

March 2007

Procyclical TFP and the Cyclicalities of Growth in Output per Hour, 1890-2004

by

**Alexander J. Field
Department of Economics
Santa Clara University
Santa Clara, CA 95053
email: afield@scu.edu**

Abstract

Procyclical TFP growth has been a persisting feature of the US economy for over a century. Everything else equal, a reduction of one percentage point in the unemployment rate has added approximately .9 percentage points to the TFP growth rate, and consequently to the rate of growth of total output, and an increase of one percentage point in the unemployment rate has done the reverse. This relationship is estimated on data for the private nonfarm economy from 1890 through 2004 and is stable across subperiods during which the trend growth rate of TFP has been quite different. This paper lays out the empirical evidence for this regularity, discusses its implications for our understanding of the much weaker cyclicalities of growth in output per hour, and reflects on why the sources of procyclical TFP differ from those that fuel secular advance.

Introduction

In a series of recent papers I have argued that TFP growth during the Depression years (1929-41) is critical in understanding and placing in perspective a variety of periods in U.S. economic history including but not limited to the Depression period itself (Field, 2003; 2006a,b; 2007a,b,c; 2008). This research has demonstrated not only that TFP growth was high over these years, but also that it was strongly procyclical, a finding that reinforces the first conclusion. 1941 was the last year before full scale war mobilization, but unemployment was still 9.9 percent. Because of TFP procyclicality, a cyclical adjustment for 1941 TFP raises the estimated TFP growth rate for the private nonfarm economy over the Great Depression years from the 2.31 percent per year derived from Kendrick (Kendrick, 1960; Field, 2003) to 2.78 percent per year (Field 2006a, 2007b). It thus strengthens the conclusion that the Depression years experienced extraordinarily high TFP growth, in the process laying the groundwork for the successful prosecution of the Second World War and the age of high mass consumption (Rostow, 1960) that followed.

This paper is not, however, primarily concerned with the Depression, although I return in the last section to the implications of its growth experience. It has rather been motivated by the question of how generalizable is the finding of procyclicality in the 1930s. The answer turns out to be quite striking. The coefficient on the change in the unemployment rate derived from the original twelve observation regression differs little from one obtained from a regression on data from 1890 through 2004, or from a variety of subperiods. For over a century, TFP growth in the United States has been strongly

procyclical, and the empirical magnitude of this procyclicality has been remarkably stable in the years both before and after the Second World War and in various subperiods during which the trend growth rate of TFP was quite different. These conclusions are robust to substituting the pre 1948 unemployment series generated by Weir (1992) for the Lebergott numbers which continue to be used by most researchers. They are important in explaining and forecasting short term movements in GDP, as well as understanding why inflationary pressures may be quite moderate as the economy approaches potential output.

A number of papers since the 1960s have suggested a tendency toward procyclical productivity. But these have typically focused on labor rather than total factor productivity growth, the majority have relied on data for the postwar period,¹ and most have restricted attention to the manufacturing sector. Over the last half century, manufacturing has contributed a relatively small and declining share of U.S. GDP. Even at its peak during the Second World War, that share barely exceeded a third, and today it contributes less than a sixth. This paper focuses on the private nonfarm economy, which has typically accounted for about three fourths of GDP (the declining share of agriculture and the rising share of government have kept the PNE share roughly stable over the last century). Rather than restricting attention to a few decades of the postwar period, this paper casts a broader statistical net, running a series of bivariate regressions that extend back until 1890 and forward through 2004. The longer time frame enables us to identify both what have been persistent aspects of the cyclical behavior of the U.S. economy over more than a century, and what has varied. Finally, the starting point, the proximate concern here, is an exploration of TFP, not labor productivity growth, although

¹ Bernanke and Parkinson (1991) is an exception.

understanding the weaker procyclicality in that variable remains a matter of ultimate interest.

The first section of this paper lays out the empirical evidence for procyclical TFP as a persisting feature of the US economy. Section 2 examines the procyclicality of output per hour, and the relationship between the procyclicality of TFP and labor productivity. Section 3 considers the microeconomics of user costs that underlie the macroeconomic results. Section 4 explores more generally why the sources of procyclical TFP differ from those that contribute to its longer term growth.

I. Procyclical TFP Growth

The evidence for the persistence of procyclical TFP and stability of the empirical magnitude of this relationship comes from a series of bivariate regressions of the change in the natural log of TFP on the change in the unemployment rate in percentage points. The use of the unemployment rate as a cyclical indicator is based on its systematic relationship with the output gap (Okun's Law). In determining business cycle chronology the National Bureau of Economic Research places principal emphasis on movements in real GDP, but recognizes that a chronology based on fluctuations in unemployment rates is equally defensible.²

²In its document "The NBER Business Cycle Dating Procedures", the Bureau committee responsible for dating cycles notes: "While the NBER has traditionally placed substantial weight on output measures, one could instead define expansions and recessions in terms of whether the fraction of the economy's productive resources that is being used is rising or falling (in which case the behavior of the unemployment rate would be a critical guide to whether the economy was in expansion or recession), or in terms of whether the quantity of productive resources being used was rising or falling (in which case employment would be a critical indicator). Either of these alternative definitions is defensible..." In response to a FAQ about the 2001 recession, and why more emphasis was not placed on trends in the unemployment rate and

The theoretical framework of this paper is one in which long term growth is explicable within the context of a neoclassical (Solow) growth model while the explanation of short run fluctuations lies primarily within the province of aggregate demand. In particular, the regressions entail a maintained hypothesis that fluctuations in the unemployment rate and, by implication, the output gap, are determined by fluctuations in aggregate demand. Fluctuations in TFP around the trend growth rate are thus assumed to be influenced by factors largely unrelated to those affecting the long run evolution of potential output.

The original regression from my work on the Depression (see Field 2006a, 2007b) is reported as equation 1.1. The TFP data are for the private nonfarm economy for the years 1929-1941, and are drawn from Kendrick, 1961, Table A-XXIII. The unemployment data are taken from Lebergott (1964).

$$\begin{aligned} \Delta \text{TFP} = & \quad .0283 \quad - \quad .0092 * \Delta \text{UR} \\ (1.1) \quad R^2 = & .647 \quad (3.02) \quad (-4.28) \\ & \text{(t statistics in parentheses; data are for 1929-41; } n = 12) \end{aligned}$$

The coefficient on the constant term can be interpreted as an estimate of the trend growth rate of TFP over these years: in this case 2.83 percent per year.³ The coefficient on the right hand side variable shows that, everything else equal, a one percentage point decrease in the unemployment rate boosts the TFP growth rate by .92 percentage points.

employment in determining its end, the document simply states that to have dated it in this fashion would have been “inconsistent with the procedures it had used to date earlier recessions” (Hall et. al, 2003, p. 7).

³ The fitted trend growth rate estimate differs very slightly from the actual calculation (2.78 percent per year) measuring from the actual 1929 level to the adjusted 1941 level (See Field, 2007b).

The first question posed in this paper is strictly empirical: is the sign and magnitude of the cyclical effect similar in other, or across longer periods, in US economic history. Equation 1.2 runs the same regression for 1900 through 1941. While it returns a slower trend growth rate, the cyclical coefficient is virtually identical:

$$\begin{aligned} \Delta TFP &= .0197 - .0091 * \Delta UR \\ (1.2) \quad R^2 &= .337 \quad (2.83) \quad (-4.45) \\ &\text{(t statistics in parentheses; data are for 1900-41; n = 41)} \end{aligned}$$

Because of potential problems in valuing GDP during the Second World War, given the amount of military materiel produced (Higgs, 1992), and the presence of shortages and rationing in the civilian sector, one might hesitate to include the war years. But again, and continuing to use data from Kendrick and Lebergott, it makes little difference if we do. The trend growth rate estimate is lower, because of slow TFP growth rate across the war years (see Field, 2007b), but the cyclical coefficient is not:

$$\begin{aligned} \Delta TFP &= .0175 - .0091 * \Delta UR \\ (1.3) \quad R^2 &= .307 \quad (2.65) \quad (-4.52) \\ &\text{(t statistics in parentheses; data are for 1900-48; n = 48)} \end{aligned}$$

Adding in the 1890s produces a modest weakening of the cyclical coefficient:

$$\begin{aligned} \Delta TFP &= .0166 - .0084 * \Delta UR \\ (1.4) \quad R^2 &= .289 \quad (2.75) \quad (-4.77) \\ &\text{(t statistics in parentheses; data are for 1890-1948; n = 58)} \end{aligned}$$

On the other hand, substituting Weir's unemployment series for the 1948 and earlier years slightly strengthens the procyclicality estimate:

$$\begin{aligned} \Delta TFP &= .0165 - .0103* \Delta UR \\ (1.5) \quad R^2 &= .255 \quad (2.68) \quad (-4.38) \end{aligned}$$

(t statistics in parentheses; data are for 1890-48; n = 58)

We now move to the postwar period, switching to data on TFP (MFP) and the unemployment rate provided by the Bureau of Labor Statistics. The first regression below is on data for the golden age (1948-73). We see here a strong and precisely estimated trend growth of 2.16 percent per year and a coefficient on the unemployment change variable which is slightly lower and less precisely estimated.

$$\begin{aligned} \Delta TFP &= .0216 - .0078* \Delta UR \\ (1.6) \quad R^2 &= .279 \quad (7.02) \quad (-2.99) \end{aligned}$$

(t statistics in parentheses; data are for 1948-73; n = 25)

Moving from the golden age to the dismal age (1973-1995), note the dramatically lower trend growth rate estimate as well as an estimate of the cyclical effect which is closer to estimates for the prewar period:

$$\begin{aligned} \Delta TFP &= .0066 - .0095* \Delta UR \\ (1.7) \quad R^2 &= .308 \quad (1.98) \quad (-3.06) \end{aligned}$$

(t statistics in parentheses; data are for 1973-95; n = 23)

Equation 1.8 examines data from 1948 through 2004:

$$\begin{aligned} \Delta TFP &= .0144 - .0081 * \Delta UR \\ (1.8) \quad R^2 &= .226 \quad (6.66) \quad (-3.98) \end{aligned}$$

(t statistics in parentheses; data are for 1948-2004; n = 56)

Finally, equation 1.9 covers the entire period from 1890 through 2004:

$$\begin{aligned} \Delta TFP &= .0155 - .0084 * \Delta UR \\ (1.9) \quad R^2 &= .297 \quad (4.82) \quad (-6.64) \end{aligned}$$

(t statistics in parentheses; data are for 1890-2004; n = 114)

Equation 1.10 uses Weir's unemployment series through 1948 and BLS thereafter:

$$\begin{aligned} \Delta TFP &= .0155 - .0100 * \Delta UR \\ (1.10) \quad R^2 &= .307 \quad (4.72) \quad (-6.13) \end{aligned}$$

(t statistics in parentheses; data are for 1890-2004; n = 114)

Equations 1.1-1.10 provide the empirical grounds for concluding that procyclical TFP growth has been a persisting characteristic of the US economy for over a century, and that the magnitude of the cyclical effect has been relatively stable.

2. Procyclicality in TFP and Output Per Hour

In contrast to TFP, the cyclical nature of labor productivity has attracted considerable scholarly attention. Since the 1960s and the work of Hultgren (1960), Eckstein and Wilson (1964), and Kuh (1965), empirical macroeconomists have taken it as a stylized fact that the growth of output per hour (labor productivity) is procyclical. The majority of these studies deal with data from manufacturing, but Gordon (1979; 1993, p. 275) makes the claim more generally for the private nonfarm economy.

Procyclicality in output per hour is, on the face of it, anomalous. Expansions involve more rapid increase in hours than in capital input (see equations 2.6-15 below), which we would expect to be associated with capital shallowing and a consequent diminution in the marginal productivity of labor. According to this logic, labor productivity growth should be countercyclical, slowing rather than increasing as the economy approaches potential output.

Labor hoarding is the most common explanation for procyclical labor productivity. Because of fixed costs associated with turnover and hiring, firms, it is argued, retain labor during downturns and utilize it more intensely during upturns. This is not reflected immediately in data on employment or hours, and the consequence is that output rises more rapidly than hours as the output gap closes. Romer succinctly described the argument: “Firms tend to be slow to fire workers in bad years and slow to hire workers in good years” (1986, p. 6).

The reality, however, is not quite so simple or clear cut. Using the methodology applied to TFP in section I, we find that there is indeed evidence of procyclicality in labor productivity for the private nonfarm economy (equations 2.2-2.5 below). But the cyclical effect is smaller and less stable than is the case for TFP, and for the postwar

period it's not possible to reject the hypothesis of acyclicity. The dynamics of employment, hours, and output are, moreover, more complex than the labor hoarding story suggests. In particular, there appears to be, at least for the postwar period, an exhaustion of the more intensive exploitation of already hired labor well before the end of an expansion. In the last one or two years of a cycle, as one nears a peak, firms begin to add both employees and hours at a rapid rate. Gordon (1979, 1993) calls this the end of expansion effect. It has the consequence of slowing growth in output per hour, which attenuates the overall cyclicity of labor productivity.

This helps explain the relatively weaker tendency toward procyclicality of output per hour. But why is there a tendency towards procyclicality at all? The explanation is basically the same as that for why TFP growth is strongly procyclical. Both are the consequence principally of the inability of the private business sector to deaccession capital in a downturn. Capital can't be fired. It must be held by someone. Because of this fact, for most asset categories, aggregate user cost is largely independent of how intensively the capital stock is used. Stated more precisely, the aggregate user cost of capital is in the short run largely unaffected by scale, where scale is indexed by how much output is produced. A corollary is that across broad swaths of the economy, unit costs of capital fall over as one approaches potential output from below.

Having outlined the argument, which is elaborated upon in section 3, I now return to empirics, beginning with the question of what we can actually say about cyclicity in output per hour in the private nonfarm economy. Data for the entire period examined here -- 1890 through 2004 -- indicate some procyclicality, but the relationship is weaker than for TFP and becomes much weaker after the Second World War.

Here's what the data show for the 1890-1948 period, using rate of change in output per hour ($y - n$) as the dependent variable:

$$\begin{aligned}
 y - n &= .0210 - .0052 * \Delta UR \\
 (2.1) \quad R^2 &= .139 \quad (3.58) \quad (-3.01) \\
 &\text{(t statistics in parentheses; data are for 1890-48; } n = 58)
 \end{aligned}$$

This indicates that for the 1890 to 1948 period, output per hour grew at a long term trend growth rate of 2.1 percent per year, and that a one percentage point decline in the unemployment rate added about a half percentage point to the growth rate of output per hour.

For the golden age, the trend growth rate is substantially higher, but the relationship between the change in the unemployment rate and output per hour growth is weaker and statistically insignificant, and this becomes even more the case in the years that follow:

$$\begin{aligned}
 y - n &= .0275 - .0032 * \Delta UR \\
 (2.2) \quad R^2 &= .073 \quad (10.11) \quad (-1.37) \\
 &\text{(t statistics in parentheses; data are for 1948-1973; } n = 26)
 \end{aligned}$$

For 1973 and after, there is no statistically significant evidence of procyclicality, although the coefficient still has the right sign:

$$\begin{aligned}
 y - n &= .0185 - .0027 * \Delta UR \\
 (2.3) \quad R^2 &= .009 \quad (7.29) \quad (-.555) \\
 &\text{(t statistics in parentheses; data are for 1973-2005; } n = 33)
 \end{aligned}$$

If one estimates across the entire 1890-2004 period, one does get statistically significant procyclical movement in output per hour:

$$(2.4) \quad y - n = .0217 - .0049^* \Delta UR$$

$$R^2 = .125 \quad (6.95) \quad (-4.00)$$

(t statistics in parentheses; data are for 1890-2004; n = 114)

Why is the procyclicality of labor productivity weaker than that of total factor productivity? Gordon's work suggests that the labor hoarding effect operates only in the early stages of an expansion. In the initial stages output per hour also goes up, because additional output can be accommodated with only modest increases in employment or hours. In the later stages, as employment and hours begin to rise more rapidly, output per hour increases weaken.

Most of the anecdotal evidence on labor hoarding comes from manufacturing. This may help explain why the procyclicality effect weakens after the Second World War. Assume that labor hoarding is a more pronounced phenomenon within manufacturing. Diminished procyclicality would then reflect the downward trend in the share of output and employment in the sector, a decline that has been particularly precipitous after 1973.

From the standpoint of a challenge to traditional theory it is not important whether labor productivity is procyclical or simply acyclical (having no relationship with the cycle). So long as it's not countercyclical, we would need to explain what factors counteract the effect of capital shallowing on growth in output per hour.

The Solow model and the standard growth accounting framework derived from it allow us to decompose growth in output per hour into the sum of the TFP growth rate (a) plus capital's share (β) times the rate of capital deepening ($k - n$):⁴

$$(2.5) \quad y - n = a + \beta(k - n)$$

If the rate of capital deepening is countercyclical, then the combination of countercyclical capital deepening (procyclical shallowing) and procyclical TFP growth is, in terms of the Solow framework, what would account for the weak procyclicality or acyclicity of labor productivity growth.

It is not however obvious that capital deepening should be countercyclical. To the degree that accelerations in capital accumulation are associated with the closing of an output gap as unemployment falls, it could go the other way. The data nevertheless do confirm the presumption that capital deepening is countercyclical: during the expansion phase of a cycle, hours tend to rise faster than capital services, whose growth is essentially acyclical. Note that a positive coefficient on the change in unemployment variable indicates countercyclicality in the rate of capital deepening: When the unemployment rate falls, the rate of capital deepening falls, and vice versa. The dependent variable in equation 2.6 is the rate of change of the capital/labor ratio; the data are for the 1948-2004 period:

$$(2.6) \quad k - n = .0235 + .0194* \Delta UR$$

$$R^2 = .751 \quad (14.57) \quad (12.76)$$

(t statistics in parentheses; data are for 1948-2004; n = 56)

⁴ Lower case letters refer to continuously compounded rate of growth.

Similar results hold for the 1890-1948 period. The trend growth rate estimate is much lower, reflecting the cessation of private sector capital deepening across the Depression years.

$$\begin{aligned}
 (2.7) \quad k - n &= .0121 + .0147* \Delta UR \\
 R^2 &= .738 \quad (3.02) \quad (12.57)
 \end{aligned}$$

(t statistics in parentheses; data are for 1890-48; n = 58)

Excluding the war years and the 1890s raises the cyclical coefficient closer to the postwar value:

$$\begin{aligned}
 (2.8) \quad k - n &= .0073 + .0162* \Delta UR \\
 R^2 &= .805 \quad (1.67) \quad (12.68)
 \end{aligned}$$

(t statistics in parentheses; data are for 1900-41; n = 41)

Equation 2.9 runs the numbers on the entire period:

$$\begin{aligned}
 (2.9) \quad k - n &= .0177 + .0151* \Delta UR \\
 R^2 &= .721 \quad (7.88) \quad (17.10)
 \end{aligned}$$

(t statistics in parentheses; data are for 1890-2004; n = 114)

For more than a century, a one percentage point decline in the unemployment rate has reduced the growth rate of the capital labor ratio by about 1.5 percentage points, with this elasticity closer to 2 percentage points in the postwar period.

The growth of the capital labor ratio depends upon the difference between the growth rate of capital and the growth rate of hours. I now analyze the behavior of each

component of the ratio individually, and show that although, as we might expect, hours are strongly procyclical, capital is not.

Equations 2.11-2.12 indicate that each percentage point decline in the unemployment rate adds about 1.5 percentage points to the growth of hours prior to 1948, about 2.2 percentage points after it. Equation 2.10 runs the numbers for the entire sample:

$$\begin{aligned} \text{(2.10)} \quad n &= .0151 - .0152 * \Delta UR \\ R^2 &= .74 \quad (6.96) \quad (-17.84) \\ &\text{(t statistics in parentheses; data are for 1890-2004; } n = 114) \end{aligned}$$

The trend growth rate of hours is slightly lower after the war, but procyclicality substantially stronger, perhaps reflecting greater cyclical elasticity of female labor force participation:

$$\begin{aligned} \text{(2.11)} \quad n &= .0162 - .0146 * \Delta UR \\ R^2 &= .732 \quad (4.03) \quad (-12.36) \\ &\text{(t statistics in parentheses; data are for 1890-1948; } n = 58) \end{aligned}$$

$$\begin{aligned} \text{(2.12)} \quad n &= .0141 - .0219 * \Delta UR \\ R^2 &= .848 \quad (12.13) \quad (-19.77) \\ &\text{(t statistics in parentheses; data are for 1948-2004; } n = 56) \end{aligned}$$

The growth rate of capital (k), in contrast, has no systematic cyclical component.

$$(2.13) \quad k = .0328 - .0001 * \Delta UR$$

$$R^2 = .001 \quad (17.63) \quad (-.141)$$

(t statistics in parentheses; data are for 1890-2004; n = 114)

Postwar data alone show a higher trend growth rate of capital and weak evidence of procyclicality, but the estimated coefficient is far smaller than that for growth in hours, and is estimated with low precision:

$$(2.14) \quad k = .0376 - .0026 * \Delta UR$$

$$R^2 = .060 \quad (25.87) \quad (-1.86)$$

(t statistics in parentheses; data are for 1948-2004; n = 56)

Pre 1948 data show a substantially lower trend growth rate of the capital stock, reflecting in part the experience of the Depression, and are about as close as you can get to complete acyclicality:

$$(2.15) \quad k = .0283 + .0001 * \Delta UR$$

$$R^2 = .000 \quad (8.62) \quad (.115)$$

(t statistics in parentheses; data are for 1890-48; n = 58)

The regressions above confirm that capital growth has no systematic cyclical component. There are substantial lead times in acquiring some types of producer durables (aircraft, for example) as well as virtually all categories of structures (factories, warehouses, and any type of infrastructure). These long gestation periods, in which projects are completed in a future for which the strength of aggregate demand can only be guessed at at the time they are begun, is part of the reason the growth rate of the capital stock displays no systematic cyclical component. It is true that optimism in expansions

tends to boost investment, but higher interest rates intended to curb enthusiasm often result from Federal Reserve attempts to lean against this wind, just as lower interest rates recession may reflect efforts to do the reverse. Cyclical fluctuations in the cost of materials and availability of construction labor can also make recessions attractive times in which to initiate expensive projects, and curb them during booms.

In the short run, therefore, because of a relatively stable installation of capital, and one whose growth rate is little affected by cyclical factors, increasing output as one comes out of recession tends, for many firms and sectors, to reduce costs because the fixed costs of holding capital decrease capital charges per unit output. The productivity dual of this is that total factor productivity increases, while the effect on output per hour is in the aggregate close to a wash, with the rise in TFP eventually offset by the expected effect on output per hour of capital shallowing.

An economy such as that of the United States consists of hundreds of thousands of firms and establishments, some large, many small. Each can be thought of, in the short run, as optimized for a particular level of output. Suppose that a preponderance of a nation's productive capacity is optimized for a level of output close to natural output, or even above it. This means that the typical firm in the short run reaches the minimum point on its average cost curve at points close to natural output. Thus when the aggregate economy fluctuates in a range below natural output, many firms are operating to the left of their short run minimum average cost, which means unit costs are rising as output decreases and falling as output increases. To the degree that labor hoarding is a significant phenomenon, it will add to the effect.

Our penultimate exploration is of the growth of capital productivity (y-k) (TFP growth is, arithmetically, a weighted average of labor and capital productivity growth).

$$(2.16) \quad \begin{array}{lcl} y - k & = & .0040 - .0201* \Delta UR \\ R^2 = .659 & & (1.14) \quad (-14.7) \end{array}$$

(t statistics in parentheses; data are for 1890-2004; n = 114)

This shows that since 1890 there has been almost no long term trend in capital productivity or its inverse, the capital output ratio, confirming one of Kaldor's stylized facts. Capital deepening (rises in K/N) by itself should depress capital productivity and raise the capital output ratio, but technical change over time has counteracted this. At the same time, there is strong procyclicality to capital productivity. A percentage point decline in the unemployment rate raises the growth rate of capital productivity by about 2 percentage points.

Postwar data show slightly higher procyclicality, but again, no long term trend growth rate.

$$(2.17) \quad \begin{array}{lcl} y - k & = & -.0012 - .0216* \Delta UR \\ R^2 = .600 & & (-.470) \quad (-9.00) \end{array}$$

(t statistics in parentheses; data are for 1948-2004; n = 56)

Equation 2.18, using 1948 and earlier data, again shows little trend for capital productivity, and a very similar estimate of procyclicality:

$$(2.18) \quad \begin{array}{lcl} y - k & = & .0090 - .0199* \Delta UR \\ R^2 = .671 & & (1.41) \quad (-10.68) \end{array}$$

(t statistics in parentheses; data are for 1890-1948; n = 58)

The countercyclicality of the growth of the capital labor ratio is therefore due to very strong procyclicality in hours (the denominator) and weak or nonexistent procyclicality in the capital stock (the numerator). The acyclicality of capital growth, in turn, helps account for the strong procyclicality of capital productivity growth.

In summary: TFP, capital productivity, hours, and output are all strongly procyclical. Labor productivity is weakly procyclical, although after 1948 it's not possible to reject the hypothesis of acyclicality. Capital is acyclical. The capital labor ratio is, however, strongly countercyclical. The acyclical character of labor productivity growth can therefore be thought of as due arithmetically to the combination of capital shallowing during the expansion phase of a cycle, which tends to retard its growth, and a procyclical component to TFP, which tends to augment it.

Prior to the war a one percentage point reduction in the unemployment rate increased the rate of capital shallowing by about 1.5 percentage points (Equation 2.5). Taking capital's share to be $1/3$, this shallowing effect should have reduced labor productivity growth by perhaps .55 percentage points for each percentage point decline in the unemployment rate. But this is counterbalanced by an increase in the TFP growth rate of .8 or .9 percentage points for each percentage point decline in the unemployment rate. Prior to the war, the TFP effect dominates, and we emerge with weakly procyclical growth in output per hour.

For the post 1948 data, the TFP effect is slightly weaker and the capital shallowing effect is slightly stronger. Equation 2.6 shows a one percentage point decline in the unemployment rate boosting the rate of growth of capital shallowing by 1.94 percent. With a capital share of one third, this should knock .83 percentage points off the growth

rate of labor productivity, which is roughly balanced by the positive effect of TFP procyclicality. The net result is an estimate of the cyclicity of labor productivity growth which is essentially 0.

This is a macro view: the intent here is not to reify these two forces. At the micro level, as hours and output go up in a cyclical recovery some firms experience decreasing costs while others find them rising. The phenomenon of short run economies of scale is, moreover, potentiated by external effects: cross firm and even cross sector interactions between output and costs (for further discussion see section 3).

Finally, we consider Okun's law, and the extent to which procyclical TFP growth is responsible for it. Okun's law reflects a stable and persisting relationship between the output gap and the unemployment rate. I estimate it below in a rate of change variant, asking how much a percentage point change in the unemployment rate adds to or subtracts from the growth rate of real output (y):

$$(2.19) \quad y = .0368 - .0202 * \Delta UR$$

$$R^2 = .690 \quad (11.34) \quad (-15.80)$$

(t statistics in parentheses; data are for 1890-2004; n = 114)

The trend growth rate of real output in the private nonfarm economy over this 114 year period is about 3.7 percent per year. Every percentage point increase in the unemployment rate cuts PNE output growth by about 2 percentage points, every percentage point decrease does the reverse.

Splitting the sample period at 1948, we find that the postwar data yield a cyclicity coefficient for y of about 2.4 percentage points.

$$\begin{aligned}
 y &= .0364 - .0241 * \Delta UR \\
 (2.20) \quad R^2 &= .763 \quad (18.74) \quad (-13.18)
 \end{aligned}$$

(t statistics in parentheses; data are for 1948-2004; n = 56)

The trend growth rate is almost identical in the pre 1948 period, although the Okun's law coefficient is lower:

$$\begin{aligned}
 y &= .0373 - .0198 * \Delta UR \\
 (2.21) \quad R^2 &= .684 \quad (6.09) \quad (-11.01)
 \end{aligned}$$

(t statistics in parentheses; data are for 1890-1948; n = 58)

A substantial fraction – in the range of 40 percent -- of Okun's law is thus attributable to procyclical TFP growth. The canonical growth accounting equation tells us that output growth is the sum of TFP growth (a) and a weighted average of capital and hours growth (k and n), the weights corresponding to shares of the two factors in national income (β is capital's share) :

$$(2.22) \quad y = a + \beta k + (1 - \beta)n$$

Consider the postwar period. Equation 2.21 indicates that a one percentage point decline in the unemployment rate yields a 2.4 percentage point acceleration in output growth. Equation 2.11 shows that a percentage point decline in the unemployment rates adds 2.2 percentage points to the growth of hours. Using a labor share of two thirds, this

should add 1.46 percentage points to output growth. The remainder is principally attributable to TFP procyclicality.

We can now identify an important distinction between the forces underlying output and output per hour increases as an economy comes out of a recession and those associated with long term economic growth. The former are associated, in the aggregate, with capital shallowing, whereas long term economic growth is fueled, in part, by capital deepening. Thus whereas there is rough acyclicity in growth in output per hour, particularly after 1948, the long term trend growth rate of output per hour is, thankfully, positive, about 2.2 percent per year (see equation 2.2).

3. The Cyclical Microeconomics of User Cost

A critical assumption in all of these calculations is that capital services are adequately proxied using estimates of its stock. Starting with Solow (1957), a number of economists have attempted to make a utilization adjustment for capital when calculating TFP. Solow used the unemployment rate for labor as a proxy. While the magnitude of such an adjustment makes little difference if one is interested in long turn growth (and thus measuring peak to peak) it can make a big difference if one is concerned with the cyclicity of productivity. In particular, if the cyclical adjustment is large enough it will reduce or even eliminate the finding of procyclicality. Shapiro (1993), for example, used unpublished data on hours per day and days per week of plant operation to adjust capital input in manufacturing. After the adjustment, measured TFP procyclicality in the sector over the period 1978-88 disappears. The result is not surprising, since reducing

capital input in recessions, when facilities are operated less intensively, will raise calculated TFP levels in downturns, and thus reduce measured procyclicality.

It is important to understand why cyclical adjustments such as those made by Solow or Shapiro are much too large. If an adjustment is warranted it is in the aggregate small, and treating the service flow as proportional to the capital stock will probably give a better first approximation of economically meaningful capital input than the adjusted series suggested by Solow or Shapiro.

In a non-slave economy, capital and labor are simply not on an equal footing in terms of the options available to firms in the event of a downturn. Firms may choose, but are not required to hoard labor. With respect to capital, the private business section is in the same position as were antebellum southern plantation owners with respect to their field hands. The private business sector must hold existing capital irrespective of the stage of the business cycle. It can, in principle, adjust the rate of accessioning, but for a variety of reasons, including lead times, the growth rate of the capital stock is largely acyclical (see equations 2.13-15).

An acyclical capital stock would not be as relevant for the argument here if aggregate user cost fluctuated proportionately with utilization. But it does not, because the preponderance of the user cost of capital is unaffected by utilization. That proportion varies by asset category, but is particularly high for structures, such as warehouses, factory buildings, commercial and retail office structures, hotels and apartment buildings, railway permanent way, pipelines, telephone landlines and microwave installations, and fiber optic cable.⁵ This is also the case for producer durables in the transportation sector,

⁵ Structures remain dominant today within the US private fixed asset stock, as they were throughout the twentieth century. In 2005, total private fixed assets comprised \$29.3 trillion, with equipment and software

such as aircraft, railroad rolling stock, busses, and barges. Even for producer durables for which the depreciation cost is a larger portion of the user cost, much of this charge may be unrelated to utilization. This is the case, for example, with computers, cellular telephones and software, where technological obsolescence drives depreciation far more than utilization rates.

In the case of durables such as aircraft or vehicles, it is true that depreciation will rise with operating hours or miles. But the relevant output or scale variable is passenger or ton-miles, not simply miles. In an airline system, for example, much of the increase in passenger miles as one comes out of recession is accommodated by a rise in load factors, not an increase in aircraft operating hours. Consequently, the rise in output as one approaches potential will have little effect on aggregate capital costs. The situation is even more dramatic for structures, such as hotels, apartments, warehouses, or retail and commercial office buildings. The user cost of the warehouse or the hotel is largely the same whether it is full or half empty. We can attribute the resulting reductions in unit costs to economies of scale, provided we recognize that we are indexing scale to output (cubic meters of goods stored, or moved per year), not to a combined input measure

Ignoring the possible effect of capital gains and losses, we can characterize the annual user cost of capital C as the product of the capital stock K times the sum of the interest rate r and the rate of depreciation rate δ .

$$(3.1) \quad C = K(r + \delta)$$

User costs are therefore the sum of rK , the pure cost of holding physical capital, and δK , depreciation costs. The first term is entirely unaffected by utilization. Much

totaling only \$4.8 trillion. Nonresidential structures accounted for \$8.8 trillion; the remainder was residential structures. <http://www.bea.gov>, Fixed Asset Table 2.1 accessed March 10, 2007. For historical data, see Field (1985).

depreciation is also unrelated to utilization, reflecting technological obsolescence or exposure to the elements, functions of elapsed time since installation rather than the direct effects of wear and tear related to utilization.⁶ Imagine the uproar if the IRS announced that it was modifying its depreciation schedules and requiring a utilization adjustment, so that in the depths of a recession allowances would go down, reflecting lower utilization. Firms would likely complain that they could actually hear their assets depreciating, even as they sat idle or only partially full.

Since the aggregate annual user cost of holding the existing stock of capital is largely unrelated to utilization, and since the net additions to the capital stock, and thus the growth rate of capital input are basically acyclical, the economy experiences rising output per unit of capital and per unit of total factor input as it comes out of a recession. As aggregate output goes up, unit costs go down, principally because the largely fixed costs of holding capital are spread over a larger flow volume of output.

Procyclical TFP is not simply a statistical artifact produced by failure to make an adequate utilization adjustment to capital input. It is real and economically meaningful. The capital stock is optimized for production levels at or close to potential output, and this fact helps explain falling unit costs (rising productivity) as the output gap closes. Falling unit costs are driven by reduced unit costs within firms, by production synergies or externalities at the industry level, and by externalities that may be reaped between sectors and thus at the level of the aggregate economy.

Firm costs in the short run are not solely a function of their own decisions about output: costs can also be influenced by levels of output in other firms (Caballero and

⁶ The rate of deterioration (depreciation) of a tar and gravel roof on a warehouse is independent of how much is stored inside it.

Lyons, 1990; Hall 1991). The findings of Ciccone and Hall (1996) on the impact of increasing density on output per hour are consistent with the importance of such external effects.⁷ An additional consideration that may bias or push minimum SRAC toward or even above natural output is a tendency in industries that are potentially oligopolistic or monopolistic for firms to invest in or to retain excess productive capacity as a deterrent to entry.

These effects mean that the economy benefits from short term economies of scale, where the index of scale is output.⁸ The economies are short term, because they are based on an installed capital base optimized for output close to the economy's current potential, and they will gradually diminish in importance as the economy approaches potential.⁹

Learning by doing as a result of cumulated output could, over time, and in a world in which some capital installations are very long lived, have the effect not only of shifting average costs curves down but also of moving their minimum points to the right. To the degree that we interpret such learning as positive supply shocks, we can acknowledge that they play a role in conditioning the firm demography that results in short run

⁷ The argument here is about positive external effects. But obviously, as aggregate output approaches and then exceeds natural output, negative external effects, in the form of scarcities and higher real costs of inputs such as labor, will also be felt.

⁸ One could call this increasing returns to scale, but the usage here is potentially problematic. Increasing returns are usually defined as a situation in which a given percentage increase in all inputs leads to a larger percentage increase in output. That is not exactly what happens as one comes out of recession, because output increases first without much increase in either labor or capital inputs, and subsequently as the result of a more rapid increase of hours than of capital input. Increasing returns can also be understood more generally to mean a reduction in cost per unit as output increases. The first definition implies the second, but the second, which is applicable here, doesn't necessarily imply the first. In particular, I am not claiming that a 20 percent increase in both labor and capital would, in the long run, and given current technological and organizational knowledge, lead to a more than 20 percent increase in output.

⁹ As has been the case at least since Marshall, the short run is understood as referring to a period of time during which it is not easy to alter the level or rate of growth of the firm's capital stock. To say that a firm is optimized for a particular output level is to say that there is some output at which the firm's minimum average cost is attained.

economies of scale in response to aggregate demand fluctuations. Thus while supply shocks play little direct or immediate role in determining the ups and downs of TFP in the short run, they do play a role in creating the environment of firm cost structures in which fluctuations in aggregate demand generate procyclicality.

Of course, a dynamic economy, even one with a steady rate of growth of aggregate demand, would be subject to relative demand shifts (often unanticipated at the time facilities were constructed) that would push some firms on to the upward sloping portions of their cost curves even when the economy was close to potential. What we would expect to find, then, at any moment of time, is a preponderance of individual firms experiencing short run economies of scale in a range of output below potential. But this would not be true for all firms or sectors. This is precisely the pattern found by Hart and Malley (1999) in their study of U.S. manufacturing.

When an economy drops below potential output the fraction of firms pushed to the left of their minimum average cost point increases, which means costs rise and productivity falls. The corollary is that unit costs drop as output increases within a range of output below natural output. Some of the productivity gain/cost reductions are not necessarily experienced at the firm level, but represent spillovers – externalities – at higher levels of aggregation, not just at the sectoral level, for example within manufacturing, but between sectors, particularly manufacturing on the one hand and transportation/distribution on the other (see Field, 2003, 2007a,c). These show up as procyclical TFP growth at the level of aggregates such as the private nonfarm economy.

When hours continue to rise above levels associated with natural output, the sources of these TFP gains dissipate, as the fraction of firms operating to the left of their

minimum SRAC point declines. The inflationary acceleration that is definitionally experienced above natural output, is due to a combination of upward pressure on input prices, particularly labor, as the result of scarcity, and a short run deterioration in productivity growth.

Natural output is defined as the highest rate of output the economy can sustain without having aggregate demand so stimulated that the consequence is an acceleration of the inflation rate. This analysis suggests that that output level reflects something of a sweet spot in terms of controlling inflation, with increased cost pressures due to deterioration of productivity growth likely to be experienced on either side. At the same time, there will be an asymmetry, because above natural output the productivity effect will be augmented by the upward pressure on wage and materials prices resulting from scarcities and tightness of input markets.

Potential or natural output is the barrier beyond which the effects of procyclical TFP are no longer operative. Factories, warehouses, hotels, and airplanes are close to full and pools of available labor have been exhausted. Output can be sustained above this level in the short run only by tolerating continued accelerations in the inflation rate. The barrier is relaxed over the longer run by growth in the labor force, by growth in the capital stock through accumulation, and through technical progress. We now turn to the different determinants of TFP growth in the short and long run.

IV: TFP Growth in the Short and Long Run

In recent years, much attention has been devoted to analysis in which the framework for explaining short run fluctuations is essentially the same as that commonly

used for long term growth. This approach, known as real business cycle (RBC) theory, an aspect of the freshwater or Minnesota approach to macro, suggests an alternate explanation for procyclical TFP. Rapid TFP growth as one comes out of a recession, for example, could be attributable to positive supply shocks. Indeed, they could be the cause of the recovery itself. This is not necessarily inconsistent with the framework spelled out at the start of this paper. If positive supply shocks increased the anticipated return from new investment projects, and if this led to an increase in planned investment at given interest rates, then although the rise in aggregate demand would be the proximate cause of the closing of the output gap, the technological shock would be its ultimate cause.¹⁰

It is unlikely, however, that supply shocks can provide an entirely satisfactory explanation for short run cyclical fluctuations in the output gap, the unemployment rate, or TFP. Variations in the rate of arrival of innovations might explain alterations in a positive rate of growth of TFP, but it is not so plausible that such variations would periodically cause it to go negative. If you have a trend growth of TFP of 2 percent a year, with a standard deviation of one percentage point, a series that almost never declined, one might consider whether this could be due to variability in the arrival of innovations. The actual numbers for the years 1890 through 2004, however, indicate an average annual rate of PNE TFP growth of 1.5 percent with a standard deviation of over 4 percentage points. There are many years in which TFP didn't just grow more slowly, it declined, often sharply.

¹⁰ Although new technologies play some role in affecting investment fluctuations, a number of other influences probably predominate. These include cycles of overbuilding, interest rates, and volatility of expectations about future levels of industry or aggregate demand.

For 1948 and earlier, mean TFP growth was 1.7 percent per year and the standard deviation was 5.4 percent. TFP declined in 23 of the 58 years: 1893, 1894, 1896, 1898, 1902, 1904, 1907, 1908, 1910, 1912, 1914, 1917, 1920, 1922, 1925, 1927, 1930, 1931, 1932, 1933, 1944, 1946, and 1947.

For the 1948-2004 period, average TFP growth is lower and less variable: mean of 1.4 percent; standard deviation of 1.8 percent. The reduced cyclical volatility of TFP after the war is arguably simply because cycles were weaker (for a contrary view, see Romer, 1986). Certainly the case for a moderation in the business cycle after the Second World War has been strengthened by the experience of recent decades: in the last quarter century (this is written in 2007) the US economy has experienced only two relatively minor recessions. Even with a lower ratio of standard deviation to mean, however, the level of TFP, not just its rate of growth, declined in 1956, 1969, 1970, 1974, 1980, 1982, 1991, and 1995. RBC proponents can make a case for 1974 (oil shocks), but most of the other years are problematic. What, for example, is the negative supply shock in 1982?

Most cyclical fluctuations reflect the operation of the economy in a range of output below natural output. The view taken in this paper is that the preponderance of short run economic fluctuations, *unlike* the trend growth rate of output, is to be explained as the result of fluctuations in aggregate demand that have little to do with technology shocks. There is no smoking gun that can, from the supply side, explain the more than 30 percent drop in real output between 1929 and 1933, 12 percentage points of which (in the private nonfarm economy) are attributable to a drop in TFP. And there is a paucity of plausible supply shock explanations for the many other instances in which TFP growth becomes negative during recessions.

The factors contributing to procyclical TFP are thus likely quite different from those responsible for its long run advance. My argument is that the cyclical behavior of TFP is the result of short run economies and diseconomies of scale attributable to the relative inflexibility of capital input in the context of output gap fluctuations driven by fluctuations in aggregate demand. These TFP fluctuations are unlikely to be explicable as the consequence of a sequence of positive and negative technology shocks.

To strengthen the case that the determinants of cyclical and secular changes in TFP differ, I also need to engage those who would take an opposite tack in attributing both short and long run movement to the same cause: those who might attribute them both principally to economies of scale. Like RBC proponents, although for different reasons, they would see the short and long determinants of TFP growth as similar.

The preponderance of opinion within the economics profession is that economies are not subject to long run increasing returns, in the sense that if, using current technological and organizational knowledge, we increased all inputs by x percent, we would get an increase in output of y percent, $y > x$. But some, including proponents of endogenous growth, might differ.¹¹

My view is that the principal determinant of the residual over the long run is technological and organizational change – new products, new processes, and new ways of organizing production. These new blueprints are positive supply shocks, and their contribution is part of what we try to measure when we make peak to peak calculations of TFP. Testing econometrically for long run increasing returns to scale is, however, a

¹¹ Even in endogenous growth theory, the proximate cause of TFP improvement would be growth of useful knowledge, useful knowledge presumably not available in the initial period. It's just that the rate of this growth would be positively influenced by scale.

challenge, because inputs grow historically alongside of technical and organizational advance.

As suggested in footnote 7, it can make a difference in our thinking about increasing returns whether we index scale to output or to a combined input measure. There are at least two widely used definitions of increasing returns. The most general indexes scale to output, and identifies increasing returns with a reduction in unit costs associated with higher output. The more common definition refers to a situation where all inputs increase by x percent, but output goes up by y percent, with $y > x$. This definition implicitly indexes scale to a combined input measure.

Disentangling the respective effects on the residual of such technical advance and possible increasing returns is, after the fact, often difficult. Economics, particularly macroeconomics, is a largely nonexperimental science, so we must learn from the experiments history gives us. By returning to the Depression experience, we can elaborate upon and refine a case study which, while not dispositive, is consistent with the view that secular TFP growth, as opposed to its cyclical component, is driven by technological and organizational innovations as opposed to increasing returns and the economies of scale they would entail.

Consider the most common definition of increasing returns detailed above. Should it make a difference if $x = 0$? Formally, it should not. But as a practical matter, it can matter in terms of our ability to isolate the effects of advance of knowledge. If combined inputs rose 5 percent over a ten year period, and output rose 10 percent, it's hard to tell whether this was due to true advance of knowledge or to economies of scale. If you attribute this entirely to economies of scale, you are implicitly saying that if, ten years

ago, given then existing knowledge levels, you had increased inputs by 5 percent, you could have had 10 percent more output. Without being able to run the experiment, however, you can't tell whether or not this would have been true.

Using the most common definition of increasing returns, a situation in which all inputs increased by 0 percent (in other words, do not change), would represent an increase in scale. Therefore, any output increase associated with a 0 percent increase in combined inputs would have to reflect advance of knowledge.

The Depression experience is unusual in coupling a very high rate of TFP advance with virtually no growth in inputs. According to Kendrick, hours input in 1941 was virtually identical to what it had been in 1929 (annual rate of increase of +.12 percent per year), while capital input, at least in the private sector, was slightly lower (annual rate of decrease: -.13 percent per year). Over a twelve year period, we thus have virtually no increase in combined inputs, yet a 32.3 percent increase in real output in the private nonfarm economy. PNE output grew at 2.33 percent per year, which was almost all attributable to TFP growth (2.31 percent per year).

Kendrick's work was published in 1961 and, in a number of respects, has not been improved upon. There do not, for example, appear to be superior alternatives to his series on annual hours. The Bureau of Economic Analysis has, however, done additional work on both capital and output, and I will consider how their work affects his conclusions. The most recent capital stock estimates are found in the BEA's Fixed Asset Tables, which include data beginning in 1925.¹² I use them to recalculate the growth rate of the capital stock in the private non farm sector in the following manner. Grow the 1929

¹²For the current version of the tables, see <http://bea.gov/bea/dn/FA2004/index.asp>, Tables 2.1, 2.2. The calculations in the text are based on the 2002 versions, which include more detail.

current cost estimates of the total private fixed asset stock to its 1941 real value using the ratio of the 1941 chain type quantity index for this category to its 1929 level. To get to the private nonfarm economy, perform the same procedures for each of these four subcategories: farm tractors, agricultural machinery except tractors, farm related buildings and housing, and farm housing. Subtract the 1929 current cost values for these asset types from the 1929 current cost of the private fixed asset aggregate, and subtract their “grown” 1941 real values from the “grown” value of the 1941 private fixed capital stock. The result, in 1929 dollars, is a private nonfarm capital stock of \$233,031 million in 1929 and \$239,531 million in 1941, yielding a +.17 annual rate of growth (continuously compounded) over the twelve year period.

Having increased the capital stock growth rate modestly using newer series we should do the same with output. The latest numbers from the BEA website have real GDP, using the chained index method, rising 39.99 percent over the twelve year period.¹³ What we are interested in, however, is growth in the private nonfarm economy, data not so easily accessible. We can, however, compare Kendrick’s estimate of the growth rate of real GDP (Commerce concept) over this twelve year period (33.5 percent) with his estimate for the increase in private nonfarm economy output (32.3 percent). Real GDP growth is only slightly higher than the increase for the private nonfarm economy (farm product grew slower than the aggregate economy, but government product grew faster) (Kendrick, 1961, Table A-III, column 4, p. 300).

Using the ratio of Kendrick’s PNE increase over this period to that for GDP, we get a factor by which to reduce estimated GDP growth from the BEA to PNE growth:

$$32.3/33.5 = .964.$$

Multiplying this by 39.99 percent gives us 38.55 percent, and

¹³ <http://www.bea.gov/bea/dn/nipaweb/index.asp> Table 1.1.3.

converting to a continuously compounded rate of growth, we have 2.72 percent for the best current estimate of the annual growth rate of the real private nonfarm economy across the Depression years. Taking +.12 percent as the growth rate of hours, and +.17 percent as the growth of capital, and using an estimate of one third as capital's share, we get a weighted average of combined input growth rates of +.14. Our best estimate of TFP growth, without a cyclical adjustment, would then be 2.58.

Even with the slightly higher estimate for capital growth, we are talking about a miniscule combined rate of increase in hours and capital in the face of a very substantial increase in real output. The cause was technological and organizational progress. Although TFP progress within manufacturing proceeded at half the rate it did during the 1920s, it was still world class by the standards of any other period. The bulk of the remainder came out of transportation and distribution, which benefited from spillovers associated with the build out of the surface road network, including the growth of trucking and its closer integration with rail transport (see Field, 2003, 2006a, 2008).

This suggests that this estimate of TFP growth could mislead because it does not take into account the substitution of publicly owned capital such as streets and highways for privately owned capital such as railroad permanent way. How important might this be? What happens if we add streets and highways to the private fixed asset stock and calculate the growth rate of an "augmented" capital stock? Again, from the Fixed Asset Tables, streets and highways at current cost in 1929 were worth \$16,415 million, and "grown" to 1941 were worth \$27,556 million in 1929 dollars. Adding this infrastructure to private nonfarm fixed assets, we get 1929 capital at \$249,446 million and 1941 at \$267,087 million, yielding a continuously compounded growth rate of .57 percent per

year. Again using weights of two thirds for labor input growth and one third for capital input growth, this yields a combined input growth rate of .26 percent per year – about a quarter of a percent per year. Using the augmented capital stock in our calculations would therefore lop .12 percentage points off the estimated TFP growth rate, bringing it to 2.46 percent. We are left with an augmented input growth rate of a quarter of a percent a year associated with a real output growth rate almost ten times larger. Either true economies of scale are playing a relatively small role or we are seeing them on a magnitude that nobody has dared propose before.

All of this is before a cyclical adjustment. Recall, going back to Equation 1.1, that a 1 percentage point decline in the unemployment rate adds .92 percentage points to the growth of TFP, and that this elasticity has been remarkably stable over more than a century. In 1941 unemployment was still 9.9 percent. Suppose it had been 3.8 percent – the rate experienced during 1948, a rate we can view as corresponding to a fully employed peacetime economy. 1941 unemployment would then have been 6.1 percentage points lower. That means, using equation 1.1 to make the adjustment, that the 1941 level of TFP would have been 5.61 percent higher than it was ($-6.1 * -.92 = 5.61$). Using augmented capital and adjusted 1941 TFP as an endpoint yields TFP growth of 2.91 percent per year. Omitting streets and highways from the capital stock, we are at 3.03 percent.

It is thus no accident that the U.S. emerged victorious in the Second World War. An enormous (and largely unrecognized) expansion of potential output took place during the Depression, one associated with minimal increments in hours or real capital. No other peak to peak period in US economic history even approaches 3 percent annual TFP

growth. Across the entire 25 year golden age (1948-1973) the rate for the private nonfarm economy was 1.90 percent per year. From 1995 through 2004, it clocks in at 1.85 percent per year. It is striking that a period associated with the most rapid secular advance in TFP was also one in which input growth was so small. Because the real growth of inputs was small, true economies of scale cannot be said to have had much to do with this. The remarkable macroeconomic record of the Depression reinforces the argument that the factors influencing long run TFP growth differ from those contributing to procyclical TFP.

:

Note on Sources

All data are for the private nonfarm economy. The convention is to calculate the 1947-48 growth rate from historical data (Kendrick, Lebergott, or Weir) and to calculate the 1948-49 growth rate from Bureau of Labor Statistics data. All annual deltas are differences in natural logs, except the unemployment rate, which is change in percentage points.

TFP:

1890-1948: Kendrick, 1961, Table A-XXIII.

1948-2000: <http://www.bls.gov/mfp/historicalsic.htm> accessed 10/26/2006

2001-2004: <http://www.bls.gov/mfp/home.hm#data>, series MPU750023 (K)

Unemployment rate

1890-1948: Lebergott, 1964 (variant 1)

1890-1948: Weir (1992) (variant 2)

1948-2005: <http://data.bls.gov/cgi-bin/surveymost>, series LNS14000000

Hours:

1890-1948: Kendrick, 1961, Table A-XXIII

1948-2005: <http://data.bls.gov/cgi-bin/dsrv>, series PRS85006033

Output (Private Nonfarm Economy):

1890-1948: Kendrick, 1961, Table A-XXIII

1948-2005: <http://data.bls.gov/cgi-bin/dsrv> series PRS85006043

Capital:

1890-1948: Kendrick, 1961, Table A-XXIII.

1948-2000: <http://www.bls.gov/mfp/historicalsic.htm>.

2001-2004: <http://www.bls.gov/mfp/home.hm#data>, series MPU750025 (D)

BIBLIOGRAPHY

- Bernanke, Ben and Martin Parkinson. 1991. "Procyclical Labor Productivity and Competing Theories of the Business Cycle: Some Evidence from Interwar U.S. Manufacturing Industries." Journal of Political Economy (June) 99: 439-59.
- Caballero, R.J. and R.K. Lyons. 1990 "Internal Versus External Economies in European Industry," European Economic Review 34(4): 805-826.
- Caballero, R. J. and M. L. Hammour. 1994. "The Cleansing Effects of Recessions." American Economic Review 84: 1350-68.
- Eckstein, Otto and Thomas Wilson. 1964. "Short Run Productivity Behavior in U.S. Manufacturing." Review of Economics and Statistics 46 (February): 41-54.
- Field, Alexander J. 1985. "On the Unimportance of Machinery." Explorations in Economic History 22 (October): 378-401.
- Field, Alexander J. 2003. "The Most Technologically Progressive Decade of the Century." American Economic Review 93 (September): 1399-1413.
- Field, Alexander J. 2006a. "Technical Change and U.S. Productivity Growth: The Interwar Years." Journal of Economic History 66 (March): 203-236.

Field, Alexander J. 2006b. Technical Change and U.S. Economic Growth: The Interwar Years and the 1990s,” in Paul Rhode and Gianni Toniolo, eds., The Global Economy in the 1990s: A Long Run Perspective . Cambridge: Cambridge University Press, pp. 89-117

Field, Alexander J. 2007a. “The Equipment Hypothesis and U.S. Economic Growth.” Explorations in Economic History 43 (January): 43-58.

Field, Alexander J. 2007b. “The Impact of World War II on U.S. Productivity Growth.” Economic History Review 60 (forthcoming)

Field, Alexander J. 2007c. “The Origins of U.S. Total Factor Productivity Growth in the Golden Age.” Econometrica 1 (forthcoming).

Field, Alexander J. 2008. “U.S. Economic Growth in the Gilded Age.” Journal of Macroeconomics 29 (forthcoming).

Gordon, Robert J. 1979. “The "End-of-Expansion" Phenomenon in Short-Run Productivity Behavior.” Brookings Papers on Economic Activity (1979:2): 447-461.

- Gorson, Robert J. 1993. "The Jobless Recovery: Does it Signal a New Era of Productivity-Led Growth?" Brookings Paper on Economic Activity (1993:1) 271-316.
- Gordon, Robert J. 2003. "Exploding Productivity Growth: Context, Causes and Implications." Brookings Papers on Economic Activity (2003:2): 207-279.
- Hall, Robert E., Martin Feldstein, Jeffrey Frankel, Robert Gordon, Christina Romer, David Romer, Victor Zarnowitz. 2003. "The NBER's Business Cycle Dating Procedures." <http://www.nber.org/cycles/recessions.pdf>. Document dated October 21, 2003; accessed March 8, 2007.
- Hall, Robert E. 1990. "Invariance Properties of Solow's Productivity Residual." in Peter Diamond (ed.), Growth/ Productivity/Unemployment: Essays to Celebrate Bob Solow's Birthday, Cambridge: MIT Press, pp. 71-112.
- Hart, Robert A. and James R. Malley. 1999. "Procyclical Labour Productivity: A Closer Look at a Stylized Fact." Economica 66: 533-550.
- Higgs, Robert. "Wartime Prosperity? A Reassessment of the U.S. Economy in the 1940s." Journal of Economic History 52: 41-60.
- Hultgren, Thor. 1960. "Changes in Labor Cost During Cycles in Production, Business." NBER Occasional Paper No. 74.

- Kendrick, John. Productivity Trends in the U.S. Economy. Princeton: Princeton University Press.
- Kuh, Edwin. 1965. "Cyclical and Secular Labor Productivity in United States Manufacturing." Review of Economics and Statistics. 47 (February): 1-12.
- Lebergott, Stanley. 1964. Manpower in Economic Growth. New York: McGraw Hill.
- Romer, Christina. 1986. "Spurious Volatility in Historical Unemployment Data." Journal of Political Economy 94 (February): 1-37.
- Rostow, W.W. 1960. The Stages of Economic Growth: A Non-Communist Manifesto. Cambridge: Cambridge University Press.
- Shapiro, Mathew. 1987. "Are Cyclical Fluctuations due More to Supply Shocks or Demand Shocks?" American Economic Review 77 (May): 118-124.
- Shapiro, Mathew. 1993. "Cyclical Productivity and the Workweek of Capital." The American Economic Review 83 (May): 229-33.
- Weir, David. 1986. "The Reliability of Historical Macroeconomic Data for Comparing Cyclical Stability." Journal of Economic History 46 (June): 353-365.

Weir, David. 1992. "A Century of U.S. Unemployment, 1890-1990." Research in Economic History 14: 341-3. See also series Ba475, Historical Statistics of the United States, volume 2. Cambridge: Cambridge University Press, 2006.