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

by

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Abstract

Procyclical TFP growth has been a persisting feature of the US economy for more than 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 cyclicality of growth in output per hour, and considers 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; 2008a,b). 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, 2008a). 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 section 5 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 procylicality has been remarkably stable in the years both before and after the Second World War and in a variety of 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.

A number of papers since the 1960s have suggested a tendency toward procyclical productivity. Although there are exceptions to each of these generalizations, this body of work tends to rely on data for the postwar period alone, restrict attention to the manufacturing sector, and have as its principal focus labor rather than total factor productivity growth.[1] The research reported on here differs along each of these dimensions.

Although data for the manufacturing sector is generally more detailed than that available for the rest of the economy, trends within the sector do not offer a consistently accurate guide to what is happening in the economy as whole. Manufacturing has contributed a declining share of U.S. GDP over the last half century. 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 instead 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).

A second difference is that rather than restricting attention to a few decades during the postwar period, this research casts a broader statistical net, constructing a dataset that allows 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

[1] There are exceptions to each of these generalizations. For example, Bernanke and Parkinson (1991) consider prewar data.

behavior of the U.S. economy over more than a century, and what has varied. Finally, the immediate focus here is an exploration of TFP, not labor productivity growth, although understanding the weaker procyclicality or acyclicality in output per hour is also of interest.

The evidence for the persistence of procyclical TFP and the stability of its empirical significance comes from a series of 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 warranted because of its systematic relationship with the output gap, the difference between actual and potential output (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]

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 cyclicality of labor productivity, and the relationship between the procyclicality of TFP and the weaker procyclicality or acyclicality of output per hour. Section 3 considers whether these results are a statistical artifact due simply to the failure to make a cyclical adjustment to capital input. Section 4 addresses the implicit macro model underlying the interpretation

[2] In 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 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).

of the regressions, and the need for a continuing distinction between aggregate demand and aggregate supply shocks in understanding short run economic behavior. Section 5 argues that although procyclical TFP can be interpreted as reflecting short run economies of scale, it is doubtful that long run TFP advance should be understood as resulting principally from increasing returns. The determinants of short run fluctuations in TFP differ from those governing its longer term evolution.

1. The Evidence for Procyclical TFP

The original regression from my work on the Depression (see Field 2006a, 2008a) 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. ΔTFP is the difference in natural logs of the level of TFP between two years. The unemployment data are taken from Lebergott (1964).

$$\Delta TFP = .0283 - .0092 * \Delta UR$$

$$R^2 = .647 \quad (3.02) \quad (-4.28) \qquad (1.1)$$

(t statistics in parentheses; data are for 1929-41; n = 12)

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.

[3] The fitted trend growth rate estimate differs very slightly from the 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 cyclicality effect similar in other, or across longer periods, in U.S. economic history. Equation 1.2 runs the same regression for 1900 through 1941. While it returns a slower trend growth rate, the cyclicality coefficient is virtually identical:

$$\Delta TFP = .0197 - .0091^{*} \Delta UR$$

(1.2) $R^2 = .337$ (2.83) (-4.45)

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

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, 2008a), but the cyclicality coefficient is not:

$$\Delta TFP = .0175 - .0091^{*} \Delta UR$$

(1.3) $R^2 = .307$ (2.65) (-4.52)

(t statistics in parentheses; data are for 1900-48; n = 48)

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

$$\Delta TFP = .0166 - .0084^{*} \Delta UR$$

(1.4) $R^2 = .289$ (2.75) (-4.77)

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

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

$$\Delta TFP = .0165 - .0103^{*} \Delta UR$$

(1.5) $R^2 = .255$ (2.68) (-4.38)

(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.

$$\Delta TFP = .0216 - .0078^{*} \Delta UR$$

(1.6) $R^2 = .279$ (7.02) (-2.99)

(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 cyclicality effect which is closer to estimates for the prewar period:

$$\Delta TFP = .0066 - .0095^{*} \Delta UR$$

(1.7) $R^2 = .308$ (1.98) (-3.06)

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

Equation 1.8 examines data from 1948 through 2004:

$$\Delta TFP = .0144 - .0081^{*} \Delta UR$$

(1.8) $R^2 = .226$ (6.66) (-3.98)

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

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

$$\Delta TFP = .0155 - .0084^* \Delta UR$$

(1.9) $R^2 = .297$ (4.82) (-6.64)

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

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

$$\Delta TFP = .0155 - .0100^* \Delta UR$$

(1.10) $R^2 = .307$ (4.72) (-6.13)

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

The magnitude of the elasticity of the growth rate with respect to a change in the unemployment rate does not depend on whether one is close to potential output or substantially below it. Equation 1.11 shows that inclusion of the level of unemployment (UR), along with its rate of change has little effect on the originally estimated coefficient, and the coefficient on the level variable is very small and not statistically significantly different from 0:

$$\Delta TFP = .0116 - .0087^* \Delta UR + .0005^*UR$$

(1.11) $R^2 = .29$ (1.98) (-6.61) (.801)

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

Equations 1.1-1.11 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 cyclicality effect has been relatively stable.

2. Procyclicality in TFP and Output Per Hour

The cyclicality of labor productivity has attracted more scholarly attention than that of TFP. 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 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.

That finding is, on the face of it, surprising. Economic expansions involve more rapid increase in hours than in capital input (see equations 2.6-15 below). Because of this, procyclical capital shallowing should result in a diminution in the marginal product of labor. If this mechanism alone were operative, labor productivity growth would move against the cycle, slowing rather than increasing as the economy approached potential output. If labor productivity growth is not countercyclical, we need to identify what counterbalances the effect of procyclical capital shallowing, producing acyclicality or even procyclicality in output per hours.

Equations 2.2-2.5 below confirm a tendency toward procyclicality in labor productivity, although 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 acyclicality. From the standpoint of a challenge to the conventional narrative, however, it does not matter whether labor productivity is procyclical or simply acyclical. So long as it doesn't move against the cycle, we need to explain what counteracts the effect of capital shallowing on growth in output per hour.

Labor hoarding is the most common explanation for why labor productivity is procyclical (see, e.g. Hall, 1988, p. 929). The argument is that because of fixed costs associated with turnover and hiring, firms retain labor during downturns and utilize it more intensely during upturns. This is not reflected, at least immediately, in data on employment or hours, and the consequence is that output rises more rapidly than hours as the output gap closes. As Christina Romer put it, "Firms tend to be slow to fire workers in bad years and show to hire workers in good years" (1986, p. 6).

The dynamics of employment, hours, and output are, however, more complex than the labor hoarding story suggests. In particular, at least for the postwar period, firms complete the more intensive exploitation of already hired labor well before the end of an expansion and, in the last one or two years before a peak, hire additional workers at a rapid rate. What Gordon (1979, 1993) calls the end of expansion effect has the consequence of slowing growth in output per hour, which attenuates the overall cyclicality of labor productivity.

Since the growth of capital is essentially acyclical (see equations 2.13-15 below), the end of expansion effect strengthens the procyclicality of capital shallowing, and thus helps us understand why the procyclicality of output per hour is weaker than that of TFP. But this is not quite the right framing: we need to understand, for the labor productivity data, why there a tendency towards procyclicality at all. In my view labor productivity is not countercyclical because TFP is procyclical, and for the same reasons that TFP is procyclical. Both are the consequence principally of the inability of the private business sector to deaccession capital in a downturn. Unlike labor, capital can't be fired. It must be held by someone. The involuntary "hoarding" of capital is thus more important than the voluntary hoarding of labor in understanding procyclicality in TFP and any tendency in that direction for labor productivity.

Not only are the costs of holding existing capital unavoidable, but for most asset categories, total user cost is largely independent of how intensively the stock is used. The capital costs of a warehouse, hotel, or an airplane, for example, don't depend much on how full each is.[4] Stated more precisely, over the short run, and in a region below potential output, the aggregate user cost of capital is largely invariant to scale, where scale is understood to mean how much output is produced (see Field, 2008c). A corollary is that across broad swaths of the economy, unit costs of capital fall as one approaches potential output from below. This fact imparts downward pressure to overall unit costs during an expansion, counterbalancing to some degree the rising cost of labor towards its end. The downward pressure from this source ends with a marked discontinuity as fixed assets such as railroads, aircraft, or hotels run out of empty cars, seats, or rooms.

At potential output many units of fixed capital have reached or are close to their capacity. In capital constrained sectors of the economy, unit costs of capital cease their downward trajectory and hit a brick wall. The event or flight or hotel is sold out; there is no more space in the storage facility, production runs are placed on allocation. The impacted goods and services, particularly nontradeables, are simply no longer available at any price, at least in the short run. The challenge in avoiding overstimulation of an economy is that the onset of inflationary pressures from this source may be quite sudden,

[4] These points are developed further in Section 3. This second effect applies equally to variable capital: the holding costs of a stock of wholesale or retail inventory is invariant to how frequently it turns over. For a similar analysis, which places more emphasis on the market power which is the logical concomitant of large fixed capital installations, see Hall (1988). See also Field (1987).

one reason the core inflation rate can be quiescent for so long before suddenly spiking upwards.

Closely related to the concept of natural output is the natural unemployment rate: the lowest level of unemployment that can be sustained without so stimulating the economy that it experiences an acceleration of the inflation rate. Analogously, one can define a natural capital utilization rate, a measure denoting the highest load factors the existing capital stock can accommodate without giving rise to an acceleration of the inflation rate.[5] We currently lack adequate economy wide measures of it. An imperfect approximation is the Federal Reserve's capacity utilization index, an index to which experienced inflation watchers nevertheless pay close attention. Its chief deficiency is that it applies only to manufacturing capital.

A more satisfactory index would also cover fixed assets in transportation, commercial and residential housing, wholesale and retail distribution, and other portions of the service sector. To the degree that production or fulfillment capacity becomes unavailable, measures of the rate of increase of the GDP deflator won't fully capture the deleterious effects of the arrival of shortages: the true extent of upward pressure on prices may be disguised by the existence of waiting lists, lotteries, and other nonprice allocation schemes.[6] Note also that we can expect inflation to begin to accelerate when the proportion of capital constrained firms and sectors that have hit their brick wall is below 100 percent.[7]

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[5] As Winston (1974) pointed out, much of our capital stock sits intentionally "idle" a good part of the time

[6]Disguised inflation was a widely noted characteristic of the US economy during the Second World War. Some civilian goods were unavailable at any price, and other required both cash and ration coupons to purchase. But the phenomenon can exist even in the absence of government mandated systems for managing shortages.

[7] Thus students of existing capacity utilization indexes have rules of thumb regarding rates (say 85 percent) above which inflationary acceleration is likely.

Having outlined the microeconomic underpinnings of the argument, I now return to empirics, beginning with the question of what we can actually say about cyclicality 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:

$$y - n = .0210 - .0052 * \Delta UR$$

(2.1) $R^2 = .139$ (3.58) (-3.01)

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

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:

$$y - n = .0275 - .0032 * \Delta UR$$

(2.2) $R^2 = .073$ (10.11) (-1.37)

(t statistics in parentheses; data are for 1948-1973; n = 26)

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

$$y - n = .0185 - .0027 * \Delta UR$$

(2.3) $R^2 = .009$ (7.29) (-.555)

(t statistics in parentheses; data are for 1973-2005; n = 33)

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

$$y - n = .0217 - .0049^{*} \Delta UR$$

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

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

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):[8]

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

This equation is typically used to decompose long term growth in labor productivity into the effects of accumulation (which over the longer term deepens capital), and advance of knowledge, which we measure by TFP growth. The same accounting framework, however, can also be used to understand the cyclicality of growth in output per hour. Over the long run the process of capital deepening means that the ratio of capital to labor rises. But from a cyclical point of view, capital shallows in an expansion and deepens in a contraction. The combined effects of procyclical TFP growth and countercyclical capital deepening (procyclical shallowing) account for the acyclicality or weak procyclicality of labor productivity growth. Capital shallowing reduces growth in output per hour while procyclical TFP advance increases it. Prior to

[8] Lower case letters refer to continuously compounded rate of growth.

the Second World War the latter effect dominates whereas after the war it has been closer to a wash.

The data confirm that capital deepening is countercyclical, indeed strongly countercyclical: during the expansion phase of a cycle, hours rise much faster than capital services, whose growth is, rather surprisingly, essentially acyclical. 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. Note that the positive coefficient on the change in unemployment rate indicates countercyclicality in the rate of capital deepening:

$$k - n \quad = \quad .0235 \quad + \quad .0194^* \Delta UR$$

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

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

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.

$$k - n \quad = \quad .0121 \quad + \quad .0147^* \Delta UR$$

(2.7) $\quad R^2 = .738 \quad (3.02) \quad (12.57)$

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

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

$$k - n \quad = \quad .0073 \quad + \quad .0162^* \Delta UR$$

(2.8) $\quad R^2 = .805 \quad (1.67) \quad (12.68)$

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

Equation 2.9 runs the numbers on the entire period:

$$k - n = .0177 + .0151^* \Delta UR$$

(2.9) $R^2 = .721$ (7.88) (17.10)

(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 rate 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 2.10-2.11 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 2.12 runs the numbers for the entire sample. The trend growth rate of hours is slightly lower after the war, but procyclicality is substantially stronger, perhaps reflecting greater cyclical elasticity of female labor force participation:

$$n = .0162 - .0146^* \Delta UR$$

(2.10) $R^2 = .732$ (4.03) (-12.36)

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

$$n = .0141 - .0219^* \Delta UR$$

(2.11) $R^2 = .848$ (12.13) (-19.77)

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

$$n = .0151 - .0152^* \Delta UR$$

$$(2.12) \quad R^2 = .74 \quad (6.96) \quad (-17.84)$$

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

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

$$k = .0328 - .0001^* \Delta UR$$

$$(2.13) \quad R^2 = .001 \quad (17.63) \quad (-.141)$$

(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:

$$k = .0376 - .0026^* \Delta UR$$

$$(2.14) \quad R^2 = .060 \quad (25.87) \quad (-1.86)$$

(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 one can get to complete acyclicality:

$$k = .0283 + .0001^* \Delta UR$$

$$(2.15) \quad R^2 = .000 \quad (8.62) \quad (.115)$$

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

The regressions above confirm, perhaps surprisingly, that capital growth over more than a century 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 whose strength of aggregate demand can only be guessed at when they are begun, is part of the reason for the acylicality of the growth rate of the capital stock. It is true that optimism in expansions tends to boost planned 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 in 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 unit 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 largely 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.[9] This means that the typical firm in the short run reaches the minimum

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[9] In deciding how large a hotel or wafer fabrication plant to build, businesses must balance the losses from being unable to satisfy demand in a boom period with the losses from having to hold capacity in slack

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).

$$y - k = .0040 - .0201^{*} \Delta UR$$

(2.16) $R^2 = .659$ (1.14) (-14.7)

(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 (Kaldor, 1961). Capital deepening (rises in K/N) by itself should depress capital productivity and raise the capital output ratio, but technical change over times counteracts 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.

$$y - k = -.0012 - .0216^{*} \Delta UR$$

(2.17) $R^2 = .600$ (-.470) (-9.00)

(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:

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periods. The optimization problem is essentially identical to that faced by a retailer or wholesaler in deciding how much inventory to hold: the lost sales resulting from outages vs. the carrying costs of inventory stocks. The difference is that inventory stocks can be adjusted much more easily than fixed capital, particularly structures.

$$y - k = .0090 - .0199^{*}\,\Delta UR$$

$$(2.18) \qquad R^2 = .671 \qquad (1.41) \qquad (-10.68)$$

(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. Indeed, suppose we take .5 as the most favorable estimate of a 1 percentage point decline in the unemployment rate on labor productivity growth. The impact of the cycle on capital productivity is thus at least four times as large as its impact on labor productivity.

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 was 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 dominated, 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 cyclicality of labor productivity growth after the war which is essentially 0. If there is continued debate about whether labor productivity growth is truly procyclical, the reason is understandable: using data from 1948 through 2004 for the entire private nonfarm economy, labor productivity is essentially acyclical. The robust empirical regularity is the procyclicality of TFP.

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):

$$y = .0368 - .0202 * \Delta UR$$

(2.19) $R^2 = .690$ (11.34) (-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 cyclicality coefficient for y of about 2.4 percentage points.

$$y = .0364 - .0241^{*} \Delta UR$$

(2.20) $R^2 = .763$ (18.74) (-13.18)

(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:

$$y = .0373 - .0198^{*} \Delta UR$$

(2.21) $R^2 = .684$ (6.09) (-11.01)

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

A substantial fraction – upwards of 40 percent -- of Okun's law is thus attributable to procyclical TFP growth. A variant of equation 2.5 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):

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

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 rate adds 2.2 percentage points to the growth of hours. Using a labor share of two thirds, this adds approximately .46 percentage points to output growth. The remainder is principally attributable to TFP procyclicality.

We can begin now more fully to appreciate the differences between the forces influencing 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 acyclicality in growth in output per hour, particularly after 1948, the long term trend growth rate of output per hour is positive, about 2.2 percent per year (see equation 2.2).

4. A Statistical Artifact?

A key question in interpreting these results is whether the finding of procyclicality is a statistical artifact due to the failure to make a cyclical adjustment to capital input. In all of these calculations capital services are proxied using estimates of its stock. Beginning 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 peak to peak measures) it can make a big difference if one is concerned with the cyclicality of productivity. In particular, if the cyclical adjustment to capital input 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 troughs.

It is important to understand why cyclical adjustments such as those made by Solow or Shapiro are 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 not on an equal footing in terms of the options available to business owners in the event of a downturn. Firms may choose, but are not required, to hoard labor. Insofar as capital is concerned, the private business sector 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 acyclical (see equations 2.13-15).

This acyclicality would be less germane to the analysis here if aggregate user cost fluctuated proportionately with utilization. But it does not, because, I argue, *the preponderance of the user cost of capital is unaffected by utilization* (Hall, 1988, p. 923, makes a similar assumption about depreciation). 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.[10] This is also the case for producer durables in the transportation sector, such as aircraft, railroad rolling stock, busses, and barges. Even for producer durables for which the depreciation

[10] In spite of a rise in the share of equipment, 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 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). In Field (2008c) I expand on this argument, producing an empirical estimate of how little the aggregate user cost of capital should be influenced by fluctuations in the output gap.

cost is a larger portion of the user cost, for many assets decisions about when the asset has been fully depreciated are largely unrelated to utilization. This is particularly the case, for example, with computers, cellular telephones and software, where technological obsolescence is far more important than how many hours of operation the equipment has experienced.

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 reductions in unit costs as the output gap closes 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. Since 1925, the first year for which we have BEA Fixed Asset data, structures have never fallen below 80 percent of fixed assets (see Field, 2008c).

Ignoring the possible effect of capital gains and losses, we can, following Jorgenson, 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.

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

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 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[11] 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.

4. Aggregate Supply and the Cyclical Behavior of TFP

A second set of questions concerns the implied macro model underlying the interpretation of the regressions. The basic mechanism assumed here, in its simplest form, is that aggregate demand determines the output gap (as measured by the unemployment rate), and procyclical TFP results from interactions of the output gap with inflexible capital input. According to this paper, procylical TFP is real and economically important, but is not the consequence of technology shocks.

A contrary view is associated with the real business cycle (RBC) tradition. RBC models assume that markets always clear, that all unemployment is voluntary, and that

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

deviations from detrended TFP series reflect technology shocks. Procyclical TFP is assumed to be the cause of business cycles, not a consequence of cycles that may have their origin in the sphere of aggregate demand. There is indeed no meaningful place, within this tradition, for an output gap variable, because output is always at potential.

A problem with this approach is the inability to provide plausible historical narratives consistent with how the economy has actually behaved. A look at some of the basic data shows how unlikely it is that technology shocks can provide a satisfactory explanation for short run cyclical fluctuations in the output gap, the unemployment rate, or TFP. Variations in the arrival rate of innovations might plausibly explain alterations in a positive rate of growth of TFP, but it is hard to see, in the absence of some very good stories, how such variations would periodically cause it to go negative. If one has 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. Actual data 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.

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. There is no smoking gun[12] that can, from the supply

[12] Russian/Soviet GDP and, presumably, TFP, declined sharply after 1913 and did not reattain its prewar level until 1926. But an historical narrative can point to large negative supply shocks, including the disastrous participation of the Russians in the First World War, the Treaty of Brest-Litovsk (which reduced Russian territory), the March 1917 Revolution, the October 1917 Bolshevik revolution, the Civil War

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.

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 during this period is arguably because cycles were weaker, at least since the end of the 1982 recession. In the last quarter century the U.S. 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.

In producing their effects on output, employment, and the unemployment rate, changes in monetary policy, or tax and spending changes that affect monetary velocity, or changes in private spending propensities (for example the schedule linking planned investment to various interest rates) that do the same, may interact with expectational inertias, informational asymmetries, overlapping union contracts, downward or upward rigidities in nominal wages or prices, or other governmental policies or legal rules that affect microeconomic decision making. These latter factors could be considered aspects of the supply side of the economy. Their introduction or removal could be considered a negative or positive supply shock. But although they represent contingent factors that may be part of an overall account of why changes in aggregate demand are nonneutral, it

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between the Reds and the Whites, foreign intervention, and the political turmoil associated with the death of Lenin and the rise of Stalin. It is the absence of a comparable and convincing narrative for the US for 1929-33 and many other years that poses problems for the RBC approach.

is implausible to maintain that they are the proximate cause of most short run fluctuations in real output or employment. A distinction between aggregate demand and aggregate supply remains necessary and indeed essential in understanding the behavior of the economy in the short run, and it is not terminologically useful to refer to any of the factors that influence aggregate demand – such as a change in spending propensities or the growth rate of the money supply -- as aspects of technology.

5. Procyclicality and Increasing Returns

A third set of concerns involves whether the empirical results might be interpreted as reflecting a more general phenomenon of increasing returns to scale. Although this paper maintains that procyclical TFP reflects *short run* economies of scale, it is more doubtful that long term trend growth rates are truly due to increasing returns. The historical (time series) evidence suggests pretty clearly that that they are not, in the sense that if, starting from potential output, all inputs suddenly increased by x percent, we would be able, using today's technological and organizational knowledge, to increase output by more than x percent (see, e.g., Jones, 1995, p. 702).[13] And the substantial variability in trend growth rates in TFP over the past century seems much more likely to be the result of differential rates of arrival of new technological and organizational products and processes and products than some historically variable increasing returns process.

Endogenous growth theorists, like RBC proponents, attribute cyclical and secular changes in TFP to the same causes, but these causes differ for the two groups. For RBC

[13] 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.

theorists it is technology shocks, for endogenous growth theorists, increasing returns to scale. Although the distinction between the effects of advance of knowledge and increasing returns is not sharp, the implication of the latter view is that if the economy had been larger at an earlier date, we could have enjoyed current productivity levels earlier. Proponents of the (exogenous) advance of knowledge view would dispute this: the recipes we have available today simply weren't known earlier. Discriminating econometrically between advance of knowledge and long run increasing returns to scale is difficult, because inputs grow historically alongside of technical and organizational advance. But an important historical episode sheds light on the question.

Note first that there are two widely used definitions of increasing returns which differ subtly. The most general indexes scale to output, and identifies increasing returns with a reduction in unit costs associated with higher output. The more frequently encountered definition, however, indexes scale to inputs, and refers to a situation where all inputs increase by x percent, but output goes up by more than x percent. As discussed further in footnote 22, it can make a difference in our thinking about increasing returns whether we index scale to output or to a combined input measure.

Returning to the Depression experience, we can refine a case study which, while not dispositive, is consistent with the view that secular TFP growth, as opposed to its cyclical component, is mostly driven by technological and organizational innovations. Consider the second definition of increasing returns. Should it make a difference if the growth rate of inputs is 0 rather than some positive number? 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 increasing returns to scale. If one attributes this entirely to scale, one is implicitly saying that if, ten years ago, given then existing knowledge levels, we had increased inputs by 5 percent, we could have had 10 percent more output. Without being able to run the experiment, however, we can't tell whether or not this would have been true.

If we index scale to inputs, a situation in which all inputs increased by 0 percent (in other words, did not change) would not 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 private sector 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. Since that time the Bureau of Economic Analysis has done additional work on both capital and output series (although the hours series are relatively unchanged), and these revisions strengthen the point I am making. The most recent capital stock estimates are found in the BEA's Fixed Asset Tables, which include data beginning in 1925.[14] I use them to recalculate the growth rate of the

[14]For 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.

capital stock in the private non farm sector in the following manner. Grow the 1929 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.[15] 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:

[15] http://www.bea.gov/bea/dn/nipaweb/index.asp Table 1.1.3.

32.3/33.5 = .964. Multiplying this by 39.99 percent gives us 38.55 percent, and 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 must have been 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, 2007b).

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 that 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 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 private sector real capital. No other peak to peak period in U.S. 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 so small, true economies of scale cannot be said to have had much to do with this.

The fastest trend growth rate of TFP in the past century occurred during a period marked by the slowest growth of inputs. This poses a challenge for those wishing, as a general theoretical principle, to link long term TFP growth to increasing returns to scale. The analysis in this section reinforces the view that the determinants of short run fluctuations in TFP differ from those governing its long run evolution, a position that both RBC and endogenous growth theorists question from different perspectives.

6. The Cyclical Microeconomics of User Cost

This paper has argued that the cyclical behavior of TFP is the result of short run economies[16] 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. If we assume that the capital stock is optimized for production levels at or close to potential output, unit costs will fall (productivity will rise) as the output gap closes. Falling unit costs are driven by reduced unit costs within firms, by production synergies

[16]Note however that there is a distinction between short run economies of scale, which I endorse as an explanation or procyclical TFP, and short run increasing returns to scale, which I do not. Increasing returns entails a balanced increased in inputs. An economic expansion involves a change in factor proportions since hours rise faster than capital.

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 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.[17] An additional consideration that may bias or push minimum short run average cost (SRAC) toward or even above natural output is a tendency in industries that are potentially oliogopolistic 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.[18] 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 the economies will, in the aggregate, diminish in importance as the economy approaches potential.[19]

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[17] 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.

[18] Note again that I am specifically calling this short term economies of scale, not short term increasing returns to scale, because the latter usage is potentially problematic. Increasing returns are commonly defined as a situation in which a given percentage increase in all inputs leads to a larger percentage increase in output. That is not 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 more general definition, 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. See also section 5.

[19] 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.

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 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 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 decline 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, 2006a,b, 2007b). 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 by definition 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 can thus be interpreted as representing a sweet spot in the struggle to achieve maximum levels of output and employment while controlling inflation, with increased cost pressures due to deterioration of productivity growth likely to be experienced both above and below it. At the same time, there will be an asymmetry in the sources and inflation correlates of these deteriorations, because above natural output the productivity deterioration will be augmented by the upward pressure on wage and materials prices resulting from scarcities and tightness of markets in other inputs.

Potential or natural output is a barrier beyond which the main contributors to procyclical TFP have greatly diminished empirical importance. 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. That barrier is relaxed over the longer run by growth in the labor force, by growth in the capital stock through accumulation, and through advance of knowledge.

7. Conclusion: TFP Growth in the Short and Long Run

Procyclical TFP growth has been a persisting feature of the US economy for more than a century. Its cyclical fluctuations, and in particular its procyclicality, reflects short run economies and diseconomies of scale as relatively inflexible capital input interacts with output gap fluctuations driven by fluctuations in aggregate demand. In contrast, TFP grows over the long run as the result principally of the advance of knowledge. Neither the RBC approach of linking both short and long run changes in TFP to supply shocks, nor the endogenous growth approach, in which both short and long run changes are linked to increasing returns, is satisfactory. The causes of secular and cyclical changes in TFP differ.

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)

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