2006

Technical change and US economic growth: the interwar period and the 1990s

Alexander J. Field

Santa Clara University, afield@scu.edu

Follow this and additional works at: <http://scholarcommons.scu.edu/econ>

Part of the [Economics Commons](#)

Recommended Citation

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

This material has been published in *The Global Economy in the 1990s: A Long Run Perspective* edited by Paul Rhode & Gianni Toniolo. This version is free to view and download for personal use only. Not for re-distribution, re-sale or use in derivative works. © Cambridge University Press.

<https://doi.org/10.1017/CBO9780511616464.006>

This Book Chapter is brought to you for free and open access by the Leavey School of Business at Scholar Commons. It has been accepted for inclusion in Economics by an authorized administrator of Scholar Commons. For more information, please contact rsroggin@scu.edu.

5 Technical change and US economic growth: the interwar period and the 1990s

Alexander J. Field

5.1 Introduction

Looking back over the twentieth century, the years 1948–1973 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 (MEP) growth and robust rates of capital deepening. The period 1973–1989, 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 towards 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 most of the standard series maintained by the Bureau of Labor Statistics (BLS) begin. This chapter, in contrast, pushes the time horizon back to the beginning of the twentieth century, with particular attention to the period following the First World War and preceding US entry into the Second World War in 1941. It combines a summary of the magnitude and sources of productivity advance during the interwar years (for more details, see Field, 2003, 2006a) 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 common 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 striking. 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.

Table 5.1 *Compound annual growth rates of MFP, labor, and capital productivity in the US private non-farm economy, 1901–2000*

	MFP	Output/hour	Output/adjusted hour	Output/unit capital input
1901–1919	1.08	1.71	1.44	0.01
1919–1929	2.02	2.27	2.33	1.09
1929–1941	2.31	2.35	2.21	2.47
1941–1948	1.29	1.71	1.42	1.32
1948–1973	1.90	2.88	2.64	0.18
1973–1989	0.34	1.34	1.03	–1.24
1989–2000	0.78	1.92	1.41	–0.61
1973–1995	0.38	1.37	0.98	–0.98
1995–2000	1.14	2.46	2.08	–0.84

NB: “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: 1901–1948 – 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,” and 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 12 April 2004; the labor productivity section contains more recent data and is updated more frequently.

That said, 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 to the peak of the cycle in 2000, the end-of-century labor productivity advance remained well below “golden age” rates. Perhaps more surprisingly, it remained in the same range as that registered during the interwar period (see table 5.1). And multifactor productivity growth was less than half what it was during the Depression years.¹

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 the middle of the century, was expected to persist (Abramovitz, 1993, p. 224).

By and large it did so for another quarter-century. But the sixteen-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 had 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 chapter focuses on the two major cycles of the interwar period (1919–1929 and 1929–1941) and the more recent 1989–2000 period. 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.

5.2 Overview of twentieth-century growth trends

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 little capital deepening.

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 capital deepening continued at somewhat slower rates but multifactor productivity growth in the US 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 5.1; data are for the private non-farm economy (PNE)). At the end of the century labor productivity growth again approached golden age rates, principally as the result of a revival of MFP growth.

5.3 The rise in output per hour during the Depression: causes and consequences

A number of economists have been aware of the rise in output per hour during the Depression, but most of the attention in explaining this has been on the effects of the selective retention of workers, particularly during the 1929–1933 downturn (Margo, 1991). By 1941, however, when recovery had finally pushed unemployment rates into single-digit levels, much of this should have been unwound. There were secular improvements in labor quality during the Depression years as well, but a comparison of columns 2 and 3 of table 5.1 suggests that such improvements can explain only a small fraction of the growth

in output per hour between 1929 and 1941.² Clearly, other factors had to have been operative – and these could not have included physical capital deepening, as can also be seen from table 5.1.

Since there was virtually no increase in private sector inputs conventionally measured between 1929 and 1941, MFP advance accounted for *all* of the 32 percent increase in the real output of the private non-farm economy over these years. And, since there was no private sector capital deepening, the same was true for the increase in output per hour. Masked by the continuing levels of high unemployment, an impressive expansion of the potential output of the US economy was taking place.

Does the claim that the Depression years witnessed the highest MFP growth rates of the century include consideration of the end-of-century “new economy” boom? The short answer is that it does. My offices at a university in the heart of Silicon Valley offered a ringside view of the investment boom, the rising share prices, and some of the hyperbolic claims that drove both. For better or for worse, this enthusiasm led to a 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 data from the end of the twentieth century, even after incorporating the use of hedonic methods to adjust for quality changes, tell a more nuanced story. Revolutionary technological or organizational change – the sort that shows up in MFP growth – was concentrated in 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 36,³ sectors that include the production of semiconductors, computers, networking, and telecommunications equipment. Aggregate MFP growth remained modest by the historical standards of the twentieth century.

Evidence from the beginning of the twenty-first century suggests the possibility of more substantial MFP payback in the IT-using sectors, albeit delayed (*Wall Street Journal*, 2003). Labor productivity grew at 3.04 percent per year continuously compounded from 1995 through 2004 (BLS series PRS85006093, accessed 19 June 2005). This represents very strong performance, particularly after 2000. At the time this chapter was written, however, we did not have MFP estimates beyond 2002, so it remains unclear how much of early twenty-first-century growth must be due to an increase in the labor composition contribution due to selective retention (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, which grew at over 2 percent per year between 1995 and 2000, declined at 1.85 percent per year between 2000:2 and 2003:2. Even with

subsequent recovery, hours in 2005:1 were still 3 percent below their peak in 2000. Until we have the most recent capital services numbers we can't know what has happened to the capital/hours ratio. Between 2000 and 2002 (the latest year for which we have capital services data) capital services per hour rose very rapidly – a total of 12.4 percent – as the numerator continued to rise and the denominator declined. We will 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 bottom line is that, measuring from 1989 through the end of the boom in 2000, aggregate MFP growth, including that in the IT-using sectors, although more than double the rate in 1973–1989, was only a third that registered between 1929 and 1941 (see table 5.1).

Why 1989? And why 2000? Multifactor productivity data is available only on an annual basis. According to the National Bureau of Economic Research (NBER) business cycle chronology, the peak of activity in July 1990 was followed by a recession that bottomed out in March 1991, followed by the long expansion of the 1990s, culminating in the peak 120 months later (March 2001). But 2001 was also a year of economic downturn, with the trough reached only eight months afterwards, in November that year. Similarly, 1990 included five post-peak months. Since we are using annual data, I measure from the last full year of expansion (1989) before a downturn to the subsequent final full year of expansion before a downturn (2000).⁴

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 a cyclical acceleration in both labor and multifactor productivity common in later stages of a business expansion (Gordon, 2003c). Nevertheless, there does seem to be a break in the series *circa* 1995, and, in deference to current practice, table 5.1 also reports 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.

5.4 The role of manufacturing

If we are discussing contributions to achieved productivity levels in the inter-war period, it is appropriate to place a good deal of emphasis on a growing

Table 5.2 *The growth of MFP, labor, and capital productivity in manufacturing in the United States, 1919–2000*

	MFP	Output/hour	Output/adjusted hour	Output/unit capital input
1919–1929	5.12	5.45	5.45	4.20
1929–1941	2.60	2.61	2.46	2.96
1941–1948	–0.52	0.20	0.03	–1.82
1949–1973	1.49	2.51	n.a.	–0.03
1973–1989	0.57	2.42	n.a.	–1.22
1989–2000	1.58	3.56	n.a.	0.16
1973–1995	0.66	2.61	n.a.	–0.82
1995–2000	2.09	4.07	n.a.	0.08

Sources: 1919–29 – Kendrick (1961, table D-1, p. 464); 1929–1941 and 1941–1948 – output and labor input are from Kendrick (1961, tables D-1 and D-2), capital input is based on the index for manufacturing fixed capital in the BEA’s Fixed Asset Table (4.2, www.bea.doc.gov/bea/dN/FAweb/Index2002.htm), MFP is calculated based on an assumed share of 0.7 for labor, 0.3 for capital; 1949–2000 – Bureau of Labor Statistics, series MPU300001, MPU300002, MPU300003, accessed 22 November 2004.

manufacturing sector that by 1941 comprised almost a third of the economy. I estimate that 84 percent of MFP growth in the private non-farm 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 private non-farm MFP growth, but that total and manufacturing’s percentage point contribution to it were much smaller than was true in the interwar period.

Although Kendrick does not provide enough information to allow the calculation of MFP growth rates within manufacturing for the 1929–1941 and 1941–1948 sub-periods, one can 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 (BEA’s) Fixed Asset Tables (see table 5.2).⁵ These calculations show MFP growth within the sector over the 1929–41 period to have proceeded at the rate of 2.60 percent per year. This is higher than in any subsequent period of the twentieth century. It does, however, represent a halving of the 5.12 percent rate registered over the 1919–1929 period, years in which the flexibility offered by the unit drive electric motor facilitated the shift to a single-story layout and the assembly line production of automobiles and a host of new electrically powered consumer durables (Devine, 1983;

Table 5.3 *The employment of scientists and engineers in US manufacturing, 1927–1940*

	1927	1933	1940
Chemicals	1812	3255	7675
Electrical machinery	732	1322	3269
Petroleum	465	994	2849
Non-electrical machinery	421	629	2122
Primary metals	538	850	2113
Transport equipment	256	394	1765
Food/beverages	354	651	1712
Stone/clay/glass	410	569	1334
Fabricated metal products	334	500	1332
Instruments	234	581	1318
Rubber products	361	564	1000
Totals, eleven industries	5917	10309	26489
Totals, manufacturing	6274	10918	27777

Sources: National Research Council data, cited in Mowery (1981); Mowery and Rosenberg (2000, p. 814).

David and Wright, 2003; Field, 2004). My calculations also suggest, consistent with arguments advanced in Field (2003, 2005), a decline in the level of MFP in manufacturing over the 1941–1948 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 more impressive, however, when contrasted with what took place in the second half of the century, including the “new economy” period at the end of the 1990s. Although technical progress was broadest and most uniformly high during the 1920s, advance within manufacturing was taking place across a broader frontier during the Depression than was the case in the 1990s.

MFP advance in manufacturing during the Depression years was increasingly dependent on organized research and development. Table 5.3 summarizes National Research Council (NRC) data on the employment of scientists and engineers in US manufacturing. Total R&D employment increased from 6,274 in 1927 to 10,918 in 1933, and then almost tripled in the next seven years, reaching 27,777 in 1940.

Margo has documented the lower 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). This is indirect evidence that the sharp increase in R&D employment during the Depression was driven more by an outward shift in the demand for this type of labor than by a shift in its supply.

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, while, according to Kendrick, hours had risen 15.5 percent over the same period (Kendrick, 1961, appendix, table D-II). So, at the same time that the aggregate capital labor ratio in the sector fell, the relative demand for scientists and engineers increased. During this period complementarity was between high-end labor and the disembodied technical change that was such an important feature of the Depression years – a contrast with the capital–skill complementarity emphasized by Goldin and Katz (1998).

Table 5.3 lists the eleven two-digit industries that employed at least 1,000 scientists and engineers in 1940. The chemical industry tops the list by a wide margin, followed by electrical machinery and petroleum. These three industries alone account for almost half the total R&D employment on the eve of the Second World War. Absent from the list are tobacco, textiles, apparel, lumber, furniture, paper, publishing, and leather – industries that, with the possible exception of tobacco manufacture, one can identify with the first industrial revolution, before the Civil War. Although the emphasis here is on R&D-intensive industries such as chemicals, which turned in stellar productivity results during the Depression, it should be noted that a number of these latter industries, including tobacco and textiles, also turned in very respectable MFP performance over the period.

The overall trends revealed in the employment data are echoed in other R&D indicators. Between 1929 and 1936 the annual rate of founding of new R&D labs (seventy-three) exceeded the comparable statistic between 1919 and 1928 (sixty-six), and real spending on R&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 compared with 1919–1929 (see table 5.2). There are two closely related questions here. On the one hand, why did MFP growth fall from 5.12 percent per year to 2.60 percent per year? The main explanation is that the across-the-board gains from exploiting small electric motors, and reconfiguring factories from the multi-story pattern that mechanical distribution of steam power required to the one-story layout made possible by electrification, were nearing exhaustion by the end of the 1920s. By 1929 79 percent of manufacturing horsepower in the United States was already provided by electricity (Devine, 1983). 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 related question, then, is, why didn't MFP growth in manufacturing fall 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 Thomas Edison at Menlo Park. The lion's share of private R&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.

The growing importance of the manufacturing sector – it generated about a quarter of national income in 1929, almost a third in 1941 – helped counter-balance 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 percent continuously compounded growth rate reported in table 5.1 for the private non-farm economy.

That acceleration 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 non-farm economy, but we know that the farm sector's productivity growth in the 1930s also lagged behind that of the rest of the economy (see Field, 2003).

With the exception of water transport, productivity performance in transportation and public utilities between 1929 and 1941 was stellar (Field, 2006a). Of the 4.67 percent per year MFP growth in the sector, trucking and warehousing accounted 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 sectoral advance took place in surface transportation, and trucking and warehousing alone accounted for approximately 10 percent of MFP growth in the entire PNE.

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 this infusion was in manufacturing, and a large part 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. This boom in equipment investment was associated with negative MFP growth in manufacturing between 1941 and 1948 and, partly as a result, a slowdown in PNE MFP growth overall (see Field, 2005, 2006a). In contrast, the infrastructure spending during the 1930s had positive spillovers in the private sector, particularly in transportation and distribution.

The achievements of the 1930s built on foundations put in place during the Depression years as well as work done in the 1920s and earlier. By establishing the groundwork for subsequent advance, the period also restocked the larder. For example, almost all the development work carried out by Philo Farnsworth on the quintessential postwar consumer commodity was carried out during the Depression, supported by venture capital funding. The new product (television) 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.

Overall, of the 2.31 percent CAAGR (compound average annual growth rate) of MFP in the private non-farm economy between 1929 and 1941, 48 percent was contributed by manufacturing, 24 percent by transport and public utilities, and 18 percent by wholesale and retail distribution, with the remainder of the PNE contributing about 11 percent (see Field, 2006a).

We can now summarize the main distinctions between 1919–1929 and 1929–1941 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 non-farm economy accounted for by manufacturing, from 84 percent in the 1920s to 48 percent in the 1929–1941 period. This was primarily due to a halving of within-sector MFP growth, only partially compensated for by the expanding size of the manufacturing sector. There was also a change in the sources of advance – away from the one-time gains associated with the final stages of electrification to those associated with exploiting the results of organized and expanding research and development efforts. This interpretation is supported by the aforementioned R&D employment and expenditure data (see table 5.3) and by chronologies of major process and product breakthroughs (Kleinknecht, 1987; Mensch, 1979; Schmookler, 1966; Field, 2003), which all show peaks during the 1930s, particularly its latter half.

5.5 The end-of-century episode

The aim of the second part of this chapter is to examine the end-of-century episode in historical perspective, and, in particular, to consider how much of the recent 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 one 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; 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 it can be demonstrated, a portion of non-cyclical MFP growth in IT-using industries such as securities trading and wholesale and retail distribution. The inclusion of the third component is more problematic, although it is endorsed by many, including Barro and Sala-I-Martin (1995, p. 352) and Klenow and Rodríguez-Clare (1997, p. 608).

The objection to including a portion of the capital deepening effect is this. What one is 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. One wants 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.⁶

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 (these are typically referred to as spillovers or productive externalities).

But, 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.⁷ 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 percentage

of GDP at either the US 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 both within the United States and outside the country. 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 would also need to argue, in order to justify the inclusion of the third component, that saving responded. And we would be hard-pressed to do so.

There is a large literature on the responsiveness of saving to after-tax interest rates. 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. Empirically, the evidence is inconclusive, although consistent with a conclusion of little net effect. As far as the income distribution mechanism, there is no question that there was a trend towards 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. 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 were improperly measured because they did not include unrealized capital gains. But the conventionally measured saving rate was largely invariant both to the expansion of stock market valuations in the 1990s and their collapse in the early twenty-first century.

Between 1995 and 2000 consumption spending in the United States increased by 34 percent, from \$4,969 billion to \$6,683.7 billion nominal.⁸ 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 0.41 percent per year (1973–1995) to 1.03 percent per year (1995–2000). Part of this acceleration came at the expense of the services of other components of the stock within the United States, the growth of which declined from 0.30 percent per year in the earlier period to 0.06 percent per year (US Council of Economic Advisors, 2001, p. 29). How was the boom in capital formation, much of it IT capital, financed?

Table 5.4 shows that between 1995 and 2000 there was a \$611.6 billion increase in gross private domestic investment as well as an increase in government investment of \$81.6 billion. How was this financed? Not by an increase in personal saving, which fell by a third, or by retained business saving (net business saving), which fell by a quarter. Gross business saving rose, however, as a consequence of a \$274.3 billion increase in corporate and unincorporated

Table 5.4 *Changes in the uses and sources of saving in the United States, 1995–2000*

	1995	2000	Change in	
			uses	sources
Gross private domestic investment	1143.8	1755.4	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	1017.9		
Gross business saving ^a	963.6	1170.5		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

^a Includes wage accruals and disbursements not shown separately.

NB: All numbers are billions of dollars, nominal. This table is based on a rearrangement of the open economy investment savings identity. Private domestic investment must be financed by the sum of private domestic saving, government saving, and inflows of foreign saving (capital account surplus or current account deficit). Note that negative net foreign investment is entered as a positive number in the sources of saving column.

Source: US Council of Economic Advisors (2003, table B-32).

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.

The increase in gross domestic investment was \$693.2 billion. After taking into account the effect of changes in gross private saving, a saving gap of almost \$600 billion remains. It was filled through two main mechanisms. First, a movement in the consolidated government surplus from –\$8.5 to \$435.8 billion – a swing of \$444.3 billion in the surplus direction, and, second, 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.

The end-of-century investment boom was enabled on the one hand by the willingness of foreign wealth holders to divert their saving flows from investment in their own countries or elsewhere and make it available to the United States, and on the other hand by the tax policies of the Clinton administration

and the second half of the George W. Bush administration. Their fiscal policies, in particular modest tax increases in conjunction with an economy operating at close to capacity, provided the foundation for the big increase in government saving.

It is conceivable that, although the IT accumulation spurt was not associated with a rise in the private saving rate within the United States, it was associated with a rise in the world saving rate. This seems unlikely, and no one has made this 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 productivity trends within the United States. But it does have welfare implications, particularly for the future. Reliance on foreign borrowing meant that the United States was able to forgo the sacrifice of current consumption that would otherwise have been the price of capital deepening. 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 that 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 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 1973–1995. 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 US private saving simply compensated collectively for the rise in government saving. But this seems doubtful, since the saving rate has been trending downwards for decades through periods of government deficit and surplus. It is more likely that, in the absence of the tax increases of the early 1990s, the deterioration of the current account would have been even worse.

If the enabling technologies of the IT revolution diverted towards the United States some portion of world saving flows that would not otherwise have come this way *even though US and world saving rates remained largely 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

United States, 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.”

5.6 The IT contribution and social saving controversies

The framework for reckoning the impact of the IT revolution advocated in this chapter, 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. It can be better appreciated by comparing the challenge of coming to terms with IT in the 1990s 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 US railroads. W. W. Rostow (1960) 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 alternative channels for saving flows (into canal building and river dredging, for example) and ultimately how much lower US GDP would have been in this alternative 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 4 percent higher than it otherwise would have been? About 0.15 percent per year, continuously compounded.

In fact, Abramovitz’s and Kendrick’s analyses of nineteenth-century growth after the Civil War suggest, as was true for the 1973–1995 period, that, at least up until 1889, almost all 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 growth in living standards in the 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.⁹

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 the 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.¹⁰ But, since the counterfactual suggested here imagines saving behavior largely unaffected by the presence or absence of the IT blueprints, our estimate of the portion of labor productivity growth attributable 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 the country. But, from the standpoint of their contribution to US standards of living, labor productivity gains from capital deepening financed by foreign borrowing come encumbered in a way that similar gains financed by domestic saving do not.

It is true that, if we are operating below capacity, 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). Under these circumstances, we can argue that it is investment that drives saving.

But, once the economy reaches 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 that make sense from a long-range growth perspective but are contra-indicated if one is below capacity. By and large, in growth accounting one tries 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 the effect of the IT-enabling technologies is on the growth of potential output. If we are concerned with contributions to long-run growth, an appeal to the role of IT capital formation role in “contributing” to increases in real output based on these Keynesian arguments is misplaced.

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 obscured the fact that, once the economy was 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

speeding up the turnover of inventories in the economy and by enabling a superior exploitation of regional comparative advantage. But it was close.

5.7 MFP growth versus 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 is to ask how much of the *acceleration* in labor productivity growth each is responsible for. For the private non-farm economy, that acceleration, comparing 1995–2000 with 1973–1995, was 1.09 percentage points, and about three-quarters of this is attributable to MFP acceleration.

The contribution to the output per hour growth of the labor composition change was about the same during the two periods (slightly lower between 1995 and 2000). Comparing 1995–2000 with 1973–1995, 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 increased from 2.36 to 3.28 percent per year between 1995 and 2000.

But, assuming a capital share of 0.32,¹¹ this 0.92 percentage point increase should have accounted for an increase in the growth of output per hour of a modest 0.29 percentage points. In fact, the growth of output per hour rose 1.09 percentage points, from 1.37 to 2.46 percent per year. Almost all the balance – about three-quarters of the total – was due to MFP acceleration.¹²

A second approach is to ask what portion of 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 0.32, this yields a capital deepening contribution of 1.05 percent per year. The remainder, about 0.27 percent per year, is the contribution of labor quality improvement. Looked at 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 5.5 summarizes these calculations.

There is no hard and fast guide to what metric we should prefer here, although 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 should also be interested in levels.

5.8 MFP growth in the IT-producing and -using sectors

In spite of the various frameworks that researchers have used to measure the overall impact of IT on productivity growth, there is now enough consensus to

Table 5.5 *The MFP contribution to labor productivity growth and acceleration in the United States, 1995–2000*

Labor productivity growth, 1995–2000 ^a	2.46
MFP ^a	1.14
Capital deepening ^a	1.05
Labor composition ^a	0.26
Labor productivity growth acceleration, 1995–2000 vs. 1973–1995 ^b	1.09
MFP ^b	0.76
Capital deepening ^b	0.32
Labor composition ^b	–0.01

^aPercent per year.^bPercentage points.

NB: Components do not sum exactly to aggregates due to rounding errors.

Table 5.6 *Contributions to labor productivity acceleration in the United States*

	1995–1999 over 1987–1995	1995–2000 over 1975–1989
Total acceleration	1.33	1.61
Wholesale trade	0.37	0.27
Retail trade	0.34	0.46
SIC 35 (includes semiconductors)	0.12	0.23
SIC 36 (includes computers)	0.17	0.08
Securities trading	0.25	0.32

NB: All figures are percentage points.

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

make some non-controversial 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 to labor productivity growth and its acceleration 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.

Third, it is likely, although the inferences are more indirect and the statistical support 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 US Council of Economic Advisors, 2001) are suggestive. The McKinsey study focuses on four years' growth (1995–1999) 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.

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, one can't reason directly from decompositions of labor productivity 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 support this view.

Distribution was an extremely heavy user of IT capital. Largely as a consequence, its overall use of capital services soared. An index of capital services input in wholesale distribution rose 18.8 percent a year between 1973 and 1995 and 20.5 percent a year between 1995 and 2000. Hours in wholesale rose only 1.32 percent per year from 1995 to 2000. Therefore, capital deepened in the sector at a rate of 19.2 percent per year over the last five years of the century, 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.¹³

The BLS "industry productivity indexes and values table" shows labor productivity growth in wholesale trade rising from 2.82 percent per year (1987–1995) to 4.17 percent per year (1995–2000). In retail trade the comparable numbers are 1.95 percent per year (1987–1995) to 3.72 percent per year (1995–2000). So labor productivity growth in distribution did accelerate.

The problem for the residual is that, assuming a capital share of 0.32, 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 accelerated 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 uncertain whether the results through 2000 fully justify the massive IT expenditure.

Some of this uncertainty and pessimism 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 a controversial suggestion, since a number of economists have actively pressured the BLS to make more use of hedonic methods to estimate the rate of quality improvement (and implied price decline) and praised it for what efforts it has made (see, for example, Nordhaus, 1997a).

The most compelling argument as to why these methods might lead to some overestimate of real product growth is that, in products where the 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.

Hedonic price techniques have yielded end-of-century estimates in the range of -27 percent per year for the rate of decrease of quality-adjusted computer prices (Berndt, Dulberger, and Rapaport, 2000). This rate of price decrease would reduce a 1999 computer priced at \$2000 to \$500 over five years. Thus, if one used a laptop in 1999 and another in 2004 selling at the same nominal price, the BEA would conclude, based on the price data received from the BLS, that there had been a fourfold increase in the ratio of capital services to hours in one's work. Readers can judge, based on their own experience, whether or not this is reasonable.

For the sake of argument, grant that the BLS estimates of the rates of decline of IT capital prices may 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 chapter 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 advocated in this chapter credits most of the effect of capital deepening on labor productivity to saving, rather than the availability of IT technology, one is 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.¹⁴

For the analysis of smaller subsectors of the economy, however, the effects will not cancel out, and the standard value-added approach 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 (capital, labour, energy, materials, services) methodology, which uses growth of 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 0.8 percent a year in wholesale although not at all in retail between 1992 and 1997.¹⁵ It is likely that, were data available through 2000, calculated rates of growth of MFP between 1995 and 2000 would be higher.

With respect to retail distribution, the McKinsey study argues that virtually all the gains in labor productivity have been attributable to “big box” retailers such as Costco, Wal-Mart, and Circuit City. And it is the relative ease with which these can be put 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, 2003a).¹⁶

Although the McKinsey group was willing to lay at IT’s doorstep only about half the gains in wholesale and retail distribution (assuming one could demonstrate them), it is important to keep in mind that these were 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 weak. There are enough straws in the wind, however, to speculate that we are in fact in the midst of a second IT revolution in distribution, a revolution the trace of which on sector MFP data has been temporarily clouded, or even obliterated, by the over-deflation of IT prices.¹⁷

5.9 Summary: the 1990s and the 1930s

Let’s now try and bring together what we can say about the 1995–2000 episode and how it relates to the 1929–1941 period. In this instance, because of the paucity of disaggregated sectoral data outside of manufacturing, I divide the private non-farm economy into three subsectors: manufacturing, wholesale and retail trade, and other. Excluding agriculture, government, non-farm housing, and the non-profit sector, the private non-farm economy accounts for 72.4 percent of value added. Using year 2000 sectoral shares, one can calculate a manufacturing weight (share of PNE) of 0.214 and a wholesale and retail trade weight of 0.223.

Again, the calculations begin with BLS numbers for MFP growth for the PNE between 1995 and 2000 (1.14 percent per year), and the BLS estimate for manufacturing as a whole of 2.08 percent per year (see tables 5.1 and 5.2). For wholesale and retail trade, one lacks data on MFP growth. As noted, unpublished estimates using the KLEMS methodology show 0.8 percent per year between 1992 and 1997 in wholesale, and no growth in retail. Allowing for

Table 5.7 *Sectoral contributions to MFP growth in the United States, 1995–2000*

	Share of PNE	Sectoral MFP growth	Contribution to PNE MFP growth	Share of PNE MFP growth
Manufacturing	0.214	2.08	0.45	0.39
Trade	0.223	0.70	0.16	0.14
Other	0.563	0.94	0.53	0.47
Total	1.000		1.14	

NB: “Private non-farm economy” excludes non-farm housing, health, agriculture, and government, which leaves 72.4 percent of value added. This is approximately the BLS’s current definition of the PNE.

Sources: Sectoral shares – www.bea.doc.gov; MFP growth in manufacturing – see table 5.2; MF in trade – see text.

some acceleration towards the end of the decade in both wholesale and retail, and considering the relative weights of wholesale and retail, one can hazard an estimate of 0.7 percent per year for the sector between 1995 and 2000.

Multiplying sectoral shares by sectoral MFP growth rates, one can estimate that of the 1.14 percent per year growth of MFP within the PNE between 1995 and 2000, 0.45 percentage points originated in manufacturing, most of it due to the IT-producing industries, and 0.14 percentage points in distribution. Given the rest of the PNE’s weight of 0.563, we can back out an implied MFP growth within it of 0.94 percent per year contributing the remaining 0.53 percentage points. This “other” category includes stand-out sectors such as securities trading, as well as laggards such as construction and trucking. Table 5.7 summarizes these calculations.

Suppose that one now credits 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.¹⁸ We would then conclude that 0.68 percentage points of the 1.14 percent MFP growth between 1995 and 2000 could be credited to IT innovations. Thus, we would attribute about 28 percent of labor productivity growth between 1995 and 2000 (0.68/2.46 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 non-farm economy cover less than three-quarters of their aggregate. Jorgenson, Ho, and Stiroh include what the BLS excludes: the farm sector, government, housing, and (presumably) the non-profit sector.¹⁹ These excluded sectors were slower-growing, and as a consequence their output aggregate grows at 4.07 percent between 1995

and 2000, versus 4.54 percent for the BLS PNE. Their hours series grows at 1.99 percent versus 2.09 percent for the PNE. Their labor quality adjustment is also lower: 0.22 percent versus 0.37 percent per year. Finally, their MFP growth estimate is much lower (0.62 versus 1.14) and their output per hour rises more slowly (2.07 percent versus 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 PNE (3.28).

All these comparisons speak to the extent to which the sectors excluded by the BLS and added back in by Jorgenson and Stiroh (1999) tend 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 0.85 percentage points to IT capital deepening and 0.45 percentage points to IT-related MFP growth. In other words, they “attribute” about two-thirds of labor productivity growth ($1.30/2.02 = 0.64$) 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 chapter, 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 do now acknowledge some MFP growth in the rest of the economy. If one applied my framework to their data, one would add the 0.45 percentage points of IT-related MFP growth and a third of the “other” MFP growth ($0.17/3 = 0.056$) to obtain 0.51 out of a total of 2.02 percent per year attributable to the enabling technologies of IT. This is approximately one-quarter 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 (0.45 percentage points per year, versus 1.24 percentage points per year between 1929 and 1941 and 1.69 percentage points in the 1919–1929 period. Although rapid MFP advance within manufacturing was somewhat more localized in the 1930s than it had 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 that characterized the 1930s. Although sectoral MFP estimates are not available across the board, labor productivity data, such as that contained in US Council of Economic Advisors, 2001, show growth rates declining,

comparing 1995–1999 with 1989–1995, in trucking and warehousing, communications, and electric, gas, and sanitary services. For trucking and warehousing, labor productivity actually fell (US Council of Economic Advisors, 2001, table 1.2).

Finally, we need to re-emphasize that, for the private non-farm economy as a whole, aggregate MFP advance in the 1929–1941 period was more than twice as fast as in 1995–2000, more than three times as fast as in 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.

5.10 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 more rapidly than inputs conventionally measured. The plummeting costs of producing quality-adjusted central processing units and memory, mass storage, and display devices have been for the late twentieth century an even more dramatic version of 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 eighteen months to twelve months. The revolutionary character of advances 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 was made possible by IT investments, and we should credit the enabling technologies of the IT revolution 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 IT-using sectors have been somewhat more modest, the boost to the growth of overall output per hour remains modest in comparison, for example, with the impact of MFP growth in the 1930s

This accounting does not attribute a portion of the effect of capital deepening to IT innovation – arguing that this is attributable to saving. An objection is that technical improvement, whatever its sources, might have affected saving behavior 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 have risen, leading to a redistribution of income, to households with higher saving propensities. Versions of these arguments have been made for the period after the Civil War in the United States, when, it has been suggested, such innovations as the railroad and Bessemer and Siemens Martin steel elicited an upward surge in aggregate saving behavior that propelled the economy to higher labor productivity levels as predicted by the Solow model (David, 1977; Williamson, 1973, p. 591).²⁰

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 2000.²¹ And the national saving rate did rise, barely, because government saving compensated for a continued decline in private sector saving. It is doubtful that private saving rates fell because tax rates were raised (the Ricardian equivalence argument), since saving rates fell in the last quarter of the century through periods of government deficit and surplus alike. And no one has claimed that the changes in fiscal policies in the early 1990s that led to a rise in government saving 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.

These are the grounds for attributing the effect of capital deepening on labor productivity largely to the forces of thrift rather than innovation. In the absence of IT, 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 used to guide 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 a change in the way that government statistics on fixed assets are collected, classified, and presented. In the BEA's "Fixed Asset Tables," for example, the assets produced by information technology industries are now listed first, in separate and detailed categories. 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."

A problem with this argument is that the rise in the equipment share in capital formation in the United States, which began after the Second World War (Field, 2006b), has been associated with a generally declining rate of MFP growth. To the degree that it is true, we will pick up these effects 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 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 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 all also been mentioned. The identification of one or several GPTs 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 (see chapter 8) 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 the production of which they enabled. Does that make steel a GPT? It took Carnegie and others time to persuade users that 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 software, sector-specific semiconductor manufacturing, and the thin film technology and mechanical engineering that underlies most mass storage.

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 twenty-five years after the Civil War (compare here the estimate of 0.15 percent per year for the railroad with the 0.68 percent per year I attribute to IT between 1995 and 2000), overall MFP advance at the end of the twentieth century was still much slower than it had been during the 1930s.

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 chapter, 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.

Notes

For comments on earlier versions of this work, I am grateful to Nick Crafts, Stanley Engerman, Robert Gordon, Robert Solow, and Gavin Wright. I also thank seminar and conference participants at Duke, Virginia, Indiana, Michigan, Yale, UCLA, the All Ohio Economic History Seminar, the World Cliometrics conference in Venice, and the Economic History Association meetings at San Jose, California.

1. Some scholars restrict the term “Depression” to the years 1929–1933. This chapter treats it as extending over the twelve-year period 1929 to 1941, during which output was persistently depressed below its potential. In 1941 unemployment dipped into the single-digit range (9.9 percent) for the first time in more than a decade. Even so, this was 6.7 percentage points above the 3.2 percent recorded for 1929, and 6.1 percentage points above the 3.8 percent recorded for 1948, so 1929–1941 does not make for an ideal peacetime peak-to-peak comparison. The data in table 5.1 are reported without a cyclical adjustment for 1941. A recent paper (Field, 2005) includes one, based on a regression of the change in MFP on the change in the unemployment rate in percentage points between 1929 and 1941. This regression is then used to predict MFP had unemployment in 1941 been at the 1948 level. Because of the strong procyclicality of productivity during the Depression years, the adjustment raises MFP growth for the 1929–1941 period to 2.78 percent per year, and lowers it for the 1941–1948 period to 0.49 percent. This adjustment serves to accentuate further the distinctiveness of the 1929–1941 period.
2. For a more extended discussion of this issue, see Field (2004a).
3. The Standard Industrial Classification (SIC) codes are being replaced in post-1997 reporting with North American Industrial Classification System (NAICS) codes, but I use the older vocabulary throughout this chapter.

4. The story told here is only weakly sensitive to using 1990 rather than 1989 (the level of MFP in the private non-farm economy was identical, so the annual rates calculated would rise slightly if we measured from 1990), although choosing 2001 rather than 2000 reduces the calculated growth rates, since MFP fell between 2000 and 2001.
5. "Chain-type quantity indexes for net stock of nonresidential fixed assets by industry group and legal form of organization," US Bureau of Economic Analysis (2003), or www.bea.doc.gov/bea/dN/FAweb/Index2002.htm.
6. The "dual" approach to estimating MFP growth looks at relative price changes across sectors as an alternate means of inferring its incidence.
7. Assertions or assumptions of such a link are numerous. "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" (US Council of Economic Advisors, 2001, p. 33).
8. All the subsequent discussion of the financing of the 1995–2000 investment boom uses nominal data, which ensures that the saving–investment identities hold for each year. Inflation was relatively modest over this period.
9. In this respect as well 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, inflows of capital from outside the country.
10. Estimates of the amount of the surge in physical capital formation 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).
11. The BLS capital share for 1995 is 0.3268; for 2000, 0.3109.
12. Alternatively, 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 that the increase in the rate of capital deepening should have been responsible for a 0.36 percentage point increase in the growth in output per adjusted hour (0.34×1.06). Adding in the increase in MFP growth (0.76 percentage points), one concludes that output per adjusted labor hour should have increased a total of 1.10 percentage points ($0.36 + 0.76$).
13. The source is the Bureau of Labor Statistics: for capital, "Capital and related measures from the two-digit database, 1948–2001"; for hours, "Industry productivity indexes and values table," 5 November 2003.
14. Overestimating the real flow of IT goods increases the estimated growth of real output and 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 therefore ambiguous, although it is likely to reduce it.
15. I am grateful to Larry Rosenblum of the BLS for making these data available to me.
16. In a paper broadly consistent with this view, Foster, Haltiwanger, and Krizan (2002) 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."

17. For discussion of an earlier revolution associated with the simultaneous deployment of the telegraph and the railroad, see Field (1987, 1992, 1996) and Chandler (1977).
18. The McKinsey study places a great deal of emphasis on the Wal-Mart effect, both in terms of its growing share of retail trade and through its role as an object of imitation by such firms as Target. But, although the report 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. The implication is that, although it is defensible within manufacturing to credit virtually all the MFP growth to IT, outside manufacturing this is not so. Many of the productivity-enhancing management improvements could and probably would have been implemented in the absence of new IT technology.
19. Their output measure also includes an estimate of the imputed service flow from consumer durables.
20. According to David, the nineteenth-century traverse was "set in motion by Thrift, that is, by a pronounced rise in the proportion of output saved." In some passages he appears to treat it as exogenous, in others as 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 (2000), 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 led to the upsurge in the saving rate. Williamson's 1973 paper is more consistently based on an 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" (p. 593).
21. 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, overbuilt.