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ABSTRACT

Between 1890 and 2004, total factor productivity (TFP) growth in the United States has been strongly procyclical, while labor productivity growth has been mildly so. This chapter argues that these results are not simply a statistical artifact, as Mathew Shapiro and others have argued. Procyclicality results principally from demand shocks interacting with capital services which are relatively invariant over the cycle. This account contrasts with that offered by the real business cycle (RBC) program, which attributes economic cycles to technology shocks as measured by deviations in TFP from trend.

## Introduction

Between 1890 and 2004, total factor productivity (TFP) growth in the United States has been strongly procyclical, while labor productivity growth has been mildly so. The paper argues that these results are not simply a statistical artifact, as Mathew Shapiro and others have argued. Procyclicality results principally from demand shocks interacting with capital services which are relatively invariant over the cycle. This account contrasts with that offered by the real business cycle (RBC) program, which attributes economic cycles to technology shocks as measured by deviations in TFP from trend. In real business cycle models causality runs entirely from the side of aggregate supply.

The difficulty with the RBC approach is that TFP does not just experience retardation in its growth rate during recessions. It declines. TFP not only declined between 1929 and 1933, it has declined during almost every economic downturn since 1890. There are conceivably adverse supply shocks that could account for this, although such events are historically quite unusual. Since the statistical results themselves cannot ultimately tell us which process is producing such declines, narrative history, at its best integrating the analysis of qualitative and quantitative data, plays a critical role in efforts to persuade that one or the other of these explanatory frameworks is preferable. The challenge for RBC proponents is to provide plausible accounts for why TFP declines in most downturns.

## 1. The Evidence for Procyclical TFP

In several papers I have documented the high rate of TFP growth across the Depression years and considered its causes and implications for understanding US economic growth in this and other periods (Field, 2003, 2006a,b, 2007b, 2009a). A byproduct of this work has been the finding that total factor productivity growth was strongly procyclical during the Depression years (Field, 2008). When the unemployment rate went up, the level of TFP went down, and vice versa. How generalizable is the phenomenon of Depression era TFP procyclicality? The answer is striking. Similar regression analyses show that for over a century TFP growth in the United States has been strongly procyclical. The elasticity of TFP growth with respect to a change in the unemployment rate has been remarkably stable in the years both before and after the Second World War and in a variety of subperiods during which trend growth rates of TFP were quite different.[1]

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 (ΔTFP) on the change in the unemployment rate in percentage points (ΔUR):

$$\Delta TFP = \alpha + \beta \, \Delta UR + \mu$$

The estimated constant term in the equation ($\alpha$ ) can be interpreted as an estimate of the trend growth rate of TFP over the period studied. The coefficient ($\beta$) describes the relationship between the TFP growth rate and the change in the unemployment rate, and is thus a measure of cyclicality.

The regressions reported in Table 1 have two striking features. First, the coefficients on the change in the unemployment rate all lie within a tight range bounded by -.83 for the post-World War II era (equation 1.8) and -1.03 for the entire period from 1890 to 2004 (equation 1.10).[2] Over more than a century TFP was strongly procyclical and in a remarkably consistent fashion: a fall in the unemployment rate by one percentage point led to an increase in the growth rate of TFP of about 0.9 percent per year. The strong procyclical relationship holds across all time periods, even the World War II years, despite the fact that nearly half of all production went to the military and there were shortages and rationing in the civilian sector (Higgs, 1992). The size of the procyclicality coefficient does not depend on whether one is close to potential output or substantially below it. A comparison of Equations 1.10 and 1.11 shows that inclusion of the level of unemployment (UR), along with its rate of change (ΔUR) has little effect on the originally estimated coefficient.

These equations 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. It is striking that the estimates pre- and post- World War II are so similar. Although Kendrick felt comfortable publishing annual TFP estimates, Kuznets worried about the use of his early national income estimates for cyclical analysis, primarily because of unease about the inventory investment series he had constructed.[3] There are many ways in which inaccurate data might lead to spurious conclusions. But if the process producing short run procyclicality was similar pre- and postwar, and if there was simply more noise in the prewar data, we might have expected the estimated prewar relationship to be weaker. It is not.

The second striking feature of Table 1 is substantial variation in growth rates across different historical epochs, a finding common in the work of pioneers in the study of TFP growth rates such as Abramovitz (1956). The trend growth rates represented by the estimates of the constant term vary from a low of 0.53 percent per year during the dismal age from 1973 to 1995 (equation 1.7) to 1.95 during the golden era from 1948 to 1973 (equation 1.6) to a high of 2.83 percent per year in the Depression years from 1929 to 1941 (equation 1.1).

Running separate regressions across different subperiods whose demarcations reflect judgment contrasts with the ahistorical and mechanical use of the Hodrick-Prescott filter in real business cycle studies. Kehoe and Prescott (2008, pp. 9-10), for example, "view the increase in the stock of useful knowledge … as exogenous. Our view is that this stock increases smoothly over time and is not country-specific."[4] The variation in trend growth rates identified in these different regressions is consistent with a contrasting view that the arrival of economically important innovations may be quite discontinuous, and cluster in particular epochs, rendering some periods more technologically progressive than others.

## 2. Procyclicality in TFP and Output per Hour

Interest in the procyclicality of TFP, as opposed to other measures of productivity, like output per labor hour, is recent.[5] Since the 1960s and the work of Hultgren (1960), Eckstein and Wilson (1964), and Kuh (1965), however, empirical macroeconomists have taken it as a stylized fact that the growth of labor productivity is procyclical:[6] the growth rate of output per hour (like TFP) is negatively related to changes in the unemployment rate. 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.

Table 2 explores the cyclicality of output per hour and related measures as well as their long run growth paths. Its regressions replace the TFP growth rate in Table 1 with other dependent variables, including the growth rates of output per hour, the capital/labor ratio, hours, capital, output per unit of capital, and total output. The results show first (equations 2.1-2.4) that although output per hour, like TFP, is procyclical, the relationship between its growth rate and the change in the unemployment rate is weaker, and for the period after 1973 (equation 2.3), one cannot reject the hypothesis of acyclicality. In an arithmetic sense, the procyclicality of labor productivity is due to the fact that the response of output to a change in the unemployment rate (equations 2.18-20) is stronger than the response of hours (equations 2.9-11).

Whereas both output and hours change systematically with a change in the unemployment rate, the coefficient in the capital growth rate equation is so small that the growth rate in capital appears to be acyclical (equations 2.12.-14). Why? 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, houses, and any type of infrastructure). These long gestation periods, in which projects are completed in an uncertain future and where the strength of aggregate demand down the road can only be guessed at the time the projects are begun, is part of the explanation. It is true that optimism in expansions tends to boost planned investment, but central banks often attempt to lean against the wind by raising interest rates and dampening enthusiasm. 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. That said, there is a slight negative correlation between the unemployment rate and an index of gross private investment spending, but it is too weak to influence the overall acyclicality of the capital stock numbers, from which our estimates of service flow are drawn (see Section 3).[7]

The acyclicality of capital combined with the procylicality of hours means that during expansions, labor hours grow more than capital, so that the capital-labor ratio is countercyclical (equations 2.5-8). If the capital labor ratio were all that changed in an expansion, its decline should cause the marginal product of labor to fall.[8] This effect operating in isolation would mean that output per hour should fall as the unemployment rate falls. Since the results in Equations 2.1 through 2.4 in Table 2 show the opposite, some other factor must be counterbalancing the fall in the capital/labor ratio in an expansion.

Labor hoarding is the most common explanation for why labor productivity rises with declines in unemployment (see, e.g. Hall, 1988, p. 929). As Christina Romer puts it, “Firms tend to be slow to fire workers in bad years and slow to hire workers in good years” (1986, p. 6). Because of fixed costs associated with turnover and hiring, firms retain labor during downturns and seek increased work intensity per man hour during upturns. The rise in intensity of work is not initially reflected by increases in employment or hours, and the consequence is that output rises more rapidly than hours as unemployment declines.

The dynamics of employment, hours, and output are, however, more complex than the labor hoarding story suggests. During the postwar period, for example, firms typically completed the more intensive exploitation of already hired labor well before the end of an expansion. In the last one or two years before a peak, they tended to hire additional workers at a rapid rate. Robert Gordon (1979, 1993) suggests that this "end-of-expansion" effect slows growth in output per hour and attenuates the overall pro-cyclicality of labor productivity. Since the growth of capital is acyclical, the end-of-expansion effect causes the capital-labor ratio to decline as one completes recovery from recession. The resulting downward pressure on the marginal product of labor helps explain why the procyclicality of output per hour is weaker than that of TFP.

The competing roles of TFP growth and capital shallowing in influencing the cyclicality of output per hour can be illustrated using the Solow growth accounting framework, often used to decompose the growth rate in output per hour (y – n) in the long run into the sum of the TFP growth rate (a) plus capital's share (β) times the growth rate in the capital/labor ratio ((k – n):

$$y - n = \alpha + \beta\,(k - n)$$

The equation can also be used to explore the influences on the cyclicality of growth in output per hour by differentiating with respect to a change in the unemployment rate. Tables 1 and 2 establish empirically the signs of the relevant relationships. First, d(y-n)/d(UR) is negative – when the unemployment rate declines, the rate of growth of output per hour rises. Second, dα/d(UR) is negative – when the unemployment rate declines, the TFP growth rate rises (Table 1) Finally, d(β (k – n))/d(UR) is positive: when the unemployment rate declines, the growth rate of the capital labor ratio declines (I ignore here any cyclical influences on capital's share).

When the unemployment rate falls as the economy comes out of recession, the fall in the capital labor ratio tends to reduce growth in output per hour while procyclical TFP advance tends to increase it. During the period 1890-2004, for example, reductions in the unemployment rate by one percent were associated with increases of 0.5 percent in the growth rate of output per man hour (equation 2.4). This is a slower rate than the average TFP rise of 0.83 percent associated with a one percent decline in the unemployment rate. Assuming that the capital share (β) is 0.22, the decomposition suggests that this difference is driven by a fall in the growth rate of the capital/labor ratio of 1.5 percent per year (equation 2.8). Thus for each percentage point decline in the unemployment rate the TFP growth rate rises by .83 percentage points per year, but the growth rate of output per hour increases by this amount less an offset of .33 (.22*1.5) due to capital shallowing. It is the strong procyclicality of TFP that keeps labor productivity growth mildly procyclical

The argument advanced here is that labor productivity and TFP are both procyclical because of the inability of the private business sector to get rid of capital in a downturn. Unlike labor, capital can't be fired. It must be held by someone, who incurs real holding costs, and real depreciation costs largely unaffected by utilization. This involuntary "hoarding" of capital is thus more important than the voluntary hoarding of labor in explaining 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, do not depend much on how full each is.[9] As a result, as unemployment declines, the average cost of capital declines because utilization-invariant depreciation charges and the largely fixed costs of holding capital are spread over a larger flow volume of output. The productivity dual of these cost reductions is that total factor productivity increases. Meanwhile, the effect on output per hour in the aggregate is closer to a wash because the rise in TFP is partially offset by the effect on output per hour of the reduction in the capital-labor ratio as one approaches potential output from below.

## 3. A Statistical Artifact?

Is TFP procyclicality a statistical artifact due to the failure to make a cyclical adjustment to capital input? In all of these calculations capital services are proxied by 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. The magnitude of such an adjustment may not make much difference if one is interested in long term growth, but 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.

Mathew 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, the procyclicality of measured manufacturing TFP 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.[10] But such adjustments are too large. If any adjustment is warranted, it is in the aggregate small, and treating the service flow as proportional to capital stock will probably give a better first approximation of economically meaningful capital input than the adjusted series suggested by Solow or Shapiro.

It is important to understand why cyclical adjustments such as those made by Solow or Shapiro are too large. 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 estimates in Table 2 show that the growth rate of the capital stock is basically acyclical.

This acyclicality would be less relevant here if the aggregate cost of capital 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.[11] It should be noted that structures account for a large majority of capital assets in the economy. Since 1925, the first year for which the Bureau of Economic Analysis (BEA) provides Fixed Asset data, the value of structures has never fallen below 80 percent of the value of fixed assets (see Field, 2009b).

The majority of the user cost of capital is unaffected by utilitization for other asset classes, as well, including producer durables in the transportation sector, such as aircraft, railroad rolling stock, busses, and barges. Even for producer durables for which depreciation is a larger portion of the user cost, decisions about when the asset has been fully depreciated are largely unrelated to utilization for many assets. This is particularly true for items like 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.

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

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

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, because it reflects technological obsolescence or exposure to the elements, rather than the direct effects of wear and tear related to utilization.[12] [13]

Since the aggregate annual user cost of holding the existing stock of capital is largely unrelated to utilization, and since the growth rate of capital inputs are basically acyclical in Table 2, the economy experiences rising output per unit of capital and rising TFP 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.

## 4. Aggregate Supply and the Cyclical Behavior of TFP

If in fact the growth rate of TFP has behaved procyclically in the United States, there remain differences over how this is to be explained. Real business cycle theory provides an alternate account. RBC theorists view business cycles as "small deviations in trend" of real output (Kehoe and Prescott, 2008, p. 11), and they view productivity shocks, defined as deviations from a detrended TFP series, as the impulses causing the cycles (Prescott, 1986). Rather than demand shocks causing short run TFP movements, and this being something one can test empirically, TFP is by definition procyclical.

RBC pioneers such as Lucas and Prescott initially granted that their approach was not applicable to major macroeconomic disruptions such as the Great Depression.[14] But Prescott subsequently changed his mind, influenced, according to his own account, by the work of Harold Cole and Lee Ohanian (de Vroey and Pensieoroso, 2006). RBC research has now merged into a broader umbrella known as dynamic stochastic general equilibrium (DSGE) analysis, which includes neoKeynesian variants.

A unifying precept in RBC modeling is that sources of measured productivity change, in both the short and long run, lie outside of economics – in the realm of politics or in an independent dynamic of technological advance. If there is a unifying feature of the broader DSGE program, it is the insistence on providing strong microeconomic foundations for macroeconomic relationships, which has always seemed to me more of an aesthetic preference than a scientific imperative. That said, many DSGE models escape from the narrow strictures of the original RBC initiative. Some adopt features of macroeconomic research from over half a century ago, exploring the influence of monetary or fiscal policy shocks within the context of non-market clearing imperfections, and returning to an empirical strategy relying on the estimation of structural equations rather than calibration (Woodford, 2009).

Cole and Ohanian, however, see their work as still very much within the original RBC tradition, and the assumption that short run TFP fluctuations are exogenous is part of their maintained hypothesis. This is true as well for the broader Great Depressions project run by Timothy Kehoe and Edward Prescott at the Federal Reserve Bank of Minneapolis.[15] For the contributors to Kehoe and Prescott (2007), the source of the large drops in TFP associated with depressions is to be found in technological regress, or, in the absence of plausible candidates, in bad government supply side policies.

In contrast, the view advanced here is that cycles are caused principally by aggregate demand fluctuations, with the output gap as proxied by the unemployment rate reflecting the strength of negative demand shocks.[16] TFP declined with recession and depression because as the output gap widened, output fell, but capital inputs and costs generally didn't.

These approaches involve different understandings of the primary causes of business cycles, differences highlighted in the competing principles used by the NBER's Business Cycle committee in its ex post dating of cycles. The committee places "substantial weight" on movements in real GDP but acknowledges that one can also look at the output gap in which case the unemployment rate would be a "critical guide."[17] An RBC perspective leads one to put most weight on the former criterion, and indeed some have suggested that cycles can be dated mechanically, and a committee is not needed.

A challenge for the RBC approach, however, is to provide plausible historical narratives consistent with the periodic and often substantial declines in TFP associated with recessions. Variations in the arrival rate of innovations might account for alterations in a positive rate of growth of TFP, but it is more difficult to see how such variations would periodically cause it to go negative.[18] Data for the years 1890 through 2004 indicate an average annual rate of private non-farm TFP growth of 1.46 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 (see Figure 1).

(FIGURE 1 ABOUT HERE)

For 1948 and earlier, average annual 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. On the face of it, it seems unlikely that all of these declines can be attributed to negative technological shocks or, absent that, innovations in bad government supply side policy, with the implied counterfactual that within a minimalist state they would not have occurred. The most striking and problematic declines prior to the Second World War take place in 1930, 1931, 1932 and 1933 in the context of the most serious output shortfall in U.S. economic history. 12 percentage points of the more than 30 percent drop in real output between 1929 and 1933 is attributable to downward movement in TFP.

In understanding what happened during these years, we have well established narratives detailing the effects of collapsing banks, a shrinking money supply, the interactions of debt and deflation, and plummeting velocity due to declines in spending on consumer durables and investment goods (Bernanke, 1983, Eichengreen, 1992; Field, 1984; Friedman and Schwartz, 1963; Romer, 1990; Temin, 1976).[19] These accounts differ in terms of their relative emphasis on national and international factors, or on monetary vs. velocity shocks, but they reflect a shared view that the Great Depression was principally the consequence of aggregate demand shocks.

Lee Ohanian (2009) has suggested that a meeting with President Hoover in November of 1929 persuaded industrialists to maintain high real wages in manufacturing, and that this explains part of the shrinkage in that sector through 1931. Much of the drop took place in durables and there is considerable evidence that overextended, overindebted, and uncertain consumers cut back sharply on this category of their spending (Mishkin, 1978; Romer, 1990). To this can be added the decline in orders attributable to the drop in the producer durables portion of investment expenditure.[20] These should be considered the primary causes of the drop in manufacturing up through the banking crisis of October 1931. At best, a failure of nominal wages to decline faster can be seen as an institutional factor contributing to the nonneutrality of a negative aggregate demand shock.

Moreover, a more rapid decline in nominal wages in manufacturing – Ohanian's posited counterfactual – would have worsened the debt deflation problem. There is nothing in the modeling to capture the threat posed to output and employment by deflation in a world in which most borrowing and lending involved instruments with fixed nominal repayment obligations. There are many institutional features of an economy that can contribute to nonneutrality, and, as both our historical and current experience with financial fragility indicates, it is far from clear that the most significant of these are in the labor market.

The other shocks emphasized by Cole and Ohanian, such as the National Industrial Recovery Act or the National Labor Relations Act, all took place after

1933, during a period of very rapid TFP growth (see Figure 1). At best they could account for why TFP growth wasn't even faster. They could not have played a role in the cumulative 12 percent decline in TFP under President Hoover.

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 between the Reds and the Whites, foreign intervention, and the political turmoil associated with the death of Lenin and the rise of Stalin.[21] We lack such a narrative for the productivity declines during the worst years of the Depression. The most plausible explanation for TFP declines during this period – and most others -- is that demand shocks widened the output gap, and as the output gap widened, output fell, while capital input and cost largely didn't.

For the 1948-2004 period, average TFP growth is lower and less variable. The mean growth rate is 1.4 percent with a standard deviation of 1.8 percent. The reduced cyclical volatility of TFP during this period is arguably because cycles were weaker, at least between the 1982 recession and the 2007-09 downturn. In the quarter century prior to 2008, the U.S. economy 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 1954, 1956, 1969, 1970, 1974, 1979, 1980, 1981, 1982, and 1991.

For the postwar period, however, there is a plausible source of negative supply shocks, particularly between 1972 and 1985. Sharp increases in the price of oil resulting from political decisions made by the Organization of Petroleum Exporting Countries produced deteriorations in the efficiency of the machine (foreign trade) whereby the United States transformed wheat, soybeans, plywood and aircraft into oil. Prior to mid century, when the U.S. was still the world's largest oil producer, oil shocks are of little relevance in understanding the aggregate economy. And, in part because of controls, there is relatively little change in the real price of a barrel of crude oil from the end of the Second World War through 1970. Between December 1973 and January 1974, however, the price more than doubled as a direct consequence of OPEC actions. And in April of 1979, the price began rapidly rising. Following a peak in April of 1980, at which point it had more than doubled from a year earlier, it began a steady decline before bottoming out in 1985. Aside from a brief spike during the first Gulf War, it then remained relatively steady until after 2005.

(TABLE 3 ABOUT HERE)

Table 3 reports an additional regression for the post war period. The dependent variable, as in Table 1, is the rate of change of TFP. Equation 3.1 adds the level of real oil prices in 2008 dollars to the change in the unemployment rate on the right hand side. This regression shows that oil prices do have a negative impact on TFP growth rates. But the size of its coefficient is quite small, and not statistically significant. Independently of fluctuations in the output gap, a $10 increase in the real price of a barrel of crude subtracts less than a quarter of a percentage point from the TFP growth rate.

It is commonly argued that, in contrast with 1980 or 1981-82, the 1974-75 recession was made in Vienna and Riyadh, rather than Washington. It was 1974-75, after all, that turned the Philips curve into an unidentified flying object. Still, the Federal Funds rate, which was under 5 percent as late as September 1972, was more than twice that a year later, and remained above 10 percent between July 1973 and November of 1973 and then again between April and October of 1974. The role that monetary stringency played in inducing this recession has been perhaps underplayed. It was clearly implicated in the decline in investment spending which marked this recession as well as so many others.

The proportional increase in the real price of oil was larger in 1979-80 than what occurred between December of 1973 and January of 1974, although its disruptive impact was less because, as a consequence of the first oil price shock, the U.S. economy had begun moving towards a more energy efficient capital stock. A review of the sequence of oil price, interest rate, and unemployment rate movements between 1979 and 1982 helps explain why, in spite of the second oil price shock, the recessions of 1980 and 1981-82 are almost universally attributed to changes in aggregate demand conditions resulting from the tightening of monetary policy engineered by Chairman Volcker to fight inflation.

(FIGURE 2 ABOUT HERE)

Even before the real price of oil began its year long upward movement in April of 1979, the Federal Funds rate began a climb into historically unprecedented territory. Following the seven month period in 1974 when it had exceeded 10 percent, the rate declined to a trough in January of 1977 at 4.71 percent, then began a gradual upward movement. In December of 1978 it broke 10 percent again, hit 11.4 percent in September of 1979, and then 13.8 percent in October, when Chairman Volcker announced a new monetary regime in which the Fed would target monetary aggregates, and allow the funds rate to seek its own level. By April of 1980 the rate had increased to an eye-popping 17.61 percent.

Unemployment began to rise sharply, from 6.3 percent in March of 1980 to a peak of 7.8 percent in July. Concerned that the unprecedented monetary stringency would take the real economy into a major recession, the Fed relented, slashing the funds rate by almost half to a low of 9 percent in July of 1980. In reaction to monetary easing, the unemployment rate stopped rising, and remained in a range of 7.2-7.6 percent through September of 1981.

In the meantime, however, reconsidering the impact of its easing on inflationary expectations in both the bond and labor markets, the Fed again allowed the funds rate to move upward. It reached a new and unprecedented peak of 19.1 percent in January of 1981. The rate dropped to 14 percent in April but then rose again to 19.1 percent in June. In July of 1981 the unemployment rate began a relentless year and a half rise to a peak of 10.8 percent in November and December of 1982, as of this writing still the highest unemployment rate experienced since the Great Depression.

Economists such as Robert Lucas, pioneers of rational expectations modeling, had predicted that we could have costless disinflation but were proved wrong. The rise in the unemployment rate from 7.2 percent in July of 1981 to its peak of 10.8

percent a year and a half later can't be attributed to negative supply shocks. The real price of oil had been declining steadily since April of 1980. The level of total factor productivity dropped .7 percent in 1979, 2.2 percent in 1980, .4 percent in 1981, and 3.6 percent in 1982.

With the possible exception of 1974-75, the most serious economic downturns of the twentieth century were precipitated by aggregate demand shocks. In most instances it is the linkage running from aggregate demand to the output gap that generates the negative TFP movements associated with recession.

## 5. Conclusion

Receptivity to procyclical TFP as a stylized feature of US growth has been influenced by macroeconomic theorists placing greater emphasis on aggregate supply, and by empirical investigations involving relatively short data runs usually limited to the manufacturing sector. The regressions discussed in sections 1 and 2 cover more than a century, and are broad in coverage, examining data for the U.S. 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). Manufacturing has contributed a declining share of U.S. GDP, particularly since the 1970s. Even at its high point in the mid-century decades, that share barely exceeded a third, and today it contributes less than a sixth..[22] Although data for the sector is more detailed than that available for the rest of the economy, trends within the sector do not necessarily offer an accurate guide to what is happening in the economy as a whole.

These regressions show that although labor productivity is weakly procyclical, approaching acyclicality after 1973, there is a stable and systematic relationship between the business cycle, as manifested in the unemployment rate, and total factor productivity that has endured for over a century. A decline of one percentage point in the unemployment rates adds about .9 percent to the TFP growth rate, irrespective of whether the trend growth rate is fast or slow.

The paper rejects the argument of Shapiro and others that the TFP findings are a statistical artifact. It explains procyclicality as resulting principally from demand shocks interacting with capital services which are relatively invariant over the cycle. The gains in total factor productivity as one comes out of a recession are real. They represent short run increasing returns to scale, as hotels, warehouses, transportation systems and other capital assets experience higher load factors.

Real business cycle models provide an alternate account of procyclicality, in which deviations in TFP from trend are cause, not consequence if business cycles. But RBC proponents have difficulty providing compelling narratives consistent with the observation that TFP often declines during recessions, rather than simply experiencing growth retardation.

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Table 1

Dependent Variable: ΔTFP [a]

| Eq. No. | Years | n | Constant | ΔUR [b] | UR [c] | $R^2$ |
|---|---|---|---|---|---|---|
| (1.1) | 1929-41 | 12 | .0283 (3.02) | - .0092 (-4.28) | | .647 |
| (1.2) | 1900-41 | 41 | .0197 (2.83) | - .0091 (-4.45) | | .337 |
| (1.3) | 1900-48 | 48 | .0175 (2.65) | - .0091 (-4.52) | | .307 |
| (1.4) | 1890-1948 | 58 | .0166 (2.75) | - .0084 (-4.77) | | .289 |
| (1.5) | 1890-1948[d] | 58 | .0165 (2.68) | - .0103 (-4.38) | | .255 |
| (1.6) | 1948-73 | 26 | .0195 (6.51) | - .0082 (-3.16) | | .294 |
| (1.7) | 1973-95 | 23 | .0053 (1.57) | - .0098 (-3.14) | | .319 |
| (1.8) | 1948-2004 | 56 | .0129 (6.08) | - .0083 (-4.11) | | .235 |
| (1.9) | 1890-2004 | 114 | .0148 (4.59) | - .0084 (-6.65) | | .283 |
| (1.10) | 1890-2004[e] | 114 | .0148 (4.50) | - .0100 (-6.14) | | .252 |
| (1.11) | 1890-2004 | 114 | .0105 (1.79) | - .0087 (-6.64) | .0006 (.889) | .288 |

Note: t statistics in parentheses.

[a] ΔTFP is the difference in the natural log of TFP from one year to the next. It is thus a measure of the continuously compounded annual rate of increase of total factor productivity.

[b] ΔUR is the change in the unemployment rate in percentage points from year t-1 to year t.

[c] UR is the level of the unemployment rate in year t.

[d] Uses Weir rather than Lebergott unemployment data

[e] Uses Weir unemployment data through 1948, BLS thereafter.

Sources and notes. 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. Each growth rate is calculated as the change in the natural log from year t-1 to year t. The dependent variables are therefore logged and differenced, mitigating autocorrelation problems; Durbin-Watson statistics are within acceptable ranges. The change in the unemployment rate is the change in percentage points between year t-1 and year t.

Total Factor Productivity data for 1890-1948 are from Kendrick (1961, Table A-XXIII); data for 1948-2004 are from the Bureau of Labor Statistics, "Net Multifactor Productivity and Cost, 1948-2008, SIC 1948-87 linked to NAICS 1987-2008" release of May 6, 2009. Variant 1 of the unemployment rate for 1890-1948 is from Lebergott (1964) and variant 2 for 1890-1948 is from Weir (1992). The unemployment rates for 1948-2004 comes from the Bureau of Labor Statistics, "Employment Status of the Civilian Noninstitutional Population. 1940 to Date," available at http://www.bls.gov/cps/cpsaat1.pdf , accessed on August 14, 2009.

Table 2

Dependent Variable: ΔY/N

| Eq. No. | Years | n | Constant | ΔUR | $R^2$ |
|---|---|---|---|---|---|
| (2.1) | 1890-1948 | 58 | .0210<br>(3.58) | - .0052<br>(-3.01) | .139 |
| (2.2) | 1948-73 | 26 | .0253<br>(8.68) | - .0060<br>(-2.37) | .189 |
| (2.3) | 1973-2004 | 32 | .0154<br>(5.69) | - .0028<br>(-1.12) | .009 |
| (2.4) | 1890-2004 | 114 | .0203<br>(6.48) | - .0051<br>(-4.15) | .133 |

Dependent Variable: ΔK/N

| Eq. No. | Years | n | Constant | ΔUR | $R^2$ |
|---|---|---|---|---|---|
| (2.5) | 1948-2004 | 56 | .0275<br>(16.65) | .0190<br>(12.10) | .727 |
| (2.6) | 1890-1948 | 58 | .0121<br>(3.02) | .0147<br>(12.57) | .738 |
| (2.7) | 1900-41 | 41 | .0073<br>(1.67) | .0162<br>(12.68) | .805 |
| (2.8) | 1890-2004 | 114 | .0195<br>(8.49) | .0151<br>(16.70) | .713 |

Dependent Variable: ΔN

| Eq. No. | Years | n | Constant | ΔUR | $R^2$ |
|---|---|---|---|---|---|
| (2.9) | 1890-1948 | 58 | .0163<br>(7.53) | - .0152<br>(-17.88) | .741 |
| (2.10) | 1948-2004 | 56 | .0164<br>(14.18) | - .0213<br>(-19.36) | .872 |
| (2.11) | 1890-2004 | 114 | .0163<br>(7.53) | - .0152<br>(-17.88) | ..741 |

Dependent Variable: $\Delta K$

| Eq. No. | Years | n | Constant | $\Delta UR$ | $R^2$ |
|---|---|---|---|---|---|
| (2.12) | 1890-2004 | 114 | .0346 | - .0001 | .000 |
| | | | (18.08) | (-.167) | |
| (2.13) | 1948-2004 | 56 | .0416 | - .0029 | .071 |
| | | | (27.93) | (-2.04) | |
| (2.14) | 1890-48 | 58 | .0283 | - .0001 | .000 |
| | | | (8.62) | (-.115) | |

Dependent Variable: $\Delta Y/K$

| Eq. No. | Years | n | Constant | $\Delta UR$ | $R^2$ |
|---|---|---|---|---|---|
| (2.15) | 1890-2004 | 114 | .0020 | - .0200 | .654 |
| | | | (0.61) | (-14.52) | |
| (2.16) | 1948-2004 | 56 | -.0052 | - .0212 | .579 |
| | | | (-.2.00) | (-8.70) | |
| (2.17) | 1890-48 | 58 | .0090 | - .0199 | .671 |
| | | | (1.41) | (-10.68) | |

Dependent Variable: $\Delta Y$

| Eq. No. | Years | n | Constant | $\Delta UR$ | $R^2$ |
|---|---|---|---|---|---|
| (2.18) | 1890-2004 | 114 | .0366 | -.0203 | .690 |
| | | | (11.20) | (-15.81) | |
| (2.19) | 1948-2004 | 56 | .0361 | - .02458 | .777 |
| | | | (18.38) | (-13.84) | |
| (2.20) | 1890-48 | 58 | .0373 | - .0198 | .684 |
| | | | (6.09) | (-11.01) | |

Sources and notes: $\Delta Y$, $\Delta N$ and $\Delta K$ are defined as the change in the natural log of output, hours, and capital input respectively between year t-1 and year t. They are thus a measure of the continuously compounded growth rate of these variables from one year to the next. $\Delta Y/N$ is the difference between the growth rate of output and the growth rate of hours; it is thus a measure of the growth rate of labor productivity. $\Delta K/N$ is the difference between the growth rate of capital and the growth rate of hours; it measures the growth of the capital-labor ratio. $\Delta Y/K$ is the difference between the growth rate of output and the growth rate of capital. It measures of the growth rate of capital productivity (the inverse of the capital output ratio). $\Delta UR$ is the change in the unemployment rate measured in percentage points

Data for real output, capital services, and labor hours for the private non-farm economy for 1890-1948 are from Kendrick, 1961, Table A-XXIII; for 1948-2004, they are from the Bureau of Labor Statistics, "Net Multifactor Productivity and Cost, 1948-2008, SIC 1948-87 linked to NAICS 1987-2008," release of May 6, 2009.

Table.3

Dependent Variable: ΔTFP

| Eq. No. | Years | n | Constant | ΔUR | Oil | $R^2$ |
|---|---|---|---|---|---|---|
| (3.1) | 1946-2004 | 58 | .0185<br>(3.82) | - .0098<br>(-4.48) | -.00021<br>(-1.62) | .303 |

Sources: ΔTFP and ΔUR: See Table 1

Oil: Real Price of a barrel of Crude Oil, annual data. Deflation is based on the Consumer Price Index, urban. Values are in November 2008 dollars. http://www.inflationdata.com/inflation/Inflation_Rate/Historical_Oil_Prices_Table.asp , accessed October 24, 2009.

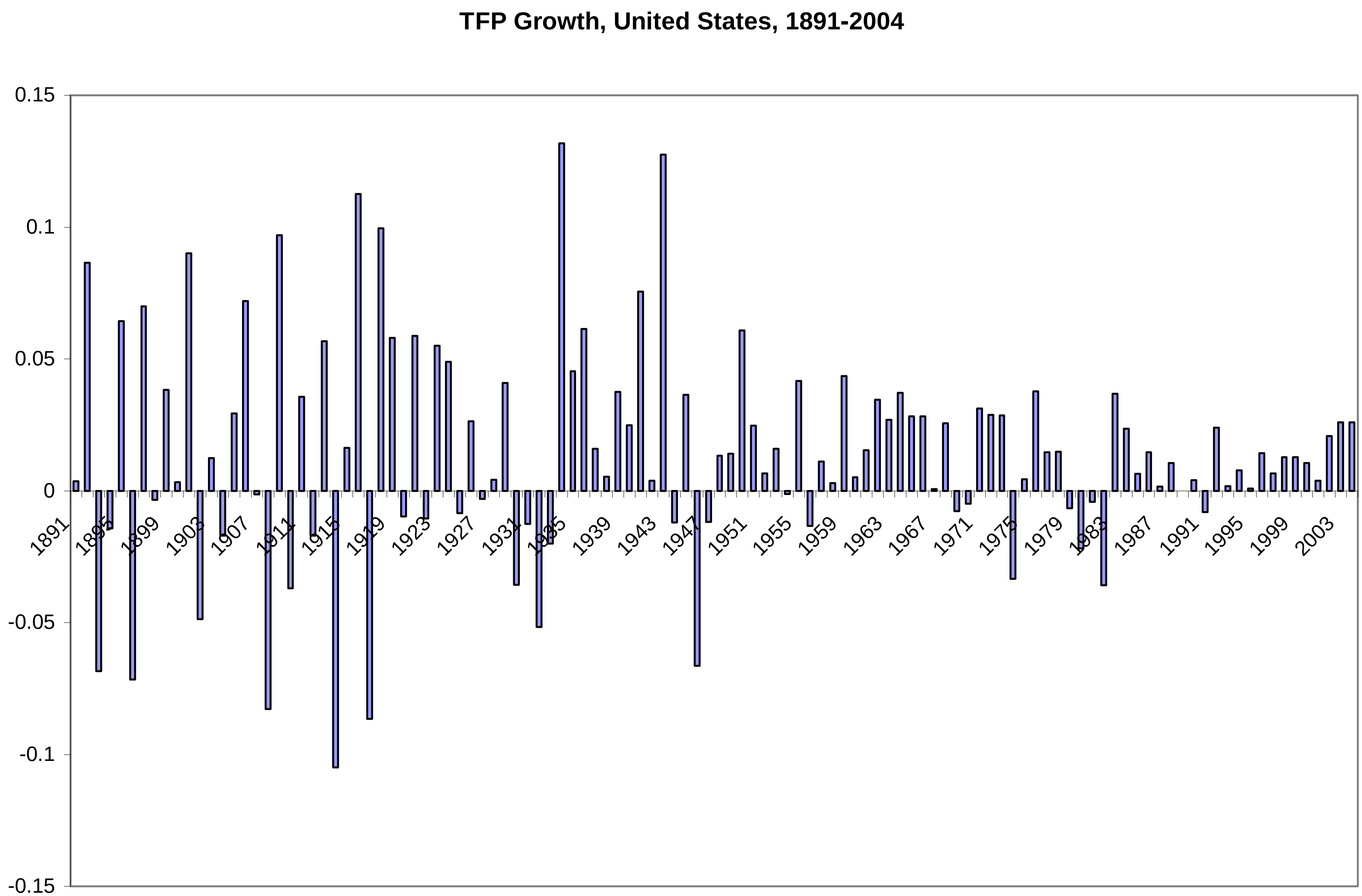
TFP Growth, United States, 1891-2004
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1891
1895
1899
1903
1907
1911
1915
1919
1923
1927
1931
1935
1939
1943
1947
1951
1955
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
1999
2003

**Figure 2**
**Real Oil Price, Federal Funds Rate, and the Civilian Unemployment Rate, 1978-85**

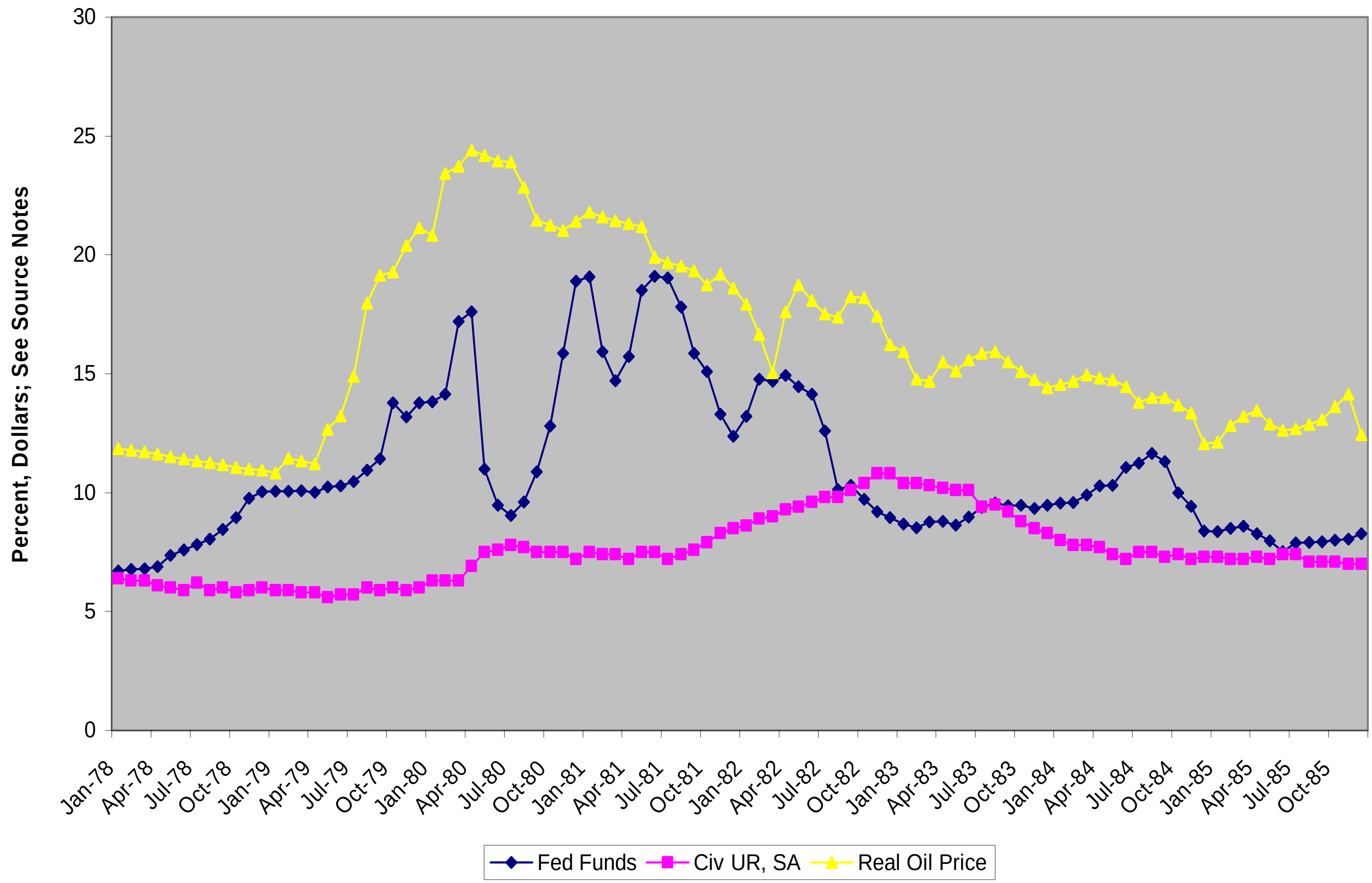

Figure 2

Sources: Monthly Real Oil Price. Nominal is Spot Oil Price, West Texas Intermediate, http://research.stlouisfed.org/fred2/series/OILPRICE , accessed October 24, 2009. Deflator is CPI-U, Seasonally Adjusted, 1982-84 =100, http://www.bea.gov, accessed October 24, 2009. Plotted data are half the values in 1982-4 dollars.

Federal Funds rate: http://research.stlouisfed.org/fred2/data/FEDFUNDS.txt , accessed October 24, 2009. Left hand scale is percent

Civilian Unemployment rate, seasonally adjusted: http://www.bls.gov , accessed October 24, 2009. Left hand scale is percent.

FOOTNOTES

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[1] 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.

[2] In the text, coefficient estimates are multiplied by 100 so they can be interpreted in percent per year terms.

[3] Personal communication from Paul David, November 2, 2008.

[4] Kehoe and Prescott "hypothesize that the growth rate [in the stock of knowledge] is two percent per year" (2008, p. 10). Their estimate is roughly half a percentage point higher than the estimates of 1.5 percent per year suggested by the constant terms in the 1890-2004 regressions in equations 1.9-1.11 in Table 1.

[5] A JSTOR search shows almost all articles referencing the phenomenon appearing after 1995.

[6] Basu and Fernald , for example, take it as a given that both TFP and labor productivity are procyclical. "Productivity is procyclical. That is, whether measured as labor productivity or total factor productivity, productivity rises in booms and falls in recessions" (2000, p. 1). Data for the private nonfarm economy, however, show labor productivity approaching acyclicality after 1973 (see Table 2). The more robust empirical regularity is the procyclicality of TFP.

[7] The simple correlation between the unemployment rate and the BEA's chain type quantity index for investment in private fixed asset (Table 6.8 in the Fixed Asset Tables, available at http://www.bea.gov, accessed on August 16, 2009) is -.14.

[8] Capital shallowing, the opposite of deepening, refers to situations in which the capital-labor ratio declines.

[9] 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).

[10] Basu and Fernald (2000, p. 35)) also make utilization adjustments that reduce the procyclicality of TFP. Their adjustments, designed to correct for utilization of both labor and capital, are based on sectoral data on changes in hours worked per worker, combined with the assumption that these data proxy both for unmeasured changes in the intensity of work and the "workweek of capital" (flow of capital services). The adjustment applicable to capital is, however, too large. The capital stock is dominated by structures, and the service flow contributed by a warehouse or hotel is largely invariant to how full or empty they are, let alone to how many hours employees within them work.

[11] 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 2007, total private fixed assets comprised $33.4 trillion, with equipment and software totaling only $5.3 trillion. Nonresidential structures accounted for $10.2 trillion; the remainder was residential structures. http://www.bea.gov, Fixed Asset Table 2.1 accessed June 22, 2009. For historical data, see Field (1985).

[12] Hall, 1988, p. 923, makes a similar assumption about depreciation.

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

[14] "…the Great Depression [. . . ] remains a formidable barrier to a completely unbending application of the view that business cycles are all alike" (Lucas, 1980, p. 273). RBC theorists have also had little to say about the 2007-10 financial crisis and recession.

[15] De Cordoba and Kehoe (2009, p. 2) summarize the contributions of Kehoe and Prescott (2007).: "The authors of each of the studies … start by decomposing the decline in output during the depression into declines in inputs of labor and capital and a decline in the efficiency with which these factors are employed, measured as productivity. They find that a large drop in productivity always plays a large role in accounting for the depression." "Accounting for" means here more than simply contributing to in an arithmetical sense. It means causing. Most economists are comfortable with this interpretation for long term analysis. The differences involve its applicability to short term cyclical fluctuations.

[16] The rationale is the close and systematic relationship between the unemployment rate and the output gap, first identified by Arthur Okun and known colloquially as Okun's Law (Okun, 1962).

[17] 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).

[18] As Rebelo (2005, p. 9) has written, "Macroeconomists generally agree that expansions in output, at least in the medium to long run, are driven by TFP increases that derive from technical progress. In contrast, the notion that recessions are caused by TFP declines meets with substantial skepticism because, interpreted literally, it means that recessions are times of technological regress."

[19] The literature is voluminous; these references are illustrative. .

[20] In nominal terms investment in producer durables dropped by more than half between 1929 and 1931 ($5.5 to $2.6 billion). Consumption spending on durables dropped 40 percent, from $9.8 to $5.5 billion. Spending on nondurables dropped less than a quarter and on services less than 15 percent. http://www.bea.gov, NIPA Table 1.1.5, accessed October 25, 2009.

[21] For other examples of negative TFP growth, see Baier, Dwyer, and Tamura (2006).

[22] Manufacturing's share of national income averaged 30.6 percent between 1941 and 1960. The share declined modestly in the 1960s and then more rapidly beginning in the 1970s (Carter et al., 2006, Series Ca35 and Ca41).