents the slowest growth of the measured American standard of living recorded during the past two centuries.

Despite their pessimism, the conclusions of this paper are not wild guesses but rather emerge from discipline in distinguishing between the NFPB sector and the total economy, in distinguishing between labor productivity and MFP, and in providing a unique interpretation of twentieth history based on a revision to conventional measures of pre-1948 MFP growth.

And the conclusions of this paper, even if they are bolstered with a greater reliance on historical precedents, are not wildly deviant from contemporary forecasts. Maddison (2009) predicts that growth in U. S. real GDP will be at a rate of 2.5 percent until 2030, not far from our estimate of 2.4 percent through 2027. Jorgenson *et al.* (2008) reports several estimates of future real GDP growth at 2.5 percent, including mine in the original 2006 version of this paper. Further consideration has required me to reduce the 2.5 number to 2.4, not a major change. For those who may disagree about the pessimistic conclusions of this paper, there is an obligation to pick out the numbers that are wrong or dubious and to suggest a more convincing set of numbers to propel the discussion.

DATA APPENDIX

This data appendix provides a guide to the sources used in the figures and tables.

Figures 1 through 3 and Table 1

These figures and Table 1 display growth rates for real GDP and the components of the output identity, equation (1). Real GDP (*Y*) is obtained from NIPA Table 1.1.6. The unpublished BLS series on aggregate hours for the total economy *(H)* was obtained from Juliet A. Whittle of the BLS on February 17, 2010 and does not incorporate the major revisions to the payroll employment data set to be released in March, 2010. BLS household data on the working-age population *(N)* are smoothed to eliminate periodic jumps in census years; the method of smoothing is explained in Gordon (2003), pp. 275-7. BLS household data on employment *(E)* and the labor force *(L)* incorporate the same smoothing procedure and are calculated by applying the published BLS employment rate *(E/L)* and labor-force participation rate (*L/N)* to the smoothed population *(N)* data.

Table 4 on Twentieth Century Growth

Private Nonfarm Nonhousing Output. From 1929 the source is nonfarm private business output in 2005 dollars from NIPA Table 1.3.6 minus gross housing value added from line 14 of the same table. For 1891-1929 the source is Kendrick (1961), Table A-III, p. 298 for GDP minus government and farm output, but not excluding housing output.

Labor Input. From 1948 the source is hours worked in the nonfarm private business economy from NIPA Table 6.9 minus hours worked in real estate, where the latter takes real estate persons engaged from NIPA Table 6.8 and applies hours worked per employee for the broader finance, insurance, and real estate sector from Table 6.9. For 1891-1948 the source is private nonfarm manhours from Kendrick (1961), Table A-XXIII p. 338.

Capital Input. From 1925 the source is Tables 4.1 and 4.2 of the Fixed Assets section of the BEA web site. For 1891-1925 the source is nonfarm private nonresidential capital stock from Kendrick (1961), Table A-XVI, p. 323.

Multifactor Productivity Growth. This is calculated from output, labor input, and capital input, by using uniform weights of 0.7 for labor and 0.3 for capital.

Table 5 on BLS MFP Data

All data were obtained from the BLS web site. Growth rates for 1950-88 were calculated from a text file "mfp2ddod.txt" available for the discontinued SIC-basis data for 1948-2002, and growth rates for 1988-2007 were calculated from a downloadable Excel file "mfptables.xls", except for those associated with capital stock, which was acquired through the efforts of Randy

Kinoshita of the BLS . These tables provide separate series on hours, composition-adjusted labor input, and the size of the labor composition adjustment. They also provide separate series on capital services and the size of the capital composition effect, allowing the capital stock to be calculated indirectly for 1950-1966. The income shares of labor and capital are included, allowing MFP to be calculated either with unadjusted labor hours and the capital stock, or the adjusted series on labor input and capital services.

Table 6 on Labor Quality Adjustments

The Denison adjustments were copied from Gordon (2000a), Table 3. The BLS composition adjustments were taken from the same sources as Table 5.

Table 7 on Capital Quantity and Quality Adjustments

Source by Column:

(1) The BLS capital composition adjustment comes from the same sources as Table 5 for 1950-2007. The capital composition adjustment for 1913-50 computed in column (1) is divided by the 1950-2007 ratio of column (1) to column (2), namely 0.30.

(2) The stock of BEA equipment and nonresidential structures used to compute the capital stock in Table 4 was reweighted by multiplying the real dollar value of equipment by three. The difference between the annual growth rate of the reweighted and unweighted capital stocks is the capital composition effect in column (2).

(3) The ratio of the variable retirement capital stock to the fixed retirement capital stock was taken separately for structures and equipment from Gordon (2000a), p. 72. These ratios were applied to the revised BEA capital stock data used in the calculations of Table 4.

(4) GOPO capital was taken from Wasson, Musgrave, and Harkins (1970), Table 7 and restated from 1958 to 2000 dollars.

(5) Highway capital data for 1921 to 1995 was provided by Barbara Fraumeni

(6) Column (6) is the sum of column (1) plus (3) through (5).

Table 8 on Adjusted MFP Growth

(1) Column (1) is identical to MFP growth in the top section of Table 4.

(2) Column (2) is equal to column (1) minus the labor income share times the labor composition adjustment, from the BLS after 1950 and as reported in line 5 of Table 6 before 1950.

(3) Column (3) is equal to column (2) minus the capital income share times the capital composition adjustment, from Table 7, column (1).

(4) Column (4) is equal to column (3) minus the capital income share times the effect of variable retirement as calculated in Table 7, column (3).

(5) Column (5) is equal to column (4) minus the capital income share times the effect of GOPO and highway capital as calculated in Table 7, columns (4) and (5).

Note that in Table 8 the capital income shares are taken from the BLS MFP sources used in Table 5 for each interval of the postwar period and are extrapolated before 1950 by taking the 1950 shares of roughly 0.68 for labor and 0.32 for capital.

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Figure 1. Annual Growth Rate of Actual and Trend Real GDP, Quarterly Data, 1952:Q1 - 2009:Q4

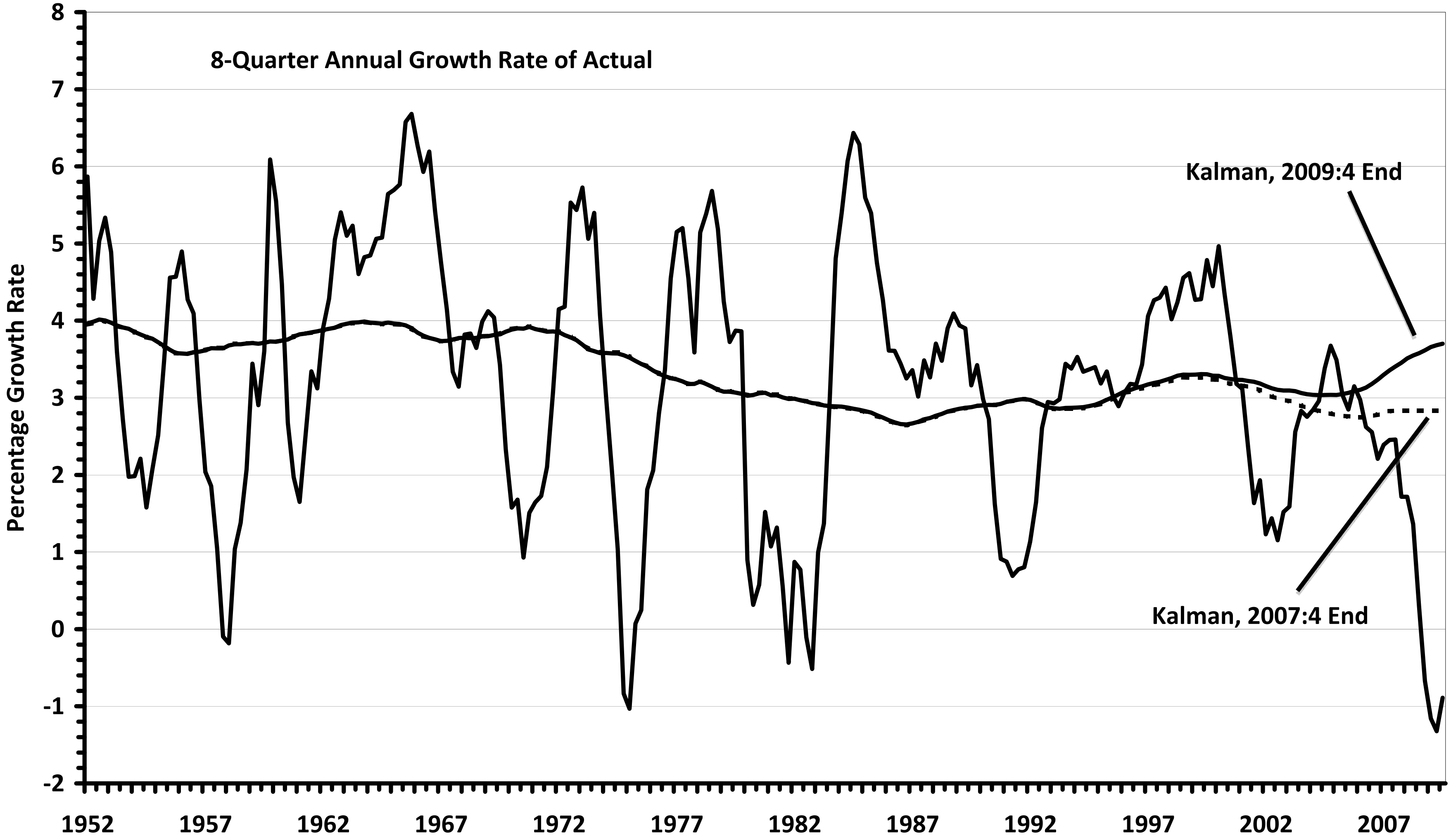


Figure 2. Annual Growth Rate of Actual and Trend Total Economy Hours, Quarterly Data, 1952:Q1 - 2009:Q4

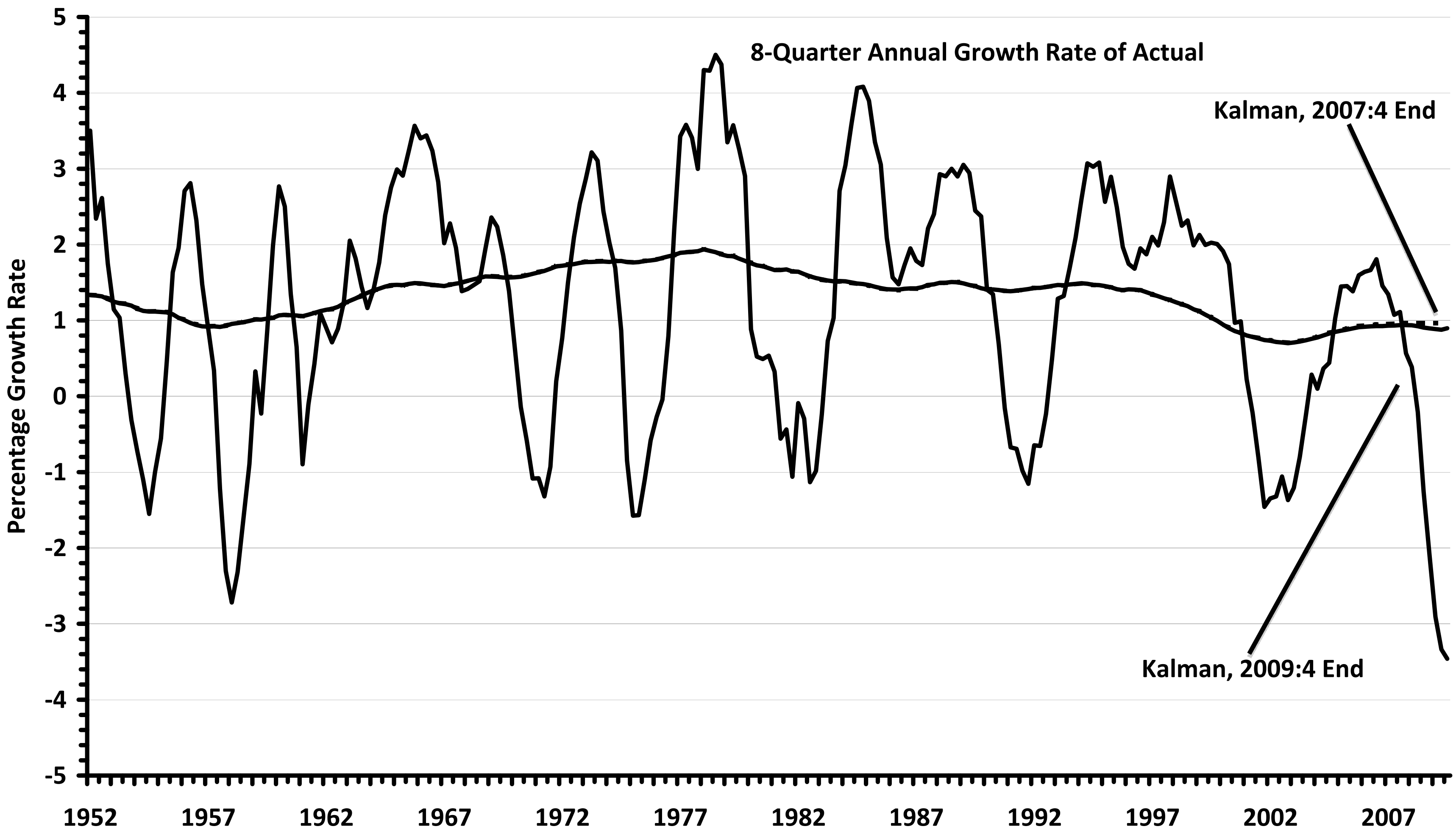
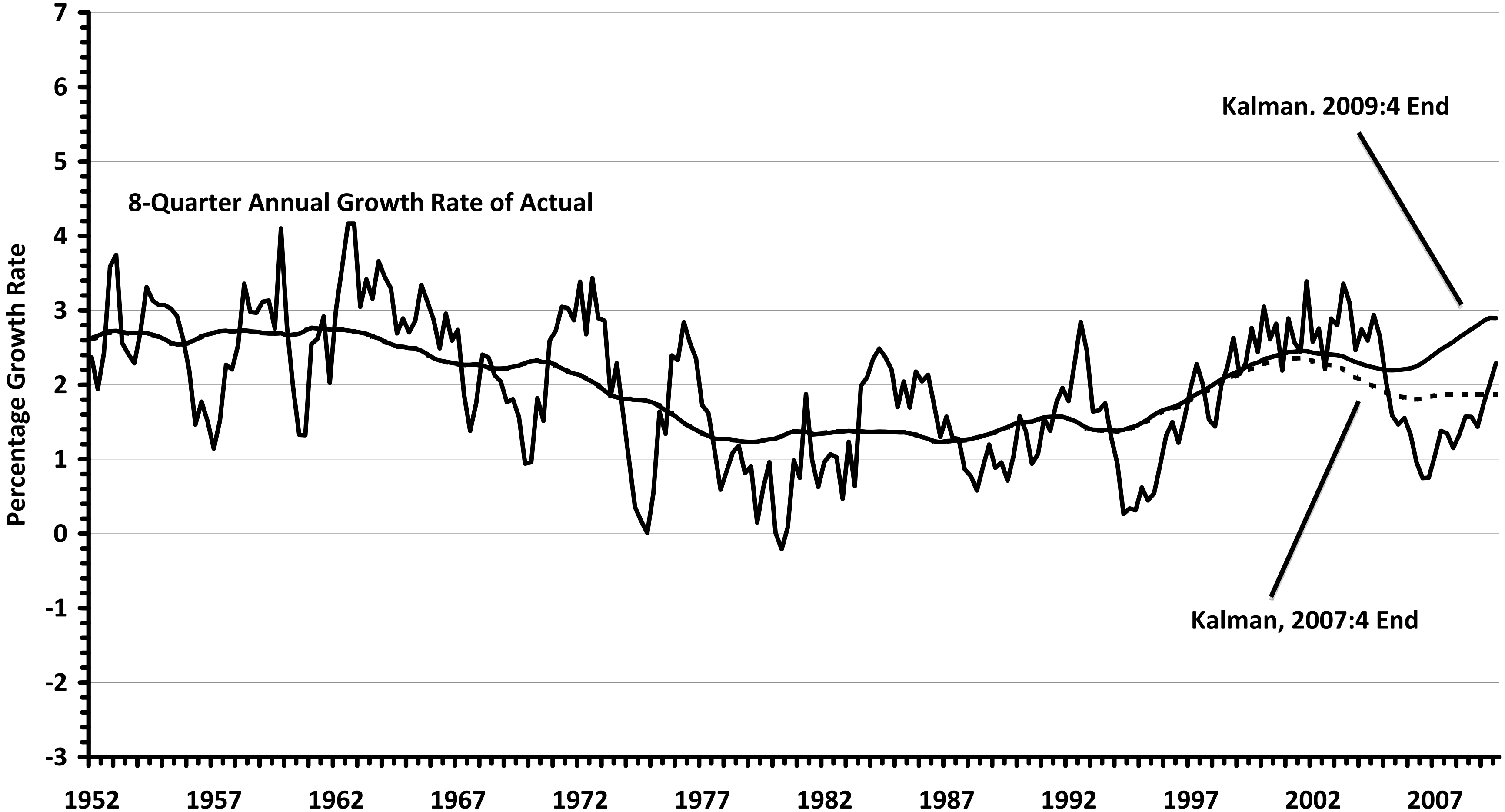


Figure 3. Annual Growth Rate of Actual and Trend Total Economy Output per Hour, Quarterly Data, 1952:Q1 - 2009:Q4



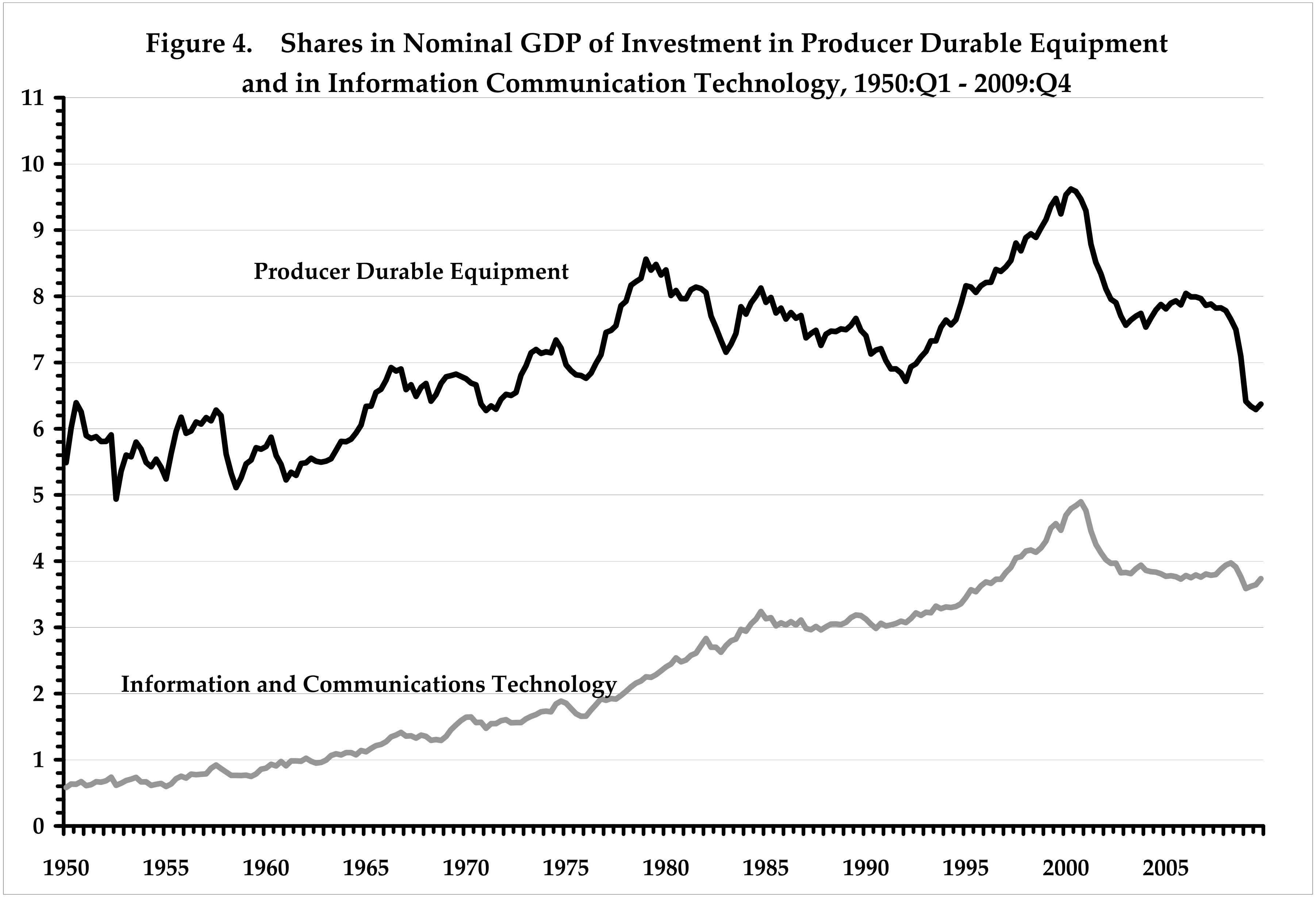


Figure 4. Shares in Nominal GDP of Investment in Producer Durable Equipment
and in Information Communication Technology, 1950:Q1 - 2009:Q4
Producer Durable Equipment
Information and Communications Technology
0
1
2
3
4
5
6
7
8
9
10
11
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

Table 1
Growth Rates of Components of Output Identity between Benchmark Quarters, Total Economy, 1954:Q4 - 2007:Q4

	1954:Q4 - 1964:Q2	1964:Q2 - 1972:Q1	1972:Q1 - 1978:Q2	1978:Q2 - 1987:Q2	1987:Q2 - 1996:Q3	1996:Q3 - 2007:Q4
1. Real GDP *(Y)*	**3.68**	3.78	3.65	2.73	2.88	3.06
2. Real GDP per Capita (Y/N)	2.28	1.96	1.70	1.37	1.85	1.74
3. Hours per Capita (H/N)	-0.39	-0.27	0.05	0.11	0.53	-0.42
4. Output per Hour (Y/H)	2.68	2.23	1.64	1.26	1.32	2.16
5. Hours per Employee (H/E)	-0.49	-0.48	-0.65	-0.28	0.20	-0.34
6. Employment Rate (E/L)	0.01	-0.08	-0.04	-0.03	0.11	0.04
7. Labor-Force Participation Rate (L/N)	0.08	0.29	0.73	0.41	0.21	-0.12
8. Working-Age Populatoin (N)	1.40	1.82	1.95	1.36	1.03	1.32
9. Sum of Lines 4 through 8	3.68	3.78	3.64	2.73	2.88	3.07

Table 2
Decomposition of Labor Productivity Growth and MFP
Percentage points, annual rate

	1973-1995	1995-2000	2000-2007
1. Output per hour	1.47	2.51	2.48
2. Capital deepening	0.77	1.13	0.87
3. ICT	0.46	1.09	0.60
4. Hardware	0.25	0.60	0.27
5. Software	0.13	0.34	0.19
6. Communications	0.07	0.15	0.13
7. Other	0.31	0.04	0.28
8. Labor quality	0.27	0.26	0.35
9. Aggregate MFP	0.43	1.13	1.26
Contribution of:			
10. ICT	0.29	0.76	0.47
11. Computer Hardware	0.12	0.19	0.09
12. Semiconductor Hardware	0.09	0.45	0.22
13. Software	0.04	0.08	0.11
14. Communications	0.04	0.04	0.04
15. Other	0.14	0.37	0.79
16. Sum of ICT Contribution (3+10)	0.75	1.85	1.07
17. Share of ICT in Total (16/1)	0.51	0.74	0.43
18. Memo: ICT Investment as % of GDP	2.67	4.19	3.95
Nominal Value-added Shares of:			
18. Computer Industry	1.10	1.50	1.01
19. Semiconductor Industry	0.40	0.90	0.61
20. Software Industry	1.00	2.40	2.60
21. Communications Industry	1.50	1.90	1.31
22. Other Sectors	96.40	94.20	94.97
MFP Annual Growth Rate in:			
23. Computer Industry	11.00	12.80	8.84
24. Semiconductor Industry	27.20	49.80	33.64
25. Software Industry	4.20	3.70	4.30
26. Communications Industry	2.40	1.90	3.29
27. Other Sectors	0.14	0.39	0.83

Source: Unpublished update of Oliner and Sichel (2002), obtained from Daniel Sichel on February 15, 2010. Line 18 from NIPA Tables 1.1.5 and 5.3.5.

Table 3
Sources of Output and Productivity Growth, 1959 - 2006

	1959-1973	1973-1995	1995-2000	2000-2006
1. Private Output	4.18	3.08	4.77	3.01
2. Hours worked	1.36	1.59	2.07	0.51
3. Average labor productivity	2.82	1.49	2.70	2.50
4. Contribution of Capital Deepening	1.40	0.85	1.51	1.26
5. Information Technology	0.21	0.40	1.01	0.58
6. Non-information Technology	1.19	0.45	0.49	0.90
7. Labor Quality	0.28	0.25	0.19	0.31
8. Multi-factor Productivity	1.14	0.39	1.00	0.92
9. Information Technology	0.09	0.25	0.59	0.38
10. Non-information Technology	1.05	0.14	0.42	0.54
11. Contribution of Information Technology	0.30	0.65	1.60	0.96
12. Share Attributed to Information Technology	0.11	0.44	0.59	0.38

Source: Jorgenson, Ho, and Stiroh (2008), Table 1

Table 4

Output, Inputs, and MFP Growth, Nonfarm NonHousing Private Economy, New and Old Data, 1891-2007

New Data Years	Output	Labor	Capital	MFP
1891-1913	4.48	2.68	4.46	1.26
1913-1928	3.13	1.10	2.84	1.51
1928-1950	4.08	0.67	0.86	3.36
1950-1964	3.51	1.16	3.18	1.75
1964-1972	4.18	1.85	4.52	1.53
1972-1979	3.70	2.34	3.63	0.98
1979-1988	3.06	1.47	3.40	1.01
1988-1996	2.92	1.47	2.38	1.18
1996-2007	3.60	1.15	2.82	1.95

Old Data Years	Output	Labor	Capital	MFP
1891-1913	4.43	2.92	3.85	1.14
1913-1928	3.11	1.42	2.21	1.42
1928-1950	2.75	0.91	0.74	1.90
1950-1964	3.50	1.41	2.89	1.47
1964-1972	3.63	1.82	4.08	0.89
1972-1979	2.99	2.38	3.46	0.16
1979-1988	2.55	1.09	3.35	0.59
1988-1996	2.74	1.74	2.26	0.79

Difference between New and Old Data Years	Output	Labor	Capital	MFP
1891-1913	0.05	-0.24	0.61	0.12
1913-1928	0.02	-0.32	0.63	0.09
1928-1950	1.33	-0.24	0.12	1.46
1950-1964	0.01	-0.25	0.29	0.28
1964-1972	0.55	0.03	0.44	0.64
1972-1979	0.71	-0.04	0.17	0.82
1979-1988	0.51	0.38	0.05	0.42
1988-1996	0.18	-0.27	0.12	0.39

Source: See Data Appendix.

Table 5

BEA and BLS Data on Output, Inputs, and MFP Growth, Nonfarm Nonhousing Private Economy, 1950-2007

BLS MFP Data					*Contributions of*		
Years	**Output**	**Labor Hours**	**Capital Stock**	**non-Adj MFP**	**Labor Composition**	**Capital Composition**	**Adj MFP**
1950-1964	3.70	1.03	1.99	2.36	0.27	0.43	1.66
1964-1972	4.22	1.68	3.27	2.05	-0.01	0.53	1.54
1972-1979	3.69	2.19	3.09	1.23	0.00	0.45	0.78
1979-1988	3.15	1.63	3.06	1.08	0.33	0.60	0.15
1988-1996	2.97	1.32	1.98	1.44	0.42	0.50	0.52
1996-2007	3.32	0.84	2.47	1.95	0.23	0.53	1.19

BEA Data				
Years	**Output**	**Labor**	**Capital**	**MFP**
1950-1964	3.51	1.16	3.18	1.75
1964-1972	4.18	1.85	4.52	1.53
1972-1979	3.70	2.34	3.63	0.98
1979-1988	3.06	1.47	3.40	1.01
1988-1996	2.92	1.47	2.38	1.18
1996-2007	3.60	1.15	2.82	1.95

BLS minus BEA				
Years	**Output**	**Labor**	**Capital**	**MFP**
1950-1964	0.19	-0.13	-1.19	0.62
1964-1972	0.04	-0.16	-1.25	0.52
1972-1979	-0.01	-0.15	-0.54	0.26
1979-1988	0.09	0.16	-0.34	0.07
1988-1996	0.05	-0.15	-0.40	0.26
1996-2007	-0.28	-0.31	-0.35	0.01

Source: See Data Appendix.

Table 6

Adjustments for Changes in Labor Composition, Selected Intervals

	1913-28	1928-50	1950-64	1964-72	1972-79
1. Denison Composition Adjustment for Hours	0.39	0.42	0.18	0.19	0.14
2. Denison Composition Adjustment for Education	0.57	0.62	0.60	0.67	0.75
3. Denison Composition Adjustment for Age, Gender	0.11	0.02	-0.06	-0.45	-0.47
4. Alternative Education Adjustment	0.49	0.48	0.54	0.71	0.84
5. Alternative Total Labor Composition Adjustment (equals line 3 + line 4)	0.60	0.50	0.48	0.25	0.37
6. BLS Composition Adjustment	----	----	0.39	-0.01	0.00

Source: Gordon (2000a), Table 3.

Table 7

Adjustments to Capital Input Growth for Changes in Capital Composition, Variable Retirement, and Highway/GOPO Capital, Selected Intervals

	Reweight Equipment 3-to-1 (1)	Back-Cast BLS Comp Adjustment (2)	Effect of Variable Retirement (3)	Add GOPO Capital (4)	Add Highway Capital (5)	Total Capital Adjustment (6)
1891-1913	-0.29	-0.97	----	----	----	-0.97
1913-1928	0.09	0.31	----	----	0.35	0.66
1928-1950	0.27	0.92	0.86	0.14	0.18	2.09
1950-1964	0.32	1.33	-0.98	-0.12	0.29	0.52
1964-1972	0.72	1.64	-0.64	-0.09	0.24	1.15
1972-1979	0.75	1.41	-0.21	-0.07	-0.12	1.00
1979-1988	0.18	1.89	-0.16	-0.05	-0.23	1.45
1988-1996	0.47	1.56	0.22	----	-0.08	1.70
1996-2007	0.67	1.67	----	----	----	1.67

Source: Data Appendix

Table 8

Alternative Measures of MFP Growth for Nonfarm Nonhousing Business GDP, Annual Growth Rates for Selected Intervals, 1891-2007

	Standard Inputs (1)	Add Labor Composition Adjustment (2)	Add Capital Composition Adjustment (3)	Add Variable Retirement (4)	Add GOPO and Highway Capital (5)	Total Impact of Labor and Capital Adjustments (6) = (5) - (1)
1891-1913	1.26	0.92	1.23	1.23	1.06	-0.20
1913-1928	1.51	1.10	1.01	1.01	0.89	-0.62
1928-1950	3.36	3.02	2.72	2.45	2.35	-1.01
1950-1964	1.75	1.48	1.06	1.37	1.32	-0.43
1964-1972	1.53	1.53	1.00	1.21	1.16	-0.37
1972-1979	0.98	0.98	0.52	0.59	0.65	-0.32
1979-1988	1.01	0.68	0.08	0.13	0.22	-0.79
1988-1996	1.18	0.77	0.27	0.20	0.18	-1.00
1996-2007	1.95	1.72	1.19	1.25	1.25	-0.70
1891-2007	1.79	1.50	1.25	1.25	1.19	-0.60

Source: Data Appendix

Table 9
Alternative Estimates of MFP Growth in the NFPB Sector, 1972-2007

	Slowdown Period	Revival Period
BLS from Table 5 (1972-96 and 1996-2007)	0.46	1.19
Oliner-Sichel from Table 2 (1973-95 and 1995-2007)	0.43	1.21
Jorgenson-Ho-Stiroh from Table 3 (1973-95 and 1995-2006)	0.39	0.96
Gordon from Table 8 (1972-96 and 1996-2007)	0.33	1.25

Table 10

Actual and Predicted Growth Rates of Components of Real GDP and Related Variables, Total Economy and Nonfarm Private Business Sector Actual for 1988-2007 and Projected for 2007-2027

	Actual *1987:Q4-2007:Q4*		Actual *2000:Q4-2007:Q4*		Projected *2007:Q4-2027:Q4*	
	Total Economy	**NFPB Sector**	**Total Economy**	**NFPB Sector**	**Total Economy**	**NFPB Sector**
Output *(Y)*	2.93		2.38		2.40	
Components						
Output per Hour *(Y/H)*	1.79	2.23	2.02	2.48	1.70	2.05
Hours per Employee *(H/E)*	-0.13		-0.54		-0.10	
Employment Rate *(E/N)*	0.05		-0.13		0.00	
Labor-force Part. Rate *(L/N)*	0.02		-0.21		-0.20	
Working-age Population *(N)*	1.19		1.24		1.00	
Related Variables						
Aggregate Hours *(H)*	1.14		0.36		0.70	
Household Employment *(E)*	1.26		0.90		0.80	
Labor Force *(L)*	1.21		1.04		0.80	
Output per Capita *(Y/N)*	1.74		1.14		1.50	
Decomposition of NFPB Labor Productivity Growth						
Output per Hour		2.23		2.48		2.05
Capital Deepening		0.96		0.87		0.85
ICT		0.71		0.60		0.60
non-ICT		0.25		0.28		0.25
Labor Quality		0.32		0.35		0.15
Multi-factor Productivity		0.96		1.26		1.05
ICT		0.50		0.47		0.45
non-ICT		0.45		0.79		0.60
Share of ICT Investment in GDP		3.69		3.95		4.00

Sources: See Data Appendix and text discussion