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Before, During, and After the Great Recession**

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Productivity and Potential Output Before, During, and After the Great Recession

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Abstract

U.S. labor and total-factor productivity growth slowed prior to the Great Recession. The timing rules out explanations that focus on disruptions during or since the recession, and industry and state data rule out “bubble economy” stories related to housing or finance. The slowdown is located in industries that produce information technology (IT) or that use IT intensively, consistent with a return to normal productivity growth after nearly a decade of exceptional IT-fueled gains. A calibrated growth model suggests trend productivity growth has returned close to its 1973-1995 pace. Slower underlying productivity growth implies less economic slack than recently estimated by the Congressional Budget Office. As of 2013, about $\frac{3}{4}$ of the shortfall of actual output from (overly optimistic) pre-recession trends reflects a reduction in the level of potential.

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1. Introduction

When we look back at the 1990s, from the perspective of say 2010, ...[w]e may conceivably conclude...that, at the turn of the millennium, the American economy was experiencing a once-in-a-century acceleration of innovation....Alternatively, that 2010 retrospective might well conclude that a good deal of what we are currently experiencing was just one of the many euphoric speculative bubbles that have dotted human history.

Federal Reserve Chairman Alan Greenspan (2000)

Disappointing productivity growth...must be added to the list of reasons that economic growth has been slower than hoped....

Federal Reserve Chairman Ben Bernanke (2014).

The past two decades have seen the rise and fall of exceptional U.S. productivity growth. This paper argues that labor and total-factor-productivity (TFP) growth slowed prior to the Great Recession. It marked a retreat from the exceptional, but temporary, information-technology (IT)-fueled pace from the mid-1990s to the early 2000s. This retreat implies slower output growth going forward as well as a narrower output gap than recently estimated by the Congressional Budget Office (CBO, 2014a).

Industry and state data show that the pre-Great-Recession productivity slowdown was in sectors that produce information technology (IT) or that use IT intensively. Sectors that were obviously unusual or “euphoric” in the 2000s— including housing and finance—were not the source.

Figure 1 illustrates that the mid-1990s surge in productivity growth ended prior to the Great Recession. The surge in labor-productivity growth, shown by the height of the bars, came after several decades of slower growth.¹ But in the decade ending in 2013:Q4, growth has returned close to its 1973-95 pace. The figure shows that the slower pace of growth in both labor productivity and TFP was similar in the four years prior to the onset of the Great Recession as in the six years since.

That the slowdown predated the Great Recession rules out causal stories from the recession itself. Theory and previous empirical literature (discussed in Section 2.4) provides only limited support for the view that the Great Recession should have changed the underlying path of TFP. And Figure 1 suggests no evidence that productivity was slower (or much faster) from 2007-2013 than in the several years before that. The evidence here complements Kahn and Rich’s (2013) finding in a regime-

¹ The appendix discusses data sources for the figure and the rest of the paper. Section 2.2 defines and discusses the growth-accounting decomposition.

switching model that, by early 2005—i.e., well before the Great Recession—the probability reached nearly unity that the economy was in a low-growth regime.

A natural hypothesis is that the slowdown was the flip side of the mid-1990s speedup. Considerable evidence, discussed in Section 3.1.1, links the TFP speedup to the exceptional contribution of IT—computers, communications equipment, software, and the Internet. IT has had a broad-based and pervasive effect through its role as a general purpose technology (GPT) that fosters complementary innovations, such as business reorganization.

Industry TFP data provide evidence in favor of the IT hypothesis versus alternatives. Notably, the euphoric, “bubble” sectors of housing, finance, and natural resources do not explain the slowdown. Rather, the slowdown is in the remaining $\frac{3}{4}$ of the economy, and is concentrated in industries that produce IT or that use IT intensively. IT users saw a sizeable bulge in TFP growth in the early 2000s, even as IT spending itself slowed. That pattern is consistent with the view that benefiting from IT takes substantial intangible organizational investments that, with a lag, raise measured productivity. By the mid-2000s, the low-hanging fruit of IT had been plucked.

State data on GDP per worker rule out indirect channels through which the housing bubble and bust might have mattered. States differ in how much house prices ran up in early 2000s and collapsed after 2006. Those differences could have influenced innovation through net-worth channels. But there is little evidence that housing dynamics contributed much to the dynamics of the productivity slowdown. Rather, it is the common cross-state slowdown in IT-intensive industries that predominates.

I then turn to two implications of the mid-2000s productivity slowdown. First, a multi-sector neoclassical growth model implies steady-state business-sector labor-productivity growth of about 1.9 percent, as shown at the far right of Figure 1. Prior to the Great Recession, typical estimates were notably higher. Using demographic estimates from the CBO (2014a), my benchmark estimate implies longer-term growth in GDP of about 2.1 percent per year. As Figure 1 shows, three out of the past four decades have shown this slower pace of productivity growth. That pace, rather than the exceptional 1995-2003 pace, appears normal.

Second, by 2013, the output gap, defined as the difference between actual and a production-function measure of potential output, is narrower than estimated by CBO (2014a). I decompose CBO’s gap into a “utilization gap” that reflects cyclical mismeasurement of TFP as well as an “hours gap.” CBO estimates that the utilization gap in 2013 was as deep as any time in history other than 1982 and

2009, and was comparable to its level in 1975. In contrast, empirical estimates from Fernald (2014, following Basu, Fernald, Fisher, and Kimball, BFFK, 2013) suggest a small utilization gap.

Figure 2 shows two alternatives to the CBO estimates of potential, with different estimates of the utilization gap. Both use the CBO labor gap to measure deviations of hours worked from steady state. One uses actual TFP, which imposes a utilization gap of zero. When utilization eventually returns to normal—as it plausibly did prior to 2013—this measure is appropriate. The second, labeled ‘Fernald,’ uses my utilization estimate. By 2013, the alternatives imply that about $\frac{3}{4}$ of the 2013 shortfall of actual output from the estimated pre-crisis trend reflects a decline in potential output. These estimates lie well below CBO (2014a), which itself is well below its pre-recession trend. The differences arise from the CBO’s assumed path for potential TFP. In contrast to the evidence in this paper, the CBO has no mid-1990s pickup in productivity and much less of a mid-2000s slowdown.

An important caveat is that production-function measures of potential output are inherently cyclical because investment is cyclical. Slow aggregate-demand growth in the recovery has led to slow closing of the output gap. Cyclically weak investment, in turn, has contributed to slow potential growth; indeed, capital input grew at the slowest pace since World War II. Slow capital growth does not directly affect output gaps—in the CBO definition (as well as the usual DSGE definition), it affects both actual and potential output. But in standard models, capacity should rebound (raising potential growth above its steady-state rate) as the economy returns towards its steady-state path.²

Section 2 discusses “facts” about the slowdown in measured labor and total-factor productivity, and compares the experience during and since the Great Recession to previous recessions and recoveries, finding that productivity experience was comparable. Section 3 assesses explanations for the productivity slowdown, using industry data and (maybe) regional data. Section 4 uses a multi-sector growth model to project medium- to long-run potential output growth. The section also discusses key uncertainties. Section 5 then draws on the preceding analysis to discuss current potential output and slack, in the context of the general methodology followed by the Congressional Budget Office.

2. Productivity Growth before the Great Recession

Trend productivity growth slowed several years *before* the Great Recession.

² Reifschneider, Wascher, and Wilcox (2013) and Hall (2014) discuss this channel

2.1. The mid-2000s slowdown in labor productivity growth

Figure 3 shows the log-level of business-sector labor productivity, which rationalizes the subsamples shown in Figure 1.³ The mid-1990s speedup in growth is clear. The literature discussed in Section 3.1.1 links that speedup to information technology (IT). The slowdown in the mid-2000s is also clear. The dates of the vertical bars are suggested by Bai-Perron test for multiple structural change in mean growth rates for the period since 1973. I have shown the “traditional” new-economy 1995:Q4 start date along with a slowdown date of 2003:Q4. The breaks are statistically significant.⁴

The Bai-Perron results complement the findings of Kahn and Rich (2007, 2013). They estimate a regime-switching model, using data on labor productivity, labor compensation, and consumption. They find that productivity switched from a high-growth to a low-growth regime around 2004. By early 2005, the probability that the economy was in a low-growth regime was close to unity.

2.2. Growth-accounting identities

Growth accounting provides further perspective on the forces underpinning the slowdown. Suppose there is a constant returns aggregate production function for output, Y :

$$Y = A \cdot F(W \cdot K(K_1, K_2, \dots), E \cdot L(H_1, H_2, \dots)) \quad (1)$$

A is technology. K and L are observed capital and labor. W is the workweek of capital and E is effort—i.e., unobserved variation in the utilization of capital and labor. K_i is input of a particular type of capital—computers, say, or office buildings. Similarly, H_i is hours of work by a particular type of worker, differentiated by education, age, and other characteristics. Time subscripts are omitted.

³ As discussed in the data appendix, “output” combines expenditure- and income-side data, so labor productivity differs slightly from the BLS productivity and cost release (which uses expenditure-side data).

⁴ I test whether mean growth (the drift term for a random walk) has breaks. Estimated break dates differ slightly for (real) income- and expenditure side estimates of labor productivity; but significance levels are similar. For the expenditure side, the point estimate for the speedup is 1997:Q2; for the income side, it is 1995:Q3. I stuck with the traditional 1995:Q4 date. For the slowdown, with expenditure the estimated date is 2003:Q4, shown in the figure; with income, it is 2006:Q1. For utilization-adjusted TFP, described in the next section, it is 2005:Q1. Despite uncertainty on exact dates, it clearly predates the Great Recession. In terms of statistical significance, looking at, say, expenditure-side labor productivity from 1973:Q2 through 2013:Q4, the Bai-Perron WDmax test of the null of no breaks against an alternative of an unknown number of breaks rejects the null at the 2-1/2 percent level. The UDmax version of the same test rejects the null at the 5 percent level. The highest significance level is for the null of no breaks against the alternative of 2 breaks, which is significant at the 5 percent level. In the full sample from 1947:Q1 on, there appears to be an additional break at 1973:Q2, as expected.

The first-order conditions for cost-minimization imply that output elasticities for a given type of input are proportional to shares in cost. Let α be total payments to capital as a share in total costs and $c_i^j, j \in K, L$, be the shares in the total costs of capital and labor, so that $\sum_i c_i^j = 1, j \in K, L$. Then the output elasticity for a given type of capital, say, is αc_i^K . Differentiating logarithmically (where hats are log-changes) and imposing the first-order conditions yields:

$$\begin{aligned}\hat{Y} &= \alpha \hat{K} + (1 - \alpha)(\hat{H} + \widehat{LQ}) + \widehat{Util} + \hat{A} \\ &= \alpha \hat{K} + (1 - \alpha)\hat{L} + \widehat{Util} + \hat{A}.\end{aligned}\tag{2}$$

Various input aggregates on the right-hand-side are defined as:

$$\begin{aligned}\hat{K} &\equiv c_1^K \hat{K}_1 + c_2^K \hat{K}_2 + \dots, \\ \hat{L} &\equiv c_1^L \hat{H}_1 + c_2^L \hat{H}_2 + \dots \\ \hat{H} &\equiv \hat{H}_1 + \hat{H}_2 + \dots \\ \widehat{LQ} &\equiv \hat{L} - \hat{H} \\ \widehat{Util} &\equiv \alpha \hat{W} + (1 - \alpha)\hat{E}\end{aligned}\tag{3}$$

Growth in capital services, \hat{K} , is share-weighted growth in the different types of capital goods. Similarly, growth in labor services, \hat{L} , is share-weighted growth in hours for different types of workers. Total hours growth, \hat{H} , is the simple sum of hours worked by all types of labor. Labor quality growth, \widehat{LQ} , is the contribution of changing worker characteristics to labor services growth beyond raw hours. Finally, \widehat{Util} captures variations in capital's workweek and labor effort.

TFP growth, or the Solow residual, is output growth not explained by (observed) input growth:

$$\begin{aligned}\widehat{TFP} &\equiv \hat{Y} - \alpha \hat{K} - (1 - \alpha)\hat{L} \\ &= \widehat{Util} + \hat{A}\end{aligned}\tag{4}$$

The second line follows from equation (2). I will always take TFP growth to be this measured Solow residual, defined by the first line in (4), and refer to \hat{A} as utilization-adjusted TFP.

A large literature discusses why measured TFP might not reflect technology over the business cycle.⁵ A key reason is unobserved variations in the intensity with which factors are used, \widehat{Util} . Basu,

⁵ See Basu and Fernald (2002) for discussion and references. They also discuss how to interpret measured TFP when constant returns and perfect competition do not apply and an aggregate production function does not exist.

Fernald, and Kimball (BFK, 2006) and Basu, Fernald, Fisher, and Kimball (2013) implement a theoretically based measure of utilization. Their method essentially involves rescaling variations in an observable intensity margin of (detrended) hours per worker. I return to this measure below.

From (2) and (4), labor productivity growth, defined as growth in output per hour, is then:

$$\begin{aligned}\hat{Y} - \hat{H} &= \alpha(\hat{K} - \hat{H} - \widehat{LQ}) + \widehat{LQ} + \widehat{Util} + \hat{A} \\ &= \alpha(\hat{K} - \hat{H} - \widehat{LQ}) + \widehat{LQ} + \widehat{TFP}\end{aligned}\quad (5)$$

Loosely, labor productivity rises if workers have more capital or better skills (quality); or if innovation raises technology. In the short run, cyclical variations in utilization also matter.

2.3. Aggregate data and growth-accounting results

Both TFP and capital deepening contributed to the mid-2000s slowdown in labor productivity growth. Specifically, Figure 4 shows components of equation (5) using the quarterly growth-accounting dataset described in the appendix. These data provide quarterly business-sector growth accounting variables through 2013. Variables shown are in log-levels (i.e., cumulated log-changes). The utilization measure applies annual estimates from BFFK (2013) to quarterly data. Utilization is based on variations in industry hours per worker. Using restrictions from theory, BFFK relate unobserved intensity margins of capital's workweek and labor effort to this observed intensity margin.

Panel A shows TFP and utilization-adjusted TFP.⁶ These series grew rapidly from the mid-1990s to mid-2000s, then essentially hit a flat spot. Panel B shows capital-deepening, $K/(H \cdot LQ)$. In the early 2000s, capital deepening growth slowed (consistent, perhaps, with the slowdown in technology growth). Panel C shows that labor quality accelerated in the Great Recession as low-skilled workers disproportionately lost jobs. Finally, Panel D shows utilization itself. This series is clearly highly cyclical. By early 2011, this measure had recovered to a level close to its pre-recession peaks. Indeed, by the end of the sample, labor productivity (Figure 3) or TFP (Figure 4A) appear to lie more or less on the slow trend line from the mid-2000s.

⁶ The UDMax and WDMMax tests for the null of no breaks against the null of an unknown number of breaks in utilization-adjusted TFP is significant at about the 5 percent level.

2.4. Productivity growth during the Great Recession

That the slowdown predated the Great Recession suggests it was not a result of the recession itself. Still, if productivity during the recession were unusual, that might suggest a role for the recession. For example, a few years of bad productivity luck before the recession could have been followed by the greater, and more persistent, bad luck of a severe recession. This section argues this was not the case. Rather, productivity behaved similarly to previous deep recessions: TFP and utilization fell very sharply, but recovered strongly once the recession ended.⁷

Figure 5 shows “spider charts” comparing the Great Recession to the nine previous recessions (1953-2001). In each panel, the horizontal axis shows the number of quarters from the peak. In the Great Recession, for example, quarter 0 corresponds to 2007:Q4. The vertical axis is the percent change since the peak. I remove a local trend from all data.⁸

Panels A and B shows how unusual output and hours were, with steep declines in both. For the first three quarters (through 2008:Q3), the declines in output and hours worked relative to trend were modest—at the top of the range of historical experience. After Lehman and AIG in quarter 4, output and employment fell precipitously. The trough in detrended output is about as deep as previous deep recessions, but is reached later. (In unfiltered data, the decline is deeper than previous recessions. Detrending has a larger effect in previous deep recessions when trend growth was faster.)

Panel C shows that labor productivity was solidly inside the range of historical experience—indeed, not much different from the average (the white line). Relative to trend, labor productivity fell less than during the 1973 or 1981 recessions.

⁷ Gali, Smets, and Wouters (2012) focus on the recovery and, as I do, argue that, following the Great Recession, productivity performance was in line with historical experience. That is, they argue that during the recovery, the problem was slow output growth, not unusual productivity growth. Daly et al. (2013a) discuss the cyclical behavior of labor productivity and TFP (and the degree to which it has changed) using the same data as here. In 2007 and 2008, a few commentators noted that productivity might be slowing (e.g., Fernald, Thippavong, and Trehan, 2007, and Jorgenson, Ho, and Stiroh, 2008). With hindsight, the pre-recession origins are now clear. Before and during the Great Recession, real-time data obscured the slowdown in trend, and overstated productivity’s strength early in the recession. Almost every revision since 2005 has lowered the path of labor productivity, with most revision to output (the numerator). Until the 2010 revision, productivity appeared to have risen sharply and steadily throughout the recession. Daly et al. (2014) discuss how data revisions helped resolve apparent deviations from Okun’s Law.

⁸ Detrending does not affect conclusions. Following a Jim Stock recommendation, I removed local trends with a biweight kernel with bandwidth 48 quarters. The local means for both output and labor productivity growth decline from about 2-1/4 percent in 2007:Q4 to under 2 percent by 2013:Q4.

Of course, labor productivity includes endogenous capital-deepening and labor quality, both of which were strong during the recession (see Figure 4B and C). Controlling for those, Panel D shows that TFP was right at the bottom of historical experience. TFP plunged about 5 percent during the recession and then quickly bounced back in the early phases of the recovery (quarters 6-8, especially).

Factor utilization in Panel E “explains” the plunge and rebound in TFP. Utilization fell below the range of historical experience in the recession, then recovered rapidly during the recovery. These estimates suggest that firms substantially used the intensive as well as extensive margin.

Finally, Panel F shows utilization-adjusted TFP. That series lies in the middle of historical experience, with a spike from quarter 4 (2008:Q4) to quarter 6 (2009:Q2). The spike could reflect temporary effects on utilization-adjusted TFP from the recession. A temporary breakdown in financial intermediation could have led the least productive firms to lose financing (Petrosky-Nadeau, 2013). Or, panicked firms could have cut workers exceptionally fast and found temporary efficiency gains that reversed in the recovery. Or, it could reflect fear-induced effort by workers. Lazear, Shaw, and Stanton (2013) look at how long it takes a given worker to complete a well-defined task at a single large firm from 2006 to 2010. (They argue the “usual” labor-and capital-hoarding effects are not in their data.) Task-level productivity rose as the Great Recession began. When the recession ended, task-level productivity declined—much like utilization-adjusted TFP.

Overall, though the counterfactual is unknown, the figures do not obviously suggest a major influence of the Great Recession on underlying TFP growth.

Theory is ambiguous about the effects of severe recessions (including financial ones) on the longer run path of TFP (utilization-adjusted or otherwise). In some models, reduced innovation during and after a crisis could lead to a persistently lower level of TFP (e.g., Comin and Gertler 2006). Decker et al. (2013) find that the Great Recession has substantially reduced “dynamism” of the economy, which could reduce the efficiency of resource allocation (see 3.1.4). Liu and Wang (2013) model a financial accelerator that leads to procyclical reallocation and productivity. That said, the reallocation effect in some models goes the other way, raising measured TFP in a credit crisis (e.g., Petrosky-Nadeu, 2013, or

the “cleansing effects” of Caballero and Hammour, 1994). And Bloom (2013) points out that high uncertainty can stimulate longer-run innovation.⁹

Overall, there is little empirical evidence for *developed* countries that business cycles (financially related or otherwise) permanently harm the level or growth rate of TFP. The Great Depression was an extraordinarily innovative period (Field, 2003, Alexopoulos and Cohen, 2009). Fatas (2002) finds that, for the richest countries (but not overall), higher volatility is, if anything, associated with *faster* growth in GDP per capita. Oulton and Sebastiá-Barriel (2014) look at growth-accounting variables following financial crises. They find that, for developed countries, the long-run level of TFP is not significantly changed by a financial crisis; indeed, the point estimate is positive.

3. Why Did TFP Growth Slow?

The data suggest that TFP slowed in the mid-2000s primarily because of the waning of the exceptional growth effects of information technology as a general purpose technology (GPT).

3.1. Hypotheses

This section discusses several hypotheses for the slowdown. I focus on implications for industry and state data, which I use in the subsections that follow to help differentiate the stories.

3.1.1. Waning of the IT-induced surge

Studies with aggregate, industry, and plant data link the mid-1990s productivity surge to the direct and indirect effects of IT. Below, I find evidence that the slowdown in the mid-2000s reflected the waning of that exceptional pace. For example, once retailing was reorganized to take advantage of faster information processing, the gains may have become more incremental.

Some IT links are direct. For IT production, the key development was the mid-1990s speedup and subsequent post-2000 slowdown in the pace of technological progress in semiconductors. In the mid-1990s, as Jorgenson (2001) highlights, the semiconductor industry moved to a shorter product

⁹ Basu and Fernald (2009) discuss additional channels. Reifschneider, Wascher, and Wilcox (2013) discuss a broader range of possible supply-side effects from recessions, including on labor markets.

cycle, which meant faster gains in performance and quicker price declines. However, several studies find that semiconductor performance gains and price reductions slowed after about 2000.¹⁰

The indirect effects of IT are more complex and nuanced. In retailing, for example, IT led firms to innovate in how they manage sales, inventories, and supply chains; the Internet is an extreme example, in that it made possible completely new ways of doing business. In addition, reallocation towards higher-productivity establishments amplified the effects, as new or existing firms that were particularly adept at using new technologies (and thus more productive) grew, while less capable establishments exited.¹¹ In valve manufacturing, Bartel, Ichniowski, and Shaw (2007) find that IT led to a change in business strategies to focus on product customization rather than large commodity runs. Implementing this change required changes in worker skills as well as in management and human-resource practices. More broadly, Brynjolfsson and Hitt (2000) and others highlight the lags associated with complementary managerial and organizational innovations.

These nuances reflect the GPT nature of IT.¹² For a wide swath of the economy, improved ability to manage information and communications has led to changes in how firms do business. But it was unclear a priori how long the transformative, explosive opportunities would last.

Basu, Fernald, Oulton, and Srinivasan (BFOS, 2003) discuss how to map these indirect GPT effects to conventional growth accounting. They model a tight link between accumulating IT capital and intangible organizational capital. Intangible capital leads to interesting dynamics for measured TFP, because it involves both unobserved investment (i.e., output) and unobserved capital (i.e., input).

The BFOS model implies that, as in the data, measured TFP should have surged, temporarily, in the early 2000s. The reason is that growth in IT capital—and, by assumption, intangible capital—skyrocketed in the late 1990s but slumped in the early 2000s. That pattern implies that in the 1990s, firms were increasingly diverting resources to producing unmeasured/intangible output. But in the early 2000s, those resources returned to producing measured output—boosting measured productivity for a time. Using the BFOS model on aggregate data, Oliner, Sichel, and Stiroh (OSS, 2007) find that falling investment in unmeasured IT-related intangibles, and the corresponding shift of resources towards

¹⁰ See Jorgenson, Ho, and Stiroh (2008), Byrne, Oliner, and Sichel (2013), and Pillai (2013) for references.

¹¹ See Doms (2004) and Foster, Haltiwanger, and Krizan (2006). Fernald and Ramnath (2004) provide a brief case study of how Walmart used IT to raise productivity.

¹² See, e.g., Greenwood and Yorokoglu (1997), Brynjolfsson and Hitt (2000), Basu, Fernald, Oulton, and Srinivasan (2003), and Brynjolfsson and McAfee (2014).

producing measured output, accounted for 2/3 of the measured TFP surge in their data from 1996-2000 to 2000-2006 (0.50 out of 0.81 percent per year).¹³ But with less “seed corn” for the future, they argued that future productivity gains would be slower.

In the empirical work, I examine the broader implication that, regardless of the specific model, the measurement effects are associated with the use of IT. Hence, the slowdown should be concentrated in IT-intensive industries.

3.1.2. Housing and finance in a bubble economy

The IT story emphasizes unusual aspects of the U.S. economy that began in the 1990s and before. But there were unusual features in the 2000s, including the housing boom and bust, the explosion of often-dodgy financial products and services, and large movements in commodity prices.

To assess the importance of direct effects, I throw out those industries. Indirect channels are more subtle. For example, changes in entrepreneurial net worth associated with the housing boom and bust could affect the ability of firms to start or expand, which might influence productivity (possibly with a lag). A priori, it’s not clear that the timing works for a 2004-2007 slowdown. Household net worth relative to disposable income peaked in the 2005-2007 period (averaging almost 650 percent). So net worth was highest just when productivity growth was slowing. Still, the housing boom could have mattered through some (perhaps unspecified) channel, and state data can provide insight into whether it might be quantitatively important.

Even if the 2004-2007 slowdown is hard to explain with home prices, the collapse after 2006 and/or the Great Recession itself could have contributed further to the slowdown. Fort et al. (2013) report that young and small firms are particularly sensitive to fluctuations in housing prices through a range of credit channels and that startups and job churning were hit hard during and since the Great Recession. Regional home price differences are also clearly linked to the intensity of the recession across states (Mian and Sufi, 2012). So I explore the degree to which state labor productivity responds to state-specific variation in home prices during the recession and (through 2012) recovery.

¹³ The online appendix discusses the BFOS model in more detail. In my quarterly TFP dataset, IT capital (information processing and software) grew 16 percent/year from 1995:Q3-2000:Q4, but only 8 percent/year from 2000:Q4-2004:Q4. (The IT-capital share of total income actually edged up slightly, but remained between 6 and 7 percent throughout.) Corrado, Hulten, and Sichel (2006) discuss broader measures of intangible investment and ways to measure them. Van Reenen et al. (2010) report substantial evidence for the IT-linked-intangibles story in micro data.

Finally, a very different channel is that the output of financial services is poorly measured. One concern in the literature (e.g., Wang, Basu, and Fernald, 2009) is mismeasurement of value added between producers and users of financial services. I explore that hypothesis by seeing whether the magnitude of the slowdown depends on the intensity of use of financial services.

3.1.3. Other sources of mismeasurement, cyclical or otherwise

Perhaps productivity growth didn't actually slow but measurement got worse? Cyclical mismeasurement from utilization and non-constant returns does not fit the timing. More complex stories are hard to rule out a priori, but also seem unlikely to explain the magnitude of the slowdown.

Controlling for utilization makes the post-2004 slowdown in TFP growth somewhat larger than measured. In the early 2000s, utilization was flat to down (measured in my quarterly data or with Federal Reserve capacity utilization). In contrast, during the 2004-07 boom, utilization ticked up.

Increasing returns and markups of price over marginal cost imply that measured TFP should rise when inputs rise (Hall, 1990). But input growth (share-weighted capital and labor) was relatively rapid (2+ percent per year) in the fast-productivity-growth late 1990s as well as in the slow-productivity-growth 2004-07 period. Conversely, input growth was relatively slow (¼ to ½ percent per year) in the fast-productivity-growth early 2000s as well as in the slow-productivity-growth 2007-2013 period.

Indeed, the sign goes the wrong way. Share-weighted input growth sped up by 2 percentage points from the 2000-04 period to 2004-07. With constant or modestly increasing returns to scale (e.g., Basu and Fernald, 1997), measured TFP growth should, if anything, have sped up a little. Even large diminishing returns (say, 0.8) imply only a modest slowdown—and would imply, counterfactually, that measured TFP growth should have been relatively slow in the late 1990s and relatively fast after 2007.

Basu, Fernald, and Shapiro (BFS, 2001) assume that investment adjustment costs reduce measured productivity as firms divert resources to installing capital. This story does not explain the TFP slowdown because fixed private non-residential investment grew at a very similar pace (5 to 6 percent per year on average) from 1995-2004 and from 2004-2007. The BFS calibration implies that adjustment costs subtracted about 0.2 percentage points from measured TFP growth in both subperiods.

Unmeasured quality change is more challenging. IT itself increases product variety, decreases search costs, and provides valuable services for free. For example, producers can readily offer customized, non-standard products; there are enormous, poorly measured gains to being able to easily

obtain any book in the world in a few days (or via immediate download); and GPS and entertaining cat videos on YouTube increase consumer surplus. Brynjolfsson and McAfee (2014) estimate that free Internet goods provide some \$300 billion/year in consumer surplus, or about 2 percent of GDP. But even if that all appeared over a decade, it's still only 0.2 pp per year.

Moreover, mismeasurement was also severe in the past. There were missing quality improvements for both capital goods (Gordon, 1990) and consumer goods and services (e.g., Gordon, 2006). In terms of product variety, Broda and Weinstein (2006) measured a four-fold increase in the variety of U.S. imports in the 1970s, 1980s, and 1990s—long before the 2000s slowdown. Similarly, Nakamura (1998) notes that, with IT-related improvements in inventory management, the average supermarket carried 2-1/2 times as many items in 1994 as in 1970. Americans no longer had to settle for “bright yellow mustard, canned peas, and gelatin desserts” (p.7)

Careful work on measurement requires detailed, often product-specific analysis. In the industry data, I take a simpler, high-level approach of decomposing the data based on where different industries plausibly fall on the “well-measured” continuum, as in Griliches (1994) and Nordhaus (2002).

Finally, Oliner, Sichel, and Stiroh (2007) discuss other stories why the early 2000s strength might have been overstated, consistent with a subsequent slowdown. I do not assess them explicitly but, to the extent they contribute, they reinforce the “return to normal” message of the IT story.

3.1.4. Reduced dynamism in the economy

By many measures, the U.S. economy has become less dynamic over time (e.g., Decker et al., 2013). For example, rates of firm entry and job creation and destruction have trended steadily down over the past 30 years with notable further declines in the Great Recession. Such dynamism improves factor allocations and fosters the spread of new ideas. The existing literature does not clearly establish why dynamism has declined. For example, an aging population could be more risk averse; increasing regulation could raise the cost of business entry; or the “idea production function” might have shifted in favor of large, established firms and away from new entrants.

Given the links between home-price dynamics and firm entry noted earlier, the state data may shed light on the recent quantitative importance of this channel. Still, as a longer-term secular trend, reduced dynamism is unlikely to explain the abrupt productivity slowdown in the mid-2000s: Dynamism was higher in the slow-productivity-growth 1980s than in the fast-productivity growth late

1990s and early 2000s.¹⁴ That said, the decline in dynamism could complement the IT story, to the extent that ongoing gains from IT require new businesses to enter or expand at the expense of incumbents. More generally, reduced dynamism reinforces the message of this paper that growth has slowed, and that major forces were in train prior to the Great Recession.

3.2. Evidence from industry data

Industry data support the IT story for the mid-2000s TFP slowdown. The TFP surge after the mid-1990s, and its subsequent slowdown, was in IT-producing and intensive-IT-using industries. IT-producing industries saw productivity explode in the 1995-2000 period. After 2000, productivity returned close to its pre-1995 pace. IT-intensive industries saw only a modest pickup in the late 1990s but a marked burst in 2000-2004. After 2004, TFP growth receded close to its pre-1995 pace.

I use BLS data for 60 manufacturing and non-manufacturing industries from 1987-2011. I express everything in value-added terms, so that they are conceptually identical to TFP in equation (4).¹⁵ The data do not control for labor quality, LQ , and predate the 2013 NIPA revisions. Nevertheless, when aggregated (using value-added weights) to a private-business level, year-to-year changes comove closely with the Fernald TFP series (the correlation is 0.84).

Table 1 shows TFP growth by subperiod for selected industry groupings. Consistent with the earlier results, TFP growth for all business industries sped up in the late 1990s and sped up further (to 2.19 percent per year) in the early 2000s. During 2004-2007, growth slowed markedly to only 0.63 percent. From 2007-2011, business TFP growth recovered a touch, to 0.90 percent. Some of this apparent pickup reflects the spike in labor quality during the Great Recession. Since the 2007-2011 period might still be affected by cyclical variations in LQ and utilization, below I focus primarily on the pre-Great-Recession period. But broad conclusions are robust to using the full sample period.

Line 2 shows TFP growth for the bubble-economy sectors of natural resources, construction and real estate, and finance. TFP for that group decelerated from 2000-04 (-0.28 percent per year) to 2004-

¹⁴ An exception is high-tech industries, where Haltiwanger, Hathway, and Miranda (2014) report high dynamism in the late 1990s tech boom; but, as the industry has matured, job and firm turnover has eased.

¹⁵ Value-added is like a partial Solow residual, controlling for share-weighted intermediate inputs. Apart from small approximation error, value-added-weighted growth in industry value-added TFP is equivalent to Domar-weighted growth in gross-output TFP. Conceptually, this bottom-up approach differs from top-down TFP measurement because of input-reallocation terms. Jorgenson, Ho, and Samuels (2013) find these terms are, on average, small.

07 (more substantially negative at -1.38 percent). Weakening TFP in natural resources (line 3) and construction (line 4a) was partially offset by stronger TFP in real estate (line 4b) and finance (line 5).

But importantly, the remaining, non-bubble $\frac{3}{4}$ of the business economy (line 6) slowed even more than overall private business. Thus, the slowdown did not merely reflect the unusual features of commodities, housing, and finance. This narrow business sector slowed further after 2007.

The lines below show additional summary “cuts” of this narrow business sector. These show that the slowdown was particularly pronounced in IT-producing industries (line 7) and in intensive IT-using industries (line 9). Figure 6A shows these points graphically. IT-producing sectors saw a burst in TFP growth in the late 1990s, consistent with the studies of the semiconductor industry noted in Section 3.1.1. (Table 1, line 7a, locates this burst primarily in the production of computers and semiconductors.) The pace from 2000-2007 was not much different from its pre-1995 pace. Intensive-IT-using industries saw only a modest pickup in the late 1990s but then productivity exploded in the early 2000s. From 2004-07, productivity in that group more or less receded to its pre-1995 pace. In contrast, non-IT-intensive industries saw more consistent performance over time.¹⁶

Figure 6B shows the importance of IT intensity another way. It plots the post-2004 TFP slowdown (through 2007) for bins of industries grouped by IT intensity. Bin “1” on the x-axis is the least IT-intensive, bin 6 is the most. The figure shows that more IT intensive industries (to the right) had more of a slowdown after 2004. The two least IT-intensive bins on the left showed little slowdown.

A second way to cut the data is well measured versus poorly measured. Well-measured industries are predominately manufacturing and utilities (in addition to natural resources, which I exclude), whereas poorly measured industries are predominately services. As the table shows, both well-measured (line 11) and poorly-measured (line 17) industries picked up somewhat in the late 1990s, sped up further in the early 2000s, and then slowed markedly (by 1-1/4 to 1-3/4 percentage points) after 2004. Thus, first-cut measurement issues do not seem to be at the heart of the productivity slowdown.

A third cut is finance-intensive versus non-finance-intensive industries. If there was systematic and growing mismeasurement of intermediate financial services—or, perhaps, growing rent extraction by financial firms—then the slowdown should be more pronounced in finance-intensive industries.

¹⁶ In discussing this paper, John Haltiwanger questioned the reliability of the industry capital-flow table that underlies the BLS estimates of industry IT intensity. It is based largely on occupational employment, and so may be more directly related to IT *workers* than IT capital. Importantly, the link to IT remains, as emphasized here.

However, the slowdown turns out to be more pronounced for non-finance-intensive industries. These industries have a larger productivity bump in the early 2000s—and, thus, had further to fall. Nevertheless, there is no evidence here that the productivity burst was particularly related to finance.

Thus, the industry data suggest the important role played by the production and use of information technology in explaining the TFP slowdown from 2000-04 to 2004-07. These results, and the literature in 3.1.1, suggest that IT-intensive industries saw transformative organizational changes associated with IT, which fueled a burst of productivity in the early 2000s. Once the low-hanging fruit of reorganization had been plucked, growth returned to normal.

3.3.Evidence from the U.S. states

Labor productivity slowed broadly in almost all states—especially in IT-intensive industries. More importantly, the state data provide insight into indirect financial and housing channels, since states differ in housing dynamics during the boom and bust. These dynamics explain little of the cross-state variation in the degree to which productivity slowed.

The state data are for GDP per worker. Cross-state variation could reflect innovation, perhaps because, as discussed in Section 3.1.2, credit-market access by innovative entrepreneurs is affected by net worth.¹⁷ But credit market access could affect capital deepening, as well. And to the extent house-price fluctuations affect aggregate demand, it could affect relative factor utilization across states around the national average. Since the innovation, capital-deepening, and utilization channels are likely to move in the same direction in response to shocks to housing wealth, any effects on labor productivity are an upper bound on the persistent effect on technology or innovation.

Table 2 shows that almost all states saw a broad labor-productivity slowdown. For the entire private economy, 47 out of 51 states (including D.C.) had slower productivity growth in 2004-07 relative to 1997-2004. (Extending the slowdown period to 2012, the figure rises to 48.) Natural resources slowed substantially in most states, as did construction and FIRE.

¹⁷ In regressions not shown, I confirm that across states, changes in startup activity are, indeed, associated with (instrumented) changes in home equity. In some specifications, startup activity is associated modestly with state labor-productivity growth—though the explanatory power was always low. The state data are probably too coarse to provide substantial evidence on this channel.

Still, as in the industry data, IT rather than the bubble sectors are the story. As in Table 1, IT production (line 7) slowed substantially; and, in line 8, within the narrower category that excludes the bubble sectors and IT production, almost all states slow. Within that narrow grouping, IT-intensive industries (line 9) slowed in 50 out of 51 states (Washington, D.C. was the exception)—and the median slowdown was large. In contrast, only 35 states saw slowdowns in non-IT-intensive industries, and the median slowdown was small. Labor productivity in wholesale trade (line 11), where substantial research has documented the role of IT in fostering reorganizations, slowed in all 51 states after 2004.

What about indirect channels? Table 3, Panel A, examines whether the slowdown (2004-2007 relative to 1997-2004) is related to cross-state home-price changes. I instrument for home-price changes with the Saiz (2010) housing-supply elasticity (based on geographic features of metropolitan areas). Mian and Sufi (2012) argue that the elasticity is a good instrument for home price changes in this period: When credit standards changed in the early 2000s, areas with inelastic land supply saw a larger increase in housing prices. Conversely, when credit standards tightened after 2006, areas with inelastic land supply saw larger housing busts. (Units for home-price movements are standard deviations relative to the cross-section of states.)¹⁸

There is scant evidence that cross-state productivity slowdowns are related to home-price changes during the boom. The house-price change is significant for IT-intensive industries (column 3) and natural resources (column 8). Still, in both cases, the R^2 is low and the coefficient is positive. Since the average state saw a housing boom, the sign goes the wrong way to explain a widespread slowdown.

For natural resources, a possible channel is that, where home-prices ran up more, marginal agricultural land was converted to residential uses—so the quality of land in agricultural production went up. (The share of natural resources in the economy did fall in areas with greater increases in home prices.) Alternatively, the net worth channel could be particularly important for capital investment in agriculture, where farmers are often land rich but liquidity constrained.

For IT-intensive industries, the significance could reflect net-worth channels. But it could easily reflect that aggregate demand was stronger where house-prices ran up more, boosting capital investment

¹⁸ I do not remove the mean before standardizing by the cross-sectional standard deviation, so that the constant term is net of the contribution of the mean change in house prices over the period.

and factor utilization. In any case, the R^2 is low and the constant term is a large negative. So any effects of the housing bubble were swamped by other factors—such as IT.

Table 3, Panel B, uses a different cut of the data to address the post-2006 housing collapse and Great Recession. National home prices peaked in 2006 and slid to 2009. Mian and Sufi (2012) argue that the depth of the recession across states is related to the magnitude of this decline. So the state home-price data provide an indicator of where the recession itself might have contributed to weak productivity. Under the hypothesis that there were a couple years of pre-recession bad luck, followed by the Great Recession, it considers the 2005-2012 period relative 1997-2005 period. The right-hand-side variable is the change in home prices from roughly peak to trough (2006 to 2009).

Here, the effects are generally larger, and in line with the Mian-Sufi story for the bubble sectors. For the entire private economy (column 1), house-price changes have a strong association with labor productivity. The effects are located in the bubble sectors—construction and FIRE (columns 5 and 6) and, to a lesser degree, natural resources (column 7). Excluding those sectors (column 2), as well as for IT-intensive and not-IT intensive sectors, the effect of the housing decline is small and insignificant. Again, for IT-intensive industries, the large and negative constant term is where the action is.

All told, the state data do not suggest that home-price movements are an important part of the story. Rather, the state data are consistent with the IT-linked story for the slowdown.

4. Implications for Medium and Long-Run Growth

In a multi-sector neoclassical growth model, the slowdown in TFP growth plausibly implies a pace of labor productivity growth comparable to 1973 to 1995. What follows assumes constant returns, perfect competition, and that utilization growth is zero in steady-state. Hence, steady-state growth in technology and measured TFP are equal: $\hat{A}^* = \widehat{TFP}^*$, where stars (*) denote steady-state values.

4.1. Multi-sector projections of labor productivity growth

In one-sector neoclassical growth models, capital deepening depends on exogenous TFP growth. In the steady state of that model, the capital-output ratio is constant. In U.S. data, however, reproducible capital input grew about 1 pp per year faster than output from 1973 through 2007.

Multi-sector models, where one (or more) sector produces investment goods and other sectors do not, fit the data better because they generate a rising capital-output ratio. Steady-state capital

deepening depends solely on investment TFP: $(\hat{K} - \hat{H}^* - \widehat{LQ}^*) = \widehat{TFP}_I^* / (1 - \alpha)$. In the data, land is an important form of non-reproduced capital, earning 10 percent of payments to capital from 2000-2007. If c_T is land's share of capital payments, $\alpha^R = \alpha(1 - c_T)$ is the reproducible (non-land) capital share in output, and land use grows at the same rate as labor, then steady-state labor productivity growth is:¹⁹

$$\hat{Y}^* - \hat{H}^* - \widehat{LQ}^* = \widehat{TFP}^* + \alpha^R \cdot \widehat{TFP}_I^* / (1 - \alpha^R) \quad (6)$$

In the one-sector model without land, the right-hand-side simplifies to the usual expression:

$\widehat{TFP} / (1 - \alpha)$. Land somewhat attenuates the endogenous capital-deepening effect.

In practice, \widehat{TFP}_I^* needs to be the user-cost weighted average of multiple types of capital goods. The price of equipment—especially but not solely information-technology related—has fallen rapidly relative to the prices of other goods. In contrast, the relative price of structures has risen steadily over time. Hence, I assume there are three final-use sectors as well as (exogenously growing) labor:

$$\begin{aligned} D &= (K_D)^\alpha (AN_E)^{1-\alpha} \\ B &= Q_B (K_B)^\alpha (AN_B)^{1-\alpha} \\ C &= Q_C (K_C)^\alpha (AN_C)^{1-\alpha} \end{aligned} \quad (7)$$

The **Durable** sector produces equipment and consumer durables. The **Building** sector produces structures. The **Consumption** sector produces non-durables and services. The production functions are identical apart from building-specific and consumption-specific technology shocks, Q_B and Q_C .

Some durable goods, D , are invested and become equipment capital; all new buildings become structures. Both equipment and structures accumulate according to the standard perpetual inventory formula. Land grows exogenously. All three sectors use the same capital aggregate:²⁰

¹⁹ See the online appendix. Because land and labor grow at the same rate, equation (6) omits an “excess” land-growth term: $\alpha^T \cdot (\hat{T}^* - \hat{H}^* - \widehat{LQ}^*) / (1 - \alpha^T)$, where \hat{T}^* is land (Terra) and $\alpha^T = \alpha c_T$ is the share of land in total cost. That term adds 2 basis points over the entire sample period and 0 basis points from 1995 through 2007.

²⁰ The appendix discusses the general properties of this model and discusses its fit. In the empirical implementation, I add inventories as a durable output, which effectively increases the equipment weight, c_E .

The model abstracts from potentially important issues. First, production functions and the capital aggregate are equal across sectors, but actual sectoral factor shares are not (see BFFK, 2013); second, all functions are taken to be Cobb-Douglas. These first two assumptions simplify steady-state calculations, which are best interpreted as a local approximation when shares do not change too much. Third, the model assumes a closed economy. If, say, the ability to import computer components reduces the relative price of computers, the model interprets the lower price as faster

$$K = E^{c_E} S^{1-c_E-c_T} T^{c_T} = K_D + K_B + K_C .$$

With perfect competition, relative output prices reflect relative marginal costs. With identical factor prices, relative marginal costs in the model depend solely on relative technologies. In growth rate terms, the relative price of, say, consumption to durable equipment thus gives relative technology:

$$\widehat{P}_C - \widehat{P}_D = \widehat{MC}_C - \widehat{MC}_D = -\widehat{Q}_C \quad (8)$$

This approach follows the literature on investment-specific technical change (ISTC, e.g., Greenwood, Hercowitz, and Krusell, 1997). It relies on strong assumptions that hold imperfectly in practice; see Basu, Fernald, Fisher, and Kimball (BFFK, 2013) for an alternative identification. But in the long-run, BFFK find that relative prices do primarily reflect relative technologies.

Figure 7 shows the implied (cumulated) final-use TFPs, where overall TFP is decomposed using equation (8). The final-use TFP measures do not control for utilization, but in the longer-run should provide reasonable indicators of technology trends. All three sectors move roughly together until the mid-1960s. Buildings TFP then begins to drift steadily downward. By the early 1970s, consumption TFP largely levels off. In contrast, durables TFP continues to rise steadily until the 1990s.

The difference between the durable and consumption lines is what the literature calls ISTC. In contrast to the implicit interpretation in that literature, the faster apparent pace of ISTC in the 1970s arises from slower growth in consumption TFP, not from faster growth in durables (equipment) TFP.

In the mid-1990s, durables TFP does, in fact, accelerate, reflecting IT production. It's difficult to see in the figure, but consumption TFP also grew more quickly. Buildings TFP continues to trend down. In the mid-2000s, prior to the Great Recession, all three series show a reversal in their post-1995 growth pace. Durables TFP grows more slowly; consumption TFP dips a bit; and buildings TFP plunges. In the Great Recession itself, all three series fall somewhat and then bounce back.

relative TFP. The lower relative price, in the closed-economy model or in a comparable open-economy model, encourages capital deepening. Hence, for the incentives to purchase computers, the closed-economy assumption seems fine. Fourth, recent literature, some discussed in Section 3.1.1, focuses on intangible capital. Conceptually, this is an additional capital good that the economy produces and uses, where we do not observe the investment or the stock of intangibles. At different times, the investment versus service flow effect may dominate measurement. Corrado and Hulten (2013) find that, over the 1980-2011 period, accounting for intangibles makes only a few basis points of difference to “adjusted” GDP per hour, though the split between capital deepening and TFP is affected.

Despite these caveats, the online appendix shows that the model fits historical experience well.

How should we use estimates of final-use TFP growth? Pesaran, Pick, and Pranovich (PPP, 2013) argue that break-analysis of the sort done in Sections 2 and 3 is important for understanding history but *not* for forecasting. The exact magnitude and dates of breaks are uncertain, and post-break samples are short. In the current problem, for example, each series may break at different times and provide only a short window of (volatile) post-break data. PPP show that using estimated break dates is suboptimal in terms of mean-squared forecast errors (MSFE). They argue for forecasting using all available data but adjusting the weights on different observations.

As a benchmark, I use a simple approach that PPP call AveW, where one forms forecasts for a range of historical windows and then averages. PPP find that AveW works well in both Monte Carlo simulations and actual applications. It deals with uncertainty about the precise timing and magnitude of breaks by averaging across them. It is similar to exponential smoothing in that it puts more weight on recent observations, since those observations appear in all of the windows.

I include all possible windows since 1973:Q2 of 24 quarters or longer. Then, for each of the 139 starting dates $s \in [1973:Q2-2007:Q4]$, I calculate average TFP growth from s through 2014:Q1 for durables, buildings, and consumption and use those growth rates to forecast labor productivity growth, $LP^f(s)$, with equation (6). I then average the forecasts. Hence, $LP^{AveW} = (1/139) \cdot \sum_{s=1973:2}^{2007:4} LP^f(s)$.

The model requires values for (reproducible) capital's share, α^R , and for $c_J, J \in (E, S, T)$. I focus on average values prior to the Great Recession, averaged from 2001:Q4 through 2007:Q4. The reproducible capital's share, α^R , averaged 31 percent, and capital share overall averaged 35 percent. As an alternative, I use the 2014:Q1 reproducible capital share of 34 percent (the overall share had risen to almost 39 percent). Other things equal, a higher capital share implies faster growth from equation (6).

The first column of Table 4, row 6, shows my benchmark estimate of steady-state labor-productivity growth of a little under 1.9 percent per year. That estimate uses the LP^{AveW} measure. Row (8) shows that, with the 2014 value of capital's share, the projection is about 0.2 pp per year faster.

The columns to the right show particular windows. For example, row (6) of the "Since 1973:Q2" column shows $LP(1973:Q2)$, i.e., the prediction for labor productivity with average TFP growth 1973:Q2-2013:Q4. Using just the past decade, $LP(2003:Q3)$, implies a forecast of under 1 ½ percent, close to the forecast using data since 1973:1. The benchmark AveW forecast of about 1.9 percent labor-productivity growth turns out to be similar to $LP(1986:Q4)$.

Finally, productivity influences the long-run equilibrium real interest rate. From the consumption Euler equation for the multi-sector model, and with a unit intertemporal elasticity of substitution, the steady-state real rate is $r = [TFP_C + \alpha TFP_I / (1 - \alpha)] + n + \rho$. n is population growth and ρ is the rate of time preference. With a reproducible capital share of 0.31, the AveW estimate of the term in brackets is 1.27 percent. This compares with an average (not shown) during the Great Moderation period (1984:Q1-2007:Q4) of 1.47 percent, and in the 1995:Q4-2007:Q4 period of 1.99 percent. Thus, the direct effect of slower growth on the equilibrium real interest rate may be in the range of $\frac{1}{4}$ to $\frac{3}{4}$ percent. This is on top of the effects of slowing population growth (n).

4.2. Key uncertainties

The model and discussion highlight key issues that will influence future growth. An important question is whether the IT revolution might return after a pause? Syverson (2013) points out that labor-productivity during the early-20th-century electrification period showed multiple decades-long waves of slowdown and acceleration. Pessimists (e.g., Gordon, 2014) think a renewed wave of strong growth is unlikely; optimists (e.g., Brynjolfsson and MacAfee, 2014) think it's on its way.

Another issue is model's steady-state assumptions. Fernald and Jones (2014) discuss a model in which relatively steady U.S. historical growth of GDP per hour of around 2 percent reflects transition dynamics of rising educational attainment and an increasing share of the labor force devoted to research. The steady-state of that model suggests much lower growth in labor productivity (about $\frac{1}{2}$ percent per year) than I project here. But transition dynamics could continue to play out for a long time to come, or even intensify. For example, the rise of “frontier” research in China, India and elsewhere—as well as machine learning and robots—could lead to faster growth in the next few decades, even if the eventual path is much lower. Fernald and Jones interpret steady-state projections of the sort done here as a local approximation that might be reasonable over the span of a few decades but not forever.

Not surprisingly, standard errors around long-run projections are large. Mueller and Watson (2013) estimate an 80 percent confidence interval for 10-year projections of non-farm business output per hour from 1.0 to 3.0 percent per year; for overall TFP, it ranges from -0.1 to 2.1 percent.

4.3. From labor productivity to GDP growth

To translate labor productivity to GDP, I use projections for potential labor input and non-business output from the CBO (2014a) and labor quality estimates from Jorgenson et al. (2013).

The CBO projects that potential non-farm business hours by 2024 will slow to 0.64 percent per year, from 1.4 percent per year from 1949 through 2007. Labor quality exacerbates this demographic slowdown, since new labor-market cohorts are no more educated than retiring cohorts. I therefore assume zero labor-quality growth. These estimates imply that, in the benchmark case, business output will grow with productivity (1.85 percent) and hours (0.64 percent) = 2.49 percent per year. For non-business sector output—mainly general government and the service flow from owner-occupied housing—CBO forecasts 0.85 percent per year growth at the end of 10 years (in 2024).

Together, the business and non-business projections imply anemic long-run GDP growth of about 2.1 percent per year. In terms of total GDP per hour, this corresponds to growth of only about 1.6 percent per year. This projection lies below the average from 1950-2007 of 2.0 percent per year.

Prior to the Great Recession, a typical long-run projection for GDP growth was 2-1/2 percent or higher. For example, in early 2007, the CBO projected growth 10 years out of 2.5 percent per year, and GDP per hour of 2.0 percent per year—close to its long-run trend. Since 2009, Federal Open Market Committee participants have published “longer run” projections for GDP growth. In January 2009, 10 out of 16 participants projected 2-1/2 percent growth, with the remaining six higher than that.²¹

When the first versions of this paper were written, in late 2011 and early 2012, the projection of 2.1 percent growth, and 1.6 percent for GDP per hour, was low. In contrast, by early 2014, the numbers reported here are in line with, or above, many other projections. The CBO (2014a) itself projects growth of potential GDP (in 2024) of 2 percent and GDP per hour of 1.5 percent. Jorgenson et al. (2013) and Gordon (2014) project GDP per hour growth approximately 10 years out of 1.3 percent. Byrne, Oliner, and Sichel (2013) project GDP per hour of about 1-1/2 percent.

²¹ Numbers are reported in the minutes at <http://www.federalreserve.gov/monetarypolicy/fomccalendars.htm>. Projection data are presented in bins. I have rounded the “2.4 to 2.5 percent” bin to 2-1/2 percent. Estimates are for total GDP; it is not possible to decompose FOMC projections into productivity versus demographics.

5. Implications for Recent Measures of Slack

The pre-Great-Recession productivity slowdown implies that, as of 2013, economic “slack” using a production-function definition may be narrower than CBO (2014a) estimates. The CBO does, in fact, build in slower TFP growth after 2004. But the slowdown is more modest than in the data. If potential is lower than the CBO estimates, then the gap between actual and potential output is smaller.

5.1. Alternative definitions of potential

The CBO’s defines potential in terms of a production function: “the maximum sustainable amount of real (inflation-adjusted) output that the economy can produce” (CBO, 2014b, page 1). The dynamic stochastic equilibrium (DSGE) literature offers a theoretically coherent alternative: Potential (or natural) output is its value when nominal frictions (sticky prices and wages) and, often, markup shocks are absent.²² Technology shocks directly affect the natural rate of output. But other shocks—say, to the labor-leisure choice or the rate of time preference—may also cause changes in hours worked or factor intensity even in the absence of nominal frictions. The CBO definition excludes these effects.

Nevertheless, the DSGE approach is challenging in the present context. Most models assume that growth in technology has a constant mean—inconsistent with the interpretation in this paper. A fully-specified regime-switching (or more general) model is complicated. More generally, estimates tend to be model-specific. Different models may interpret the same data quite differently.

Still, Kiley (2013) finds that, in the Federal Reserve EDO model, the natural-rate measure of the output gap comoves reasonably closely with a production-function-based measure. Indeed, technology fluctuations affect potential output in DSGE models as well in the production-function (CBO) approach; and demand shocks that lead to inefficient fluctuations in hours worked and factor utilization would be captured in both approaches. Finally, the CBO estimates provide a widely cited benchmark.

²² See, Basu and Fernald (2009) or Kiley (2013) for an extended discussion and references.

5.2. Alternative estimates of slack in the CBO approach

Historically, the CBO attributes almost all movements in the output gap for overall GDP to the (non-farm) business sector, so I assume the GDP gap is simply a rescaled version of the business-sector gap.²³ In the Cobb-Douglas case, if ω is the business share of the economy:

$$\frac{Y_t}{Y_t^*} = \left(\frac{Y_t^{Bus}}{Y_t^{Bus,*}} \right)^\omega \quad (9)$$

For the business sector, suppose the production function is Cobb-Douglas:

$$Y_t^{Bus} = K_t^\alpha H_t^{1-\alpha} (LQ_t^{1-\alpha} Util_t A_t) \quad (10)$$

The CBO does not explicitly consider labor quality, so the term in brackets on the right side is measured TFP gross of LQ . The production-function measure of potential output is what the economy could produce given current technology and capacity, assuming that labor and capital are utilized at “normal” (steady-state) levels. Setting $Util^* = 1$, potential output is:

$$Y_t^{Bus,*} = K_t^\alpha H_t^{*1-\alpha} (LQ_t^{*1-\alpha} A_t). \quad (11)$$

Taking the ratio, the output gap for the business sector is:²⁴

$$\frac{Y_t^{Bus}}{Y_t^{Bus,*}} = \left(\frac{H_t}{H_t^*} \right)^{1-\alpha} Util_t \left(\frac{LQ_t}{LQ_t^*} \right)^{1-\alpha} \quad (12)$$

The CBO publishes annual estimates of the business-sector output and hours gaps. Potential hours draws on analysis of demographics, trend labor-force participation, mismatch, and other factors. This equation implicitly defines a CBO “utilization gap” (inclusive of LQ) as:

$$\ln(Util_t^{CBO,LQ}) \equiv \ln(Y_t^{Bus} / Y_t^{Bus,*}) - (1-\alpha) \ln(H_t / H_t^*) \quad (13)$$

Figure 8A plots this utilization gap, using the 2001-2007 average capital share of 0.34. It also shows the cumulated Fernald utilization series (annual, normalized to match the CBO as of 1987) and the Federal Reserve (FRB) manufacturing capacity-utilization series (relative to its 1981-2007 mean). Over the full sample, the correlation of the CBO and Fernald series is 0.78, which matches the correlation of the CBO

²³ The correlation of the gap from equation (9) with the actual CBO GDP gap is 0.998. CBO (2014b) discusses some of their underlying assumptions. As shorthand below, I refer to “nonfarm business” as “business.”

²⁴ Kiley (2013) uses this decomposition (apart from labor-quality) to derive a “CBO gap” in the EDO DSGE model. Note also that any cyclical deviations from “potential TFP,” regardless of source, is labeled as utilization.

and FRB series. But the Fernald and FRB series are even more highly correlated (0.82), especially since the early 1990s. The Fernald and FRB measures both suggest a smaller utilization gap in 2012 and 2013 than does the CBO. Indeed, only at the troughs of deep recessions was the CBO gap more negative than in 2013: 2009, 1982, and (barely) 1975.²⁵

CBO's (2014a) large utilization gap reflects its assumptions about potential TFP. Figure 8B shows that smooth series along with Fernald TFP and utilization-adjusted TFP.²⁶ The CBO shows faster trend TFP growth starting in the early- to mid-1980s, with no mid-90s acceleration. There is an upward level effect in the early 2000s, then a smooth path through the end of the sample.

But the Great Recession is a particularly striking anomaly, with no evidence of convergence of actual and "potential" TFP. Since the CBO assumes underlying technology is stronger than my estimates imply, they correspondingly need a larger utilization gap to fill in the difference.

Arnold (2009) and CBO (2014b) discuss how the CBO prefers to assume a smooth linear trend for potential TFP (inclusive of *LQ*) between business-cycle peaks. This peak-to-peak methodology is not particularly model-specific, whereas my method, depends on a particular model. The disadvantage is that the CBO's assumed (largely linear) trend is subject to large and ongoing ex-post revisions, especially after a new business cycle peak is reached.²⁷ Since 2004, for example, the CBO's views about TFP growth in the 1990s and early 2000s have changed nearly every year. The 2001-2004 bump up in potential TFP growth became much pronounced in the 2009 release; and only in 2014 did the CBO first estimate that TFP growth after 2004 was (modestly) slower than TFP growth in the 1990s. Still, the mid-2000s slowdown in potential TFP growth appears small given the analysis in this paper.

Historically, labor gaps and utilization gaps are strongly positively correlated. Indeed, prior to the Great Recession the correlation of the CBO hours gap with the utilization gap is higher with the

²⁵ FRB capacity utilization has a downward trend prior to the Great Recession, which is not accounted for here. The labor-quality gap—which is included with the CBO gap but not with the others—makes the CBO measure even more out of line. The reason is that the LQ gap tends to rise in recessions (when utilization is low), since lower-educated workers disproportionately lose jobs.

²⁶ The CBO measure has been adjusted for trend labor quality and for differences between the CBO and Fernald measures of capital's growth contribution, which makes the measures more conceptually similar. These adjustments add little volatility to the CBO estimates. The Fernald series in the figure has been converted to a non-farm business basis using the gap between the BLS estimates of business and non-farm business MFP.

²⁷ CBO (2014b, p.5) says: "Particularly significant changes in CBO's estimates of potential output can occur after the economy reaches a new business cycle peak, an event that usually leads CBO to change the period over which it estimates...trends." Arnold notes that the CBO may wait for years to implement all revisions to the historical path.

Fernald utilization measure (0.70) than with the CBO utilization measure (0.61). The CBO (2014a) estimates that a sizeable hours gap remained as of 2013, with $H / H^* = -5.4$ percent. Nevertheless, the persistence of the utilization gap, six years after the Great Recession began, is out of line with other evidence that utilization substantially bounced back.

Figure 9 shows the CBO output gap along with two alternatives with different identifying assumptions on utilization. Both continue to use the CBO hours gap. The first uses the Fernald model-based utilization measure, as plotted in Figure 8A.²⁸ The second assumes no utilization or LQ gaps by using actual measured TFP. The “output gap” is then simply a rescaled version of the hours gap. Of course, since actual factor utilization is procyclical, this measure of the output gap will not move enough over the cycle—and, correspondingly, will imply a measure of potential output that moves too much with actual output. However, once utilization and (labor quality) can safely be assumed to have returned to normal levels, it will correctly measure the gap. Even in this second case, there was a sizeable gap at the peak of the Great Recession.²⁹ The reason is that the hours gap is, historically the main driver of the output gap. In 2013, the hours gap alone contributed 2-1/2 percent to the output gap.

Because of the hours gap, all three measures of the output gap remain sizeable in 2013. But with the Fernald or the actual TFP measures, slack shows up primarily in the people who are *not* working, rather than in the intensity of use of factors that are working. The Bank of England (2014) takes a similar view of the U.K. economy, where (p.6) it states: “The Committee judges that there remains spare capacity, concentrated in the labour market....”

The alternatives in Figure 9 are illustrative and make strong assumptions. More important than specific numbers is that the analysis suggests being explicit about the sources of output gaps—and it may be more informative to take a stand on utilization gaps than on potential TFP. And, even if one assumes an exogenous path for potential TFP, it is worth looking at implied utilization.³⁰

²⁸ It is also necessary to take a stand on the labor-quality gap in equation (12). I use a biweight kernel with bandwidth of 10 years to estimate “trend” labor quality growth. That estimate implies relatively fast trend labor-quality growth in the Great Recession (around 0.4 percent per year). Actual labor-quality rose even faster, as low-skilled workers lost disproportionately lost jobs, opening up a labor-quality gap during and following the Great Recession that peaks at about a 1 percentage point (positive) contribution to the overall output gap.

²⁹ For comparison, the Federal Reserve’s FRB/US model has a gap of 2.8 percent in 2013, fairly close to the Fernald measure. (Those estimates, based on the Fleischman-Roberts,2011, state-space model, are at <http://www.federalreserve.gov/econresdata/frbus/us-models-package.htm>.; accessed April 4, 2014).

³⁰ Note that the two alternatives in Figure 9 are robust to measurement error in growth in capital or in underlying technology—neither of which appears in the “output gap” ratio (12). In contrast, assuming an exogenous

Together, these output-gap assumptions imply the “Actual TFP” and “Fernald” paths of potential shown earlier in Figure 2. The annual growth rates are model-specific and volatile. But over 6 years, they embody a much lower growth rate of potential because utilization gaps have substantially or completely closed. Either estimate decomposes about 3/4 of the shortfall relative to the 2007 trend into a downgrade of potential, with the remainder an output gap (output below potential). (Of course, the CBO has revised its views about past potential, as well, and now thinks that trend TFP and hours worked were lower in the runup to the recession than they did at the time.)

Could the level of the gap prior to the crisis have been substantially different than shown? The growth-accounting approach in this paper is inherently about growth rates. To benchmark levels, I used the CBO labor gap and set the level of utilization to match the CBO’s utilization-gap as of 1987. Given these CBO assumptions, output was close to potential prior to the Great Recession. If actual output were, in fact, further above potential prior to the crisis, then today’s output gap would be correspondingly less negative. Still, the 2013 average unemployment rate of 7.4 percent is well above most natural-rate estimates (the CBO was at 5.9 percent), consistent with substantial remaining labor-market slack. That constrains how much one can adjust the pre-crisis period.

Aspects of the U.S. economy were unsustainable in the mid-2000s. The economy produced too many houses, and households borrowed too much to finance consumption. But that does not mean that the *level* of output was unsustainable—as opposed to its composition. There is ex post misallocation, since construction workers should have produced other things—but they were producing. And the excessive consumption in part showed up as imports, not (necessarily) overproducing domestically.

Of course, the potential-output paths in Figure 2 are not exogenous, since a cyclical shortfall of investment lowers the capital stock. Lower capital affects potential as well as actual GDP. Once business-cycle dynamics play out, standard models imply that the marginal product of capital will be high relative to steady state, encouraging capital formation. Hence, potential growth will temporarily “overshoot” on its return to steady-state (see Hall, 2014).

technology process is sensitive to mismeasurement of capital or technology. For example, suppose capital was scrapped at unusual rates during the Great Recession, e.g., because the economy had too many back hoes. Then growth in true capacity would be lower than measured, and potential would be overestimated. Since actual TFP will be low, the observer would incorrectly infer (from equation (13)) that utilization was low. Of course, firms might instead have deferred scrapping of old but still serviceable capital.

Even with a smaller gap in 2013, the gap is still large—and it has closed very slowly. In other words, despite the slow growth in potential in the recent period, weak aggregate demand has also been crucial. For example, the housing collapse hit the net worth of households and slowed the housing recovery; government has contracted; and uncertainty has been pervasive (see, e.g., Williams, 2013).

My focus has been on TFP, where the Great Recession seem less important than trends related to IT that predated the Great Recession. Nevertheless, there are other channels through which the persistence of a labor gap could persistently lower potential output. These include the possibility that workers lose skills and, potentially, drop out of the labor force permanently. Reifschneider et al. (2013) discuss the implications of this view for monetary policy.

6. Conclusions

In the quotation that opened this paper, Alan Greenspan in 2000 suggested that the economy was in the midst of a "once-in-a-century acceleration of innovation." That hope has fallen short. At its peak from the mid-1990s to early 2000s, TFP growth was similar to its pace from the 1940s to early 1970s. But after 2004, the IT-induced burst in TFP growth faded. For three of the past four decades, productivity growth has proceeded relatively slowly, suggesting this slower pace is the benchmark.

Writing near the stock-market peak, Greenspan noted, in passing, the possibility of a "euphoric speculative bubble." With hindsight, the past two decades have seen speculative booms and busts in stock and housing markets, and the worst financial crisis since the Great Depression. It is tempting to point to these factors, including the Great Recession, to explain the swings in productivity growth. But the productivity retreat predated the Great Recession and is not limited to the "bubble sectors." Nor was it more pronounced in states that saw bigger housing-price swings (a proxy for indirect effects). Rather, the end of exceptional growth can be traced to industries that produce IT or use IT intensively.

Thus, the easing of productivity growth is the flip side of the productivity burst. For now, the IT revolution is a level effect on measured productivity that showed up for a time as exceptional growth. Going forward, productivity growth similar to its 1973-95 pace is a reasonable expectation.

The end of exceptional growth implies slower growth in potential output. But this fact does not mean that all the economy's problems in recent years are structural or supply-related. After all, output gaps by any measure have closed very slowly despite substantial monetary accommodation. In other words, growth in aggregate demand has also been weak. Slower productivity and population growth

also point towards a lower neutral real interest rate, which increases the challenges of providing sufficient monetary stimulus to close gaps.

Uncertainty about any such forecast is inherently high. Jones (2002) argues that 20th century U.S. growth depended on rising education and research intensity. That is, maintaining growth required us to pedal ever harder and harder. That isn't sustainable in steady state, so his model implies slower long-run growth. But, before we reach that point, there could be another wave of the IT revolution—as Brynjolfsson and McAfee (2014), Baily, Manyika, and Gupta (2013), and Syverson (2013) suggest—or some other, unexpected productivity breakthrough. In addition, as Fernald and Jones (2014) suggest, the future growth model might look substantially different from the past—perhaps reflecting the innovative potential of robots and machine learning, or the rise of China, India, and other countries as centers of frontier research. In that case, the results in this paper could reflect an extended pause, a return to normal before the next wave of transformative growth.

The 2000s slowdown has a parallel with the earlier slowdown of the 1970s. The massive oil-price shocks around the same time made them an obvious suspect. But theoretical models had difficulty generating persistent productivity-growth effects from oil; and, when oil prices retraced their increases in the mid-1980s, productivity growth did not recover. Similarly, the Great Recession is a suspect for the productivity slowdown in the 2000s, but my analysis exonerates it.

More broadly, it is the exceptional growth that appears unusual—prior to 1973, or from 1995 to 2004. Historians of technology (e.g., David and Wright, 2003; Field, 2003; and Gordon, 2000) argue that a broad wave of technological breakthroughs led to a surge in productivity growth after World War I that finally played out around the 1970s. For example, Gordon (2000) highlights (i) electricity, (ii) the internal combustion engine, (iii) “rearranging molecules” (petrochemicals, plastics, and pharmaceuticals), and (iv) entertainment, information, and communication (e.g., telephone, radio, movies, TV). Fernald (1999) and Field (2007) point to one-time gains from infrastructure: Building the Interstate Highway System was extraordinarily productive; building a second one would not be. The GPT literature suggests that these constellations, like IT, promoted a wide range of complementary innovations that propelled exceptional growth for a time, but not forever.

Appendix: Data

An online appendix provides greater detail and discussion of the data, which are described briefly here.

Fernald (2014) Quarterly Growth-Accounting Data. Data run 1947:Q2-2014:Q1. The vintage used for this paper was from May 7, 2014. Current vintage data are available at http://www.frbsf.org/economics/economists/jferald/quarterly_tfp.xls. The dataset includes quarterly growth-accounting measures for the business-sector, including output, hours worked, labor quality (or composition), capital input, and total factor productivity. Output is a geometric average from the income and expenditures sides. Factor utilization follows Basu, Fernald, and Kimball (2006) and Basu, Fernald, Fisher, and Kimball (2013).

BLS Industry Data. Appendix Table 1 provides a list of industries and subgroups.

Multifactor productivity (MFP) and IT capital data were downloaded from <http://www.bls.gov/mfp/mprdownload.htm> (accessed January 16, 2014). IT intensity is based on factor shares, i.e., payments for IT as a share of income. “IT intensive” is the set of industries with the highest IT shares that constitute 50 percent of the value-added weight (averaged 1987-2011) for the non-IT-producing “narrow business” (i.e., excluding natural resources, construction, FIRE, and IT producing) economy. “Well measured” industries follow Griliches (1994) and Nordhaus (2002). To focus on the “non-bubble” sectors, I exclude (well-measured) agriculture and mining and (poorly measured) construction and FIRE. I also exclude IT-producing industries. For finance intensity, I aggregated industries from annual BLS I-O tables (accessed January 14, 2014) at http://www.bls.gov/emp/ep_data_input_output_matrix.htm. The finance share was nominal purchases of intermediate financial services as a share of industry gross output. “Finance intensive” is set of narrow-business industries with the highest shares that constitute 50 percent of the value-added weight of narrow business excluding IT production.

State productivity and other data. BEA GDP by industry and total full time and part time employment by industry were downloaded (February 24, 2014) from <https://www.bea.gov/regional>. Chain addition and subtraction were used to construct subgroup aggregates to correspond with the BLS industry groupings. State home prices are from Core Logic; and housing elasticity measures are from Saiz (2010). Metropolitan-area elasticities were aggregated to a state level using population weights. (I thank John Krainer and Fred Furlong for providing me with these data). For exploratory regressions, Liz Laderman provided me with BDS data on small job births per capita by state.

CBO data: CBO (2014a) projections for GDP and for (non-farm) business GDP were accessed via Haver Analytics in February, 2014. The non-farm-business labor gap compares unpublished BLS data on hours worked in non-farm business relative to CBO’s published potential non-farm business hours. The unpublished BLS productivity-and-cost hours data match the published index values perfectly.³¹

³¹ I thank Bob Arnold at the CBO and John Glaser at BLS for help in understanding the data.

Appendix Table A-1
BLS industries, and definitions of sub-groups used in the paper.

| | | NAICS | IT-prod. (1) | Bus, excl. Nat Res, Con, FIRE (2) | IT-int. (in (2)) (3) | Not-IT-int. (in (2)) (4) | Fin-int. (in (2)) (5) | Not fin. Int (in (2)) (6) | Well (in (2)) (7) | Poor (in (2)) (8) |
|----|--|---------------------|-----------------|--|----------------------------|--------------------------------|-----------------------------|---------------------------------|-------------------------|-------------------------|
| 1 | Manufacturing | MN | | | | | | | | |
| 2 | Nondurable goods | ND | | | | | | | | |
| 3 | Food, beverage and tobacco product manufacturing | 311,312 | | x | | x | | x | x | |
| 4 | Textile and textile product mills | 313,314 | | x | | x | | x | x | |
| 5 | Apparel, leather, and allied product manufacturing | 315,316 | | x | | x | | x | x | |
| 6 | Paper manufacturing | 322 | | x | | x | | x | x | |
| 7 | Printing and related support activities | 323 | | x | | x | | x | x | |
| 8 | Petroleum and coal products manufacturing | 324 | | x | x | | | x | x | |
| 9 | Chemical manufacturing | 325 | | x | x | | | x | x | |
| 10 | Plastics and rubber products manufacturing | 326 | | x | | x | | x | x | |
| 11 | Durable goods | DM | | | | | | | | |
| 12 | Wood product manufacturing | 321 | | x | | x | | x | x | |
| 13 | Nonmetallic mineral product manufacturing | 327 | | x | | x | | x | x | |
| 14 | Primary metal manufacturing | 331 | | x | | x | | x | x | |
| 15 | Fabricated metal product manufacturing | 332 | | x | | x | | x | x | |
| 16 | Machinery manufacturing | 333 | | x | x | | | x | x | |
| 17 | Computer and electronic product manufacturing | 334 | x | x | | | | | | |
| 18 | Electrical equipment, appliance, and component manufacturing | 335 | | x | | x | | x | x | |
| 19 | Transportation equipment manufacturing | 336 | | x | | x | | x | x | |
| 20 | Furniture and related product manufacturing | 337 | | x | | x | | x | x | |
| 21 | Miscellaneous manufacturing | 339 | | x | x | | | x | x | |
| 22 | Agriculture, forestry, fishing, and hunting | 11 | | | | | | | | |
| 23 | Farms | 111,112 | | | | | | | | |
| 24 | Forestry, fishing, hunting, and related activities | 113-115 | | | | | | | | |
| 25 | Mining | 21 | | | | | | | | |
| 26 | Oil and gas extraction | 211 | | | | | | | | |
| 27 | Mining, except oil and gas | 212 | | | | | | | | |
| 28 | Support activities for mining | 213 | | | | | | | | |
| 29 | Utilities | 22 | | x | x | | | x | x | |
| 30 | Construction | 23 | | | | | | | | |
| 31 | Trade | 42,44-45 | | | | | | | | |
| 32 | Wholesale trade | 42 | | x | x | | x | | x | |
| 33 | Retail trade | 44,45 | | x | | x | x | | x | |
| 34 | Transportation and warehousing | 48-49 | | | | | | | | |
| 35 | Air transportation | 481 | | x | x | | | x | x | |
| 36 | Rail transportation | 482 | | x | | x | x | | x | |
| 37 | Water transportation | 483 | | x | x | | x | | x | |
| 38 | Truck transportation | 484 | | x | | x | x | | x | |
| 39 | Transit and ground passenger transportation | 485 | | x | | x | x | | x | |
| 40 | Pipeline transportation | 486 | | x | x | | x | | x | |
| 41 | Other transportation and support activities | 487,488,492 | | x | | x | | x | x | |
| 42 | Warehousing and storage | 493 | | x | | x | | x | x | |
| 43 | Information | 51 | | | | | | | | |
| 44 | Publishing (incl. software) | 511,516 | x | x | | | | | | |
| 45 | Motion picture and sound recording industries | 512 | | x | x | | | x | | x |
| 46 | Broadcasting and telecommunications | 515,517 | | x | x | | | x | x | |
| 47 | Information and Data Processing Services | 518,519 | | x | x | | | x | | x |
| 48 | Finance, Insurance, and Real Estate | 52-53 | | | | | | | | |
| 49 | Credit intermed. and related activities | 521,522 | | | | | | | | |
| 50 | Securities, commods, and other fin. invest. activities | 523 | | | | | | | | |
| 51 | Insurance carriers and related activities | 524 | | | | | | | | |
| 52 | Funds, trusts, and other financial vehicles | 525 | | | | | | | | |
| 53 | Real estate | 531 | | | | | | | | |
| 54 | Rental and leasing services and lessors of intangible assets | 532,533 | | | | | | | | |
| 55 | Services | 54-81 | | | | | | | | |
| 56 | Legal services | 5411 | | x | | x | x | | | x |
| 57 | Computer systems design | 5415 | x | x | | | | | | |
| 58 | Miscellaneous professional, scientific, and technical services | 5412-5414,5416-5419 | | x | x | | x | | | x |
| 59 | Management of companies and enterprises | 55 | | x | x | | x | | | x |
| 60 | Administrative and support services | 561 | | x | x | | x | | | x |
| 61 | Waste management and remediation services | 562 | | x | | x | x | | | x |
| 62 | Education services | 61 | | x | | x | | x | | x |
| 63 | Ambulatory health care services | 621 | | x | x | | x | | | x |
| 64 | Hospitals and nursing and residential care facilities | 622,623 | | x | | x | x | | | x |
| 65 | Social assistance | 624 | | x | | x | x | | | x |
| 66 | Performing arts, spectator sports, museums, and related industries | 711,712 | | x | | x | x | | | x |
| 67 | Amusement, gambling, and recreation industries | 713 | | x | | x | x | | | x |
| 68 | Accommodation | 721 | | x | | x | x | | x | |
| 69 | Food services and drinking places | 722 | | x | | x | | x | | x |
| 70 | Other services | 81 | | x | | x | x | | | x |

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Table 1
Industry Data on Productivity

| | | Chng after 2004 | | | | | <i>VA Weight</i> | |
|------------|--|-----------------|-------------|-------------|-------------|-------------|-----------------------------------|--------------------------|
| | | Pre-1995 | 1995-2000 | 2000-2004 | 2004-2007 | 2007-2011 | ((4)-(3), i.e., 04-07 less 00-04) | <i>(Avg., 1988-2011)</i> |
| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| (1) | Private business | 0.83 | 1.58 | 2.19 | 0.63 | 0.90 | -1.55 | 100.0 |
| (2) | Nat. resources (NR), constr., FIRE (NR-C-F) | 0.09 | 0.71 | -0.28 | -1.38 | 0.76 | -1.11 | 26.1 |
| (3) | Natural resources (NR, i.e., ag. and mining) | 0.86 | 2.46 | 2.54 | -3.88 | -0.41 | -6.42 | 3.7 |
| (4) | Construction and real estate | -0.11 | -1.62 | -1.16 | -2.57 | 1.26 | -1.41 | 13.0 |
| (4a) | Construction | 0.41 | -0.78 | -2.16 | -6.69 | 1.62 | -4.54 | 6.2 |
| (4b) | Real estate and leasing | -0.58 | -2.40 | -0.18 | 1.70 | 0.90 | 1.89 | 6.7 |
| (5) | Finance and Insurance | -0.02 | 3.27 | 0.07 | 0.90 | 0.64 | 0.83 | 9.5 |
| (6) | Business (ex NR-C-F) | 1.08 | 1.87 | 3.10 | 1.42 | 0.95 | -1.68 | 73.9 |
| (7) | IT producing | 10.49 | 16.54 | 11.82 | 9.03 | 5.44 | -2.79 | 4.9 |
| (7a) | Computer and el. product manuf. | 18.53 | 34.64 | 21.17 | 18.99 | 11.02 | -2.18 | 2.2 |
| (7b) | Publishing (incl. software) | 1.53 | 1.88 | 8.08 | 1.39 | -0.25 | -6.69 | 1.4 |
| (7c) | Computer systems design | 1.73 | 0.47 | 4.61 | 4.31 | 3.96 | -0.30 | 1.3 |
| (8) | Non-IT prod. (ex NR-C-F) | 0.49 | 0.77 | 2.48 | 0.85 | 0.60 | -1.63 | 69.0 |
| (9) | IT-intensive (ex NR-C-F AND IT-prod) | 0.36 | 0.50 | 4.06 | 0.53 | 1.18 | -3.53 | 34.9 |
| (10) | Non-IT intensive (ex NR-C-F and IT-prod) | 0.61 | 1.04 | 0.84 | 1.20 | -0.14 | 0.37 | 34.1 |
| (11) | Well measured (ex NR-C-F and IT-prod) | 1.19 | 1.33 | 3.45 | 1.59 | 0.60 | -1.86 | 42.7 |
| (12) | Nondurable goods | 0.59 | -0.79 | 4.02 | 0.23 | -0.05 | -3.80 | 8.5 |
| (12a) | Durables (ex. comp. and semicond.) | -0.94 | -0.16 | 2.70 | 2.78 | -0.39 | 0.08 | 9.3 |
| (12b) | Equipment, ex. comp. and semicond | -1.29 | -0.22 | 2.84 | 4.39 | -0.13 | 1.55 | 7.6 |
| (12c) | Non-equip dur. (metal, mineral, wood) | 0.52 | 0.07 | 2.05 | -4.14 | -2.32 | -6.19 | 1.7 |
| (13) | Utilities | 1.89 | -6.75 | 9.05 | -0.57 | 4.26 | -9.61 | 2.7 |
| (14) | Trade | 2.41 | 5.17 | 2.96 | 0.45 | -0.19 | -2.51 | 14.7 |
| (14a) | Wholesale trade | 1.99 | 6.44 | 5.08 | 0.43 | -1.33 | -4.65 | 6.7 |
| (14b) | Retail trade | 2.74 | 4.10 | 1.23 | 0.44 | 0.85 | -0.79 | 8.0 |
| (15) | Broadcasting and telecommunications | 3.02 | -2.41 | 3.94 | 10.06 | 4.30 | 6.12 | 2.6 |
| (16) | Transportation and warehousing | 2.37 | 2.08 | 3.23 | 2.61 | 1.99 | -0.62 | 4.1 |
| (17) | Poorly measured (ex NR-C-F and IT-prod) | -0.87 | -0.20 | 1.11 | -0.19 | 0.63 | -1.29 | 26.3 |
| (18) | Other informat. (not publ., broadcast.) | -3.77 | -11.14 | 16.27 | -1.90 | 0.33 | -18.17 | 1.2 |
| (19) | Services | -0.59 | 0.30 | 0.59 | 0.03 | 0.75 | -0.55 | 27.2 |
| (19a) | Professional, technical, and support | -0.15 | 0.51 | 1.59 | -0.14 | 1.07 | -1.73 | 14.9 |
| (19b) | Educ, health, and soc assist | -2.27 | -1.68 | 0.21 | 0.11 | 0.79 | -0.10 | 5.9 |
| (19c) | Entertainment, accomm., and other | 0.04 | 1.65 | -1.44 | 0.41 | -0.12 | 1.85 | 6.5 |
| (20) | Finance intensive (ex NR-C-F and IT-prod) | 0.78 | 2.16 | 1.31 | 0.08 | 0.33 | -1.23 | 40.7 |
| (21) | Non-fin. intensive (ex NR-C-F and IT-prod) | 0.16 | -1.15 | 4.37 | 2.07 | 1.06 | -2.29 | 28.3 |

Notes: Entries are percent change per year, except for value-added weight, which is average percentage share from 1988-2011.

Table 2
Number of States with Slowdowns in Labor Productivity Growth

| | | # Slowing 2004-07 fr. 1997-04 | Median 04-07 change | # Slowing 2004-12 fr. 1997-04 | Median 04-12 change |
|------|--|-------------------------------------|---------------------------|-------------------------------------|---------------------------|
| | | (1) | (2) | (3) | (4) |
| (1) | Private business | 47 | -1.84 | 48 | -1.44 |
| (2) | Nat. res. (NR), constr., FIRE (NR-C-F) | 48 | -2.72 | 43 | -0.99 |
| (3) | Nat. res. (NR, i.e., ag. and mining) | 49 | -9.45 | 49 | -6.96 |
| (4) | Construction | 46 | -4.63 | 12 | 1.33 |
| (5) | FIRE | 43 | -1.64 | 46 | -1.52 |
| (6) | Private business (ex NR-C-F) | 47 | -1.36 | 50 | -1.65 |
| (7) | IT Production | 45 | -4.94 | 51 | -7.09 |
| (8) | Private business (ex NR-C-F and IT prod) | 46 | -1.11 | 47 | -1.18 |
| (9) | IT intensive | 50 | -1.84 | 50 | -2.12 |
| (10) | Not-IT intensive | 35 | -0.56 | 36 | -0.30 |
| (11) | Wholesale trade | 51 | -5.19 | 51 | -5.73 |
| (12) | Retail trade | 49 | -2.02 | 48 | -1.33 |

Notes: Table compares growth in GDP per worker before and after 2004 for various industry groupings. For example, column (1) shows the number of states (out of 51, including Washington, D.C.) where average productivity growth from 2004-2007 was slower than from 1997-2004. Industry groupings generally follow Table 1. Columns (2) and (4) show the median slowdown across states, in percentage points at annual rate.

Table 3
Home Prices and State Labor Productivity Slowdowns

| Indep. var. | Dep var. | Panel A: $\Delta LP^{2004-07} - \Delta LP^{1997-04}$ | | | | | | |
|------------------------|----------|--|----------------------|-----------------|------------------|-----------------|-----------------|------------------|
| | | Private | Excl. NR-F-C+IT Prod | IT intensive | Not IT intensive | Constr | FIRE | NR |
| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| constant | | -2.06 (0.27) | -1.36 (0.28) | -2.66 (0.33) | -0.61 (0.40) | -4.89 (0.69) | -1.66 (0.53) | -14.50 (2.32) |
| ΔHPI (2001-06) | | -0.19 (0.15) | 0.10 (0.13) | 0.36 (0.13) | -0.024 (0.19) | 0.08 (0.30) | -0.12 (0.28) | 3.16 (1.06) |
| R^2 | | 0.02 | 0.01 | 0.05 | 0.01 | 0.01 | 0.02 | 0.01 |
| Indep. var. | Dep var. | Panel B: $\Delta LP^{2005-12} - \Delta LP^{1997-05}$ | | | | | | |
| | | Private | Excl. NR-F-C+IT Prod | IT intensive | Not IT intensive | Constr | FIRE | NR |
| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| constant | | -0.71 (0.22) | -1.00 (0.20) | -1.88 (0.34) | -0.28 (0.32) | 3.67 (0.54) | -1.18 (0.57) | -1.95 (2.31) |
| ΔHPI (2006-09) | | 0.60 (0.13) | 0.15 (0.11) | 0.11 (0.21) | 0.13 (0.20) | 1.38 (0.33) | 0.79 (0.36) | 2.63 (2.02) |
| R^2 | | 0.14 | 0.04 | 0.01 | 0.18 | 0.15 | 0.03 | 0.01 |

Notes: Cross-section, population-weighted, IV regressions on 49 U.S. states, including Washington, DC; Hawaii and Alaska are omitted because of missing data. Dependent variable is the change in average productivity for the industry aggregate shown; the top panel looks at 2004-07 from 1997-04; the bottom panel 2005-12 from 1997-05. NR is natural resources, C is construction, F or FIRE is finance, insurance, and real estate. ΔHPI (2001-06) is the change in state home-price indices from 2001Q1 through 2006Q1; ΔHPI (2006-09) is change from 2006:Q1 through 2009:Q2. ΔHPI is normalized by the cross-sectional standard deviation. The Saiz (2010) housing-supply elasticity instruments for the housing-price change.

Table 4
Projections for Labor Productivity (Output per Quality-Adjusted Hour)
 (Percent per year)

| | Variable | AveW | Since 1973:Q1 | Since 1986:Q4 | Since 1995:Q4 | Since 2003:Q4 |
|-----|---|-------------|------------------|------------------|------------------|------------------|
| (1) | Durables TFP | 3.16 | 2.67 | 3.23 | 3.84 | 2.87 |
| (2) | Buildings TFP | -0.45 | -0.51 | -0.40 | -0.65 | -0.71 |
| (3) | Consumption TFP | 0.31 | 0.32 | 0.35 | 0.47 | 0.11 |
| (4) | Overall TFP | 0.89 | 0.77 | 0.95 | 1.15 | 0.63 |
| (5) | Investment TFP | 2.12 | 1.75 | 2.19 | 2.54 | 1.84 |
| (6) | Labor prod. projection | 1.85 | 1.56 | 1.93 | 2.29 | 1.46 |
| (7) | GDP projection | 2.10 | 1.88 | 2.16 | 2.43 | 1.80 |
| (8) | <i>Lab. prod. proj. with 2014:Q1 cap. share</i> | 1.99 | 1.68 | 2.07 | 2.46 | 1.58 |
| (9) | <i>GDP proj. with 2014:Q1 cap. share</i> | 2.20 | 1.96 | 2.27 | 2.56 | 1.89 |

Notes: Each column shows inputs into projecting business-sector labor productivity (rows 6 and 8) as well as overall GDP growth (rows 7 and 9). Rows (1) to (5) show inputs into those projections under different assumptions. AveW is the arithmetic average of projections based on all windows that end in 2014:Q1, with starting quarters for the windows that range from 1973:Q2 through 2007:Q4. The remaining columns show selected windows. Labor productivity and GDP projections in rows (6) and (7) assume that capital's share in "reproducible" (non-land) capital as well as the weight on durables and buildings in total "investment" TFP is its average from 2001:Q4 through 2007:Q4. Lines (8) and (9) assume that (reproducible) capital's share remains at its estimated value in 2014:Q1.

Figure 1
Productivity Growth by Sub-Period

Contributions to Labor Productivity Growth

Business sector, percent change, annual rate

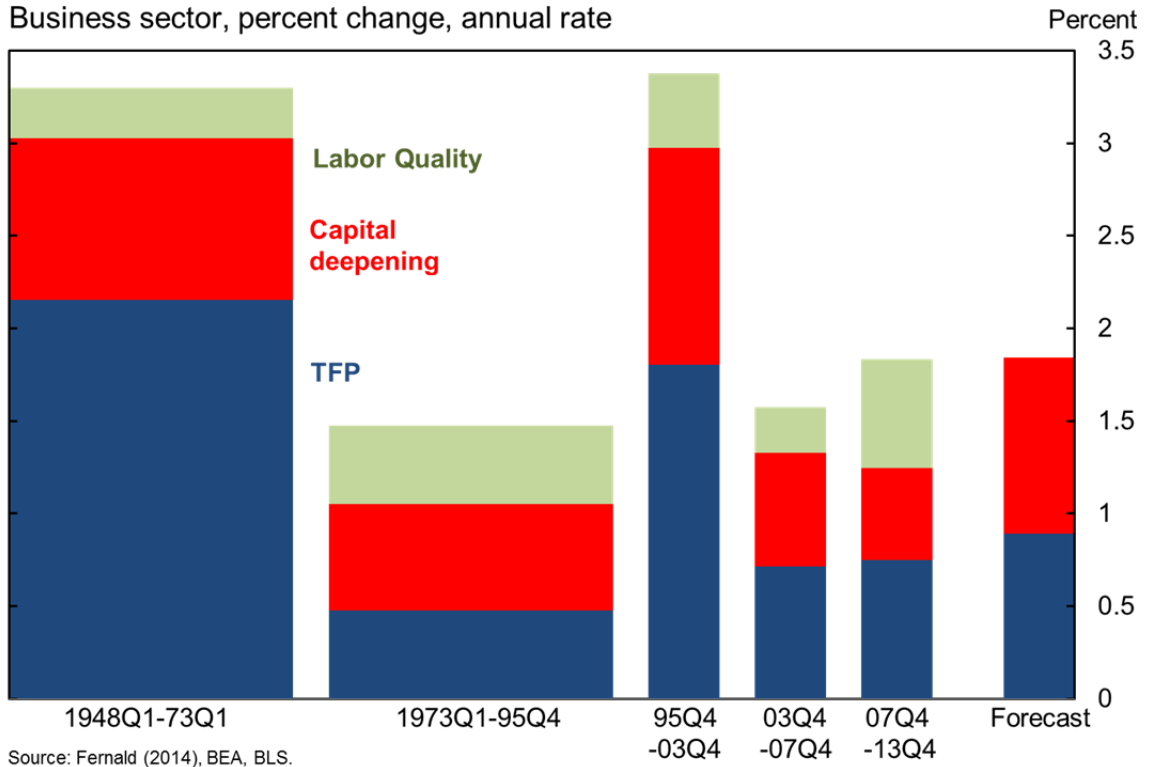
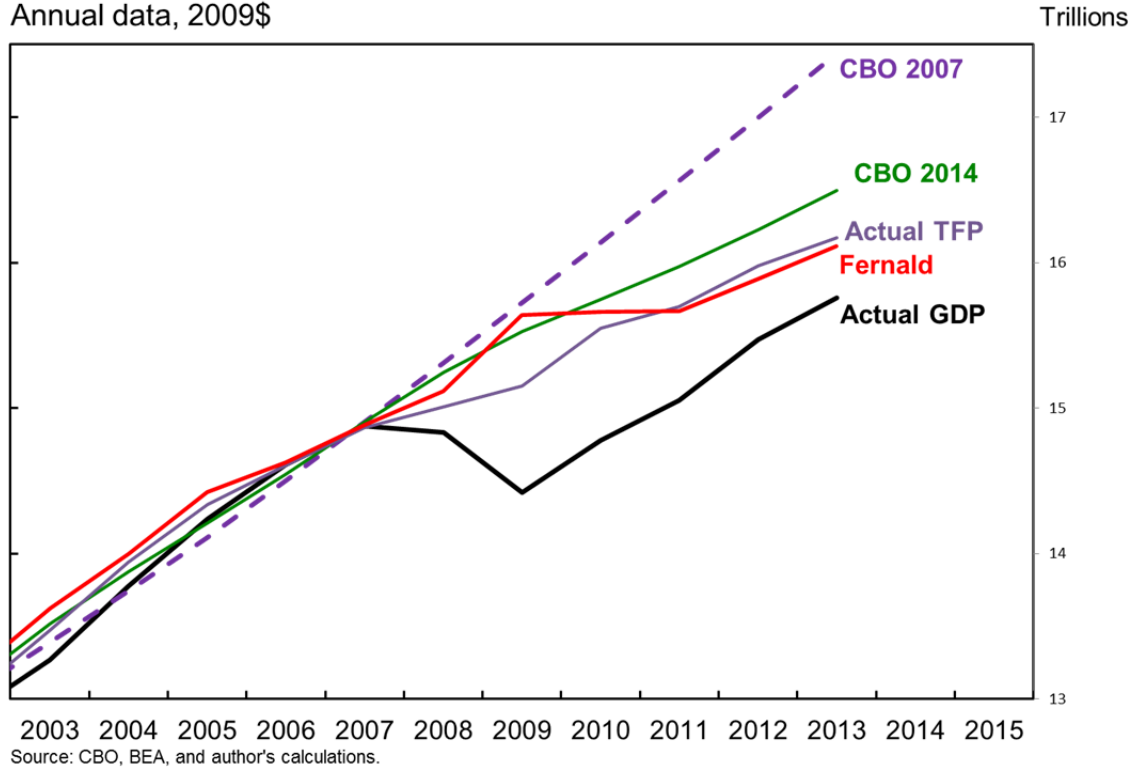


Figure 2
Potential Output and its Pre-Crisis Trend

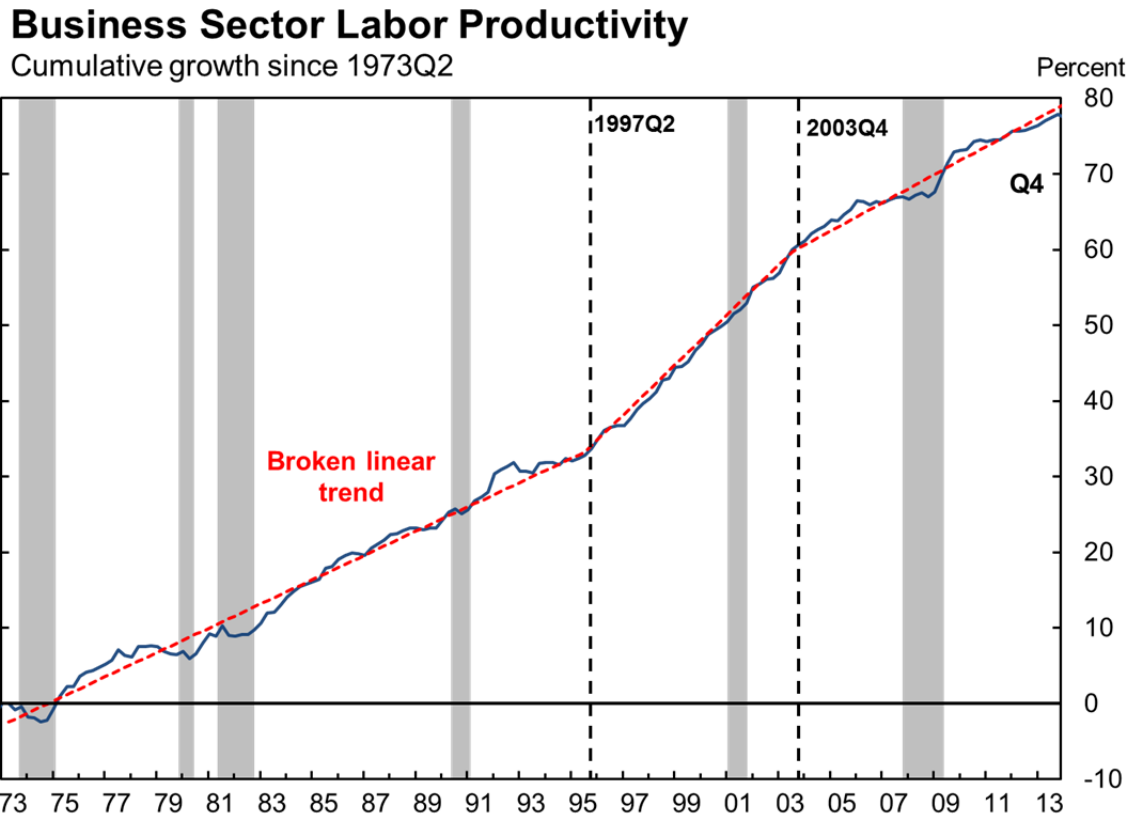
Alternative Measures of Potential

Annual data, 2009\$



Notes: Figure compares actual real GDP to the CBO's projections for potential prior to the Great Recession (the 2007 line) and CBO's (2014a) projection, as well as two alternatives that follow the CBO methodology but with different assumptions about utilization. Both alternatives use CBO's estimated "hours gap" (deviation of hours from steady-state). "Actual TFP" assumes utilization is constant, so that actual TFP measures technology. "Fernald" uses estimated utilization and labor-quality gaps. The "2007" CBO estimates are from January 2008, but are based on data through 2007:Q3. Those estimates have been rescaled to 2009\$ so that the 2007 value equals the level in CBO (2014a).

Figure 3
Labor productivity since 1973

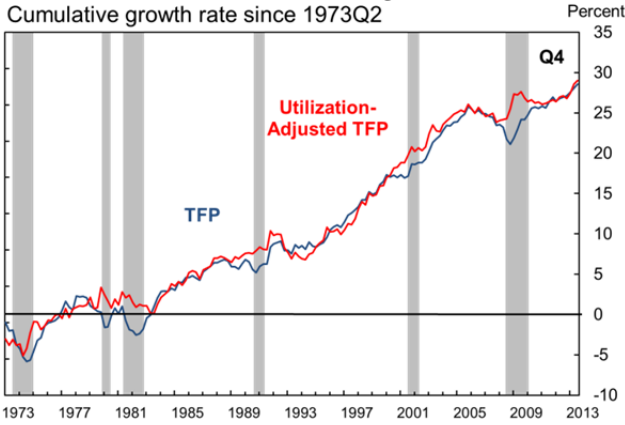


Source: BLS and Fernald (2014)

Figure 4
Evolution of Key Growth-Accounting Variables

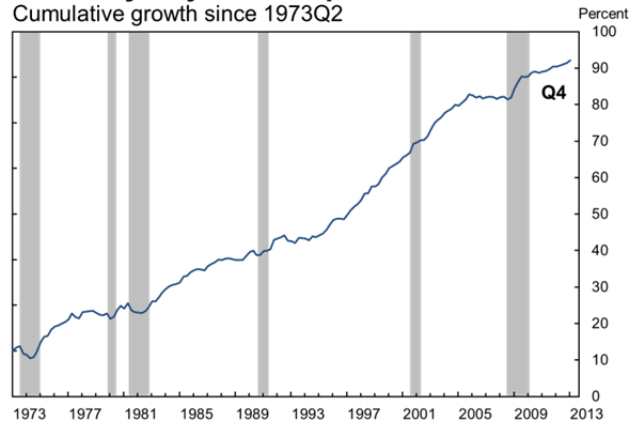
A. Total Factor Productivity

Cumulative growth rate since 1973Q2



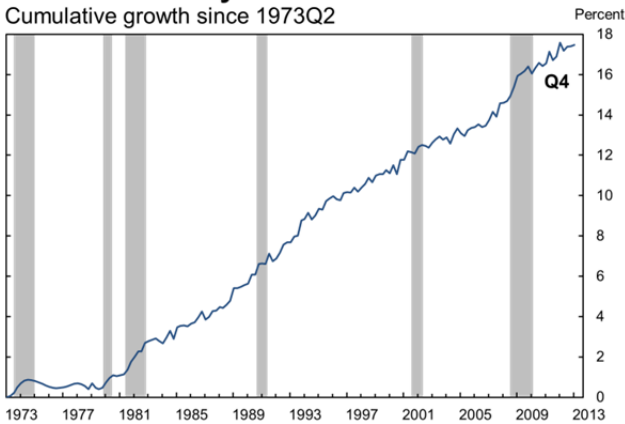
B. Quality-Adjusted Capital-Labor Ratio

Cumulative growth since 1973Q2



C. Labor Quality

Cumulative growth since 1973Q2



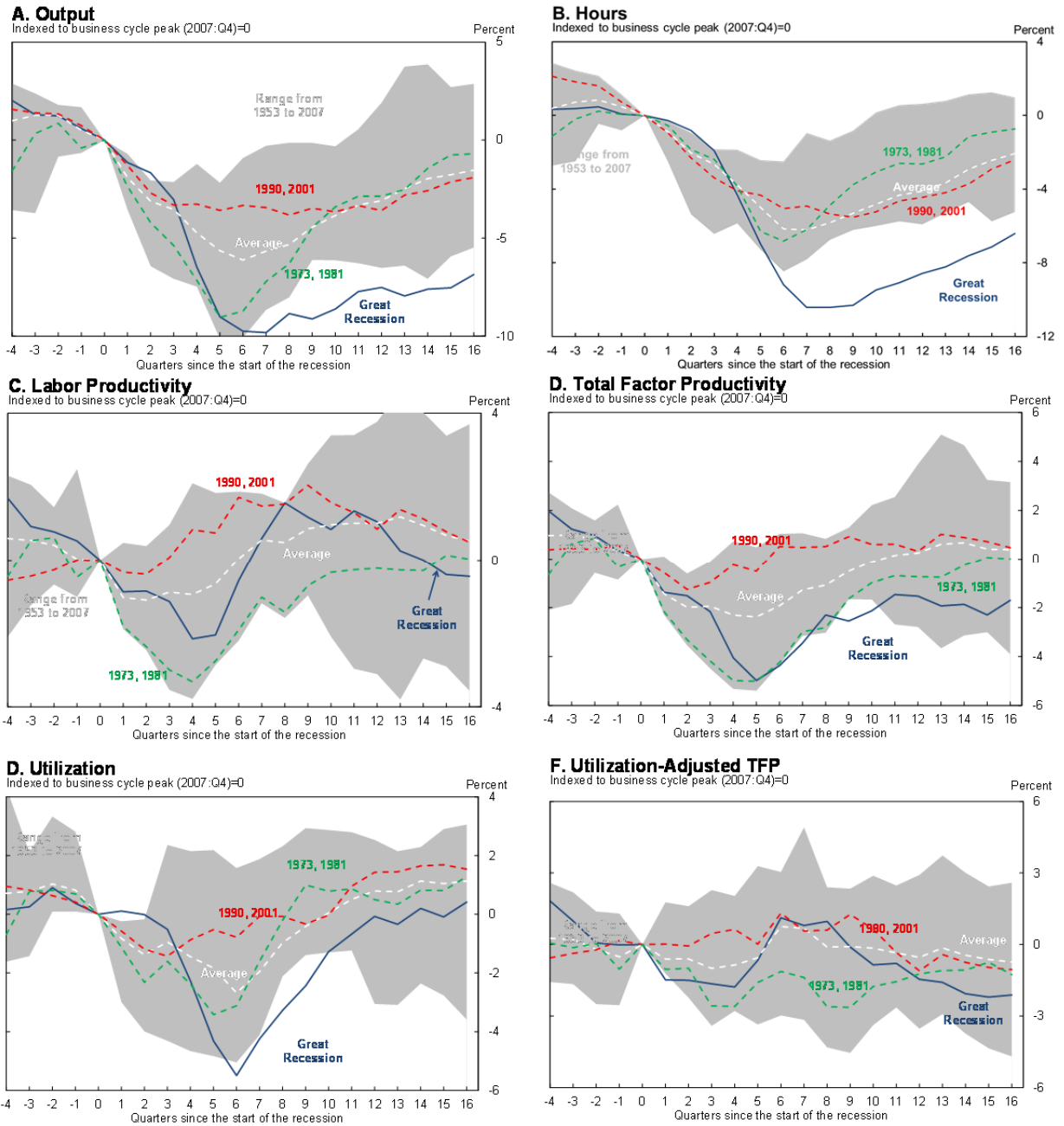
D. Utilization

Cumulative growth since 1973Q2



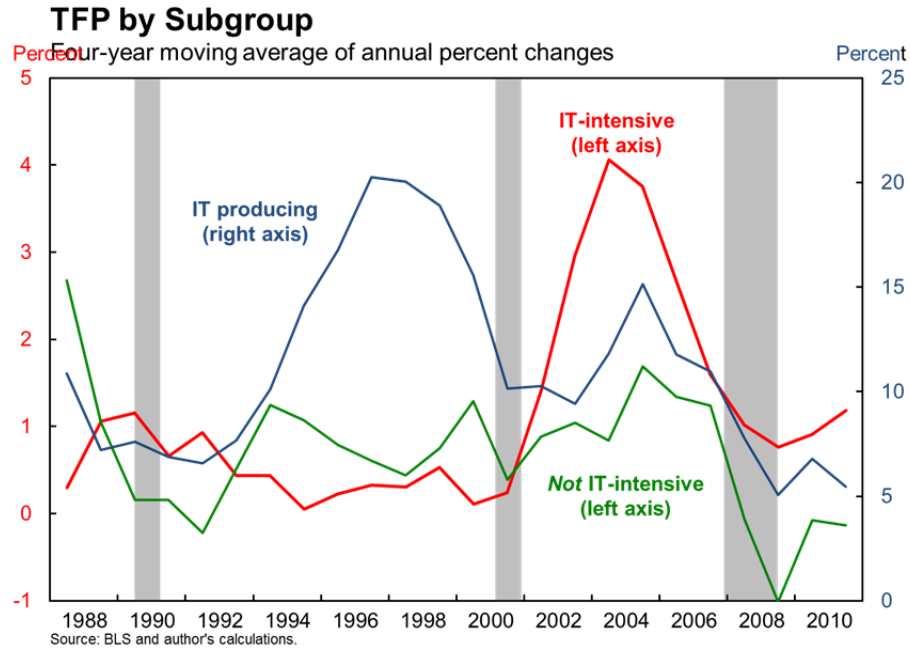
Notes: Level of utilization is set to zero in 1987:Q4, roughly consistent with the CBO's estimate that the output gap was close to zero at that point. Source is Fernald (2014).

Figure 5
Comparing Recessions

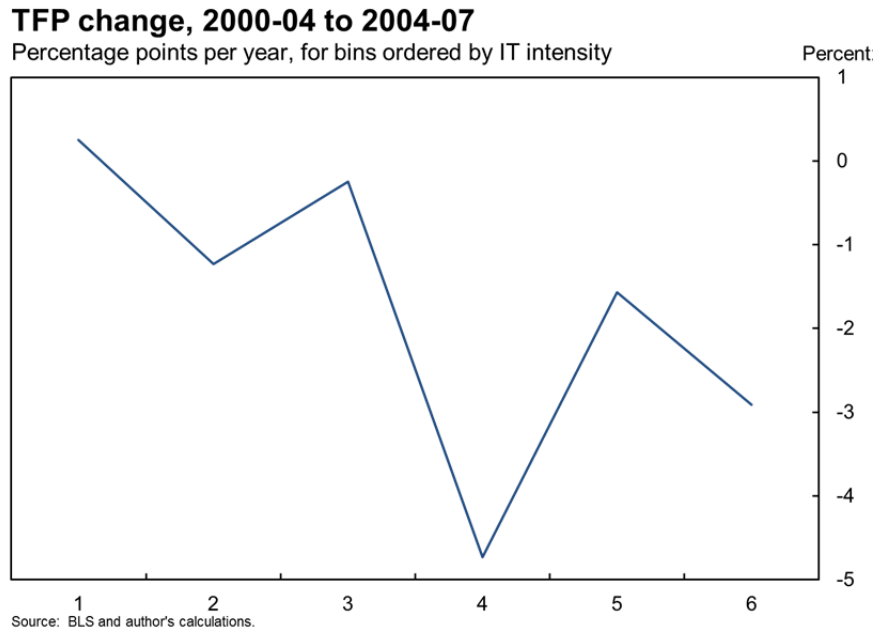


Notes: For each plot, quarter 0 is the NBER business-cycle peak which, for the Great Recession, corresponds to 2007:Q4. The shaded regions show the range of previous recessions since 1953. Local means are removed from all growth rates prior to cumulating, using a biweight kernel with bandwidth of 48 quarters. Source is Fernald (2014).

Figure 6
A. Industry TFP Growth by Subgroup



B. Slowdown in TFP Growth and IT Intensity

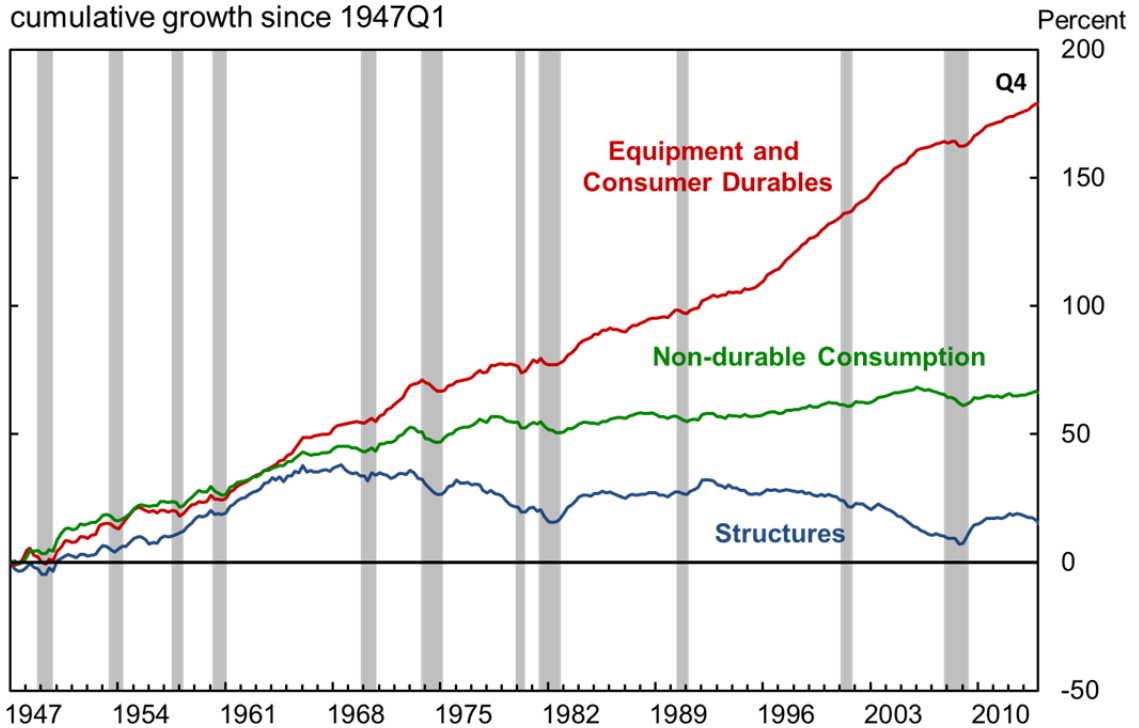


Notes: Top panel decomposes TFP for “narrow business” (i.e., excluding natural resources, construction, and FIRE) into TFP for IT producing, IT-intensive-using, and non-IT-intensive industries. Bottom panel shows slowdown in TFP growth after 2004 (2000-2004 average relative to 2004-2007 average, vertical axis) plotted against “bins” based on IT intensity (so bin 1 to the left of the horizontal axis is the least IT-intensive, bin 6 is the most IT-intensive).

Figure 7
TFP by Final Use Sector

TFP in Equipment, Structures and Consumption

cumulative growth since 1947Q1

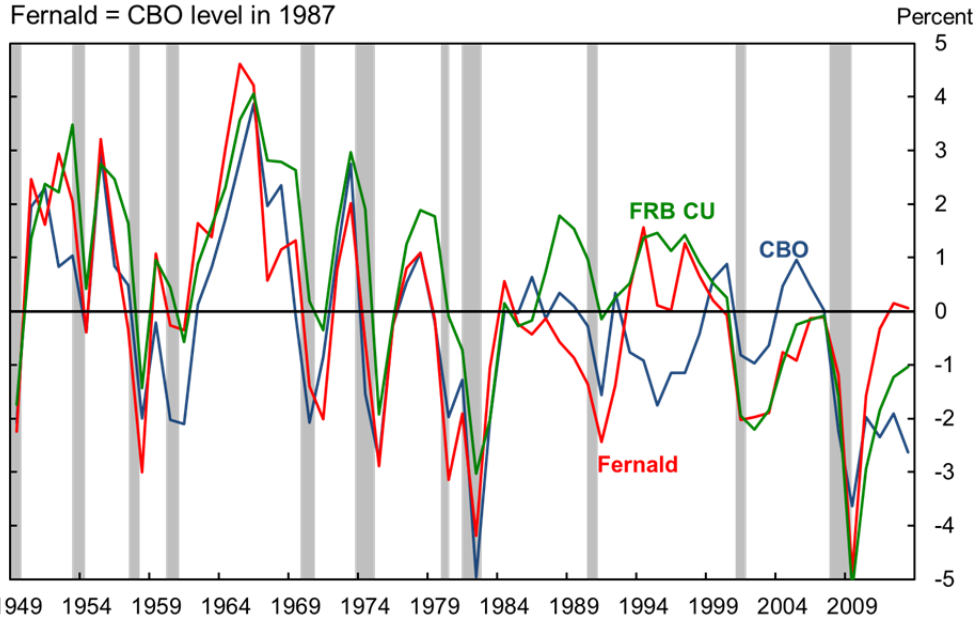


Source: Fernald (2014), NIPA, and author's calculations. Relative TFP is defined via relative prices. Cumulated percent change defined as cumulated log change multiplied by 100.

Figure 8
A. Alternative Utilization Measures

Utilization Gaps

Fernald = CBO level in 1987

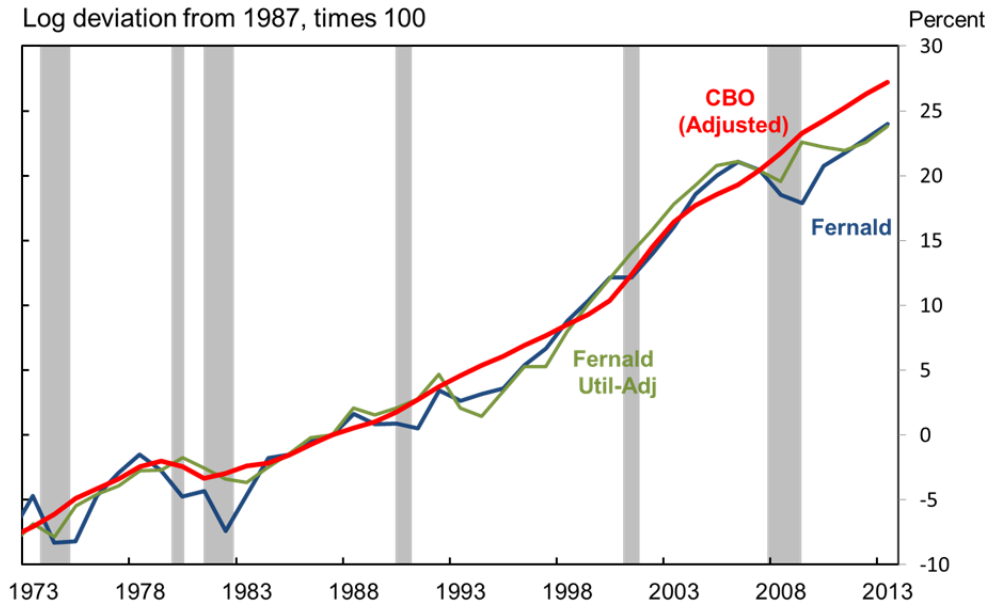


Source: Haver, Fernald (2014), and author's calculations. FRB capacity utilization is log-deviation from 1981-2007 average, rescaled so standard deviation matches CBO's utilization gap.

B. CBO and Fernald Estimates of TFP

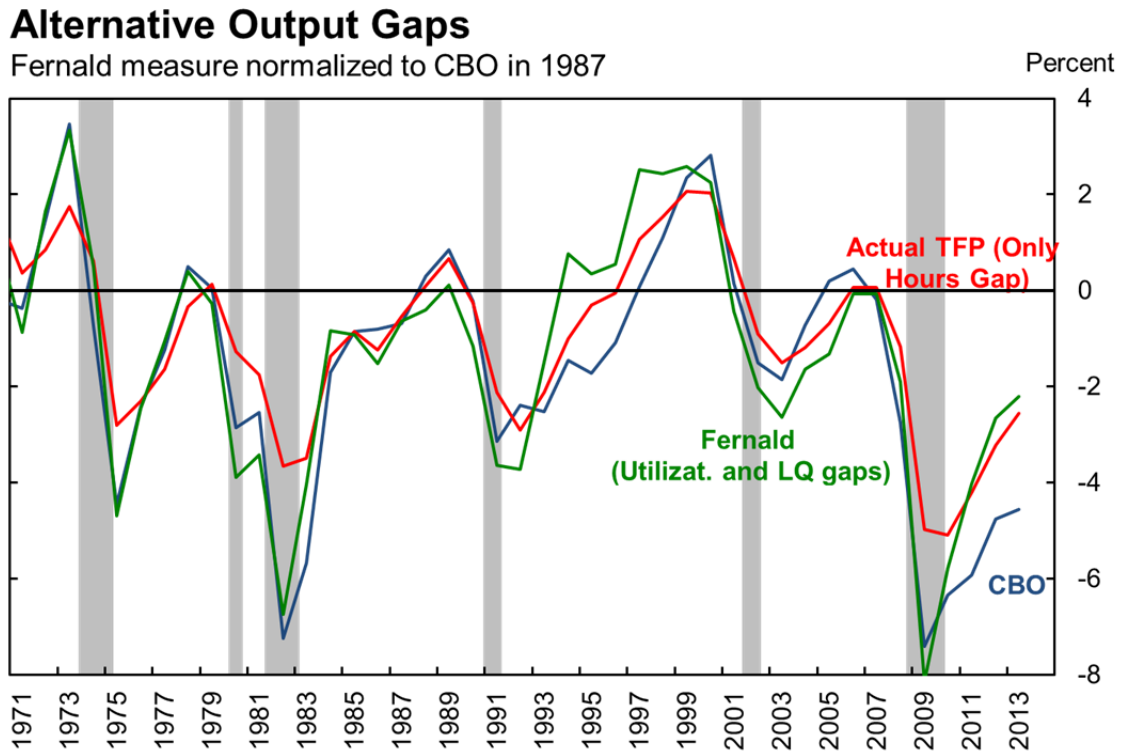
Non-Farm Business TFP

Log deviation from 1987, times 100



Note: CBO "adjusted" removes trend labor quality and (small) trend differences in capital growth. Fernald measure has been adjusted from business to non-farm-business basis.

Figure 9
Output Gaps under Different Assumptions



Source:

Notes: “Actual TFP” uses the CBO’s (2014a) hours gap but sets the utilization gap to zero. “Fernald” uses the utilization gap estimated in Fernald (2014).