August 2004

Technical Change and U.S. Economic Growth:
the Interwar Period and the 1990s

by

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

- For comments on earlier versions of this paper, I am grateful to Nick Crafts, Stanley Engerman, Robert Gordon, Robert Solow, and Gavin Wright. I also thank participants in the conference "Understanding the 1990s: The Economy in Long Run Perspective" held at Duke University, March 26-27, 2004, seminars at the University of Virginia, April 28, 2004, Indiana University, April 29, 2004, and the All Ohio Economic History Seminar (joint with the Macroeconomics Seminar), Ohio State University, April 30, 2004, and the World Cliometrics conference, Venice, Italy, July 10, 2004.

Technical Change and U.S. Economic Growth:
the Interwar Period and the 1990s

ABSTRACT

Multifactor productivity growth in the U.S. economy between 1919 and 1929 was almost entirely attributable to advance within manufacturing. Distributing steam power mechanically over shafts and belts required multistory buildings for economical operation. The widespread diffusion of electric power permitted a shift to single story layouts in which goods flow could be optimized around work stations powered by small electric motors. Within this framework, as well as opportunities to produce a variety of new products, economies of scale and learning by doing permitted rapid and across the board gains in manufacturing productivity. The sector contributed 85 percent of the 2.02 percent per year overall advance in the private nonfarm economy in this ten year period.

The Depression years witnessed manufacturing MFP growth that was not as uniformly distributed as it had been during the twenties, and only half as rapid: 2.60 as opposed to 5.12 percent per year. As a consequence, and in spite of a rise in the sector's share, manufacturing accounted for only 48 percent of PNE MFP growth between 1929 and 1941. Yet overall growth in MFP was by far the highest of any comparable period in the twentieth century – 2.31 percent per year. This resulted from combining a manufacturing contribution which by any standard of comparison other than that of the 1920s was world class, with spillovers from government financed infrastructural investment that enabled rapid advance in other parts of the economy, particularly transport and public utilities and wholesale and retail distribution.

MFP growth between 1989 and 2000 was more than twice what it had been during the years 1973-89, but less than a third that registered between 1929 and 1941. Within manufacturing, advance was narrowly concentrated within the old SIC 35 and 36, virtually all of this attributable to information technology (IT). IT was also responsible for some MFP growth in using industries, notably wholesale and retail distribution and securities trading. This paper questions the common practice of also crediting IT with the portion of capital deepening's effect on labor productivity associated with the accumulation of specific IT capital goods.

Introduction

Looking back over the twentieth century, the years 1948-73 stand out as the golden age of labor productivity growth and living standard improvement in the United States – the result of a combination of respectable multifactor productivity growth and robust rates of capital deepening. The period 1973-89, in contrast, was the most disappointing, because of the virtual collapse of multifactor productivity growth during these years. The contrast between these periods gave rise to a raft of studies trying to pinpoint the causes of the slowdown in MFP growth and, as a consequence, labor productivity growth. More recently, attention has shifted toward determining the contribution of the IT revolution to the revival of productivity growth in the 1990s.

Most of these studies, however, embrace an historical perspective that reaches back no further than 1948, the year in which the standard series maintained by the Bureau of Labor Statistics begin. This paper, in contrast, pushes the time horizon back to the end of the nineteenth/beginning of the twentieth century, with particular attention to the period following the First World War and preceding U.S. entry into World War II in 1941. It combines a detailed examination of the magnitude and sources of productivity advance during the interwar years with a comparative examination of progress during the last decade of the century.

Because of the influence of cyclical factors on productivity levels, it is customary in historical research to restrict calculations of productivity growth rates to peak to peak comparisons. For the most recent episode, this requires measurement from 1989 to 2000. Many students of the productivity revival prefer nevertheless to measure from 1995. Although 1995 is not a business cycle peak, the acceleration in output growth after 1995 does make the revival look more impressive. Whether it is desirable or appropriate to choose one's start date with the objective of making the contrast between recent and past history more dramatic is of course an open question.

Having said that, the recent achievement is impressive when measured in relation to the period of slow growth that preceded it. But even if we show the recent acceleration in its best light, by measuring from 1995 onward to the peak of the cycle in 2000, end of century labor productivity advance still remained well below golden age rates. Perhaps more surprisingly, it remained in the same range as that registered during the interwar period. For the U.S. private nonfarm economy, and measuring peak to peak, the continuously compounded rate of growth of output per hour was 2.27 percent per year between 1919 and 1929, 2.35 percent per year between 1929 and 1941, and 1.92 percent per year between 1989 and 2000 (2.47 percent per year between 1995 and 2000). Growth rates during these three periods contrast with the higher rate of 2.88 percent per year clocked over the golden age, vs. the lower rates of 1.37 between 1973 and 1995 and 1.71 percent per year between 1941 and 1948.

The seminal studies by Abramovitz (1956) and Solow (1957) showed that, in comparison with the nineteenth century, a large gap opened up in the first half of the twentieth century between the growth of real output and a weighted average of inputs conventionally measured. This gap, termed the "residual", was subsequently interpreted by Abramovitz as reflecting a shift to a knowledge based type of economic development which, from the vantage point of mid-century, was expected to persist (Abramovitz, 1993, p. 224).

By and large it did so for another quarter century. But the 16 year period of slow productivity growth generally dated from 1973 forced, or should have forced, a reassessment of the view that the Abramovitz and Solow studies identified a permanent sea change. The end of century revival of productivity growth, in turn, has focused attention on what caused the growth of the residual to accelerate and how much of it could be laid at the feet of IT.

This paper focuses on three periods in the United States: the two major cycles of the interwar period (1919-29 and 1929-41) and the more recent 1989-2000 period. Rates of labor productivity growth over these three periods were remarkably similar. And if we ignore the inflation spike immediately following the First World War, as well as the deflation between 1929 and 1933, all three were characterized by mild inflation bordering on price stability.

The experience in terms of the economy's capacity utilization and unemployment record was of course quite different. The 1919-29 period, especially after 1922, was one of relatively full employment and the 1989-2000 years encompass the longest expansion in U.S. economic history. But the 1929-41 period brackets the country's worst Depression and highest unemployment rates.

All three periods experienced comparable labor productivity growth rates. The respective contributions of multifactor productivity growth and capital deepening were, however, quite different, as were the sectoral locations of rapid advance. These differences form the principal focus of this paper.

Review of Methods

Output per hour in an economy can be thought of as growing as a consequence of two conceptually distinct forces. The first is capital deepening – which occurs when the flow of physical capital services rises faster than does hours. The causes and effects of capital deepening are a central focus of the Solow growth model: increases in saving rates drive accelerations in accumulation which propel the economy to new steady states in which output, capital, and labor again grow at identical rates, resulting in higher (but ultimately not increasing) levels of output per hour.

The second source of labor productivity growth is the increase in total or multifactor productivity, also known as the residual. The residual reflects the effects of disembodied technical change, learning by doing, improvements in the delivery of services/organization of production, or economies of scale at the aggregate level – all factors which will result in real output growing at a more rapid rate than do inputs conventionally measured. Sometimes the distinction is characterized as that between movements along and shifts of an aggregate production function, a characterization that has particular appeal when the function is rewritten (as it is in the Solow model) as one in which output per worker is a function of capital per worker.

MFP growth is traditionally calculated as the difference between the growth rate of real GDP (or a portion thereof) and a weighted average of labor and capital inputs, the weights corresponding to shares of these factors in national income:

$$(1.1) \quad a = y - \beta k - (1- \beta)n$$

where a, y, k, and n represent continuously compounded average annual growth rates of multifactor productivity, value added, capital services, and hours, respectively, and β is capital's share in national income.[1]

Alternatively, the growth of output can be viewed as the sum of MFP growth and a weighted average of the growth rates of capital and labor services:

$$(1.2) \quad y = a + \beta k + (1- \beta)n$$

A rearrangement of the above equation – subtracting n from both sides -- yields the labor productivity version: growth in output per hour is the sum of MFP growth and capital's share times the rate of capital deepening:

$$(1.3) \quad y - n = a + \beta(k - n).$$

In calculations of MFP, it has become conventional to augment the hours series to take account of improvements in worker quality; absent that adjustment the effect of rising human capital per person will also show up in the residual.

Central to the growth accounting tradition is the distinction between improvements in labor productivity (and ultimately the material standard of living) that come from accumulation, driven by saving, and requiring a trade off of current for future

[1] In the U.S., the government and nonprofit sectors, nonfarm housing, and sometimes agriculture, are often excluded. The Bureau of Labor Statistics provides measures for the Private Domestic Economy and the Private Nonfarm economy, as well as more detailed data using a different methodology for components of the manufacturing sector. For industries at the two and three digit level, a gross output rather than value added measure is used, and purchased materials, energy, and business services are included as inputs along with capital and labor services.

consumption, and those that come from other sources – the residual. Gains from this second source are sometimes referred to as manna from heaven, because they may arise without the same sort of direct sacrifice of current consumption.

Disclaimers

Of course the residual does not literally represent manna from heaven, at least not in its entirety. There are indeed instances in which serendipity or accident leads individuals to stumble upon useful knowledge (one thinks for example of Fleming's discovery of penicillin). But what is picked up in MFP calculations of the type reported in this paper also reflects a variety of related influences, including the effects of scientific and educational infrastructures, specifically targeted research and development, economies of scale and network effects, learning by doing, new organizational blueprints and managerial practices, and increases resulting from the reallocation of inputs from sectors with relatively low value added per worker to those with higher value added per worker. All of these considerations mean that the residual may overestimate the impact on labor productivity of technical change narrowly construed. By technical change I mean the effects on practice of newly available blueprints, not necessarily movement through a set of "known" but progressively more capital intensive techniques made possible by rises in accumulation rates.[2]

---

[2] There is another problem which has been pointed out repeatedly by critics of the growth accounting approach. The Solow formulation requires that technical change be Hicks neutral: increasing the marginal products (and thus returns) to labor and capital in the same proportion. Suppose real capital and labor services are growing at constant but different rates. Hicks neutral technical change would show the combined input measure continuing to grow at a constant rate. But biased change, by altering factor shares, would lead to a reweighting of the input growth rates, increasing or decreasing the rate of growth of the combined input measure used in calculating the residual. The calculated rate of growth of the residual could be increasing or decreasing even though the rate of technical change as well as the input growth rates were constant. One can acknowledge this possibility yet at the same time question how relevant it is for understanding the great questions of twentieth century economic history. Does anyone seriously maintain

There are, however, also a variety of ways in which invention and saving might interact, making it more difficult to maintain the distinction between them as separate and distinct influences on labor productivity, and possibly resulting in an understating of the impact of newly available blueprints. For example the progress of invention might cause factor shares to alter, redistributing income towards capital owners or those more highly educated, who may be wealthier and have higher propensities to save. This would lead to higher saving rates in the absence of changes in the saving preferences of any individual household. Or invention might cheapen the cost of capital goods relative to consumer goods, which would mean that a constant saving share measured in base period prices would produce a larger flow of real investment and saving. (Of course, when reckoned in new prices, saving would be a higher share of GDP, and households would have the option of taking some of these gains as increased consumption, and adjusting their behavior to reestablish the original saving rate.) Finally, invention could, through its effect on the real interest rate, alter the aggregate saving rate,[3] although, as in the case of labor supply, there is the possibility of both income and substitution effects and the empirical evidence with respect to the interest elasticity of saving is mixed. These possible interactions deserve investigation in particular historical contexts in interpreting the decomposition of the forces influencing labor productivity in the Solow growth model and the growth accounting framework with which it is associated.

---

that the differences in MFP growth rates reflected in Table 1 below are principally explicable in terms of alterations in the bias of technical change over the course of the century?

[3] This seems, for example, to be an important part of Abramovitz's account of late nineteenth century development: "In the nineteenth century, technological progress was heavily biased in a *physical* capital using direction. It could be incorporated into production only by the agency of a large expansion in physical capital per worker. And I attribute the dominant importance of nineteenth century capital accumulation as a source of productivity growth in a standard growth account to this fact" or "…in the 1800s, a tangible capital-using bias of technological progress supported a high and rising rate of capital accumulation per worker hour" (1993, pp. 224, 229).

Reflecting these and other considerations, there has been some movement in the literature to blur the distinction between the effects of invention and thrift that appears so sharply in the Solow model. I believe nevertheless that it is worth retaining. In the long run economies do not face an infinitely elastic supply of saving. If an economy is below potential output, it is reasonable to argue that, with accommodative monetary policy, it is investment that constrains saving. By this I mean that increases in planned investment will give rise to the saving flows necessary to finance them, just as will debt financed increases in government spending. The same is true for increases in autonomous consumption, and decreases will do the opposite, leading to the paradox of thrift taught to generations of students of Keynesian macroeconomics.

But these paradoxes are features of the topsy-turvy world of less than fully employed economies. When economies approach their potential output, we move into the world of long term growth. The traditional microeconomic verities again apply. In this world, it is saving behavior that constrains investment. Higher saving rates mean, ultimately, higher capital-labor ratios, higher output per worker and, up to a point, a higher standard of living. Although increases in the saving rate will continue to increase output per worker at a diminishing rate, there is a saving rate beyond which consumption per worker starts to decline absolutely, because of the increasingly voracious claims on output of the depreciation allowances required to maintain the capital-labor ratio at its elevated level.

There exists theoretically an optimal saving rate that maximizes consumption per worker. But the consensus of macroeconomic and growth economists is that most economies remain well below so called golden rule mandates. What this means is that at the aggregate level our achieved standard of living remains constrained not only by our level of scientific and technical knowledge, but also by our willingness to forego current consumption in exchange for higher levels in the future.

Whereas it may be a reasonable abstraction to view subsectors of an economy or particular industries (or even a small open economy) as facing an infinitely elastic supply of capital (or labor) at going rates, it is not reasonable to make this assumption about economies in the aggregate. It may be true, for example, that successful union organizing drives or other (perhaps government mandated) institutional changes in the labor market enable workers in a firm or industry to raise real wages, leading businesses to increase sectoral capital labor ratios. But in the long run the saving to finance this will have to come at the expense of other firms or, in the limit, other countries. So long as we accept the macroeconomic perspective that saving remains an important constraint on growth, and subject to the disclaimers noted above, the distinction between the effects on labor productivity of capital deepening on the one hand and MFP growth on the other is worth retaining.

Finally, to argue that variations in the rate of technological change, understood as the availability of new (and useful) blueprints, are an important proximate cause of twentieth century variations in MFP and labor productivity growth, is not to dismiss the importance of social capabilities and other dimensions of human capital as necessary conditions. Clearly, for example, human capital played a more important role in U.S. economic growth in the twentieth century than it did in the nineteenth. Equally obviously, the history and evolution of legal and political conditions in the U.S. is important in understanding the growth experience of this country relative to others.

Nevertheless, from the vantage point of the end of the twentieth century, the economic history of the United States poses explanatory challenges that were not apparent at mid-century, or even as late as 1973. Whatever may be the limitations of the growth accounting methodology and the statistical apparatus upon which it relies, these sources reveal substantial variations in the rate of growth of MFP during the second half of the twentieth century. The residual largely disappeared between 1973 and 1989, then returned during the 1990s, and this has been only in part the consequence of data refinements. The social capabilities/institutional/human capital factors that have been used to contrast and explain differences between nineteenth and twentieth century growth prior to 1973 don't change or don't change enough or quickly enough to account for this disappearing and reappearing act. Recent economic history requires us to take another look at a more traditional explanation: the likelihood that accelerations and decelerations in the flow of newly available and useful blueprints have been important contributors to these variations, and not just in the post 1973 period.

Multifactor (Total Factor) Productivity vs. Labor Productivity Growth

The primary focus in this paper is on total or multifactor productivity (MFP) rather than labor productivity growth. This is not because MFP growth is inherently more germane to living standard improvement. Obviously labor productivity growth has the more direct relationship to growth in output or consumption per capita. It is rather because economic growth in the Depression years is entirely a story about MFP, and because the main differences in rates of labor productivity growth in the postwar period have turned on differences in MFP growth rates. This is true both for the deceleration between 1948-73 and 1973-95 and the acceleration comparing 1973-95 with 1995-2000.

For the private nonfarm economy, capital services grew at virtually the same rate comparing 1948-73 with 1973-95 (3.90 vs. 3.94 percent per year respectively), but hours grew more rapidly in the latter period (1.58 vs. 1.22 percent per year) as a result principally of an upward trend in hours per worker between 1973 and 1995. The consequence was that the rate of capital deepening slowed somewhat, from 2.68 percent per year over the years 1948-73 to 2.36 percent per year between 1973 and 1995.[4]

But it was vanishing MFP growth rather than this mild slowdown in capital deepening that was the principal cause of the halving of the growth rate of output per hour in comparison with the 1948-73 period. If we assume a capital share of .31,[5] this .32 percentage point slowdown in the rate of capital deepening should have caused a modest .10 percentage point (.31*.32) slowdown in growth of output per hour. In the event, this was just about exactly offset by a rise in the rate of increase of labor quality.[6] Considering the effects of changes in rates of capital deepening and improvements in labor quality alone, there should have been no change in the rate of increase of output per hour between the two periods.

---

[4] Bureau of Labor Statistics, series MPU750024 (real value added output), MPU750025 (capital services), and MPU750027 (capital services per hour). The implied unadjusted hours series is derived by dividing the capital services index by the index of capital services per hour; the same result is obtained by dividing series MPU750021 (output per hour), by real value added output. All of these data are from the BLS website and are summarized in Appendix Table A-1.

[5] The capital shares used by the BLS in constructing its combined input measure were .3188 for 1948, .2938 for 1973, and .3268 for 1995. The BLS includes in labor's share compensation of employees and a portion of noncorporate income received by self employed persons. See Bureau of Labor Statistics, Handbook of Methods (1997), p. 93.

[6] Adjusted labor hours grew .23 percentage points faster than hours between 1948 and 1973; between 1973 and 1995 they grew .40 percentage points faster. So we have a .17 percentage point acceleration, which represents the difference in the growth rates of an index of labor quality between the two periods. When multiplied by labor's share, this difference yields a contribution to growth of output per hour of about +.12 (.69*.17) percentage points. Why labor's share? If we think of the growth of effective labor input as consisting of the sum of n and n*, where n is the growth of raw hours and n* is the growth of the quality index, then in moving from equation 1.2 to equation 1.3, we will end up with $y - n = a + \beta(k - n) + (1 - \beta)n^*$.

In fact, growth of output per hour fell 1.51 percentage points (see Table 1 below), almost exactly equivalent to the percentage point decline in the MFP growth rate between the two periods.[7]

Comparing the recent 1995-2000 episode with the 1973-95 years, almost three fourths of the acceleration in labor productivity growth was due to MFP acceleration, as opposed to a rise in the rate of capital deepening. The contribution to output per hour growth of labor composition change was about the same during the two periods (slightly lower between 1995 and 2000). Comparing 1995-2000 with 1973-95, capital services growth accelerated from 3.94 percent per year to 5.38 percent per year. Growth in hours rose from 1.58 to 2.09 percent per year. As a result, the rate of capital deepening did increase from 2.36 to 3.28 percent per year between 1995 and 2000.

But again, assuming a capital share of .32,[8] this .92 percentage point increase should have accounted for an increase in the growth of output per hour of a modest .29 percentage points. In fact the growth of output per hour rose 1.10 percentage points, from 1.37 to 2.47 percent per year. Almost all of the balance was due to MFP acceleration.[9]

---

[7] Output per hour is commonly reported using unadjusted hours, whereas the combined input index used in the MFP calculation is based on capital services and an *adjusted* labor input series, with adjustments made for the changing demographic and educational characteristics of the labor force. Alternately, converting everything to an adjusted hours basis, we can calculate a .49 percentage point decline in the rate of capital deepening (capital growth less adjusted hours growth), comparing 1973-95 with 1948-73. The decline in the rate of capital deepening alone should have been responsible for a .15 percentage point decline in the growth in output per adjusted hour. Adding in the decline in MFP growth we conclude that output per adjusted labor hour should have fallen a total of 1.67 percentage points (.15+1.52). Calculating such an index (see Appendix Table 1) yields a percentage point decline in growth in output per adjusted hour within the two periods of 1.66 percentage points (2.64 percent per year to .98 percent per year); the difference is attributable to rounding error.

[8] BLS capital share for 1995 is .3268; for 2000, .3109.

[9] Alternately, converting everything to an adjusted hours basis, we can calculate a 1.06 percentage point increase in the rate of capital deepening (capital growth less adjusted hours growth), implying the increase in the rate of capital deepening should have been responsible for a .36 percentage point increase in the growth in output per adjusted hour (.34*1.06). Adding in the increase in MFP growth (.76 percentage

I will return later to the question of possible linkages between technical change and accumulation rates, and whether reckoning the impact of technical advances associated, for example, with the IT revolution, should include the effects on labor productivity of that portion of capital deepening associated with the accumulation of IT capital goods.

Overview of Twentieth Century Growth Trends

A central aim of this paper is to place recent developments within a frame of reference that extends back to 1929 and then to the end of the First World War. For the moment, let's look forward from 1929. With some simplification the labor productivity growth history of the United States between 1929 and 1995 can be thought of as consisting of three periods in which the respective contributions of MFP growth and capital deepening were quite distinct. The years 1929-1948 witnessed exceptionally high rates of MFP growth, but very little capital deepening. Indeed, for the U.S. private nonfarm economy, the twelve year period 1929-41 experienced capital shallowing, but nevertheless the *highest MFP growth rates in the century.*

Between 1948 and 1973 lower but still respectable MFP growth combined with a revival of physical capital deepening to produce the highest rates of *labor productivity growth* in the century, and a golden age of living standard improvement. Between 1973 and 1995, as discussed, capital deepening continued at somewhat slower rates but multifactor productivity growth in the U.S. economy effectively disappeared. Labor productivity rose, but at greatly reduced rates (1.37 percent per year) compared with the 2.88 percent annual growth clocked during the golden age (see Table 1; data is for the private nonfarm economy). At the end the century, labor productivity growth again

---

points) we conclude that output per adjusted labor hour should have increased a total of 1.10 percentage points (.36.+.76).

approached golden age rates, principally as the result of a revival of MFP growth. Between 1989 and 2000, growth of output per hour was 1.92 percent per year; measuring from 1995 to 2000, 2.47 percent per year.

Looking back over these decades, the most remarkable period of labor productivity advance has not been the five years at the end of the century, nor was it the golden age. It was the twelve year period between 1929 and 1941, during which, in the absence of capital deepening, output per hour grew at rates almost as high as during the golden age. To the degree capital grew more slowly than hours, labor productivity should have *fallen*. But in fact it rose sharply, because of an extraordinarily high rate of MFP growth.

Table 1
Compound Annual Growth Rates of MFP, Labor, and Capital Productivity
Private Non-Farm Economy, United States, 1889-2000

	MFP	Output/Hour	Output/Adjusted Hours	Output/Unit Capital Input
1889-1901	2.21	2.20	2.79	.52
1901-19	1.08	1.71	1.44	.01
1919-29	2.02	2.27	2.33	1.09
1929-41	2.31	2.35	2.21	2.47
1941-48	1.29	1.71	1.42	1.32
1948-73	1.90	2.88	2.64	.18
1973-89	.34	1.34	1.03	-1.24
1989-2000	.78	1.92	1.41	-.61
1973-95	.38	1.37	.98	-.98
1995-2000	1.14	2.47	2.08	-.84

Note: Output per adjusted hour uses an hours index that has been augmented to reflect changes in labor quality or composition. In creating this index, different categories of labor are weighted by their respective wage rates.
Sources: 1889-48: Kendrick (1961), Table A-XXIII. The unadjusted data are from the column headed output per man hour, the adjusted data from the column headed output per unit of labor input. Capital Productivity is output per unit of capital input.
1948-2000, Bureau of Labor Statistics www.bls.gov, series MPU750021, MPU750023, MPU750024, and MPU750028. These data are from the multifactor productivity section of the website, accessed April 12, 2004. The labor productivity section contains more recent data and is updated more frequently

Over that 12 year period, labor and capital input were basically unchanged from 1929, give or take a couple of percent. Quality adjusted labor input rose at .12 percent annually (manhours declined slightly); while capital input declined at -.13 percent annually. Real output, however, rose 32.3 percent, (2.33 percent annually). Virtually all of the growth in output and in output per hour was due to multifactor productivity growth. Even though the depression experienced a collapse in private capital formation, labor productivity rose faster in the 1929-41 period (2.35 percent annually) than it had in the 1920s (2.27 percent annually), and much faster than it did over the years 1941 to 1948 (1.71 percent) (Kendrick, 1961, Table A-23; see Table 1 above).

Selective Retention and other Factors Influencing Labor Quality

A number of economists and economic historians have remarked on the high rate of labor productivity and real wage growth during the Depression years, and asked how it was that high unemployment coincided with stable or increasing real wages (see, e.g., Margo, 1993, p. 43). A common explanation for why wages increased as employment fell has been selective retention. As demand declined, firms laid off their less skilled workers, and within occupational categories, they laid off their poorer performers, a selectivity that improvements in personnel and human resource management made it easier for employers to practice. Thus the high and rising wages that appear to have accompanied the downturn were largely a compositional effect (Margo, 1991, p. 341).

The type of effect Margo describes, however, is a cyclical phenomenon, not relevant in explaining labor productivity or wage growth between peaks of a business cycle. As one comes out of a downturn, these effects would simply be unwound as labor markets tightened and the more marginal members of the labor force were rehired. In fairness to the selective retention hypothesis, 1941 still had 9.9 percent unemployment, compared with 1929 which had less than 4 percent. 1941 is far better than 1937 or 1940 in this regard, but not ideal. For the purposes of my research I would in retrospect have been grateful had the Japanese delayed by 8 – 12 months their attack on Pearl Harbor, so that the U.S. economy could have returned to full employment, as it was in the process of rapidly doing, prior to full scale war mobilization. But of course this did not happen, so some of what we observe in measured growth between 1929 and 1941 could be the result of selective retention. This assumes that we view the early years of the Depression to have been sufficiently severe so that firms abandoned any attempt to profit from labor hoarding of workers with specific human capital – a phenomenon that can impart a procyclical trend to measured labor productivity.

There are a number of reasons to doubt whether improvements in labor quality resulting from the operation of the mechanisms described by Margo were a large or dominant influence on growth in output per hour or the residual over the longer haul. Suppose we view members of the labor force, within categories, lined up in order of "quality", and fired and hired according to this ranking. If selective retention were the only, or the dominant force operative, we should have gotten progressively smaller boosts in labor productivity as employment rose and the unemployment rate fell. As we came out of the deep trough reflected in the 19.1 percent unemployment of 1938, the increment to output per hour as the unemployment rate went down over a two year period to 14.6 percent should have been greater than that obtained in going from 14.6 percent in 1940 to 9.9 percent in 1941. In fact, as can be seen in Table 2, the reverse was true, even allowing for the slightly larger percentage point decline in the unemployment rate between 1940 and 1941 as compared with 1938 to 1940.[10] Output per hour rose 6.59 percent between 1940 and 1941 as compared with 4.18 percent between 1938 and 1940.

Table 2
Recovery and Growth in Output per Hour, 1938-1941

	Unemployment (percent)	Output per Hour	Output per Unit of Labor Input	Output per Unit of Capital Input
1938	19.1	119.4	120.2	99.9
1939	17.2	123.6	123.7	110.7
1940	14.6	124.4	124.4	116.4
1941	9.9	132.6	130.3	134.5

Notes: For indices in columns 2-4, 1929=100.
Source: Kendrick (1961, Table A-XXIII).

A second factor that could have influenced labor productivity growth over the Depression years, not subject to this same critique, is secular improvement in the educational qualifications of the labor force. Goldin has called attention to the very rapid rise in high school graduation rates during the 1930s; graduation rates common in the 1930s were not exceeded until the 1960s (Goldin, 1998, p. 359). As can be seen from the data on R and D employment (Table 6 below), demand for scientific and technical personnel was very strong during the Depression, consistent with the evidence Margo has collected that managerial, scientific, and professional status or higher years of schooling provided substantial protection against unemployment during these years. The opportunity cost of high school attendance was also much lower during the 1930s, since the likelihood of unemployment as a young worker without a high school degree was considerably higher than it had been in the previous decade.

[10] One might ask, why not measure into 1942, as unemployment continued to decline? The problem is that output per hour is affected during that year by the temporary negative supply shock associated with conversion of civilian to war production.

All of these factors played a role in explaining the rise in high school graduation rates, which I interpret in part as a response to the interaction of forces on the aggregate supply side that engendered rising demands for technical, managerial, and scientific personnel and aggregate demand conditions which had knocked the bottom out of the low education-low skill sector of the labor market. By the end of the 1930s, the U.S. was also benefiting from the influx of highly educated Europeans fleeing Hitler.

Still, I am skeptical that labor quality improvements, whether they represented secular trends or the tail end of a process of selective retention, played a large role in explaining the growth in labor productivity between 1929 and 1941.[11] One way to get a fix on how much of the growth in output per hour might have been due to labor quality improvement between 1929 and 1941 is to look at the difference in that calculation when one substitutes in the denominator an index of "adjusted" labor hours (column 3 as compared with column 2 of Table 1). This index is constructed weighting different occupational or industry categories by their respective wage rates. Kendrick's data show that although "raw" hours declined slightly between 1929 and 1941, augmented hours rose slightly, at about .12 percent per year. As a consequence, output per hour growth is lower over this period using adjusted as opposed to unadjusted hours (see Table 1, columns 2 and 3). How much lower? About 6 percent.

It may be that Kendrick's adjustments are insufficient, but this calculation confirms my sense that the effect of labor quality improvement on growth in output per hour or MFP growth over the entire period 1929-41 were dwarfed by some of the other forces described in this work. Writing in 1993 Margo accepted the conventional wisdom

[11] This is not to dismiss the likelihood that levels of human capital formation help explain the greater technological progressivity of the U.S. as compared with other countries during these years.

that technical change during the Depression was "concentrated in a few industries and modest overall" (1993, p. 49). The extent to which growth in output per hour and, perforce, wages, is attributable to very rapid growth in economy-wide MFP has not been fully appreciated, even by those labor economists aware of the trends in hourly wages and labor productivity.

Capital Productivity

It is also important in thinking about what lies behind the high MFP growth rates in the Depression years, and the interwar period more generally, to consider the growing importance of capital saving technical change, its effect on capital productivity and, consequently, its contribution to the growth of the residual. During most of the nineteenth century, at least up to 1889, as well as the last quarter of the twentieth, the capital output ratio rose along with capital deepening (rises in the capital labor ratio), which is another way of saying that capital productivity fell. A rearrangement of equation 1.1 shows that whereas labor productivity rises as the result both of the growth of the residual and of capital deepening, capital productivity rises with the residual but falls with capital deepening. Diminishing returns implies that, ceteris paribus, equal percentage increases in capital per hour result in progressively smaller increments to output per hour.

(1.4) $y - k = a - (1 - \beta)(k - n)$.

This rise in the capital output ratio with capital deepening, or, equivalently, the decline in capital productivity, can be partially or even totally offset by growth of the residual. The Solow model without technical change but with accumulation implies that increases in the saving rate will produce a rise in the capital output as well as the capital labor ratio in the new steady state. With technical change, however, the capital output ratio may rise, stay the same, or fall. While capital productivity will be positively affected by any type of technical advance that increases the residual, capital saving technical change has a particularly powerful impact in this regard, because, in contrast with labor saving change, it attenuates rather than strengthens the incentives to accumulate new physical capital.

As column 4 of Table 1 shows, capital productivity in the private nonfarm economy registered a moderate upward trend between 1889 and 1901. Since capital productivity in manufacturing continued to decline over this period (see Table 5 below), the increase in the larger aggregate would have had to have been driven by improvements in output per unit of capital input in other parts of the economy. Transport and public utilities and wholesale and retail distribution, which benefited from the integrated use of new communication technologies and modern business enterprise, are likely candidates.

Capital productivity was effectively stationary between 1901 and 1919. It jumped upward between 1922 and 1923, stayed at higher levels through the 1920s, retreated during the early 1930s, but then took another big upward leap at the end of the 1930s (Kendrick, 1961, Table A-XXIII). As a consequence, and by a wide margin, 1929-41 registers the highest rates of capital productivity advance of any of the periods between 1889 and 2000 examined in Table 1. BLS data show a very slight upward trend continuing between 1948 and 1973, then decline between 1973 and 1989, and continued decline, although at a reduced rate, through the end of the century. Trends in the capital output ratio, of course, were exactly the reverse.

Equation 1.5, a rearrangement of 1.4, shows that while growth of the residual positively affects growth rates of both labor and capital productivity, it is in turn, arithmetically, a weighted average of the two. In exploring this relationship using the data in Table 1, one should keep in mind that it is output per adjusted labor hour that is used in the MFP calculations.

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

MFP growth associated with rising capital productivity reflects in part capital saving technological and organizational advances that increase the utilization rates of fixed or variable capital. In the case of inventories this means faster rates of turnover; in the case of fixed capital (structures or equipment), higher average utilization rates. In each of these instances, the cost of holding a unit of capital is spread over a larger flow volume of output, and in each of these instances, the effect is to lower the capital-output ratio, because the denominator rises faster than the numerator.

One of the most important capital saving innovations of the nineteenth century was the telegraph, an innovation that helped make possible the development of modern business enterprise (see Field, 1987, 1992a). Capital saving technological and managerial innovations contributed to moderating the tendency of the capital output ratio to rise in the face of massive infrastructural spending (and capital deepening) associated with railway construction. By the end of the nineteenth century (1889-1901), the effects of such innovations enabled the ratio actually to begin to decline. The ratio was then roughly stable through the end of the First World War. Beginning in the 1920s, however, and at an accelerating pace during the Depression years, it plunged.

The improvements in capital productivity in the private nonfarm economy during the 1920s were entirely driven by advance in manufacturing. Table 5 shows output per unit of capital in manufacturing to have risen at 4.20 percent per year between 1919 and 1929, whereas Table 1 shows capital productivity in the PNE increasing at 1.09 percent per year. Taking manufacturing's end period share of the PNE to have been .33, we can calculate that manufacturing contributed 1.39 percentage points to capital productivity growth in the PNE. This means that growth of output per unit of capital input in the rest of the economy had to have been negative during this period.

Between 1929 and 1941 growth in capital productivity in manufacturing remained above the PNE average, but the differential was much less than in the 1920s (2.92 percent per year in manufacturing vs. 2.47 percent per year in the rest of the economy). This reflects very substantial improvements in capital productivity in the rest of the economy – particularly transportation and distribution – in comparison with the 1920s. Improvements in output per unit of capital input are a big part of the interwar story. Economic historians who have cut their teeth on nineteenth century analysis, when capital saving innovation was on the whole relatively less important, should be aware of its growing significance in the twentieth, particularly in the second quarter of the century.

The Rise in Output per Hour: Causes and Consequences

We return now to consideration of trends in output per hour, which of course has the more direct welfare implications. A comparison of columns 2 and 3 of Table 1 suggests that improvements in labor quality can explain perhaps 6 percent of the growth in output per hour between 1929 and 1941. Clearly other factors had to have been operative, and among these was not physical capital deepening. What remains? In an article published in 2003 in the American Economic Review, I argued that the period from the end of the 1920s boom to the start of the Second World War was in fact the most technologically progressive of any comparable epoch in the twentieth century. My argument is based on comparing MFP growth rates over these different periods and is thus subject to all of the disclaimers noted above. Whatever interpretation one gives to it, however, there is no debating that MFP growth over the Depression years was remarkable.[12] For the private nonfarm economy, multifactor productivity grew at a continuously compounded rate of 2.31 percent per year over the twelve year period 1929-41. This compares with a rate of 2.02 percent per year between 1919 and 1929 and 1.29 percent per year between 1941 and 1948.

Since there was virtually no increase in private sector inputs conventionally measured between 1929 and 1941, MFP advance accounted for *all* growth in real output over those years. For the private nonfarm economy, Kendrick's index of total factor input (including an adjustment to hours for labor quality change) stood at 100.0 in 1929 and 100.2 in 1941. The index of real output, on the other hand, rose from 100.0 to 132.3 (Kendrick, 1961, Table A-XXIII, pp. 339-340). Behind the continuing levels of high unemployment an unprecedented expansion of the ability of the U.S. economy to produce was taking place place.

As noted, all of the labor productivity growth between 1929 and 1941 (see Table 1) is attributable to MFP growth. This contrasts with other periods of comparable labor productivity growth such as 1919-1929 or 1995-2000, during which tangible capital

[12] Some scholars restrict the term Depression to the years 1929-33. As a terminological matter, I view the Depression to have extended over the 12 year period 1929-41; over these years output was persistently depressed below its potential. If one wishes to refer to 1933 and after as recovery, I prefer to call 1929-33 the downturn.

deepening also played a role. Capital deepening played no role in labor productivity advance between 1929 and 1941, or rather, it played a negative one, since this was an unusual period in U.S. economic history characterized by capital shallowing.

My article was provocatively titled "The Most Technologically Progressive Decade of the Century", and when I advanced this thesis, many people asked, with a certain degree of incredulity (although less now than when the NASDAQ was above 5,000), whether this claim included consideration of the "New Economy" boom of the 1990s. The short answer is that it does.

The upwardly spiraling equity valuations of the 1990s were propelled by human fallibility and one of the most formidable marketing machines ever assembled in this country. With assists from research departments of brokerage firms, IT companies celebrating their own prospects, independent public relations firms, radio, television and print media and, at times, government officials and academic economists, massive quantities of warm air continuously fanned speculative fires fueled by dreams of Dow 36,000. For better or for worse, the drum beat lead to a major reorganization of the Federal government's statistical apparatus in an effort to make it more sensitive to the possible contributions of the IT revolution to growth.

But the twentieth century is over, and the NASDAQ in August of 2004 remains below 2,000. The returns are in, and this is the reality: During the last decade of the twentieth century, revolutionary technological or organizational change – the sort that shows up in MFP growth -- was concentrated within distribution, securities trading, and a narrow range of industries within a shrinking manufacturing sector. MFP advance within industry was largely localized within the old SIC 35 and 36,[13] sectors that include the production of semiconductors, computers, networking, and telecommunications equipment. If one is a booster of IT and its putative role in improving living standards the good news is that a fairly high fraction of the recent acceleration in aggregate MFP growth is probably attributable to the enabling technologies of the IT revolution. The bad news is that aggregate MFP growth remained, even at the end of the twentieth century, fairly modest by historical standards. I estimate IT's contribution to labor productivity growth between 1995 and 2000 to have been a little over a quarter of the total (see the last part of this paper). The estimate is quite sensitive both to the conceptual framework one adopts and to how much MFP growth one finds outside of manufacturing and how much of it one is prepared to attribute to IT. Recent evidence suggests that we may finally be getting more substantial MFP payback in the IT using sectors (Wall Street Journal, November 7, 2003). The latest BLS data suggest that labor productivity grew at 2.93 percent per year continuously compounded from 1995 to 2003 (129.1 over 102.1; BLS series PRS85006093).

But the staying power of recent trends remains uncertain and there have been many, many false alarms over the past decade. We do not yet have MFP estimates beyond 2001 so it is not clear how much of this might be due to an increase in the labor composition contribution due to selective retention during a recession (which would not persist at this rate through a full recovery), or how much the capital deepening contribution may have changed since the heady days of 1995-2000. Capital services grew at 5.38 percent per year between 1995 and 2000, and their rate of increase has certainly slowed. But hours,

[13] The Standard Industrial Classification (SIC) codes are being replaced in post 1997 reporting with North American Industrial Classification System (NAICS) codes, but I will use the older vocabulary throughout this paper.

which grew at over 2 percent per year between 1995 and 2000, declined at -1.72 percent per year between 2000:3 and 2003:3. Until we have the capital services numbers we can't know what has happened to the capital/hours ratio, but it seems likely that it has risen. We will really need to have the economy approach closer to potential output, and have the data for it, before we can have a clearer picture of the sustainability of these recent trends.

The facts of the matter are that measuring from 1995 through the end of the boom in 2000, aggregate MFP growth, including that in the IT using sectors, although high in comparison with 1973-1995*, was less than half that registered between 1929 and 1941* (see Table 1). Measuring from 1989 to 2000, the more methodologically defensible interval, MFP growth was more than twice what it was between 1973 and 89, but less than a third the rate evidenced between 1929 and 1941.

Why 1989? And why 2000? Multifactor productivity data is available only on an annual basis. According to the NBER business cycle chronology, the peak of activity in July of 1990 was followed by a recession which bottomed out in March of 1991 followed by the long expansion of the 1990s, culminating in the peak 120 months later (March of 2001). But 2001 was also a year of economic downturn, with the trough reached only eight months afterwards in November of 2001. Similarly, 1990 included five postpeak months. Since we are using annual data, I measure from the last full year of expansion (1989) before a downturn to the next last full year of expansion before a downturn (2000).[14]

---

[14] The story told here is not especially sensitive to using 1990 rather than 1989 (the level of MFP in the private nonfarm economy was identical, so the annual rates calculated would rise a bit if we measured from 1990) although choosing 2001 rather than 2000 would reduce the calculated growth rates, since MFP fell between 2000 and 2001.

It is well known that MFP and labor productivity grew at an accelerated pace during the second half of the 1990s, and it has become conventional to measure to and from 1995, even though the year was not a business cycle peak. The argument against 1995 is that it is not a peak, a point reflected in the controversy surrounding Gordon's claims that much of the end of century improvement reflected cyclical acceleration in both labor and multifactor productivity common in later stages of a business expansion (Gordon, 2003). Nevertheless, there does seem to be a break in the series circa 1995, and, in deference to current practice, I also report MFP advance over the last five years of the century. Here the compound average annual growth rate comes in at 1.14 percent per year. This is three times the anemic MFP growth registered between 1973 and 1995. But it is still substantially below golden age rates and, even more remarkably, *less than half the rate registered between 1929 and 1941*.

We have been holding our breath for a long time to see if the IT using sectors, especially wholesale and retail distribution, finance, insurance, and real estate, transportation, and some of the other service sectors would finally begin to throw off MFP growth in a way that would systematically bolster aggregate labor productivity growth in these sectors beyond what we should expect from capital deepening alone. Possibly, we can now exhale. The evidence, which I will discuss below, is strongest for wholesale and retail distribution and securities trading. Nevertheless, even allowing for some acceleration in MFP growth in the IT using sectors, the latest available data have yet to show rates of MFP advance for the private nonfarm economy approaching those registered during the 1930s.

The 1930s were characterized by systematic advances across a broad frontier of the economy, including manufacturing, which was then more than twice as large as a fraction of national income; transportation, communication and public utilities; and to a lesser degree, wholesale and retail distribution. The technological underpinnings of the new economy of the 1990s have been more modest in the aggregate and more narrowly concentrated in specific subsectors. We need to place recent progress within a more comprehensive historical perspective than can be obtained simply by looking back to 1973, or even to 1948.

Changes in Economic Structure

We begin by examining how the structure of the economy in 2000 differed from what it had been earlier in the century. Table 3 reports sectoral shares of current dollar national income (1929, 1937, 1941) or value added (1948, 1973, 2000) for the United States at selected business cycle peaks between 1929 and 2000. Let's look first at the postwar data, for which we have a more detailed breakdown (I have bolded lines that warrant particular attention). The first conclusion is that the shares of all of the commodity or goods producing sectors of the economy, with the exception of construction, have fallen dramatically. Between 1948 and 2000, agriculture dropped from almost 9 percent of national income to under 1.5 percent, mining from 3.5 to 1.4 percent, and manufacturing from 27.8 percent to 15.5 percent (the share of manufacturing in value added in the U.S. today is approximately what it was in 1850). The bulk of the drop in manufacturing's share occurred after 1973.

Within manufacturing, declining shares are evident at the two digit level pretty much across the board, and are especially notable in primary metals, textiles, apparel, and

Table 3
Sectoral Shares, United States, 1929-2000

	1929	1937	1941	1948	1973	2000
	Share of National Income			Share of Value Added		
Agriculture, forestry, and fishing	**9.79**	**10.31**	**8.06**	**8.89**	**3.97**	**1.37**
Farms...				8.63	3.59	0.79
Agricultural services, forestry, and fishing...				0.27	0.38	0.58
Mining	**2.42**	**2.71**	**2.30**	**3.50**	**1.73**	**1.36**
Metal mining..................................				0.37	0.14	0.05
Coal mining...................................				1.02	0.27	0.09
Oil and gas extraction........................				1.90	1.12	1.08
Nonmetallic minerals, except fuels............				0.21	0.20	0.12
Construction	**4.38**	**2.85**	**4.03**	**4.27**	**5.07**	**4.70**
Manufacturing	**25.23**	**26.46**	**31.86**	**27.76**	**23.24**	**15.47**
Durable goods.................................				14.17	14.15	9.02
Lumber and wood products....................				1.13	0.83	0.43
Furniture and fixtures......................				0.45	0.37	0.27
Stone, clay, and glass products.............				0.89	0.80	0.41
Primary metal industries....................				**2.29**	**1.82**	**0.51**
Fabricated metal products...................				1.83	1.78	1.12
Machinery, except electrical................				2.49	2.61	1.76
Electric and electronic equipment............				**1.61**	**2.05**	**1.65**
Motor vehicles and equipment................				1.71	1.83	1.23
Other transportation equipment...............				0.75	1.04	0.67
Instruments and related products............				**0.40**	**0.64**	**0.65**
Miscellaneous manufacturing industries.......				0.62	0.40	0.33
Nondurable goods..............................				13.59	9.09	6.45
Food and kindred products...................				3.80	1.97	1.29
Tobacco products............................				0.65	0.33	0.22
Textile mill products.......................				**1.95**	**0.74**	**0.24**
Apparel and other textile products...........				**1.36**	**0.78**	**0.25**
Paper and allied products...................				0.98	0.92	0.61
Printing and publishing.....................				1.31	1.18	1.08
Chemicals and allied products................				**1.62**	**1.78**	**1.72**
Petroleum and coal products.................				0.88	0.43	0.39
Rubber and miscellaneous plastics products...				**0.56**	**0.77**	**0.60**
Leather and leather products.................				**0.48**	**0.18**	**0.04**
Transportation and public utilities	**10.83**	**9.91**	**9.21**	**8.81**	**8.64**	**8.24**
Transportation................................				5.79	3.85	3.19
Railroad transportation.....................				**3.27**	**0.88**	**0.25**
Local and interurban passenger transit.......				0.66	0.22	0.19
Trucking and warehousing....................				1.03	1.61	1.26
Water transportation........................				0.42	0.23	0.15
Transportation by air.......................				**0.18**	**0.65**	**0.94**
Pipelines, except natural gas................				0.10	0.11	0.06
Transportation services.....................				0.13	0.15	0.35
Communications................................				1.40	2.43	2.84
Telephone and telegraph......................				**1.30**	**2.23**	**2.12**
Radio and television........................				**0.10**	**0.19**	**0.72**
Electric, gas, and sanitary services...........				1.61	2.36	2.20

Wholesale and Retail Trade	**15.55**	**16.82**	**16.70**	**17.96**	**16.52**	**16.12**
Finance, insurance, and real estate	**14.75**	**9.91**	**8.93**	**9.78**	**13.68**	**20.12**
Banking......................................				1.07	1.70	3.68
Credit agencies other than banks...............				0.13	0.24	0.71
Security and commodity brokers.................				0.13	0.31	1.54
Insurance carriers............................				0.82	1.18	1.86
Insurance agents, brokers, and service...........				0.27	0.46	0.63
Real estate...................................				7.33	9.77	11.44
Nonfarm housing services				**4.54**	**7.01**	**8.26**
Other real estate...........................				2.79	2.76	3.18
Holding and other investment offices...........				0.04	0.03	0.28
Services	**10.14**	**10.18**	**8.54**	**8.13**	**11.81**	**21.54**
Hotels and other lodging places................				0.61	0.61	0.89
Personal services.............................				1.17	0.74	0.60
Business services				**0.61**	**1.84**	**5.44**
Auto repair, services, and parking.............				0.35	0.68	0.97
Miscellaneous repair services.................				0.28	0.27	0.28
Motion pictures...............................				0.47	0.19	0.33
Amusement and recreation services.............				0.46	0.46	0.78
Health services				**1.54**	**3.17**	**5.58**
Legal services................................				**0.45**	**0.75**	**1.37**
Educational services..........................				0.34	0.72	0.79
Social services...............................				0.05	0.27	0.69
Membership organizations......................				0.52	0.69	0.63
Miscellaneous professional services............				0.40	1.08	3.06
Private households............................				0.88	0.35	0.14
Statistical discrepancy.........................				-0.28	0.58	-1.31
Government.......................................	**5.88**	**10.58**	**10.08**	**11.17**	**14.77**	**12.39**
Federal..				**6.88**	**6.16**	**3.97**
General government.............................				6.37	5.51	3.29
Government enterprises........................				0.51	0.65	0.67
State and local................................				**4.30**	**8.60**	**8.43**
General government.............................				3.77	7.89	7.72
Government enterprises........................				0.52	0.71	0.71

Sources: 1929, 1937, 1941: Historical Statistics of the United States, Series F 226-237,
National Income by Industrial Origin in Current Prices, volume 1, p. 239.
Shares are of national income originating in the sector as a percent of total national income.
1948, 1973, 2000: U. S. Bureau of Economic Analysis, www.bea.gov
Gross Product Originating By Industry
Shares are value added by the sector as a percent of gross domestic product
Industry assignment for 1948 and 1973 based on 1972 Standard Industrial Classification categories.
Industry assignment for 2000 based on 1987 Standard Industrial Classification categories.

leather goods, sectors which either shrank dramatically, demanded and received protection from foreign competition, or both. At the two digit level the only sectors to buck the trend were instruments and related products, electric and electronic equipment, chemicals and allied products, and rubber and miscellaneous plastic. All four had higher shares than they did in 1948, although all but the first have been declining in share since 1973. Three other sectors: non-electrical machinery, motor vehicles and equipment, and other transport equipment, increased in share between 1948 and 1973, but then declined rapidly, so that their 2000 shares were significantly below those in 1948.

If one looks back at prewar numbers, it is clear that in 1941 manufacturing's share of national income – almost 32 percent -- was close to its all time peak (it would rise further, but only temporarily, during the war). Today (2004) its share is barely above 14 percent. Yet a great deal of economic analysis continues to be written based on the history of manufacturing alone. Partly it's because we have more detailed data for this sector and because, as Griliches argued, productivity advance may be easier to measure in the goods producing sectors (Griliches, 2000). But we need to be careful how many times we justify searching for our keys under the lamppost simply because the light there is better.

If we are discussing contributions to achieved productivity levels in the interwar period, it is appropriate to place primary although not exclusive emphasis on a growing manufacturing sector that by 1941 comprised almost a third of the economy. I estimate that 85 percent of MFP growth in the private nonfarm economy between 1919 and 1929 and about 48 percent of the growth between 1929 and 1941 originated in manufacturing (see below). For 1995-2000, manufacturing's contribution was about 39 percent of total

MFP growth, but that total and manufacturing's percentage point contribution to it were much smaller than was true in the interwar period.

We need to be cautious in expecting large contributions to aggregate productivity growth from the operation of Moore's Law in the IT producing sectors, which straddle a couple of two digit industries within durable manufacturing within a shrinking sector that today contributes less than a sixth of total value added in the economy. And although these industries grew in size in the second half of the 1990s, they are still small in the aggregate. Even with exceptionally high rates of within sector MFP growth, much more of the action must come from the IT using sectors, whether the growth is to be attributable directly to IT investments or not. That is why developments in wholesale and retail distribution, for example, are so critical for aggregate trends in the United States, as well as in understanding comparative productivity performance in different countries.

Nevertheless, let's take a disaggregated look at MFP growth within manufacturing (Table 4). Table 4 shows that whereas MFP growth rates were roughly comparable in durables and nondurables between 1949 and 1973 (1.48 vs. 1.32 percent continuously compounded) MFP advance virtually disappeared in nondurables between 1973 and 1995, aside from textiles. There is a modest acceleration between 1995 and 2000 led by advance in leather goods and apparel, but these sectors were trivially small by the end of the century (see Table 3). The record in durables over the last quarter of the century is not a whole lot better, with the notable exceptions of SIC 35 and 36, where we see accelerating growth and the impact of revolutionary change in the IT producing industries.

Table 4
MFP Growth Within Manufacturing, United States, 1919-2000

SIC		1919-1929	1929-1948	1949-1973	1973-2000	1973-95	1995-2000
SIC	Manufacturing	5.12	1.71	1.52	0.93	0.66	2.09
	Durable goods.................................	5.06	1.43	1.48	1.57	1.19	3.27
24	Lumber and wood products.....................	2.49	1.42	1.67	0.65	0.98	-0.78
25	Furniture and fixtures......................	4.14	2.00	0.60	0.74	0.69	0.96
32	Stone, clay, and glass products.............	5.57	2.09	1.09	0.51	0.49	0.57
33	Primary metal industries.....................	5.36	1.30	0.39	-0.12	-0.36	0.95
34	Fabricated metal products....................	4.51	1.36	0.54	0.20	0.19	0.26
35	Industrial, Commercial Machinery, Computer Eq.	2.82	1.62	0.71	2.93	2.31	5.65
36	Electric and electronic equipment...........	3.45	2.55	2.07	3.85	3.09	7.18
37	Transport Equipment	8.07	0.39	1.47	0.18	0.05	0.72
38	Instruments and related products............	4.47*	2.36*	1.75	0.97	1.07	0.54
39	Miscellaneous manufacturing industries.......			1.55	0.47	0.33	1.10
	Nondurable goods..............................	4.89	2.22	1.32	0.14	0.06	0.47
20	Food and kindred products....................	5.18	1.47	0.67	0.26	0.39	-0.31
21	Tobacco products............................	4.28	4.19	-0.62	-3.71	-2.92	-7.19
22	Textile mill products........................	2.90	3.28	2.29	2.23	2.32	1.87
23	Apparel and other textile products..........	3.90	0.63	0.72	1.00	0.91	1.41
26	Paper and allied products....................	4.54	2.33	1.58	-0.11	-0.31	0.74
27	Printing and publishing.....................	3.67	1.43	0.48	-0.73	-0.94	0.22
28	Chemicals and allied products................	7.15	3.36	2.51	-0.25	-0.42	0.51
29	Petroleum and coal products.................	8.23	1.70	0.82	0.03	-0.14	0.77
30	Rubber and miscellaneous plastics products...	7.40	2.07	0.96	0.64	0.42	1.60
31	Leather and leather products................	2.88	1.71	0.02	0.58	0.21	2.23

Source: 1949-2000, U.S. Bureau of Labor Statistics, Multifactor Productivity in U.S. Manufacturing and in 20 Manufacturing Industries.
1919-48, Kendrick (1961), Table D-III, IV, pp.466-75.

* includes miscelaneous manufacturing

Definitions of SIC 35 and 36 change with the 1987 revision of the SIC.

Most important change is inclusion of computer equipment in SIC 35: the old Non-Electrical Machinery category

Let us now compare this record with the manufacturing sector's performance during the 1930s. The BLS data at the two digit level for manufacturing extend back only to 1948. Kendrick provides estimates at the two digit level for his benchmark years 1929, 1937, and 1948. In the absence of annual data we cannot calculate MFP growth at the two digit level for 1929-1941 directly, and the disaggregated capital stock numbers that would enable one to do so are not available in published or unpublished form from the Bureau of Economic Analysis.[15] But we can look at growth from 1929-1948.

If we compare the 1929-48 numbers with the 1973-2000 data, they show first of all a much higher across the board advance of MFP in nondurables: 2.22 percent per year for the earlier period vs. a very low .14 percent per year for 1973-2000. In durables, the 1973-2000 period registers a slight advantage: 1.57 vs. 1.43 percent, but this is entirely accounted for by SIC 35 and 36. Aside from these two sectors and apparel (SIC 23), MFP advance in *every single* two digit industry was higher over the years 1929-48 than it was between 1973 and 2000, and often by a substantial amount. Comparing 1929-48 with 1948-73, we find that the advantage again goes to the earlier period for every two digit industry except lumber (SIC 24), transport equipment (SIC 37) and, again, apparel (SIC 23).

Although Kendrick does not provide enough information to allow calculation of MFP growth rates within manufacturing for the 1929-41 and 1941-48 subperiods, I have attempted to do so for the sector as a whole using Kendrick's estimates for output and labor input combined with capital input data from the Bureau of Economic Analysis's

[15] Thanks to Randal Matsunaga of the Bureau of Economic Analysis for looking into this for me, and for providing an unpublished link to the Fixed Asset Tables after the original link was inexplicably taken down off their website in the course of writing this paper.

Fixed Asset Table 4.2.[16] The use of a net rather than gross capital stock measure as proxy for capital service flow is consistent with Kendrick's practice (for arguments as to why this is appropriate, and preferable to using a gross measure, see Kendrick, 1961, pp. 34-36). Although adjustments for capacity utilization are not explicitly made, measuring from peak to peak largely controls for the variations in capacity utilization that occur over the business cycle.

Table 5
Growth of MFP, Labor, and Capital Productivity in Manufacturing
United States, 1889-2000

	MFP	Output/Hr.	Output/ Adjusted Hour	Output/unit capital input
1889-1919	.71	1.29	1.12	-1.53
1919-29	5.12	5.45	5.45	4.20
1929-41	2.60	2.61	2.46	2.96
1941-48	-.52	.20	.03	-1.82
1949-73	1.52	2.51	n.a.	-.03
1973-89	0.57	2.42	n.a.	-1.22
1989-2000	1.58	3.56	n.a.	.16
1973-1995	0.66	2.61	n.a.	-.82
1995-2000	2.09	4.07	n.a.	.08

Sources: 1889-29: Kendrick, 1961, Table D-1, p. 464.
1929-41 and 1941-48. Output and Labor Input are from Kendrick, Tables D-1 and D-2. Capital Input is based on the index for manufacturing fixed capital in the Bureau of Economic Analysis Fixed Asset Table 4.2, Chain-Type Quantity Indexes for Net Stock of Nonresidential Fixed Assets by Industry Group and Legal Form of Organization. MFP is calculated based on an assumed share of .7 for labor, .3 for capital. See Appendix Table A-3 for complete calculations.
1949-2000, Bureau of Labor Statistics, Series MPU300001, MPU300002, MPU300003.

This calculation shows MFP growth within manufacturing over the 1929-41 period to have proceeded at the rate of 2.60 percent per year. This is higher than in any

[16] "Chain-Type Quantity Indexes for Net Stock of Nonresidential Fixed Assets by Industry Group and Legal Form of Organization." See www.bea.gov.

subsequent period of the twentieth century. It does, however, represent a halving of the 5.12 percent rate registered over the 1919-29 period, years in which the flexibility offered by the unit drive electric motor facilitated the assembly line production of automobiles and a host of new electrically powered consumer durables (David and Wright, 2003). My calculations also suggest, consistent with arguments advanced in Field (2003), a decline in the level of MFP in manufacturing over the 1941-48 period.

Technical advance in manufacturing during the 1929-1941 period was not as rapid and not as uniformly distributed across two digit industries as was true during the 1920s. The performance in the Depression years looks much more impressive, however, when contrasted with what took place in the new economy period at the end of the 1990s. In the more recent period, advance was heavily concentrated within a couple of industries in durable manufacturing within a sector that was shrinking in relative importance. Technical progress in manufacturing during the Depression was taking place across a broader frontier of an expanding manufacturing sector.

Identification of the precise loci of advance within the sector is made difficult by Kendrick's choice of 1937 as a benchmark rather than 1941. Making inferences about 1929-41 at the two digit level based on 1929-37, 1937-48, or 1929-48 estimates from Kendrick is somewhat risky. In 1937 sector output as a whole had only barely reattained 1929 levels (it was 3 percent higher). Between 1937 and 1941, however, hours went up 30 percent, capital input went up 9.6 percent, and manufacturing output increased 53 percent (Kendrick, Table D-II, p. 466; BEA Fixed Asset Table 4.2). Obviously, there was very substantial acceleration of MFP growth in the sector as a whole, but it's difficult to know exactly how it was distributed across two digit industries. Between 1941 and

1948, on the other hand, MFP declined in the sector as a whole, in part because of the heavy postwar infusion of fixed capital. Again, it's hard to know how this was distributed at the industry level.

The data do nevertheless suggest that progress in manufacturing was most pronounced in beverages, tobacco, textiles, paper, rubber, leather, electric machinery, chemicals, miscellaneous manufacturing and instruments, and petroleum and coal products (Kendrick, 1961, Table D-IV, pp. 468-475). Chemicals was the only sector to attain MFP growth of 3 percent or more in both 1929-37 and 1937-48, although tobacco, textiles and electric machinery came close. For one of the twentieth century's declining industries, textile mill products also turns in a surprisingly strong performance both pre- and postwar.[17] Notably absent from this group, however, is transport equipment, which had been the standout performer between 1919 and 1929 (see Table 4). Both labor and multifactor productivity declined in transport equipment between 1929 and 1937, and even in 1948, output per hour was only 4.8 percent higher, and MFP only 7.7 percent higher than it had been in 1929.

[17] Both labor and MFP growth in what was otherwise a declining industry may have been influenced by New Deal policies that raised minimum wages in 1933 and again in 1938. I am indebted to Gavin Wright for these observations. As the data in Table 5 reveal, however, the productivity performance of textiles has in the twentieth century is highly unusual. Its productivity growth from 1919 through the end of the century was steady and high (even as its share shrunk). Only SIC 35 and 36 turned in stronger performances over eight decades, and textiles is the only two digit industry to register higher MFP growth in the 1929-48 period as compared with 1919-1929. And it did so while ranking towards the bottom of industries in terms of the educational attainments of its workers (Goldin and Katz, 1998, p. 709). My own view is that in the aggregate, neither institutional changes in the labor market nor selective retention were the predominant causes of rapid labor productivity and real wage growth measuring from 1929 to 1941, anymore than they were responsible for the extraordinary rapid advance in SIC 35 and 36 during the 1990s. Output per hour rose a total of about 32 percent over this 12 year period; real hourly wages about 30.9 percent (Baily, 1983, Table 1, p. 23). It turned out, happily, that New Deal policies aimed at raising real wages were broadly consistent with an outpouring of technological innovation, particularly in the second half of the 1930s. Rising real wages were not the principle obstacle to recovery; for my views on what was, see Field (1992).

The sources of MFP advance in manufacturing during the 1929-41 period were different than those during the previous decade. In contrast with the 1920s, MFP advance, at least through 1937, took place in the absence of any net capital accumulation. Advance was also, in a number of subsectors, increasingly dependent on organized research and development. Table 6 examines in some detail the National Research Council data on employment of scientists and engineers in U.S. manufacturing at selected dates. It is first of all quite astonishing for those not inclined to think of the Depression period as a technologically progressive era to see the overall increase in R and D employment during the worst years of the downturn. Total R and D employment increased from 6,274 in 1927 to 10,918 in 1933, and then almost tripled in the next seven years of double digit unemployment, reaching 27,777 in 1940.

Margo has documented how much lower was the incidence of unemployment among professional, technical, and managerial occupational classifications as compared, for example, with unskilled or blue collar labor, or those with fewer years of schooling (Margo, 1991). What we are seeing during the Depression years in terms of high end labor demand, however, cannot be interpreted easily as the consequence of what Goldin and Katz (1998) have described as capital-skill complementarity, since there was no net capital formation, at least in the private sector. According to the Bureau of Economic Analysis, the real net manufacturing capital stock was less than 10 percent higher in 1941 than it had been in 1929. If there was complementarity it was between skill and the disembodied technical change that was such an important feature of the Depression years. This helps explain the sharply increasing demands for technical and scientific manpower, even in the context of capital shallowing and economy wide double digit unemployment.

Table 6
Employment of Scientists and Engineers, Selected Dates, U.S. Manufacturing

	1921	1927	1933	1940	1946
Chemicals	1102	1812	3255	7675	14066
Electrical Machinery	199	732	1322	3269	6993
Petroleum	159	465	994	2849	4750
Nonelectrical Machinery	127	421	629	2122	2743
Primary Metals	297	538	850	2113	2460
Transport Equipment	83	256	394	1765	4491
Food/Beverages	116	354	651	1712	2510
Stone/Clay/Glass	96	410	569	1334	1508
Fabricated Metal Products	103	334	500	1332	1489
Instruments	127	234	581	1318	2246
Rubber Products	207	361	564	1000	1069
Totals, 11 2 digit industries	2616	5917	10309	26489	44325
11 industry percent of total	94.27	94.31	94.42	95.36	96.48
Totals, Manufacturing	2775	6274	10918	27777	45941

Source: National Research Council; Mowery (1981); Mowery and Rosenberg (2000), p. 814.

Table 6 lists the 11 two digit industries that employed at least 1,000 scientists and engineers by 1940. Chemicals tops the list by a wide margin and, as noted, its MFP performance was stellar over the entire 1919-48 period. We can think of these 11 industries, which accounted for over 95 percent of R and D employment in 1940, as being grouped within three clusters: the processing of materials, not including primary metals: (chemicals; petroleum; rubber; and stone, clay and glass); the processing and fabrication of metals (primary metals, fabricated metal products, and nonelectrical machinery), and electrical machinery and instruments. Distinguished by their absence from the list are tobacco, textiles, apparel, lumber, furniture, paper, publishing and leather – industries which, with the possible exception of tobacco manufacture, we can identify with the first, pre-Civil War industrial revolution. The emphasis here is on industries such as chemicals for which a high R and D intensity underlay MFP advance during the thirties, but it should be noted that a number of the industries not represented in this table, including tobacco and textiles, also turned in very respectable MFP performance over this period.

The overall trends revealed in the employment data are echoed in other R and D indicators. Between 1929 and 1936 the annual rate of founding of new R and D labs (73) exceeded the comparable statistic between 1919 and 1928 inclusive (66), and real spending on R and D in manufacturing more than doubled during the 1930s, with an acceleration at the end of the decade (Mowery and Rosenberg, 2000, pp. 814, 819).

Between 1929 and 1941, as noted, MFP growth in manufacturing fell by half (see Table 5). There are really two questions that need to be addressed here; one focuses on a doughnut and the other its hole. On the one hand (to take the latter question first), why did MFP growth fall from 5.12 percent per year to 2.60 percent per year comparing the 1920s with the 1930s? The likely explanation is that the extraordinary across the board gains from exploiting small electric motors, and reconfiguring factories from the multistory pattern that mechanical distribution of steam power required to the one story layout that was now possible, were almost exhausted by the end of the 1920s. It's not that productivity levels in manufacturing were going to fall as a result of this exhaustion, it's just that one could not hope to continue to generate 5 percent per year growth in the residual from this source.

The second question, then, is why didn't MFP growth in manufacturing fall even more? Here the answer has to do with the contributions of a maturing and expanding privately funded research and development system that had begun with Edison at Menlo Park. The lion's share of private R and D spending was then and is now done in manufacturing, and a variety of new technological paradigms, most notably in chemical engineering, were ripe for exploitation. Although the rate of MFP advance in manufacturing dropped by half if we compare 1929-41 with 1919-29, it remained at very high levels by the standards of the twentieth century. What is striking about the 1930s in comparison with the entire post 1973 period in the U.S. is the broader base of productivity advance within the sector. With the exception of primary metals, transport equipment, lumber, furniture, fabricated metals and food and kindred products, MFP advance in individual 2 digit industries between 1929 and 1937 exceeded 2 percent per year. With the exception of transport equipment and apparel, MFP growth rates from 1929 to 1948 exceeded 1 percent across the board. The advance in MFP growth in manufacturing included sectors that required heavy R and D efforts as well as those, such as tobacco manufacture and textile mill products, where reorganization, economies of scale, learning by doing, or government mandated minimum wages may have played a more important role.

The growing importance of the manufacturing sector – it generated about a quarter of national income in 1929, almost a third in 1941, helped counterbalance the within sector decline in MFP growth in terms of the ability of the sector to contribute to high and indeed accelerating MFP growth in the aggregate economy during the 1930s. Still, this roughly 2.6 percentage point decline in the MFP growth rate in the sector worked in the opposite direction, reducing the overall importance of manufacturing in aggregate MFP growth. Clearly, one had to have substantial accelerations in MFP growth in other sectors in order to produce the 2.31 continuously compounded growth rate reported in Table 2 for the private non-farm economy.

That acceleration, as I will show below, came principally within transportation and public utilities (about a tenth of the economy) and to a lesser degree within wholesale and retail distribution (about a sixth of national income). The remaining sectors, on net, contributed somewhat less. Agriculture is excluded from this analysis since we are examining the performance of the private nonfarm economy, but we know that the farm sector's productivity growth in the 1930s also lagged behind that of the rest of the economy. Kendrick's data indicate that private domestic economy MFP growth between 1929 and 1941 (2.27 percent) was less than the estimate for the private non-farm economy (2.31 percent) (see Field, 2003).

Disaggregation of Productivity Growth, 1929-41

To obtain a more complete understanding of the sources of 1929-41 MFP advance I first divide the private non-farm economy into four fairly large subsectors: manufacturing, transportation and public utilities, wholesale and retail trade, and other. In 1941 agriculture, forestry and fishing generated 8.06 percent of national income, and government 10.08 percent. I also exclude nonfarm housing services and the nonprofit sector, defined as the sum of health, private education, social services, and membership organizations. In both instances, I assume that the share of these subsectors was the same in 1941 in FIRE and other services respectively as it was in 1948 (I don't have the subsector breakdown for 1941). With these exclusions, the private nonfarm economy covers three fourths of the aggregate, and approximates the BLS definition and that used by Kendrick.

I next calculate these four sectors' shares of the private nonfarm economy. Thus whereas manufacturing contributed 31.86 percent of national income in 1941, it comprised 42.57 percent of the private non-farm economy. Wholesale and retail trade comprised 22.31 percent, transport and public utilities 12.30 percent, and other, 22.82 percent.

I begin with two critical numbers, the 2.31 percent per year growth of MFP for the private nonfarm economy reported by Kendrick, and the estimate for manufacturing MFP growth (2.60 percent per year) whose calculation is discussed above. I proceed by constructing an estimate for MFP advance in transportation and public utilities (4.67 percent per year), and make a conjecture about advance in wholesale and retail trade based on 1929-48 data (1.81 percent). I am then able to back out an implied net MFP advance in the remaining "other" sector of 1.09 percent continuously compounded. Table 9 summarizes these calculations.

Transport and Public Utilities

The calculations for transport and public utilities are the most complex. This sector generated about 12 percent of national income in the private nonfarm economy – a little more than half the contribution of wholesale and retail trade. But the estimated growth of MFP (4.67 percent per year) is two and a half times as large, and the rapid acceleration of MFP growth in this sector contributed more to aggregate growth than did advance in distribution.

Table 9
Sectoral Contributions to Multifactor Productivity Growth Within the Private Nonfarm Economy
United States, 1929-1941

	1941 Share of National Income	1941 Share of Private Nonfarm Economy	Sectoral MFP Growth 1929-1941	Sector's Contribution to Aggregate (PNE) MFP Growth
Manufacturing	31.86	42.57	2.91	1.239
Transport and Public Utilities	9.21	12.30	4.67	0.575
Wholesale and Retail Trade	16.70	22.31	1.81	0.404
Other Sectors (net)	17.08	22.82	0.41	0.094
Mining	2.30			
Construction	4.03			
Finance, Insurance, Real Estate (see note a)	4.78			
Other Services (see note b)	5.97			
TOTAL	74.85	100.00		2.311

Sources: See Table 3.
Sectoral mfp growth: see text.
a excludes non farm housing services
assumes 1941 nonfarm housing services share of FIRE was the same as in 1948
b excludes health, private education, social services, and membership organizations
assumes 1941 non-profit sectors were the same share of other services as in 1948

The 4.67 percent per year figure is based on estimates for 8 subsectors: railroad transportation, local and interurban passenger transport, trucking and warehousing, water transport, air transport, pipelines, telephone and telegraph communication, and electric utilities. 1948 is the earliest year for which we can obtain data on the subsector shares in output (see Table 3). I treat these shares as an approximation for what they were in 1941, and weight the subsector MFP estimates accordingly. I also assume that half the subsector share for electric, gas, and sanitary services is accounted for by electric utilities, for which I have MFP data. All told these 8 sectors (including the truncated utility sector) cover 88.5 percent of the entire transport and public utilities sector. The largest weight is on railroads (.42), followed by telephones and telegraphs (.17), trucking (.13) and electric utilities (.10).

From Kendrick, we can obtain MFP estimates directly for railroads, local and interurban passenger transport, telephones and telegraphs, and electric utilities. For the other subsectors, one can get output and persons employed from Kendrick on an annual basis. To obtain subsector capital input series, I go to the BEA's Fixed Asset Table 2.2.[18] For trucking I use the real net capital stock data for trucks, buses, and truck trailers; for airline transport, aircraft; for water transport, ships and boats, and for pipelines, petroleum pipelines. For trucking and water transport, my calculations are for 1942 and 1940 respectively, because of the years for which Kendrick provides output and employment data.

These calculations reveal a stellar across the board productivity performance in transportation and public utilities between 1929 and 1941, with the exception of water

[18] "Chain-Type Quantity Indexes for Net Stock of Private Fixed Assets; Equipment, Software, and Stuctures; by Type," available at www.bea.gov.

transport. Of the 4.67 percent per year MFP growth in transport and public utilities, trucking and warehousing account for almost 40 percent of the total (1.80 percentage points), railroads an additional 26 percent (1.22 percentage points). Thus almost two thirds of the advance in this sector took place in surface transportation, and trucking and warehousing alone accounted for approximately 10 percent of MFP growth in the entire private nonfarm economy.

In terms of subsector rates of productivity growth, airline transport and trucking top the list, with CAAGR of MFP over the period of 14.69 and 13.57 respectively. Both of these industries benefited from public spending, the airlines from subsidized airmail transport and the construction of airports during the 1930s, and trucking from the build out of the surface road and bridge and tunnel network during the Depression (see Field, 2003, Tables 4 and 5, p. 1408). Public investment in the surface road network during the 1930s had important spillovers in the private sector, allowing very rapid MFP advance in trucking and warehousing as the economy was reconfigured to take advantage of a

Table 7
MFP Growth, Transportation and Public Utilities, 1929-1948

	Share of NI 1941(1948)	Share of T and PU	Share of Covered Subsectors	1929-41 Subsector MFP Growth	1929-41 Subsector Contrib to Sector Growth	1941-48 Subsector MFP Growth	1941-48 Subsector Contrib to Sector Growth
Railroad transportation......................	3.27	0.372	0.420	2.91	1.22 = 26%	2.56	1.07 = 33%
Local and interurban passenger transit.......	0.66	0.075	0.084	3.02	0.25 = 5%	5.59	0.47 = 14%
Trucking and warehousing.....................	1.03	0.117	0.132	13.57	1.80 = 39%	3.72	0.49 = 15%
Water transportation.........................	0.42	0.048	0.054	1.47	0.08 = 2%	4.84	0.26 = 8%
Transportation by air........................	0.18	0.021	0.023	13.73	0.34 = 7%	8.05	0.19 = 6%
Pipelines, except natural gas................	0.10	0.012	0.013	4.53	0.06 = 1%	4.85	0.06 = 2%
Transportation services......................	0.13	0.014					
Telephone and telegraph......................	1.30	0.148	0.167	2.02	0.34 = 7%	0.76	0.13 = 4%
Radio and television.........................	0.10	0.011					
Electric, gas, and sanitary services...........	1.61	0.183	0.104	5.55	0.57 = 12%	5.87	0.61 = 19%
	8.81	1.000					
TOTAL					**4.67**		**3.29**

Note: Subsector Shares are based on 1948 data. See text; Table 3.

MFP growth for electric, gas and sanitary services is for electric utilities only, assumed half of subsector.

For railroad, telephone and telegraph, local/ interurban transportation, and electric utilities, see Kendrick (1961). For other subsectors, output and hours from Kendrick, capital from Bureau of Economic Analysis, Fixed Asset Table 2.2. See Appendix Table A-2.

Subsector Contribution to MFP Growth lists the percentage point contribution of each subsector (share of covered subsector * subsector MFP growth rate) followed by the percentage point contribution as a share of the sector CAAGR growth of MFP. Percents do not sum to 100% due to rounding error.

transport system in which long haul rail distribution was integrated with local and regional use of trucks.[19]

My analysis emphasizes the importance during the Depression of private sector spillovers consequent in part upon government infrastructural investment. One might ask by how much the PNE MFP growth rate for 1929-41 would be reduced by adding to private sector capital input a portion of government infrastructural investment complementary to private sector activity, and whether this would affect the rankings of time periods by MFP growth rates reflected in Table 1. In other words, is what we see here simply a matter of private sector MFP rising because of a changeover from privately owned infrastructural capital formation in railroads to government owned infrastructural investment in streets and highways?

Table 7a reports how much calculated MFP growth rates change if we augment the private capital sector input with government streets and highway capital plus "other" government structures (electric and gas facilities, transit systems, and airports). Tables 2.1 and 7.1 of the BEA's Fixed Asset Tables provide annual estimates in current dollars of private and government capital stocks from 1925 onwards. Tables 2.2 and 7.2 provide chained index numbers for components of the real net stock starting in 1925.

In order to construct a measure of private sector fixed capital augmented by these components of government infrastructure, I start with the chained indexes, and rescale them using multiplicative constants so that the 1925 index (rather than 1996) equals 100. I then obtain series for the real net stocks as the product of this transformed index number

[19] Because of the much larger size of high schools in comparison with elementary schools, and the need to assemble students together from a much larger area, surface road improvement may also have played a contributory role in the acceleration of high school graduation rates across the country during the 1930s (see Goldin, 1998, p. 368).

and the 1925 current dollar start value. Because the growth of the chain index between two years is based on a geometric average of the differences calculated using current dollar and prior year prices, it roughly splits the difference between a Paasche and a Laspeyres index of growth of an asset component.

Using these data, I calculate the growth rate of the real net stock of fixed private assets between 1929 and 1941, and the rate of growth of this stock augmented by government street and highway capital and other structures as described above.[20] Between 1929 and 1941, the private capital stock fell by -.14 percent per year, while the augmented stock grew by .80 percent per year, a difference of .94 percentage points. Since quality adjusted labor input rose at .12 percent per year (Kendrick, 1961, Table A-XXIII), including this government infrastructure does change the Depression years from a period of capital shallowing to one of mild capital deepening. If we multiply the change in the rate of capital growth (.94) by .31, the estimate I have been using for capital's share, we conclude that adding in the services of this government infrastructural capital increases the contribution to growth attributable to capital by .29 percentage points per year. Consequently, MFP growth between 1929 and 1941 is reduced from 2.31 to 2.02 percent per year on this account.[21]

Table 7a also reports calculations of how much difference this would make in other periods. For 1919-1929, I rely on capital data for the years 1925-29. Note that for 1941-48 and 1973-89, the augmented capital stock grows more slowly than the private stock alone. In these instances the effect of including government infrastructure is to raise

[20] Most of the government infrastructural addition is streets and highways: 90.8 percent in 1929 and 90.2 percent in 1941.

[21] This calculation is based on equation 1.1. We would get the same result using equation 1.3, except that we would say that the contribution of capital deepening to labor productivity growth is increased by .29 percentage points, and MFP's contribution correspondingly reduced.

estimates of MFP growth. But the main conclusion of this exercise is that adding these components of government infrastructure to private sector capital input does not alter the preeminence of 1929-41 in comparisons of MFP growth across the twentieth century. It is not just the physical capital deepening associated with government infrastructure spending in the 1930s that helps explain high labor productivity growth rates. It is also the spillovers such investment engendered in the private sector, particularly in transport and public utilities and in distribution.

Table 7a
Effect of Including Components of Government Infrastructure on Calculations of MFP Growth

	PNE MFP Growth	Change in Capital Contribution	Adjusted MFP Growth
1919-29	2.02	.17	1.85
1929-41	2.31	.29	2.01
1941-48	1.29	-.02	1.31
1948-73	1.90	.13	1.77
1973-89	.34	-.08	.42
1989-2000	.78	.02	.76

Sources: Table 1; BEA Fixed Assets Table 2.1, 2.2, 7.1, 7.2; see text.
Note: Government Infrastructure includes streets and highways (federal and state and local) and other government structures, which includes electric and gas facilities, transit systems, and airports. Capital share used in calculating change in capital contribution =. 31. For 1919-1929, I compare growth of fixed asset stocks with and without government infrastructure between 1925 and 1929.

The impact of the government infrastructural spending on the private sector reflected not only its magnitude but also design and engineering improvements embedded within the new structures and reflected in their geospatial configuration. The construction of a substantially expanded and improved surface road network contributed to private sector MFP advance in the 1930s. It also provided foundations for subsequent progress.

Table 7 reports calculations for transport and public utilities for 1941-48 comparable to those undertaken for 1929-41 (the subsector weights used are the same, as noted). The rate of overall sectoral MFP advance is lower, but still strong at 3.29 percent per year, at a time when manufacturing MFP was falling at a rate of -.52 percent per year (see Table 5). MFP growth in trucking and warehousing slows down to "only" 3.72 percent per year, but the rate of advance in local and interurban transit almost doubles to 5.59 percent per year, and MFP growth in water transport almost triples to 4.87 percent per year. These two latter developments suggest a second round of delayed spillovers from the 1929-41 infrastructural investments. They are not the immediate consequence of surface road construction between 1941 and 1948, since very little was undertaken during these years.

Additional spillovers occurred in the 1950s along with renewed infrastructural spending. With the acceleration in construction of high speed controlled access highways, as epitomized in the launching of the Interstate Highway System in 1956, trucks were able to extend their reach by beginning to supplant railroads in the long haul goods sector. Subsequent diffusion of containerization reduced wastage as well as time and labor spent in intermodal transfer.

Another key sector was housing. During the 1930s design principles for residential subdivision in an automobile age were worked out under the aegis of the Federal Housing Authority. A few demonstration projects were constructed, but the impact on housing sector productivity was minimal before the war because there was so little overall housing construction. Nevertheless, government and university financed research and development during the 1930s provided the technical foundation for the acceleration in both housing construction and housing productivity (flow of real rental services per unit of housing capital) that took place between 1948 and 1953 and continued at somewhat slower rates in the postwar period.

Denison's data show an index of housing sector real national income at constant (1958) occupancy rates growing from 40.7 to 70.8 over this five year period (Denison, 1974, Table 3-6, p. 28; 1958=100). The BEA Fixed Asset Table 5.2 shows an index of the net stock of private residential fixed assets growing from 23.1 in 1948 to 28.2 in 1953. In other words, sector output, adjusted for occupancy rates, grew at a CAAGR of 11.1 percent a year while input grew at 3.99 percent per year, implying a sectoral productivity growth rate of over 7 percent per year.[22]

The achievements of the 1930s built on foundations put in place during the Depression years as well as work done in the1920s and earlier. By establishing groundwork for subsequent advance, the period also restocked the larder. Additional illustrations can be drawn from manufacturing. Almost all of the development work done by Farnsworth on the quintessential postwar consumer commodity was carried out during the Depression, supported by venture capital funding. The new product was introduced to a wide public in 1939 at the New York World's Fair, but the demands of war forestalled its full exploitation until after 1948.

It is useful to contrast the effects of the boom in street, highway, and other infrastructure construction during the 1930s with those of the rather different government financed capital formation boom that took place during the 1940s. The latter effort poured more than $10 billion of taxpayer money into GOPO (government owned, privately operated) plants. Almost all of this infusion was in manufacturing, and a large

[22] Since housing services are effectively produced using housing capital alone, MFP growth is the same as growth in output per unit of capital.

part of it went for equipment, particularly machine tools, in such strategic sectors as aluminum, synthetic rubber, aircraft engines, and aviation fuel refining (Gordon, 1969). Most of this was then sold off to the private sector after the war.

The most spectacular boom in equipment investment in U.S. economy history was associated with *negative* MFP growth in manufacturing between 1941 and 1948 and, partly as a result, a slowdown in private nonfarm economy MFP growth overall (see Tables 1 and 5). Note also that productivity advance in the U.S. economy outside of manufacturing picked up speed during the 1941-48 period. While billions of dollars of machine tools and other capital poured into strategic sectors of manufacturing, the remainder of the economy remained, as far as capital was concerned, on close to a starvation diet until after the war. The combination of capital starvation during the war followed by infusions afterwards seems to have been associated with more substantial MFP advance than manufacturing, with a feeding tube down its gullet, experienced.

A simple calculation reveals that if MFP growth in manufacturing was -.52 percent per year between 1941 and 1948, and overall PNE MFP growth was 1.29 percent per year over the same period, MFP growth outside of manufacturing must have been proceeding at a rate of 2.41 percent per year.[23] The calculation for transport and public utilities reported in Table 7 (MFP of 3.28 percent per year between 1941 and 1948) is consistent with this conclusion.

---

[23] Manufacturing's share of value added in 1948 was .2776. The private nonfarm economy, which excludes agriculture, government, nonfarm housing services, health services, private education services, social services, and membership organizations, was .7284 of value added. Thus manufacturing's share of the private nonfarm economy was .381, and it contributed -.20 percentage points per year to the PNE's MFP growth rate of 1.29 percent. A little algebra leads to the conclusion that MFP growth outside of manufacturing must have been 2.41 percent per year.

Important contributions during the Depression years were also made by electric utilities (12 percent of the transport and public utilities total), as well as telephone and telegraph (7 percent of the subsector total), and airline transport (also 7 percent). In order for a subsector to contribute a significant amount to aggregate productivity growth, more than simply a high rate of sectoral MFP advance was required. Its share of the sector and overall economy also had to be sizable. Airline transport's share of the sector total was much smaller than that of trucking and warehousing, which had a comparable subsector MFP growth rate, because transport by air was a smaller share of the economy.

Wholesale and Retail Trade

Wholesale and retail trade comprised over a fifth of the private nonfarm economy. Regrettably, Kendrick's data do not allow a calculation of MFP growth between 1929 and 1941. Table 8 provides estimates of labor productivity growth over the periods 1919-29, 1929-37, and 1937-48, and capital and multifactor productivity growth estimates for the latter periods. In the presence of capital shallowing between 1929 and 1937, labor productivity rose at an annual rate of 1.58 percent. MFP growth was even higher -- 1.68 percent per year. (It had to be, in order to contribute the entire increase in output per hour as well as compensate for the negative impact of capital shallowing.) Between 1937 and 1948 capital deepening resumed, with MFP growing at 1.91 percent and labor productivity at 2.65 percent per year.

How fast did MFP grow between 1929 and 1941? The Depression years present a mixed picture in terms of advances in distribution. On the one hand, it experienced the high tide of such restrictive legislation as resale price maintenance (the Robinson-Patman Act) as well as various anti chain store legislation at the state level (see Field, 1996). At the same time these legislative reactions are testimony to the inroads made by A and P supermarkets, Woolworth's, and other distributors who were taking advantage of the extension of the long distance telephone network as well as the rapidly expanding surface road network, which together facilitated a more flexible distribution system based on an integration of truck and rail delivery. Most of the acceleration in MFP productivity observed in comparing the 1937-48 period with 1929-37 was probably the result, as was true elsewhere in the economy, of acceleration over the 1937-41 years. I have ultimately chosen to assume that MFP growth over the 1929-41 period was what Kendrick estimated for the entire 1929-48 period: 1.81 percent. This is probably a modest underestimate.

Table 8
Compound Average Annual Growth Rates, Wholesale and Retail Distribution, United States, 1919-1948

	Output per Man Hour	Output per unit of Capital Input	MFP Growth
1919-29	1.10		
1929-37	1.58	4.29	1.68
1937-48	2.65	-.01	1.91
1929-48	1.93	1.74	1.81

Source: Kendrick, 1961, Table F-1, p. 506

We do not have a direct estimate of MFP growth in this sector during the 1919-29 period, but it was almost certainly below 1 percent per year. Output per man hour rose at 1.1 percent per year, but this was a period of substantial capital deepening throughout the economy. In subsequent calculations for the 1920s, I will assume MFP growth in the sector was .8 percent per year.

These estimates, in conjunction with the 2.31 percent overall increase, imply a 1.09 percent net annual MFP increase between 1929 and 1941 within the remaining sectors (about 29 percent) of the private nonfarm economy (see Table 9). This includes mining, construction, finance, insurance, and other services. I do not attempt a detailed breakdown within this remainder category, some of whose components certainly experienced MFP advance higher than 1.09 percent per year, and others lower and possibly negative rates.

Within the former category, mining is a promising candidate. If we follow procedures used within the transport and public utilities sectors (see Appendix Table A-2), using Kendrick output and labor input data and a weighted average of mining equipment/oilfield machinery and mining structures and wells from BEA Fixed Asset Table 2.2, MFP growth within the sector comes in at 1.47 percent per year between 1929 and 1941.

My candidates for laggards would include construction, which never recovered before the Second World War from its precipitous decline at the start of the Depression (see Field, 1992b). Kendrick estimates that output per man hour in the sector fell between 1929 and 1937, and in 1948 it was barely above its 1929 level (see Kendrick, 1961, Table E-1, p. 498). In a relatively non-capital intensive sector this suggests low or perhaps even negative MFP growth over the period.

A second candidate would be the remainder of the FIRE sector – that is, those components outside of real estate services themselves. Stock market trading volume plummeted, and there is no evidence of significant organizational or technological change during the 1930s. Indeed, the basic system for ordering securities trades and receiving confirmation of execution, which developed after the Civil War, persisted for almost a century, breaking down only in 1968. Peak 1929 daily trading volume was not reached again until 1968, although subsequent to that breakdown, technological and organizational changes in the sector have permitted average daily trading volume to increase by two orders of magnitude (see Field, 1998). Banking, of course, was profoundly affected by the Depression, with failures of thousands of banks and persisting disruptions of the normal functioning of financial intermediation. The entire FIRE sector shrank in relative importance between 1929 and 1941, from 14.75 percent of national income in 1929 to 8.93 percent in 1941 (see Table 3).

Table 9 summarizes the sectoral decomposition of MFP growth between 1929 and 1941. Of the 2.31 percent CAAGR of MFP, about 48 percent was contributed by manufacturing, about 24 percent by transport and public utilities, 18 percent by wholesale and retail distribution, with the remainder of the private nonfarm economy contributing about 11 percent (sums exceed 100 percent due to rounding error).

1919-1929 Disaggregation of MFP Growth

This paper is primarily concerned with looking forward from the 1930s to the 1990s. But it is also useful to look backwards, and ask how the drivers of MFP advance in the 1930s differed from those in the 1920s. Using a similar approach, we begin by using 1929 sectoral weights (see Table 3). Instead of assuming that nonfarm housing services was the same share of FIRE as it was in 1948, I somewhat arbitrarily exclude 4.5 percent of national income on its account. This adjustment is based on two considerations: First, evidence that the massive investment in residential housing during the 1920s was relatively ineffective in creating machines for producing housing services (see Field 1992b) and second, my guess that much of the decline in FIRE's share of national income is due to decline in financial services over the Depression. The adjustment to other services is similar to that made for 1929-41.

From Kendrick, we have an estimate of annual MFP growth within manufacturing (5.12 percent per year). Based on the earlier discussion of wholesale and retail trade, I estimate MFP growth within the sector at .8 percent per year. What about transport and public utilities? How much had MFP growth in this sector accelerated during the 1929-41 period, in comparison with the 1919-29 period?

The absence of detailed subsector capital stock data for 1919 (the BEA fixed asset data begin in 1925) makes it difficult to estimate MFP growth in the sector in as comprehensive a fashion as was done for the 1930s. But we can calculate from Kendrick MFP growth rates for three of the subsectors: railroads, telephones and telegraphs, and electric utilities. For the 1919-29 period, these MFP growth rates clock in respectively at 1.62, 2.03, and 2.51 percent (see Kendrick, 1961). Using the 1948 subsector weights (the best I can do here), we get an estimate of MFP growth in the sector of 1.86 percent per year between 1919 and 1929 (Table 10).

Table 10
MFP Growth, Transportation and Public Utilities, 1919-29

1919-29	Subsector Weights	Subsector MFP Growth	Contribution to Sector MFP Growth
Railroad transportation......................	0.61	1.63	0.99
Telephone and telegraph...................	0.24	2.03	0.49
Electric, gas, and sanitary services...........	0.15	2.51	0.38
TOTAL			**1.86**

Note: Subsector Shares are based on 1948 data. See text; Table 3.
MFP growth for electric, gas and sanitary services is for electric utilities only, assumed half of subsector.
Source: Kendrick (1961).

Combining this number with Kendrick's 5.12 percent figure for MFP growth within manufacturing between 1919 and 1929, and the estimate that MFP in wholesale and retail trade rose at about .8 percent, we can back out an implied net MFP growth for the remainder of the private non-farm economy (38 percent of the total in 1929) of -.38 percent per year. The most important conclusion is that during the 1919-29 period, the bulk of the 2.02 percent aggregate MFP growth for the private nonfarm economy – about 85 percent -- is attributable to manufacturing (Table 11).

We can now summarize the main distinctions between the 1919-29 and the 1929-41 periods with respect to aggregate MFP growth and its sources. First, MFP growth in the 1920s was almost entirely a story about manufacturing. Comparing the latter with the earlier period, there was a significant drop in the share of MFP growth in the private nonfarm economy accounted for by manufacturing, from 85 percent in the 1920s to 48 percent in the 1929-41 period. This is primarily due to a halving of within sector MFP growth only partially compensated for by the expanding size of the manufacturing sector. There is also, I would suggest, a change in the sources of these gains – away from learning by doing and economies of scale within the context of factories increasingly powered by a new motive source to a greater reliance on advances generated directly by expanding research and development efforts.

This interpretation is supported by the chronologies of major process and product breakthroughs (Kleincknecht, 1987, Mensch, 1979 and Schmookler, 1966; see Field, 2003) which all show peaks during the 1930s, particularly its latter half, as well as the aforementioned R and D employment and expenditure data.

Table 11
Sectoral Contributions to Multifactor Productivity Growth Within the Private Nonfarm Economy
United States, 1919-1929

	1929 Share of National Income	1929 Share of Private Nonfarm Economy	Sectoral MFP Growth 1919-1929	Sector's Contribution to Aggregate (PNE) MFP Growth
Manufacturing	25.23	33.30	5.12	1.705
Transport and Public Utilities	10.83	14.29	1.86	0.266
Wholesale and Retail Trade	15.55	20.52	0.80	0.164
Other Sectors (net)	24.16	31.89	-0.38	-0.121
Mining	2.42			
Construction	4.38			
Finance, Insurance, Real Estate	10.25			
Other Services (Legal, Medical, Education, etc.)	7.11			
TOTAL	75.77	100.00		2.014

Sources: Shares of National Income: See Table 3 and notes below.
Sectoral mfp growth: see text.
a excludes non farm housing services
assumes 1929 nonfarm housing service share of FIRE was 4.5 percent
b excludes health, private education, social services, and membership organizations
assumes 1929 non-profit sectors were the same share of other services as in 1948

The extraordinary MFP growth in manufacturing in the 1920s was driven less by immediate technological advances, and more by the learning by doing and economies of scale associated with assembly line production within newly designed and laid out factories. It's not simply that the factories were now powered by electricity. Initial applications of electric power as a prime mover simply replaced a central steam engine, with power still distributed through mechanical means of shafts and belts. It was the bypassing of the old internal power transmission system through the use of small electric motors at individual work stations that liberated factory design from its traditional layout, enabling the move to one story buildings, reconfigured layouts, and the soaring productivity gains of the 1920s.

Small electric motors were also critical on the product side, driving such new consumer products as vacuum cleaners, refrigerators, and washing machines. Other new products associated with the consumer revolution of the 1920s also exploited electricity – either to drive electronics, as in radios, or to provide heat, as in toasters.

The automobile, with its successful exploitation of the internal combustion engine, was another critical underpinning of the 1920s manufacturing sector. Aside from petroleum products (MFP growth of 8.23 percent per year), the standpoint performer at the two digit level was transport equipment, with MFP growth of 8.07 percent annually over the 1919-29 period (see Table 4). This is hardly surprising, given what we know of the cost trajectory of a Model T Ford over these years – and what brought it about. Steam power (external combustion) was increasingly crowded out of direct use in industry and transport and increasingly consigned to driving turbines in electric power generating facilities, with power then distributed over high voltage lines for use in industry and, to a lesser but growing degree, local and interurban fixed rail transport. The principal prime mover for surface road transport, the internal combustion engine, crowded out horses, ultimately freeing upwards of a sixth of American cropland that had been used to grow fuel for them.

What is striking about the first column of Table 4, however, is how high MFP growth rates in manufacturing were across the board during the 1920s. This advance is testimony not only to the delayed exploitation of electrical generation and transmission capabilities developed several decades earlier, as well as these new products, but to the growing importance of R and D investments, particularly in such sectors as rubber and plastics (7.40 percent per year) and chemicals (7.15 percent per year), foreshadowing the rising important of such sources of MFP growth within manufacturing during the 1930s.

While acknowledging the drop in Depression era manufacturing MFP growth in relation to the 1920s, we should also credit the remarkable advances of the 1930s during a time when growth in employment and physical capital services was stagnant. Nevertheless, in order to generate a 2.31 private nonfarm economy MFP growth in the 1930s, as compared with 2.02 percent during the 1919-29 period, the economy had to experience accelerating MFP growth in sectors outside of manufacturing. Here the two major loci were wholesale and retail trade, which registered moderate acceleration in a subsector with a relatively large weight, and transport and public utilities, which registered very rapid gains in a somewhat smaller sector.

There is some irony in that at precisely the moment during the 1930s when Alvin Hansen and others were expounding a theory of secular stagnation, the U.S. economy was experiencing its greatest technological efflorescence, a period of creativity which, in the aggregate, remains as yet unmatched. Hansen's colleague at Harvard, Joseph Schumpeter, had a better fix on what was going on. He developed his homage to the power of creative destruction against the backdrop of what in fact has turned out to be the most technologically dynamic epoch of the twentieth century. Schumpeter may have misjudged the terrain on the road to socialism, but his theories more successfully reflected the technological spirit of the era in which he wrote, and it is not accidental that references to his ideas increased dramatically in the 1990s, along with the NASDAQ, and, after 1995, the productivity numbers. From an informed historical perspective, however, how significant has been the end of century achievement?

The End of Century Episode

We have already gone some distance in answering this question. The key comparative points about aggregate growth were made at the start of the paper. Between 1995 and 2000 labor productivity grew a little faster than it did over the 1929-41 period (2.47 vs. 2.35 percent per year), but MFP growth was less than half what it was in the earlier period (1.14 percent vs 2.31 percent per year). The other main difference, of course, is that 1995-2000 experienced capital deepening whereas 1929-41 did not.

The idea that equipment investment is the primary instigator of disembodied technological change (and is thus responsible for most MFP growth) and the broader concept of a general purpose technology have been widely used to bolster the optimist view of the longer run productivity potential of the IT revolution. That optimist view may turn out eventually to be correct. But there are reasons for reserving judgment in the face of expressions of IT exuberance.

The breadth of MFP advance in the Depression years – in transport and public utilities, wholesale and retail distribution, as well as across a wide frontier in manufacturing -- raises questions about the broader utility of the GPT concept as a means of accounting for periods of rapid technological change. And in a related paper I show that the U.S. experience in the six peak to peacetime peak periods between 1919 and 2000 identified in Table 1 reveals a *negative* relationship between rates of MFP growth and measures of equipment investment (Field 2004). So we need to approach standard explanations of end of century productivity advance with some skepticism.

The main objective of the final part of this paper is to examine in detail what has in fact transpired (not what might), and in particular to consider how much of recent labor productivity growth and its acceleration should be credited to the *enabling technologies* of the IT revolution. If we want to take the measure of the IT revolution, we need to try and imagine a world in all respects similar save for the availability of these enabling technologies. In their absence, saving flows would have been congealed in other *not quite as good* capital goods. Output and productivity growth rates would have been somewhat lower, and we would like to know by how much.

Common practice in estimating the IT revolution's impact on labor productivity to date has been to sum three components: a contribution within the IT *producing* industries to MFP growth, a contribution within the IT *using* industries to MFP growth, and a portion of the effect on labor productivity of capital deepening associated with the accumulation of IT capital (Oliner and Sichel, 2000, or Jorgenson, Ho, and Stiroh, 2003).

There can be few conceptual objections to the first two of these components. We should credit to the enabling technologies most of the MFP growth in the semiconductor and computer/network equipment manufacturing industries (SIC 35 and 36) and, where we can demonstrate it, a portion of noncyclical MFP growth in IT-using industries such as securities trading and wholesale and retail distribution. The inclusion of the third component is common practice, and endorsed by many, including Barro and Sala-I-Martin (1995, p. 352) and Klenow and Rodriguez-Clare (1997, p. 608). Nevertheless, I question whether we should credit to IT the portion of the effect of capital deepening on labor productivity associated with the accumulation of specific IT capital goods. This would be warranted only if we believed that, by raising the return to incremental investments, the enabling technologies actually induced an upsurge in the aggregate saving rate.[24]

What's wrong with including a portion of the capital deepening effect? What we are trying to do here is to estimate the social saving of the IT revolution. In its absence, saving flows would have been congealed in a slightly less beneficial array of physical capital goods. We want to emphasize that breakthroughs such as the integrated circuit, and continuing advances in the manufacture of semiconductors, display screens, and mass storage devices, have saved us real resources in generating quality adjusted IT services. We will pick that up in MFP growth in the IT producing sectors. The very rapid MFP growth in these sectors is indeed the reason why the relative prices of semiconductors and goods embodying them have plummeted.[25]

---

[24] Assertions or assumptions of such a link are easy to find: "Ongoing technological advances in these (IT producing) industries have been a direct source of improvement in TFP growth, as well as an indirect source of more-rapid capital deepening" (Jorgenson and Stiroh, 2000, p. 128); "The spread of information technology throughout the economy has been a major factor in the acceleration of productivity through capital deepening" Economic Report of the President, 2001, p. 33.

[25] Indeed, the "dual" approach to estimating MFP advance looks at relative price changes across sectors as an alternate means of inferring its incidence.

We also want to ask whether the fact that saving flows were congealed in this slightly superior range of physical capital goods, as opposed to others, enabled a set of resource savings in other parts of the economy. This we will pick up in MFP growth in the IT using sectors (in the literature, these are referred to as spillovers or productive externalities).

But again, unless we can make the argument that the enabling technologies of IT raised the rate of return to new investment projects at the margin, *and* that there was a response of aggregate saving rates to this rise, the capital deepening effect should ultimately be credited to saving behavior, and not to the enabling technologies.

Justifications for including a portion of the capital deepening effect generally sidestep the returns to investment channel and suggest instead that the cheapening of IT capital goods relative to the GDP deflator caused a substitution away from consumption goods toward investment goods.

Everyone acknowledges that there has been extraordinarily rapid technical change in the production of IT investment goods, and that this contributed to aggregate labor productivity growth because of the rapid growth of labor productivity in these industries and their increasing shares. There is also agreement, that where we can identify it, some MFP growth in IT using industries should also be credited to IT. But should we count not only these effects, but also a portion of aggregate labor productivity growth associated with the portion of capital deepening associated with the accumulation of IT capital goods?

It is of course conceivable that the enabling technologies of the IT revolution led, by raising the incremental return to investment and perforce saving, or by redistributing income to households with higher saving propensities, to an increase in the total flow of accumulation as a percent of GDP at either the U.S. or the world level, in which case it becomes more difficult cleanly to distinguish between the roles of saving and technical change in fostering labor productivity growth. The evidence is, however, that investment in these goods did not crowd out consumption goods. Rather, it crowded out other not quite as good capital goods within the United States and outside of it.

Although we can comfortably posit an upward influence of IT innovations on marginal returns to investment and thus saving (this was after all the rationalization for rising stock market values during the 1990s), we also need to argue that saving responded. There is a large literature on the responsiveness of saving to after tax interest rates. It is empirically inconclusive. Theoretically, as in the case of the response of labor supply to increases in after tax wages, there is the possibility of both an income and a substitution effect. A variety of factors in addition to income flows and interest rates affect saving behavior and its variation over time. These include changes in age structure and dependency ratios, cultural variation, and cohort specific historical experience (such as that of the Great Depression).

As far as the income distribution mechanism, there is no question that there was a trend toward greater inequality in the last quarter of the century, particularly in the United States, and marked by a widening gap in the wages of highly and less highly educated workers. Augmented by continuing rises in female labor force participation and assortative mating (the highly educated tending to marry the highly educated) the explosion of CEO compensation, and government tax changes, trends towards greater inequality in both wealth and income at the household level are clearly evident in the data. But there is no evidence that this redistribution resulted in an increase in private sector saving rates.

Some argued, particularly in the late 1990s, that saving rates had been improperly measured because they did not include unrealized capital gains. But the conventionally measured saving rate was largely invariant to the collapse of stock market valuations in the early twenty first century. So what in fact happened during the investment boom of the last half of the nineties?

Between 1995 and 2000, consumption spending in the United States increased $1.7 trillion, from $4969 billion to $6683.7 billion nominal, a 34 percent increase.[26] Consumption rose not just absolutely, but as a share of a rising GDP, from 67.2 percent to 68 percent. At the same time, the growth of IT capital services accelerated from .41 percent per year (1973-95) to 1.03 percent per year (1995-2000). Part of the accelerated growth of the IT capital stock came at the expense of the growth of other components of the stock within the United States. Over the same interval, the growth of the services of all other physical capital goods declined from .30 percent per year in the earlier period to .06 percent per year (Economic Report of the President, 2001, pp. 29). How was the boom in capital formation, much of it IT capital, financed?

The discussion which follows is based on the open economy investment – savings identity, which states that private domestic saving (S) finances (must be equal to) the sum of gross domestic investment (I), the government deficit (G – T), and overseas capital accumulation (X – M) :

$$S = I + (G - T) + (X - M)$$

[26] In all of the subsequent discussion of the financing of the 1995-2000 investment boom, I use nominal data, which insures that the saving – investment identities hold for each year. Inflation was relatively modest over this period.

When the government is running a surplus, and thus adding to rather than subtracting from national saving, and when a country has a current account deficit/ capital account surplus, as was true for the United States in the 1990s, it is useful to restate the identity in this fashion:

$$I = S + (T - G) + (M - X).$$

This states that the sources of financing for gross domestic investment fall into three categories: gross private domestic saving (S, the sum of personal saving, retained business earnings, and capital consumption allowances); government saving (T - G); and, finally, inflows of foreign saving (M - X).

Table 12 shows that between 1995 and 2000 there was a 53.5 percent increase in gross private investment (a $611.6 billion increase) as well as an increase in government investment of $81.6 billion. How was this financed? Did personal saving rise? No! Personal saving *fell* $100.9 billion, a 33.4 percent drop. Retained business saving (net business saving) also, remarkably, fell by $51 billion – a 25 percent decrease. Gross business saving did rise, however, as a consequence of a $274.3 increase in corporate and unincorporated capital consumption allowances. This reflected the large portion of the gross investment surge comprised of relatively short lived IT capital goods, which increased the importance of short lived capital goods in the capital stock. We thus experienced a net change in gross private saving of $106.1 billion, or 8.3 percent.

The increase in gross national investment was $693.2 billion. There is a saving gap here of almost $600 billion. It was filled through two main mechanisms: First, a movement in the consolidated government surplus from $-108 to $302.8 – a swing of $410.8 billion in the surplus direction. Secondly, a deterioration of net exports from a deficit of $38 billion to one of $395.8 billion, a swing of $297.8 billion The remaining gap between the changes in the sources and uses of saving is accounted for by an increase of $155 billion in the statistical discrepancy.[27]

Table 12
Changes in the Uses and Sources of Saving, United States, 1995-2000

	1995	2000	Change in uses	Change in sources
Gross Private Domestic Investment	1,143.8	1,755.4	611.6	
Gross Government Investment	238.2	319.8	81.6	
Personal Saving	302.4	201.5		-100.9
Retained Business Earnings	203.6	152.6		
Depreciation Allowances	743.6	1,017.9		
Gross Business Saving*	963.6	1,170.5		206.9
Gross Government Saving	-8.5	435.8		444.3
Net Foreign Investment	-98.0	-395.8		297.8
Statistical Discrepancy	26.5	-128.5		-155.0
TOTALS			693.2	693.1

*Includes wage accruals and disbursements not shown separately.
All numbers are billions of dollars, nominal.
Note that net foreign investment is entered as a positive number in the sources column.

Source: Economic Report of the President, 2003, Table B-32

The surge in investment at the end of the century was not principally financed by an increase in the U.S. private saving rate, but rather by rising government surpluses and a worsening current account deficit. Our investment boom was enabled on the one hand by the willingness of foreign wealth holders to divert their saving flows from investment in

[27] All data from Table B-32, Economic Report of the President, 2003.

their own countries or elsewhere and make it available to the U.S., and on the other hand by the tax policies of the Clinton and George H.W. Bush administrations. Their fiscal policies, in conjunction with an economy operating at close to capacity, provided the foundation for the big increase in government saving.

Put another way, between 1995 and 2000, the gross private saving rate fell from 17.1 to 14 percent of GDP. It was only because government saving increased from -.1 percent to 4.4 percent of GDP that the national saving rate could rise from 17 to 18.4 percent of GDP. Since the sum of gross private and government investment rose from 18.7 to 21.1 percent of GDP, most of the remaining gap had to be made up by foreign borrowing.

It is conceivable that, although the IT accumulation spurt was not associated with a rise in the private saving rate within the U.S., it was associated with a rise in the *world* saving rate. But I have seen no data suggesting this to have been the case. We are left with the conclusion that, by and large, the IT capital accumulation spurt in the United States represented a substitution not away from consumption, but away from other not quite as good capital goods, both within the United States and abroad.

Whether the flows necessary to finance capital accumulation came from national saving or from outside the country is irrelevant from the standpoint of MFP trends within the United States. But it does have welfare implications, particularly for the future. Access to foreign borrowing meant that we were able to forego the sacrifice of current consumption that is otherwise the price of capital deepening. But the foreign debt will need to be serviced and eventually repaid. The borrowing will turn out to have been a good deal for the country if the increases in output per hour associated with the additional capital deepening exceed the increases in debt service per hour of labor input. But there is no guarantee this will be the case – it depends on how much of the additional investment turns out to have been well directed. In any event, the gains in output per hour obtained through foreign borrowing will certainly not be manna from heaven, given the obligation of debt repayment.

Within the United States, there was indubitably an acceleration in overall capital deepening, comparing 1995-2000 with 1973-95. Capital services per quality adjusted hour grew at 2.93 percent per year in the latter period, as compared with 1.96 percent per year in the former. Thus the slowdown in non-IT capital accumulation was more than compensated for by the rising rate of IT capital accumulation. One could argue that the drop in the U.S. private saving simply compensated collectively for the rise in government saving. But this seems doubtful, since the saving rate has been trending downward for decades through periods of government deficit and surplus. More likely, had the tax increases of the early 1990s not been enacted, the deterioration of the current account would have been even worse.

Because of the dependence on foreign capital flows and the absence of evidence of a notable uptick in world saving rates we should view the remaining portion of the IT capital acceleration as substitution away from, or crowding out of capital accumulation outside of the United States.

Although interest in productivity measurement began during the 1930s as the result of concerns, particularly on the part of labor, over the possibility of long term technological unemployment, the predominant interest at least since the 1950s has focused on the close link between trends in output per hour and trends in output or consumption per person – our basic measures of the material standard of living. If the enabling technologies of the IT revolution diverted some portion of world saving flows toward the United States that would not otherwise have come this way *even though U. S. and world saving rates remained unaffected and may actually have declined*, it would technically be correct to say that we should grant to the IT revolution that part of the growth in labor productivity associated with IT's share of capital deepening

But if we care about labor productivity because we care ultimately about consumption per person in the U.S., this is a misleading calculation. Much of the capital deepening has associated with it a liability tied to increased foreign indebtedness. This is in sharp contrast with the contributions to labor productivity growth of the first two components of the traditional triad used to measure IT "contributions": MFP growth within the IT producing sectors, and MFP growth within the IT using sectors.

As an empirical matter, a suggestion that IT innovations led to a substitution away from consumption goods towards investment goods mischaracterizes what happened. The U.S. economy did not substitute IT capital for consumption goods. Rather, it substituted IT capital *for other capital goods within the United States whose prices did not fall as fast*, and, through the modality of access to foreign capital markets, for capital accumulation in other countries. The portion of the surge in capital formation financed by going into debt to the rest of the world traded off a charge against future U.S. consumption that may or may not be less than the increase in future consumption enabled by the effect of higher capital labor ratios on labor productivity.

The IT Contribution and Social Saving Controversies

This framework for reckoning the impact of the IT revolution, particularly its emphasis on MFP to the exclusion of the portion of the increase in labor productivity attributable to IT's share of capital deepening, runs counter to current practice. Let me try and defend it by comparing our challenge with one of the critical disputes that gave rise to the new economic history. This involved the attempt to estimate the social saving of the U.S. railroads. W.W. Rostow (1960) had argued that railroads were "indispensable" to American economic growth. Both Albert Fishlow (1965) and Robert Fogel (1964) wanted more precision. They tried to imagine worlds otherwise similar save for access to the blueprints needed to build railroads. They calculated alternate channels for saving flows (into canal building and river dredging, for example) and ultimately how much lower U.S. GDP would have been in this alternate world.

The social savings calculations that came out of those debates four decades ago were designed to impress upon us first of all the fact that because saving flows were congealed in railroad permanent way and rolling stock, as opposed to other forms of physical capital such as canals, GDP was indeed higher than it otherwise would have been. *But not by a whole lot.* Fogel argued, for example, that 1890 US GDP was about 4 percent higher than it would have been in the absence of the availability of the railroad. What kind of an increment to MFP over a quarter of a century would one have needed to produce a GDP (or output per hour) in 1890 four percent higher than it otherwise would have been? About .15 percent per year, continuously compounded.

In fact, growth accounting studies of the post Civil War nineteenth century in the US reveal, as they do for the 1973-95 period, that almost all of the growth in real output can be accounted for by growth in inputs conventionally measured. It would make little sense to suggest that we have underestimated the contribution of the availability of railroad blueprints to living standards in the late nineteenth century because we have not accounted for the share of the increment to output per hour attributable to that portion of capital deepening associated with investments in locomotives, rolling stock, and permanent way.[28]

The key message of the classic works by Fishlow and Fogel was that, in the absence of the railroad, saving flows would have been congealed elsewhere, with results for the economy that would have been almost, but not quite as good. We should take the same approach to reckoning the importance of the IT revolution.

In defense of what has become the conventional approach, some labor productivity is certainly, in an accounting sense, attributable to capital deepening. And a large fraction of capital deepening, particularly at the end of the 1990s, was indeed associated with the accumulation of physical IT goods: computers, servers, fiber optic cable, routers, etc.[29] But since the counterfactual I have in mind imagines saving behavior largely unaffected by the presence or absence of the IT blueprints, our estimate of the portion of labor productivity growth we attribute to saving (as opposed to technical innovation) should be largely independent of the particular forms in which saving flows were congealed.

It should, to be fair, also be independent of the sources of that saving. With respect to the labor productivity growth caused by capital deepening, it is irrelevant whether the saving came from outside of the country. But we should not fool ourselves. Labor

---

[28] In another respect the railroad/infrastructure investment boom of the late nineteenth century was analogous to the IT boom of the late twentieth century: both triggered and were associated with foreign borrowing.

[29] Estimates of the amount of this capital formation surge have been augmented by the BLS's 1999 reclassification of business software acquisition as capital formation (as opposed to its previous treatment as an intermediate good.

productivity gains from capital deepening financed by foreign borrowing come encumbered in a way that similar gains financed by domestic saving do not.

The point of this exercise is to try and reach a more realistic assessment of the welfare implications of the IT revolution. It is true that if we are operating below full employment, and a new attractive invention offers profitable opportunities for new investment, it is reasonable to talk about the extent to which the innovation increases real output through its effect on the amount of real capital formation. From an aggregate perspective, such investment will be largely self financing (just as, in the presence of accommodative monetary policy, will be government deficits). The increased income flows generated through multiplier effects will produce the required increases in flows of saving. If we are below full employment, we can under certain conditions argue that it is investment that drives saving.

But once we reach potential output, the old rules of microeconomics again apply. Choices have opportunity costs, and saving constrains investment rather than the other way around. This has always been the rationale for policy changes designed to increase the after tax return to saving, and, if the elasticities are right, saving flows – policies which make sense from a long range full employment growth perspective but are contraindicated if one is below capacity. By and large, in growth accounting, we are trying to abstract from cyclical effects, and study the effect of saving and innovation on the increase of potential output. We want to know, in the long run, what is the effect of the IT enabling technologies on the growth of potential output. If the justification for emphasizing the role of IT capital formation role in "contributing" to increases in real output is based on these Keynesian arguments, it represents a confusing and ultimately inconsistent mix of short and long run perspectives.[30]

It is analogous to emphasizing, as did Rostow, the stimulus to the iron and steel and lumber industries caused by late nineteenth century railroad construction. That emphasis obscures the fact that, once we are at potential output, these resources had alternate uses, and the enormous costs of constructing the railroads raised the hurdle they had to overcome to make a positive contribution to GDP. They managed to do so, as Fogel and Fishlow demonstrated, by enabling a superior exploitation of regional comparative advantage. But it was close.

MFP Growth vs. The Capital Deepening Effect

How important, in terms of their impact on labor productivity, were the respective roles of MFP and capital deepening over the 1995-2000 period? There are a couple of ways of looking at this. The first exercise we have already undertaken at the start of the paper, and it is to ask how much of the *acceleration* in labor productivity growth each is responsible for. For the private nonfarm economy, that acceleration, comparing 1995-2000 with 1973-95, was 1.09 percentage points, and as the analysis at the start of the paper indicated, about three fourths of this is attributable to MFP acceleration.

A second approach is to ask what portion of overall labor productivity growth (2.46 percent per year) each is responsible for. Between 1995 and 2000 MFP growth was 1.14 percent per year. The rate of capital deepening was 3.28 percent per year. Multiplied by .32, this yields a capital deepening contribution of 1.05 percent per year. The remainder, about .27 percent per year, is the contribution of labor quality improvement. Looked at

[30] Inconsistent because growth accounting has always focused on explaining growth not cycles; thus its emphasis on peak to peak comparisons.

from this perspective, we can say that MFP growth accounted for less than half -- about 46 percent (1.14/2.46) -- of labor productivity growth between 1995 and 2000. Table 13 summarizes these calculations.

Table 13
MFP Contribution to Labor Productivity Growth and Acceleration, 1995-2000

Labor Productivity Growth, 1995-2000[a]	2.46
MFP [a]	1.14
Capital deepening [a]	1.05
Labor Composition [a]	.26
Labor Productivity Growth Acceleration, 1995-2000 vs. 1973-95[b]	1.09
MFP [b]	.76
Capital Deepening [b]	.32
Labor Composition [b]	-.01

[a] percent per year
[b] percentage points
Note: Components do not sum exactly to aggregates due to rounding errors.

Why does this matter? Because if one accepts the above arguments about how we should reckon the impact on living standards of the IT revolution, almost all of it is going to be registered in MFP. And whereas MFP growth is more than twice as important in accounting for the *acceleration* in labor productivity growth compared with 1973-95 (.76 vs. .32 percentage points), it is responsible for less than half of labor productivity growth between 1995 and 2000. We will overemphasize the estimate of MFP growth's impact on living standards improvement, and perforce the IT revolution's impact on living standards,[31] if we focus on its contribution to the percentage point acceleration of labor productivity growth comparing 1995-2000 with 1973-95 (second

[31] Output per hour and output per capita are not the same, nor will their growth rates be identical, but over the longer term it is impossible to have a sustained increase in the latter without a sustained increase in the former. This is simply because the growth rates of hours is ultimately constrained by the growth rate of population.

derivative with respect to time) as opposed to its rate of growth (first derivative with respect to time). There is no hard and fast answer to what metric we should prefer here, but for an individual country it seems to me that the more meaningful measure is IT's contribution to the rate of improvement, not the rate of improvement of the rate of improvement, of labor productivity. For comparisons between countries, we ought also to look at levels.

MFP Growth in the IT Producing and Using Sectors

There are a large and growing number of papers that have attempted to measure the impact of the IT revolution. Different frameworks, methodologies, data series, and time frames have yielded a variety of conclusions. In spite of the differences, there is enough information and consensus now to make some general statements about trends in MFP growth and their sources at the end of the century.

First, in spite of some initial skepticism (see Jorgenson and Stiroh, 2000), it is clear that MFP growth, and largely because of it, labor productivity growth, did accelerate between 1995 and 2000. Second, it is generally agreed that an important contributor both to labor productivity growth and to its acceleration in the second half of the decade was MFP advance associated with technical change in the semiconductor industry and in the manufacture of such products as computers, networking devices, and telecommunications equipment that embodied them. This shows up in very rapid (and accelerating) rates of MFP growth in SIC 35 and 36 (see Table 4).

Third, it is likely, although the inferences are more indirect and the statistical support substantially weaker, that some of the IT using sectors, in particular wholesale and retail trade and securities trading, began to throw off significant MFP growth. Two analyses of the contributions to the acceleration of labor productivity growth (McKinsey Global Institute 2002, and Nordhaus 2002; (see also the 2001 Economic Report of the President) are suggestive. The McKinsey study focuses on four years (1995-99) whereas Nordhaus covers five (1995-2000), and the base periods on which the acceleration is calculated differ. Both rely on BEA value added data in the numerator, although the McKinsey study uses persons employed rather than hours in the denominator.

Table 14
Contribution to Labor Productivity Acceleration (percentage points)

	McKinsey (2002)	Nordhaus (2002):
	1995-99 over 1987-95	1995-2000 over 1975-89
Total Acceleration	1.33	1.61
Wholesale Trade	.37	.27
Retail Trade	.34	.46
SIC 35 (includes semiconductors)	.12	.23
SIC 36 (includes computers)	.17	.08
Securities Trading	.25	.32

Sources: McKinsey Global Institute (2002); Nordhaus (2002), Table 6, p. 233.

Both nevertheless find that distribution contributed substantially to the acceleration of labor productivity growth, and substantially more than did manufacturing, although the two studies reverse the relative contribution of wholesale and retail trade on the one hand, and SIC 35 and 36 on the other. Of course we can't reason directly from decompositions of labor force acceleration to conclusions about MFP acceleration. Rates of capital deepening may have been exceptionally rapid in these sectors, explaining much of the acceleration of labor productivity growth. Indeed, at least through 2000, the data seem to support this view.

Distribution was an extremely heavy user of IT capital. Largely as a consequence, its use of overall capital services also soared. An index of capital services input in wholesale distribution rose from 1.3 in 1973 to 81.7 in 1995 to 227.4 in 2000, implying CAAGR of capital services of 18.8 percent a year between 1973 and 1995 and 20.5 percent a year between 1995 and 2000. An index of hours in wholesale rose from 97.1 in 1995 to 103.7 in 2000, a rate of growth of 1.32 percent. So capital deepened in wholesale distribution at a rate of 19.2 percent per year between 1995 and 2000, far higher than the average for the economy. Similar calculations for retail distribution show capital deepening at 15.3 percent per year over these years.[32]

Table 15

Labor and Multi-Factor Productivity Growth in Wholesale and Retail Trade, 1995-2000

	1973	**1987**	**1995**	**2000**	CAAGR **1973-95**	CAAGR **1987-95**	CAAGR **1995-00**
Wholesale Capital Input (Total)	1.3	34.6	81.7	227.4	18.82	10.74	20.47
Retail Capital Input (Total)	1.7	38.4	85.3	196.9	17.80	9.98	16.73
Wholesale Labor Input		89.5	97.1	103.7		1.02	1.32
Retail Labor Input		89.0	96.7	104.0		1.04	1.46
Capital Deepening wholesale						9.72	19.16
Capital Deepening Retail						8.94	15.27
Output per hour wholesale		74.3	93.1	114.7		2.82	4.17
Output per hour retail		81.3	95.0	114.4		1.95	3.72
MFP wholesale						-0.29	-1.96
MFP retail						-0.91	-1.17

Source: BLS, Capital and Related Measures from the Two Digit Database, 1948 to 2001
BLS, Industry Productivity Indexes and Values, November 5, 2003
Capital share assumed = .32.

The BLS Industry Productivity Indexes and Values Table, dated November 5, 2003, begins with data for 1987. It shows labor productivity growth in wholesale trade rising from 2.82 percent per year (1987-95) to 4.17 percent per year (1995-2000). In retail trade

[32] Sources for capital are Bureau of Labor Statistics, "Capital and Related Measures from the two Digit Database," for hours, "Industry Productivity and Values Table", November 5, 2003.
[34] Increasing the estimated real flow of IT goods increases the estimated growth of real output per hour, as well as the capital stock and thus the rate of capital deepening. IT goods are, however, a much larger fraction of investment than they are of output; the effect on estimated MFP growth is ambiguous.

the comparable numbers are 1.95 percent per year (1987-95) to 3.72 percent per year (1995-2000). So labor productivity growth in distribution has been accelerating.

The problem here, as a quick calculation will reveal, is that assuming a capital share of .32, the very high rates of capital deepening more than account for the labor productivity growth, implying negative MFP growth in both sectors overall. Moreover, this negative growth accelerates in the 1995-2000 period, along with the acceleration in capital deepening. The bottom line is that while heavy capital deepening in distribution did cause an acceleration in labor productivity growth in the sector, it is hard to claim that the results through 2000 fully justify the massive IT expenditure, let alone that IT generated accelerating MFP growth within the sector.

One can argue, however, that some of these pessimistic conclusions may be due to an overestimate of how much "true" computer prices dropped, and thus an overestimate of how much real IT output (and investment) grew. This is unlikely to be a popular argument among economists, who have been almost unanimous in pushing the BLS to make more use of hedonic methods to estimate the rate of quality improvement (and implied price decline) and praising it for what efforts it has made (see, e.g., Nordhaus, 1997).

The most compelling argument for why these methods might be leading to some overestimate of real product growth is that in products whose quality has improved, users are typically forced to purchase *bundles* of attributes, not all of which they may actually desire or value. No one disputes that the issues of quality improvement and the introduction of new products are important challenges in constructing realistic estimates of real product growth. But some of the resulting estimates do not seem to satisfy a reasonableness test.

My needs for word processing, spreadsheets and an ability to make computer presentations continue to be satisfied by an IBM Thinkpad 600E, arguably one of the best laptops IBM ever made. The keyboard and display are superior to any on more recent models, and the fact that its processor is "only" a 400 mhz Pentium II is of little concern to me. Were I to buy a new IBM laptop of about the same weight and display size, its nominal cost would be in the same range as this one five years ago. True, this new machine would have a Centrino processor, built in WIFI, and longer battery life. But how much should we allow for this quality improvement, (and perhaps disallow for other components that aficionados claim are no longer as reliable)?

Hedonic price techniques have yielded end of century estimates in the range of -27 percent per year for the rate of decrease of computer prices (Berndt, Dulberger, and Rapaport, 2000). This rate of price decrease would reduce a 1999 computer priced at $2000 to $500 over 5 years. Thus, if there were one five pound laptop produced in 1999 and one produced in 2004 selling at the same nominal price, the BEA would conclude, based on the price data received from the BLS, that there has been a four fold increase in the real output of laptops. I leave it to readers to judge whether or not this is reasonable.

For the sake of argument, grant that, in its willingness to respond to pressures to account for IT capital quality improvements, the BLS may have given us estimates of the rates of decline of IT capital prices that have resulted in an overestimate by the BEA of real product growth in the sector. Although this would of course boost MFP growth in the IT producing sectors, it has the effect of worsening it in IT *using* industries. One of the advantages of adopting the framework for reckoning the importance of IT proposed in this paper is the elimination of the possible "incentive" to push for more rapid rates of estimated price decline to make IT's contribution appear larger.

Overestimating the real growth of IT services will, of course, also overestimate the capital deepening component of its contributions within what has become the conventional triadic approach. Since the framework I advocate credits most of the effect of capital deepening on labor productivity to saving, rather than the availability of IT technology, we are left with the effect on MFP growth in the IT producing sectors, plus the effect in the IT using sectors, such as distribution, if it can be demonstrated. An overestimate of real IT output growth will increase the former component, while it will reduce the latter. The two effects may largely cancel out. [34]

For analysis of smaller subsectors of the economy, however, the effects will not cancel out, and thevalue added approach of Table 15 as applied to subsectors has been criticized precisely because it can be so sensitive to errors in deflation (see Basu and Fernald 1995). For subsectors the BLS prefers its KLEMS methodology which uses a gross output rather than value added measure, and subtracts weighted input growth rates for purchased materials, energy, and business services as well as hours and capital input. Their MFP estimates for the sector are unpublished and incomplete. But the unofficial data show MFP rising at .8 percent a year in wholesale although not at all in retail between 1992 and 1997.[35]

With respect to retail distribution, the McKinsey study argues that virtually all of the gains in labor productivity have been attributable to "big box" retailers such as Costco, Walmart, and Circuit City. And it is the relative ease with which these can be put

[35] I am grateful to Larry Rosenblum of the BLS for making these data available to me.

in place in the United States, as compared with the relative difficulty with which this can be done in Europe and other parts of the world, that Gordon has cited as a principal explanation of cross country differences in MFP growth in distribution, and, perforce, the economy as a whole (Gordon, 2003).[36]

Although the McKinsey group is willing to lay at IT's doorstep only about half the gains in wholesale and retail distribution (assuming we can demonstrate them), it is important to keep in mind that these are gains in *labor* productivity. The evidence for uncompensated productivity spillovers – increases in value added attributable to IT that aren't captured by the equipment or software manufacturers - is still shaky or incomplete Table 15 suggest that such gains, which should show up in measures of MFP in the sector, are nonexistent, although the unpublished KLEMS analysis, which extend only through 1997, suggests some advance.

I am inclined to speculate that we are in fact in the process of experiencing the impact of a second IT revolution in distribution, a revolution whose trace on sector MFP data has been temporarily clouded or even obliterated by overdeflation of IT prices. We can contrast this with an earlier revolution in the sector associated with the simultaneous deployment of the telegraph and the railroad, which, as Alfred Chandler documented, gave rise to the modern business enterprise in distribution before it did so in manufacturing, (Chandler 1977; Field 1987, 1992a, 1996). By the end of the 1880s the railroad and the telegraph had enabled the success of thriving urban department stores such as Macy's, as well as mail order operations such as Sears Roebuck, and Montgomery Ward. The profitability of these companies, the high wages they paid their

[36] In a paper broadly consistent with this view, Foster, Haltiwanger and Krizan have argued that most of the productivity advance in retail trade has been the result of "more productive entering establishments displacing much less productive exiting establishments" (Foster, Haltiwanger and Krizan, 2002).

employees, the high prices they paid suppliers, and the low prices they offered customers were enabled by techniques of supply chain management which increased the rate of inventory turn, a familiar story to those studying distribution today.

Large urban department stores and mail order houses, while growing in importance, did not by any means completely dominate distribution in the late nineteenth century. The same can be said of big box distributors today. There is thus a probability that compositional changes combined with learning by using will ultimately show more substantial MFP advance in the sector. The slowed growth of IT investment in the early years of the twenty first century will likely have a beneficial effect on sector MFP growth rates yet to be calculated.

Summary: The 1990s and the 1930s

Let me now try and bring together what we can say about the 1995-2000 episode and how it relates to the 1929-41 period. In this instance, because of paucity of disaggregated sectoral data outside of manufacturing, I will divide the private nonfarm economy into three subsectors: manufacturing, wholesale and retail trade, and other. Excluding agriculture, government, nonfarm housing, and the non-profit sector, the private nonfarm economy accounts for 72.4 percent of value added. Using year 2000 sectoral shares (Table 3), we can calculate a manufacturing weight (share of PNE) of .214 and a wholesale and retail trade weight of .223.

Again, we commence with BLS numbers for MFP growth for the private nonfarm economy between 1995 and 2000 (1.14 percent per year), and the BLS estimate for manufacturing as a whole (see Table 5) of 2.08 percent per year. For wholesale and retail trade, there are no published data on MFP growth. The calculations in Table 15 suggest it has been negative. As noted, unpublished estimates using the KLEMS methodology show .8 percent per year between 1992 and 1997 in wholesale, and no growth in retail. Allowing for some acceleration towards the end of the decade in both wholesale and retail, and considering the relative weights of wholesale and retail, we can hazard an estimate of .7 percent per year for the sector between 1995 and 2000. This is a guess, and it may be an overly optimistic one.

Multiplying sectoral shares by sectoral MFP growth rates, we can estimate that of the 1.14 percent per year growth of MFP within the private nonfarm economy between 1995 and 2000, .45 percentage points originated in manufacturing, most of it due to the IT producing industries, and .14 percentage points in distribution. Given the rest of the PNE's weight of .563, we can back out an implied MFP growth within it of .94 percent per year contributing the remaining .53 percentage points. This "other" category includes standout sectors such as securities trading as well as laggards such as construction. Table 16 above summarizes these calculations.

Table 16
Sectoral Contributions to MFP growth, 1995-2000

	Share of PNE	Sectoral MFP Growth	Contribution to PNE MFP Growth	Share of PNE MFP Growth
Manufacturing	.214	2.08	.45	.39
Trade	.223	.70	.16	.14
Other	.563	.94	.53	.47
TOTAL	1.00		1.14	

Sources: Sectoral Shares: see Table 3
Note: Private Nonfarm economy excludes nonfarm housing, health, agriculture, and government, which leaves 72.4 percent of value added. This is approximately the BLS's current definition of the PNE.
MFP growth Manufacturing: see Table 5
MFP growth Trade: see text

Suppose now we credit all of the MFP growth in manufacturing between 1995 and 2000 to the enabling technologies of the IT revolution, and a third of that in distribution and the rest of the economy [37] We would then conclude that .68 percentage points of the 1.14 percent MFP growth between 1995 and 2000 could be credited to the IT revolution. Thus, we would attribute about 28 percent of labor productivity growth between 1995 and 2000 (.68 / 2.46 percent per year) to the enabling technologies of the IT revolution.

How does this analysis compare with the recent decomposition by Jorgenson, Ho, and Stiroh (2003)? First, the BLS data for the private nonfarm economy cover less than three fourths of their aggregate. Jorgenson et. al. include what the BLS excludes: the farm sector, government, housing, and (presumably) the non-profit sector.[38] These excluded sectors were slower growing, and as a consequence their output aggregate grows at 4.07 percent between 1995 and 2000, vs 4.54 percent for the BLS private nonfarm economy. Their hours series grows at 1.99 percent vs. 2.09 percent for the PNE. Their labor quality adjustment is also lower, .22 percent vs .37 percent per year. Finally, their MFP growth estimate is much lower (.62 vs 1.14) and their output per hour rises more slowly (2.07 percent vs. 2.46 percent) (Jorgenson, Ho, and Stiroh, 2003, Table 2). The difference in labor productivity growth rates is less than the difference in MFP growth rates because their implied rate of capital deepening (3.88 percent per year) is higher than for the BLS private nonfarm economy (3.28).

[37] The McKinsey study places a great deal of emphasis on the Wal-Mart effect, both in terms of its growing share of retail and through its role as an object of imitation by such firms as Target. But although it grants that much of the company's success is based on advanced inventory control methods obviously enabled by IT investment, it also stresses that much is based on management innovations such as worker cross-training. In other words, within manufacturing it is defensible to credit virtually all of the MFP growth to IT; outside of manufacturing this is not defensible. Many of the productivity enhancing management improvements could and probably would have been implemented in the absence of new IT technology.

[38] Their output measure also includes an estimate of the imputed service flow from consumer durables.

All of these comparisons speak to the extent to which the sectors excluded by the BLS and added back in by Jorgenson et al. tended to be slower growing and, in the aggregate, relatively unprogressive technologically.

Of their 2.02 percent per year growth in labor productivity between 1995 and 2000, they attribute .85 percentage points to IT capital deepening and .45 percentage points to IT related MFP growth . In other words they "attribute" about two thirds of labor productivity growth (1.30/2.02 = .64) to IT. Conceptually, their analysis is more favorable to IT because, like Oliner and Sichel (2000), they credit the sector with a (large) portion of the effect on labor productivity of capital deepening. But in another respect their approach is less favorable than that advocated in this paper, because they credit IT innovations with *none* of the MFP growth outside the IT producing sectors, even though, in contrast to some of their earlier analyses, they now do acknowledge some MFP growth in the rest of the economy. If one applied my conceptual framework to their data, one would add the .45 percentage points of IT related MFP growth and a third of the "other" MFP growth (.17/3 = .056) to obtain .51 out of a total of 2.02 percent per year attributable to the enabling technologies of IT. This is approximately one fourth of the total.

Comparing new economy economic growth with the MFP boom period of the interwar years the following conclusions stand out. The 1920s, the 1930s and the 1990s all saw contributions to MFP growth from manufacturing but the percentage point contribution to PNE growth in the recent episode was much lower (.45 percentage points per year vs. 1.24 percentage points per year between 1929 and 1941, and 1.71 percentage points in the 1919-29 period. Although rapid MFP advance within manufacturing was somewhat more localized in the 1930s than it has been in the 1920s, it was very narrowly concentrated at the end of the century.

Distribution played an important role in both the 1930s and the 1990s, although its percentage point contribution was three times larger in the Depression. Perhaps most striking, however, in comparison with the 1930s, the 1990s lacked the broad based and very rapid advance in transportation and public utilities which characterized the 1930s. Although sectoral MFP estimates are not available across the board, labor productivity data, such as that contained in the 2001 Economic Report of the President, show growth rates declining, comparing 1995-99 with 1989-95, in trucking and warehousing, communications, and electric, gas, and sanitary services. For trucking and warehousing, labor productivity actually fell (2001 Economic Report of the President, Table 1.2).

Finally, we need to reemphasize that for the private nonfarm economy as a whole, aggregate MFP advance in the 1929-41 period was more than twice as fast as 1995-2000, more than three times as fast as 1989-2000. For the 1930s, the question of whether or not to include a technology driven capital deepening effect on labor productivity is moot, since there was effectively no capital deepening, at least in the private sector.

Taking the Measure of the IT Revolution

What has been incontrovertibly revolutionary about the IT revolution has been the operation of Moore's law: the ability to manufacture computers, peripherals, and telecommunications equipment in such a fashion that output has risen much faster than inputs conventionally measured. The plummeting costs of producing quality adjusted CPUs, memory, mass storage and display devices have been for the late twentieth century what spinning jennies and water frames were for the late eighteenth century in Britain.

There is some evidence that the rate of technical progress in semiconductors accelerated even further after 1995, as the interval required to double performance dropped from 18 months to 12 months. The revolutionary character of what has been happening in the IT industries shows up as higher and accelerating MFP and, perforce, labor productivity growth in SIC 35 and 36. Even allowing for the possibility of some overshooting in the estimate of output growth resulting from the use of hedonic techniques, we can happily and uncontroversially credit the revolution with these gains, which flow directly through to improvements in the material standard of living.

It is also likely that some – although by no means all -- of the MFP advance in wholesale and retail distribution, securities trading, and some other sectors of the economy has been made possible by IT investments, and we should credit the enabling technologies of the IT revolution (such as integrated circuits) with an appropriate share of these gains as well, where we can demonstrate them. But because the IT producing sectors are small in relation to the aggregate economy, and because the gains in the using sectors have been relatively more modest, the boost to the growth of overall output per hour remains small in comparison, for example, with MFP growth in the 1930s

Once can also argue that technical improvement, whatever its sources, might have affected saving behavior. How? By raising the rate of return to incremental investments and thus, assuming there were a positive elasticity of the saving rate with respect to the real after tax interest rate, an increase in saving flows. Or because of a bias in technical change, capital's share might rise, leading to a redistribution of income to households with higher saving propensities. Versions of these arguments have been made for the post Civil War period in the United States where, it has been suggested, such innovations as the railroad and Bessemer/ Siemens Martin steel elicited an upward surge in aggregate saving behavior which propelled the economy on a "grand traverse" to higher labor productivity levels as predicted by the Solow model (David, 1977; Williamson, 1973, p. 591).[39]

There was indeed an acceleration of gross capital formation in the last half of the 1990s, associated with a more than doubling of real investment in computers, telecom equipment, and software between 1995 and 2000.[40] And the national saving rate did rise, barely, although no thanks to the private sector. It is doubtful that private saving rates would have risen had tax rates not been raised, since saving rates have fallen steadily in recent years through both deficit and surplus periods. No one claims that the changes in fiscal policies were a response to IT innovations, as a rise in the private saving rate might have been). Finally, the gap between private saving and national investment not filled by the increase in government saving was filled by a diversion of saving flows from outside the country towards the United States, not necessarily an augmentation of the world saving rate.

Thus it seems reasonable to attribute the effect of capital deepening on labor productivity largely to the forces of thrift rather than innovation. In the absence of IT,

[39] David is clear that the nineteenth century traverse was "set in motion by Thrift, that is, by a pronounced rise in the proportion of output saved." In some passage he appears to treat it as exogenous, as opposed to a response to an upward movement in the real interest rate. In Abramovitz and David (1973), the authors speak of "technologically induced traverses." The implied argument seems to be that new blueprints lead to an increase in real returns to investment, which induces an upsurge in the saving rate, propelling one to a different steady state involving higher output per hour. In Abramovitz and David (1999) the authors suggest that the bias in technical change led to an increase in capital's share, which redistributed income to households with higher propensities to save, and this is the mechanism that leads to the upsurge in the saving rate. Williamson's 1973 paper is more explicitly based on analysis of the consequences of an upward shift in saving propensities: "For still unknown reasons the saving rate rose markedly during the Civil War decade" (1973, p. 593)

[40] Some of this surge was driven by Y2K concerns, presumably a one time event. Some of it was wasted, or as in the case of fiber optic cable in the telecom sector, vastly overbuilt.

saving flows would have been congealed in a set of not quite as good capital goods, an argument that can be, and has been made, for the railroad in the nineteenth century.

Many of the frameworks within which we now approach thinking about the impact of the IT revolution were developed during a period of sustained stock market exuberance when there was enormous pressure among academics and within government statistical offices to resolve the Solow paradox (computers were showing up everywhere but in the productivity statistics.) We need to make sure that our vision is not clouded by the legacies of the IT public relations offensives of the 1990s.

One manifestation of the effectiveness of that campaign has been that the orientation of the collection and presentation of government statistics on fixed assets has changed. As an example, in the Bureau of Economic Analysis's Fixed Asset Tables, the assets produced by information technology industries are now listed first, in separate and highly detailed categories, as if to encourage a result that the statistical apparatus had for a long time been grudgingly reluctant to yield up. But why are saving flows congealed in IT goods and software more or less important than those congealed in structures, machine tools, vehicles, nuclear fuel rods, or any of the other fixed asset categories? One might reply, because IT is a special type of capital good, one with a greater propensity to carry or embody or stimulate technical innovation within using sectors. That might be true, although Field (2004) suggests that, at least for the United States, it is not. Even if it were true, we will pick up this effect in MFP growth within the IT using sectors.

Another intellectual legacy of the IT boom has been the widespread and largely uncritical acceptance of the usefulness of the concept of a general purpose technology (GPT) and the recognition of IT or computers as its principal instantiation (Bresnahan and Trajtenberg, 1995).   While it is undoubtedly true that some advances are more important than others, to call something a GPT has in many instances been to suggest about a class of innovations or industries that there was more to them than apparently met the eye, or showed up in aggregate statistics. The enthusiasm for the concept runs the danger of placing too much emphasis on specific innovations awarded this coveted designation.

One of the difficulties with GPTs is the potential multiplicity of candidates. Steam, electricity, and IT are most frequently identified, but chemical engineering, the internal combustion engine, radio transmission and the assembly line have also been mentioned. The identification of one or several GPT's often offers an appealing narrative hook, but the criteria for designating them are not universally agreed upon, in spite of continuing efforts to nail them down. For example, why isn't the railroad also a GPT? Gordon (2004) suggests that use by both households and industry is a criterion. This works for electricity and the internal combustion engine. But steam?

Here is another concern. Bessemer and Siemens Martin processes were industry specific, and would clearly not pass muster as GPTs. They offered, to use David's words, "complete, self-contained and immediately applicable solutions" (2004, p. 22). This was not the case for the product whose production they enabled. Does that make steel a GPT? It took Carnegie and others time to persuade users they should make skyscrapers, plate ships, and replace iron rails with it. Cheap steel in turn encouraged complementary innovations such as, in the case of taller buildings, elevators.

If one follows the impact of product and process innovations far enough through the input-output table, one will eventually find products or technological complexes used as inputs in many other sectors, with the potential to generate spillover effects in using sectors. These processes, products, or complexes are the consequence of many separate breakthroughs as well as learning by doing, much of which has been sector specific. IT for example, has required advances in sector specific semiconductor manufacturing, and the thin film technology and mechanical engineering that underlies most mass storage, let alone software.

Because of the potential for multiplying GPT candidacies and the lack of an authoritative tribunal applying uniform rules passing judgment about which ones qualify, economic and technological history may well be better off without the concept. Our enthusiasm for GPTs suggests that we may still not have absorbed entirely the lessons of the Rostow – Fogel – Fishlow debate about the “indispensability” of the railroad. Whereas IT has probably been responsible for a larger increase in MFP growth between 1995 and 2000 than was the railroad in the 25 years after the Civil War (compare here my estimate of .15 percent per year for the railroad with the .68 percent per year I attribute to IT between 1995 and 2000), overall MFP advance at the end of the century was still much slower than it had been during the 1930s.

Sustained increases in our standard of living require either persisting increases in saving rates or a sustained series of *many* technological and organizational innovations across a broad frontier of the economy. The 1929-41 period shows the highest rate of MFP advance of any comparable period in the twentieth century. One could try to fit the history of that period into a GPT framework by placing the internal combustion engine or chemical engineering or some other candidate at center stage. But my expectation is that there a “great man” technological history of the 1930s will not easily be written. The siren song of the “great invention” approach to the economic history of the last decade of the century is more alluring because the technological and organizational advance of the late 1990s was weaker, more localized and more narrowly focused than that which characterized the Depression years.[41] Nevertheless, the course of recent history does not necessarily validate the GPT’s usefulness as a tool for analyzing the broad sweep of economic history.

It is important to distinguish between the proposition that it sometimes takes a long time for the productivity benefits of new technological complexes to be reaped, and the concept of a GPT. One can accept the former without necessarily embracing the usefulness of the latter. The full benefits of IT may indeed involve considerable delays before they are realized. My intent in this paper, however, has been to focus on what the statistical record allows us to conclude has actually been achieved, not on what might happen, or what we would like to believe will happen, in the future. The end of century productivity revival needs to be understood on its own terms. We should give the IT revolution its due, but not more than its due.

[41] See the narrative in Dale Jorgenson’s AEA presidential address, which tells a story built almost entirely around semiconductors (Jorgenson, 2001).

Bibliography

Abramovitz, Moses. 1956. "Resource and Output Trends in the United States since 1870." American Economic Review 46 (May): 5-23.

Abramovitz, Moses. 1986. "Catching Up, Forging Ahead, and Falling Behind." The Journal of Economic History 46 (June): 385-406.

Abramovitz, Moses. 1993. "The Search for the Sources of Growth: Areas of Ignorance, Old and New." The Journal of Economic History 53. (June): 217-243.

Abramovitz, Moses and Paul David (1973), "Reinterpreting American Economic Growth: Parables and Realities," American Economic Review 63:2 (May): 428-39.

Abramovitz, Moses and Paul David. 1999. "American Macroeconomic Growth in the Era of Knowledge-Based Progress: The Long Run Perspective." SIEPR Discussion Paper No. 99-3, Stanford, California (unpublished).

Abramovitz, Moses and Paul David. 2000. "American Macroeconomic Growth in the Era of Knowledge-Based Progress: The Long Run Perspective." In Stanley Engerman and Robert Gallman, eds., The Cambridge Economic History of the United States, volume III. Cambridge: Cambridge University Press, pp. 1-92.

Backman, Jules and M. R. Gainsbrugh**.** 1949. **"**Productivity and Living Standards." Industrial and Labor Relations Review 2 (January): 163-194.

Baily, Martin N. 1983. "The Labor Market in the 1930s" in James Tobin, ed., Macroeconomics, Prices, and Quantities. Washington: Brookings Institution.

Barro, Robert J. and Xavier Sala-I-Martin. 1995. Economic Growth. New York: McGraw Hill.

Basu, Susanto and John Fernald. 1995. "Are Apparent Productive Spillovers a Figment of Specification Error?" Journal of Monetary Economics 36 (August): 165-88.

Baumol, William J. 1986. "Productivity Growth, Convergence, and Welfare: What the Long Run Data Show." American Economic Review 76: 1072-1085.

Bell, Spurgeon. 1940. Productivity, Wages and National Income. Washington: Brookings Institution.

Berndt, Ernst R., Ellen R. Dulberger and Neal J. Rappaport. 2000. "Price And Quality Of Desktop And Mobile Personal Computers: A Quarter Century Of History." (unpublished working paper, MIT).

Bernstein, Michael. 1987. The Great Depression: Delayed Recovery and Economic Change in America, 1929-1939. New York: Cambridge University Press.

Bresnahan, Timothy F. and Manuel Trajtenberg. 1995. "General Purpose Technologies: Engines of Growth?" Journal of Econometrics 65 (January): 83-108.

Brown, E. Cary. 1956. "Fiscal Policy in the 'Thirties: A Reappraisal." The American Economic Review, 46 (December): 857-879.

David, Paul. 1977. "Invention and Accumulation in America's Economic Growth: A Nineteenth Century Parable." In Karl Brunner and Allan Meltzer eds. Carnegie-Rochester Conference Series on Public Policy vol. 6. New York: North-Holland.

David, Paul. 2004. "The Tale Of Two Traverses: Innovation and Accumulation in the First Two Centuries of U.S. Economic Growth." Gallman lecture presented at Conference on Understanding the 1990s: The Economy in Long Run Perspective, Duke University, March 26-27, 2004.

David, Paul and Gavin Wright. 2003. "General Purpose Technologies and Surges in Productivity: Historical Reflections on the Future of the ICT Revolution." In Paul A. David and Mark Thomas (eds.), The Economic Future in Historical Perspective. Oxford University Press, 2003, pp. 135-166.

De Long, J. Bradford. 1992. "Productivity Growth and Machinery Investment: A Long Term Look, 1870-1980." Journal of Economic History 52 (June): 307-324.

De Long, J. Bradford and Lawrence Summers. 1991. "Equipment Investment and Economic Growth" The Quarterly Journal of Economics, 106, No. 2. (May): 445-502.

De Long, J. Bradford; Lawrence H. Summers and Andrew B. Abel (1992) "Equipment Investment and Economic Growth: How Strong is the Nexus?" Brookings Papers on Economic Activity 1992, No. 2 (1992): 157-211.

De Long, Brad. 2002. "Do We Have a New Macroeconomy?" in Innovation Policy and the Economy volume 2. Cambridge, MIT Press, pp. 163-184.

Edelstein, Michael. 2000. "War and the American Economy in the Twentieth Century." in Stanley Engerman and Robert Gallman, eds., The Cambridge Economic History of the United States, volume III, Cambridge: Cambridge University Press pp. 329-406.

Evans, W. D. 1947 "Recent Productivity Trends and Their Implications." Journal of the American Statistical Association 42 (June): 211-223.

Fano, Esther. 1987. "Technical Progress as a Destabilizing Factor and as an Agent of Recovery in the United States between the Two World Wars." History and Technology 3: 249-74.

Field, Alexander J. 1987. "Modern Business Enterprise as a Capital Saving Innovation." Journal of Economic History 47 (June 1987): 473-85.

Field, Alexander J. 1992a. "The Magnetic Telegraph, Price and Quantity Data, and the New Management of Capital" Journal of Economic History 52 (June 1992): 401-13.

Field, Alexander J. 1992b. "Uncontrolled Land Development and the Duration of the Depression in the United States." Journal of Economic History 52 (December): 785-805.

Field, Alexander J. 1996. "The Relative Productivity of American Distribution, 1869-1992" in Research in Economic History, 16 (Greenwich: JAI Press): 1-37.

Field, Alexander J. 1998. "The Telegraphic Transmission of Financial Asset Prices and Orders to Trade: Implications for Economic Growth" in Research in Economic History 18 (Greenwich: JAI Press, 1998): 145-184.

Field, Alexander J. 2001. "Not What it Used to Be: The Cambridge Economic History of the United States, Volumes II and III." Journal of Economic History 61 (September): 806-818. .

Field, Alexander J. 2003. "The Most Technologically Progressive Decade of the Century." American Economic Review 93 (September): 1399-1413.

Field, Alexander J. 2004. "The Equipment Hypothesis and U.S. Economic Growth." (working paper).

Fishlow, Albert. 1965. American Railroads and the Transformation of the Antebellum Economy. Cambridge: Harvard University Press.

Fogel, Robert. 1964. Railroads and American Economic History: Essays in Econometric History. Baltimore: Johns Hopkins University Press.

Foster, Lucia, John Haltiwanger, and C. J. Krizan. 2002. "The Link between Aggregate and Micro Productivity Growth: Evidence from Retail Trade." NBER working paper 9120 (August).

Galambos, Louis. 2000. The U.S. Corporate Economy in the Twentieth Century." in Stanley Engerman and Robert Gallman, eds., The Cambridge Economic History of the United States, volume III. Cambridge: Cambridge University Press, pp. 927-968.

Goldin, Claudia. 1998. "America's Graduation from High School: The Evolution and Spread of Secondary Schooling in the Twentieth Century." Journal of Economic History 58: 347-74.

Goldin, Claudia and Lawrence F. Katz. 1998. "The Origins of Technology-Skill Complementarity." The Quarterly Journal of Economics 113: 693-732.

Goldin, Claudia and Robert Margo. 1992. "The Great Compression: The Wage Structure of the United States at Mid-Century." Quarterly Journal of Economics 107 (February): 1-34.

Gordon, Robert J. 1969. "$45 Billion of U.S. Private Investment Has Been Mislaid." The American Economic Review 59(June): 221-238.

Gordon, Robert J. 1999. "U.S. Economic Growth Since 1870: One Big Wave?" American Economic Review 89: 123-128.

Gordon, Robert J. 2000a. "Interpreting the "One Big Wave" in U.S. Long Term Productivity Growth," in Bart van Ark, Simon Kuipers, and Gerard Kuper, eds., Productivity, Technology, and Economic Growth. Boston: Kluwer, pp. 19-66.

Gordon, Robert J. 2000b. "Does the "New Economy" Measure up to the Great Inventions of the Past?" Journal of Economic Perspectives 14 (Fall): 49-74.

Gordon, Robert J. 2003. "Five Puzzles in the Behavior of Productivity, Investment, and Innovation." (unpublished paper)

Gordon, Robert J. 2004. "The 1920s and the 1990s in Mutual Reflection." Paper presented at Conference on Understanding the 1990s: The Economy in Long Run Perspective, Duke University, March 26-27, 2004.

Griliches, Zvi. 2000. R&D, Education, and Productivity: A Retrospective. Cambridge: Harvard University Press.

Hulten, Charles R. 2001. "TFP: A Short Biography," in Charles Hulten, Edwin R. Dean and Michael J. Harper (eds.), New Developments in Productivity Analysis. Chicago: University of Chicago Press for NBER.

Johnson, Bradford C. 2002. "Retail: The Wal-Mart Effect." The McKinsey Quarterly 1: 40-43.

Jorgenson, Dale and Kevin Stiroh. 1999. "Information Technology and Growth," American Economic Review, 89 (May): 109-115.

Jorgenson, Dale. 2001. "Information Technology and the U.S. Economy." American Economic Review 91 (March): 1-32.

Jorgenson, Dale, Mun Ho, and Kevin Stiroh. 2003. "Lessons from the U.S. Growth Resurgence." Paper prepared for the First International Conference on the Economic and Social Implications of Information Technology, held at the U.S. Department of Commerce, Washington, DC, on January 27-28, 2003.

Kendrick, John. 1961. Productivity Trends in the United States. Princeton: Princeton University Press.

Kleinknecht, Alfred. 1987. Innovation Patterns in Crisis and Prosperity: Schumpeter's Long Cycle Reconsidered. New York: St. Martin's Press.

Klenow, Peter and Andres Rodriquez-ClareLebergott. 1997. "Economic Growth: A Review Essay." Journal of Monetary Economics 40: 597-617.

Lebergott, Stanley. 1964. Manpower in Economic Growth: The American Record Since 1800.

Lipsey, Richard J. and Kenneth Carlaw 2001. "What Does Total Factor Productivity Measure?" International Productivity Monitor (Fall 2000): 23-28.

Margo, Robert. 1991. "The Microeconomics of Depression Unemployment." Journal of Economic History 51 (June): 331-41.

Margo, Robert. 1993. "Employment and Unemployment in the 1930s," Journal of Economic Perspectives 7 (Spring): 41-59.

McKinsey Global Institute, 2002. "US Productivity Growth 1995-2000: Understanding the Contribution of Information Technology Relative to other Factors." available on the web at www.mckinsey.com.

Mensch, Gerhard. 1979. Stalemate In Technology : Innovations Overcome the Depression. Cambridge: Ballinger.

Mitchell, Broadus. 1947. Depression Decade: From New Era to New Deal, 1929-1941. New York: Holt Rinehart and Winston.

Mowery, David and Nathan Rosenberg. 1989. Technology and the Pursuit of Economic Growth. Cambridge: Cambridge University Press.

Mowery, David and Nathan Rosenberg. 2000. "Twentieth Century Technological Change." In Stanley Engerman and Robert Gallman, eds., The Cambridge Economic History of the United States, volume III. Cambridge: Cambridge University Press, pp. 803-926.

National Bureau of Economic Research. 2003. "Business Cycle Expansions and Contractions." http://www.nber.org/cycles/cyclesmain.html

Nordhaus, William D. 1997. "Traditional Productivity Estimates are Asleep at the (Technological) Switch." The Economic Journal 107: 444. (Sep., 1997): 1548-1559.

Nordhaus, William D. 2002. "Productivity Growth and the New Economy." Brookings Papers on Economic Activity 2: 211-65.

Oliner, Steven D. and Daniel E. Sichel. 2000. "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" Journal of Economic Perspectives 14 (Fall): 3-22.

Rostow, W. W. 1960. The Stages of Economic Growth: A NonCommunist Manifesto. Cambridge: Cambridge University Press.

Schmookler, Jacob. 1966. Invention and Economic Growth. Cambridge: Harvard University Press.

Solow, Robert J. 1957. "Technical Change and the Aggregate Production Function." Review of Economics and Statistics. 39 (August): 312-20.

U.S. Bureau of Economic Analysis. 2003. "Fixed Asset Table 2.2;" "Fixed Asset Table 4.2;" available at www.bea.gov.

U.S. Bureau of Economic Analysis. 2003. "Gross Product Originating by Industry." available at www.bea.gov.

U.S. Bureau of Labor Statistics. 1946. "Productivity Changes Since 1939." Monthly Labor Review (December): 893-917.

U.S. Bureau of Labor Statistics. 1997. Handbook of Methods. available at www.bls.gov.

U.S. Buruea of Labor Statistics. 2003. Capital and Related Measures from the Two Digit Database." available at www.bls.gov.

U.S. Bureau of Labor Statistics. 2003. "Industry Productivity Indexes and Values Table." available at www.bls.gov.

U.S. Bureau of Labor Statistics. 2003. Multifactor Productivity in U.S. Manufacturing and in 20 Manufacturing Industries." available at www.bls.gov.

U.S. Bureau of Labor Statistics. 2003. Multifactor Productivity Estimates for Wholesale and Retail Trade (unpublished).

U.S. Bureau of Labor Statistics. 2003. "Private Nonfarm Business – Multifactor Productivity." available at www.bls.gov.

U.S. Bureau of the Census. 1975. Historical Statistics of the United States, Colonial Times to 1970. Washington: Government Printing Office.

U.S. Council of Economic Advisors. 2001. Economic Report of the President. Washington: Government Printing Office; available at http://w3.access.gpo.gov/eop/ .

U.S. Council of Economic Advisors. 2003. Economic Report of the President. Washington: Government Printing Office; available at http://w3.access.gpo.gov/eop/ .

Wall Street Journal. 2003. "Behind Surging Productivity, the Service Sector Delivers." November 7, 2003

Williamson, Jeffrey. 1973. "Late Nineteenth-Century American Retardation: A Neoclassical Analysis." The Journal of Economic History 33 (September): 581-607.

Table A-1

BLS Data, Private Nonfarm Economy, 1948 - 2000

	1948	1973	CAAGR 1948-73	1995	CAAGR 1973-95	2000	CAAGR 1995-2000
Capital Services	15.2	40.3	3.90	95.8	3.94	125.4	5.38
Hours	51.2	69.4	1.22	98.2	1.58	109.0	2.09
Hours (adjusted)	44.1	63.3	1.45	97.8	1.98	110.6	2.46
Capital Services/hr	29.7	58.1	2.68	97.6	2.36	115.0	3.28
Capital Services/hr adjusted	34.5	63.7	2.45	98.0	1.96	113.4	2.93
Combined Input	31.8	55.2	2.21	97.2	2.57	115.2	3.40
Output	18.0	50.0	4.09	95.8	2.96	120.2	4.54
Output/Hour	35.1	72.1	2.88	97.5	1.37	110.3	2.46
Output/Adjusted Hour	40.8	79.0	2.64	98.0	0.98	108.7	2.08
MFP	56.4	90.7	1.90	98.6	0.38	104.4	1.14
BLS Labor Compensation	128.56	657.25		3403.99		4789.70	
BLS Capital Income	60.18	273.44		1652.76		2160.95	
Capital's Share (percent)	31.88	29.38		32.68		31.09	

Sources: All Data is obtained from the BLS website, www.bls.gov, accessed November 2003.
For all index numbers, 1996=100.

Table A-2
Sectoral Calculations for Trucking, Airline Transport, Water Transport Pipelines, and Mining, 1929-41

Trucking Calculation, 1929-42

	1929	1942	CAAGR
Output	10.4	74.5	16.41
Hours	56.5	89.7	3.85
Capital	5.95	6.39	0.59
MFP Growth =		13.57	

Sources:
Output, Hours: Kendrick (1961), Table G-VIII, p. 553; 1947=100
Capital: Chain index of real capital in Trucks, buses and truck trailers, 1996=100; BEA Fixed Asset T
Capital Share assumed = .31.

Airline Transport Calculation, 1929-41

Output	1929	1941	CAAGR
Persons Engaged	0.5	20.4	30.91
Capital	2.3	29.3	21.21
	0.85	1.57	5.11
MFP Growth =			
		14.69	

Sources:
Output, Persons Employed: Kendrick (1961), Table G-X, p. 555; 1947=100
Capital: Chain index of real capital in Aircraft, 1996=100; BEA Fixed Asset Table 2.2.
Capital Share assumed = .31.

Water Transport Calculation, 1929-40

Output	1929	1940	CAAGR
Persons Engaged	100	99.4	-0.05
Capital	100	85.9	-1.38
	52.68	43.08	-1.83
MFP Growth =			
		1.47	

Sources:
Output, Persons Employed: Kendrick (1961), Table G-IX, p. 554; 1929=100+B30
Capital: Chain index of real capital in Ships and Boats, 1996=100; BEA Fixed Asset Table 2.2.
Capital Share assumed = .31.

Pipeline Calculation, 1929-41

Output	1929	1941	CAAGR
Persons Engaged	100	168.5	4.35
Capital	100	95.3	-0.40
	64.01	67.81	0.48
MFP Growth =			
		4.48	

Sources:
Output, Persons Engaged: Kendrick (1961), Table G-XI, p. 554; 1929=100
Capital: Chain index of real capital in petroleum pipelines, 1996=100; BEA Fixed Asset Table 2.2.
Capital Share assumed = .31.

Mining Calculation, 1929-41

Output	1929	1941	CAAGR
Labor Input	100	106.5	0.52
Structures	100	76	-2.29
Equipment	18.02	23	2.03
K Index	75.84	74.32	-0.17
	37.28	40.09	0.61
MFP Growth =			
		1.47	

Sources:
Output, Persons Employed: Kendrick (1961), Table G-X, p. 555; 1947=100
Capital: Chain index of real capital in Mining, 1996=100; BEA Fixed Asset Table 2.2.
In K Index, weighted .66; equipment .33
Capital Share assumed = .31.