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U.S. Productivity Growth in the Interwar Period and the 1990s

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Introduction

Output per hour grows in an economy as a consequence of two analytically 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, 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, real GDP, 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:

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

[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.

The hours series is typically augmented 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 framework 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 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.

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. It is rather 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 1973-95 with 1948-73 (3.94 vs. 3.90 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. 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.[2]

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[2] 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

But it was vanishing MFP growth rather than this mild slowdown in capital deepening that was the principle 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,[3] 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.[4] Considering the effects of changes in rates of capital deepening and improvements in labor quality alone, there should have been virtually no change in the rate of increase of output per hour between the two periods.

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, (see Table 2).[5]

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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.

[3] 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.

[4] 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). 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 $y - n = a + \beta(k - n) + (1 - \beta)n^*$.

[5] It would be nice if the output per hour version of the growth accounting equation worked exactly using the various data series provided by the BLS. There are some complications, which are due to the fact that output per hour is calculated 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), implying the decline in the rate of capital deepening 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

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 (a little bit 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.

But again, assuming a capital share of .32,[6] 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 1.09 percentage points, from 1.37 to 2.46 percent per year. Almost all of the balance was due to MFP acceleration.[7]

I will return later in the paper to the question of possible linkages between technical change and accumulation rates, and whether reckoning the impact of technological 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.

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total of 1.67 percentage points (.15+1.52). Calculating such an index (see Appendix Table 1) yields a percentage point decline in growth 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.

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

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

Overview of Twentieth Century Growth Trends

My interest in the history of MFP growth, which is so critical in understanding trends in living standard improvement after World War II, is not, however, limited to the postwar period. A central aim of this paper is to place recent developments within a frame of reference that extends back to 1929 and to some extent 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, 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 (1.35 percent per year) compared with the 2.76 percent annual growth clocked during the golden age (see Table 1; data is for the private nonfarm economy). During the last five years of the century, labor productivity growth again approached golden age rates, principally as the result of a revival of MFP growth.

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 Average Annual Growth Rates of Output per Hour, Private Non-Farm Economy, United States, 1919-2000

1919-29	2.27
1929-41	2.35
1941-48	1.71
1948-73	2.88
1973-95	1.37
1995-2000	2.46

Sources: 1919-48: Field (2003); Kendrick (1961).
1948-2000, Bureau of Labor Statistics www.bls.gov, series MPU750021.

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 capital formation, labor productivity rose *slightly 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). Table 1 summarizes this periodization of labor productivity growth in the U.S. economy.

In an article recently published in the American Economic Review, I argue that the period from the end of the 1920s boom to the start of the Second World War was in the United States 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. 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. (Field, 2003; Kendrick, 1961). 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. As noted, almost all of the labor productivity growth between 1929 and 1941 (see Table 1) is attributable to MFP growth, in contrast with other periods of comparable labor productivity growth, during which capital deepening played an important role.

My article was provocatively titled “The Most Technologically Progressive Decade of the Century”, and when I advance this thesis, many people ask, with a certain degree of incredulity (although less than when the NASDAQ was above 5,000), whether this claim includes 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 now over, and the NASDAQ in mid January of 2004 remains barely above 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 SIC 35 and 36,[8] 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 about a third of the total (see the end of this paper).

The estimate is quite sensitive both to the conceptual framework one adopts and to how much of the MFP growth outside of manufacturing one is prepared to attribute to IT. There is some recent evidence that we may finally be getting more substantial MFP payback in the IT using sectors (Wall Street Journal, November 7, 2003). As this is

[8] 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.

written the latest BLS releases suggest that labor productivity grew at 3.12 percent per year continuously compounded from 1995:3 to 2003:3 (131.8 over 102.7; BLS series PRS85006093).

Table 2
Compound Average Annual Growth Rates Of Multifactor Productivity, Private Nonfarm Economy, United States, 1919-2000

1919-1929	2.02
1929-1941	2.31
1941-1948	1.29
1948-1973	1.90
1973-1989	.34
1989-2000	.78
1973-1995	.38
1995-2000	1.14

Sources: 1919-1948: Field (2003); Kendrick (1961);
1948-2000: Bureau of Labor Statistics www.bls.gov.

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, 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 is 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 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*. Table 2, which reports the CAAGR of MFP in the private non-farm economy in the United States, illustrates this point.

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).[9]

It is well known however 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

[9] 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.

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, a point which has been much ballyhooed in the press. 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 very latest 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 a much larger 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 GDP 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 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

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.

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 (2003) 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 1941, it is appropriate to place primary although not exclusive emphasis on a growing manufacturing sector that by that date comprised almost a third of the economy. Indeed, I estimate that more than half the MFP growth in the private nonfarm economy between 1929 and 1941 originated in manufacturing (see below). For the 1990s, we need to be more 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.

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, 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 vs. .14 percent per year. In durables, the 1973-2000 period registers a slight advantage: 1.57

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

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 Fixed Asset Table 4.2.[10] 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.

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 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

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

calculations also suggest, consistent with arguments advanced in Field (2003), a negative rate of MFP advance in manufacturing over the 1941-48 period.

Table 5
MFP Growth in Manufacturing, United States, 1919-2000

1919-29	5.12
1929-41	2.60
1941-48	-.87
1949-1973	1.52
1973-1995	0.66
1995-2000	2.09

Sources: 1919-29: 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 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 MPU300003 (B)

The data from Tables 4 and 5 document and underline the conclusion that technical advance during the 1929-1941 period was taking place across a broad frontier of an expanding manufacturing sector, in contrast with the new economy period, in which advance was heavily concentrated within a couple of sectors of durable manufacturing within a sector that was shrinking in relative importance. Particularly striking, in comparison with the post 1948 period, is performance in chemicals, petroleum and related products, rubber and miscellaneous plastic products, and tobacco manufacture. For one of the twentieth century's declining industries, textile mill products also turns in a surprisingly strong performance both pre- and postwar.

The sources of MFP advance in manufacturing during the 1929-41 period were likely different than those during the previous decade. In contrast with the 1920s, MFP advance took place in the absence of any net capital accumulation or major increases in scale. 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 epoch 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. 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. Notable 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.

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.

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).

Although the rate of MFP advance in manufacturing dropped 50 percent comparing 1929-41 with 1919-29, it remained at 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 broad base of productivity advance within the sector. With the exception of transport equipment and apparel, the MFP growth rates from 1929-1948 exceed 1 percent across the board. The advance in MFP growth in manufacturing included sectors that required heavy R and D efforts to attain it as well as those, such as tobacco manufacture and textile mill products, where reorganization, economies of scale, or learning by doing 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 important 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), 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 7 summarizes these calculations.

Transport and Public Utilities

The calculations for transport and public utilities are the most complex. This sector generated about 11 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 almost twice as large, and the rapid acceleration of MFP growth in this sector contributed more to aggregate growth than did advance in distribution.

Table 7
MFP Growth, Transportation and Public Utilities, 1929-1941

	Share of NI*100 1941(1948)	Share of T & PU	Share of Covered Subsectors	Subsector MFP Growth	Subsector Contribution MFP Growth
1929-41					
Railroad transportation.....................	3.27	0.372	0.420	2.91	1.22
Local and interurban passenger transit..	0.66	0.075	0.084	3.02	0.25
Trucking and warehousing....................	1.03	0.117	0.132	13.57	1.80
Water transportation........................	0.42	0.048	0.054	1.47	0.08
Transportation by air.......................	0.18	0.021	0.023	14.69	0.34
Pipelines, except natural gas...............	0.10	0.012	0.013	4.48	0.06
Transportation services.....................	0.13	0.014			
Telephone and telegraph.....................	1.30	0.148	0.167	2.02	0.34
Radio and television........................	0.10	0.011			
Electric, gas, and sanitary services...	1.61	0.183	0.104	5.55	0.57
	8.81				
TOTAL					**4.67**

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, see Appendix Table A-2.

The 4.67 percent per year figure is based on estimates for 8 subsectors: railroad transportation, local and interurban passenger transport, trucking, 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.[11] 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, with the exception of water transport. Airline transport

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

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). Electric utilities clock in at 5.55 percent, followed by pipelines (4.48 percent), local and interurban transit (3.02 percent), railroads (2.91 percent) and telephones and telegraph (2.01 percent). Table 7 summarizes these calculations.

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 multiproduct 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 rises at 1.1 percent per year, but this was a period of very 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 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, 1992). 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

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	
					% Points	% of Total
Manufacturing	31.86		42.57	2.60	1.107	0.479
Transport and Public Utilities	9.21		12.30	4.48	0.551	0.239
Wholesale and Retail Trade	16.70		22.31	1.81	0.404	0.175
Other Sectors (net)	17.08		22.82	1.09	0.249	0.108
Mining		2.30				
Construction		4.03				
Finance, Insurance, Real Estate (see note		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

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).

1919-1929 Disaggregation of MFP Growth

This paper is primarily concerned with comparisons of the 1930s and 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 1992) 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?

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).

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).

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. These calculations indicate that during the 1919-29 period, about 85 percent of the 2.02 percent aggregate MFP growth for the private nonfarm economy 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 later 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 due to a drop in within sector MFP growth only partially compensated for by the expanding size of the sector. There is also, I would suggest, a change in the sources of these gains – away from learning by doing and economies of scale 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 (Kleinknecht, 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.

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. The standpoint performer at the two digit level was, of course, transport equipment, at 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. The high MFP growth rates reported across the board are, however, testimony not only to the delayed

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

exploitation of electrical generation and transmission capabilities developed several decades earlier, but to the growing importance of R and D investments, particularly in such sectors as chemicals, foreshadowing the rising important of such sources of MFP growth within manufacturing during the 1930s.

While acknowledging the drop in 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 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.

The End of Century Episode

With this perspective on MFP advance during the interwar years, let us shift our attention forward again to the end of century productivity acceleration. We have already gone some distance in placing the recent episode in historical perspective. The main 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 (2.46 vs. 2.37 percent per year), but MFP growth was less than half what it was in the earlier period (1.14 percent vs 2.37 percent per year). The other main difference, of course, is that 1995-2000 experienced capital deepening whereas 1929-41, by and large, did not.

The objectives of this final part of the paper are 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.

A common practice in estimating the IT revolution's impact on labor productivity is 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. But, if we are interested in the welfare implications of IT innovation, I question whether we should *also* credit a portion of the effect of capital deepening on labor productivity associated with specific IT capital goods. This seems to me warranted only if we believe that, by raising the return to incremental investments, the enabling technologies actually induced an upsurge in the aggregate U.S. or world saving rate.[12]

[12] "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

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 a world without the IT innovations, saving flows would have been congealed in a different array of physical capital goods, but labor productivity still would have benefited from capital deepening.

The point it to render to the IT innovations appropriate recognition. 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.[13]

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 sometimes 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 welfare enhancing effects of capital

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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.

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

deepening effect should ultimately be credited to saving behavior, and not specifically to the enabling technologies. 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), in order to link rising rates of capital accumulation to innovation rather than thrift, we must also 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).

Justifications for including a portion of the capital deepening effect (see deLong, 2002) sometimes 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. Whatever the mechanism whereby consumption is supposed to have declined, this is simply a mischaracterization of what happened between 1995 and 2000. By and large, investment in IT capital goods did not crowd out consumption goods. It crowded out other not quite as good capital goods within and outside of the United States.

Between 1995 and 2000, consumption spending in the United States increased more than \$1.7 trillion, from \$4,969 billion to \$6,683.7 billion nominal, a 34 percent increase.[14] Consumption's share of a rising GDP also rose, from 67.2 percent to 68 percent. There is no evidence within the United States that consumption declined, either absolutely or as a share of GDP.

Between 1995 and 2000 gross private investment increased 53.5 percent (a \$611.6 billion increase) and government investment went up \$81.6 billion. Gross national investment climbed from 18.7 to 21.1 percent of GDP. How was this possible, given that private consumption did not fall? The answer it that government consumption fell from 15.3 to 14.6 percent of GDP, and net foreign investment fell from -1.3 to -4.0 percent of GDP (percents do not sum exactly because of the statistical discrepancy).

Within gross investment itself, part of the accelerated growth of IT capital came at the expense of the other components of the U.S. capital stock. While the growth of IT capital services accelerated from .41 percent per year (1973-95) to 1.03 percent per year (1995-2000), the growth of the services of all other physical capital goods essentially halted, declining to .06 percent per year from .30 percent per year in the earlier period (<u>Economic Report of the President</u>, 2001, pp. 29).

Let's look now at how the surge in capital formation was financed. Did personal saving rise between 1995 and 2000? 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

[14] In all of the subsequent discussion of the financing of the 1995-2000 investment boom, I use nominal rather than chain linked real data, which insures that the saving – investment identities actually hold for each year. Inflation was relatively modest over this period, averaging about 2 percent per year.

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. Combining personal and business saving, we have a net change in gross private saving of $106.1 billion, or 8.3 percent.

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 increase in gross national investment was $693.2 billion. There is a saving gap here of almost $600 billion. How was it 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.[15]

The end of the century investment surge was financed principally by rising government surpluses and a worsening current account deficit, not by an increase in the U.S. private saving rate. Our investment boom was enabled on the one hand by the willingness of foreign wealth holders to divert saving flows from investment in their own countries or elsewhere towards the U.S., and on the other hand by the tax and expenditure policies of the Clinton and George H.W. Bush administrations. Their fiscal conservatism 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 to 4.4 percent of GDP that the national saving rate rose 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 represented a

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

[17] 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.

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 means 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. There is no guarantee this will be the case – it depends on how much of the additional investment turns out to have been wasted. 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 rate simply compensated collectively for the rise in government saving. But this seems doubtful. The politics of budgetary reform ride, by and large, on a different historical train than the ebb and flow of innovation. More likely, had the tax increases 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. The U. S. 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.

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 consumption per person – our basic measure of the material standard of living (see Kendrick, 1961, pp. 4-5). 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 U.S. 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 potentially misleading calculation. Much of the capital deepening has associated with it a liability tied to the increased foreign indebtedness of a nation that is now the world's largest debtor. 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.

The IT Contribution and Social Saving Controversies

This framework for reckoning the impact of the IT revolution, particularly its emphasis on MFP at the expense 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.[17]

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.[18] But since the counterfactual I have in mind imagines the determinants of saving behavior

[18] 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.

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 productivity gains from capital deepening fueled 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 in some sense maintain 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. Some of the emphasis on the role of IT capital formation role in "contributing" to increases in real output represents a peculiar mixing of short and long run perspectives.

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 the race between benefits and costs was closer than previous historians had imagined.

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 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,[20] if we focus on its contribution to the percentage point acceleration of labor productivity growth comparing 1995-2000 with 1973-95 (second derivative with respect to time) as opposed to its rate of growth (first derivative with respect to time). In general, I think 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.

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, we have 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

[20] 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.

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 increasingly 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, have begun to throw off significant MFP growth. Two recent 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 most if not all of the acceleration of labor productivity growth. Indeed, at least through 2000, the data support this view.

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.

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 show capital deepening at 15.3 percent per year over these years.[22]

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 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's 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 product has grown. 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).

[22] Sources for capital are "Capital and Related Measures from the two Digit Database," for hours, "Industry Productivity and Values Table", November 5, 2003.

The most compelling theoretical argument for why these methods might be leading to some overestimate of output 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. Were I to buy a new IBM laptop of about the same weight and display size, its nominal cost would be almost the same as my current machine's cost five years ago. True, the 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 imply a reduction in the price of a machine equivalent in quality to my 1999 device from $2000 to $500 over 5 years. There is the problem, of course, that I can't usefully buy one fourth of a new laptop in 2004. Nevertheless, if there was 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 completely 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 of real product growth in the sector. Although this would of course boost MFP growth in the IT producing sectors, it would have 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 an amelioration of the possible incentive to push for more rapid rates of estimated price decline to make IT's contribution appear larger disappears.

Overestimating the real growth of IT services would also, of course, 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. 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.[24] The bottom line: If you press too hard to boost real output in the IT producing sectors, you run the risk of killing MFP growth – perhaps even driving it negative – in the IT using sectors.

[24] 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.

For subsector analysis, the value added approach of Table 15 has been criticized as excessively 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 and not at all in retail between 1992 and 1997.[25] At least, however, it's not declining.

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 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).

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), the availability of IT capital has clearly been a necessary condition for reaping some of the MFP growth in distribution. To the degree that this is true, what we may be witnessing is the beginning of the impact of a second IT revolution on the sector. The first was associated with the simultaneous development of the telegraph and the railroad, which, as Alfred Chandler documented, gave rise to the modern business enterprise in distribution

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[25] The numbers are .8 percent a year for wholesale and .0 percent a year for retail. I am grateful to Larry Rosenblum of the BLS for making these data available to me.

before it did so in manufacturing, (Chandler 1977; Field 1987, 1996). By the end of the 1880s the railroad and the telegraph had enabled 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 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. It seems plausible that there has been positive and accelerating MFP growth among the big box retailers, with perhaps little or in some cases declining MFP in other parts of the sector

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 data, 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 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 their 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 unpublished series 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.

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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

Mutliplying sectoral shares by estimated 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.

Suppose now we credit all of the MFP growth in manufacturing between 1995 and 2000 to the enabling technologies of the IT revolution, and half of that in distribution and the rest of the economy [26] We would then conclude that .80 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 a third of labor productivity growth between 1995 and 2000 (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.[27] 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).

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.

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[26] 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.

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

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 half the "other" MFP growth (.17/2 = .085) to obtain .54 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 1930s (1929-41), the following conclusions stand out. Both the 1930s and the 1990s saw contributions to MFP growth from manufacturing but the percentage point contribution to PNE growth in the recent episode was lower (.45 percentage points per year vs. 1.11 percentage points per year in the earlier period; see Table 9). Distribution played a role in both periods, 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 virtually across the board 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, for the private nonfarm economy as a whole, aggregate MFP advance in the 1929-41 period was more than twice as rapid. 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.

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 have 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 is a positive elasticity of the saving rate with respect to the real after tax interest rate, an increase in saving flows. A version of this argument has 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).[28]

[28] 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." To some degree 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.

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.[29] And the national saving rate did rise, barely, although no thanks to the private sector. It is doubtful, however, that private saving rates would have risen had taxes not been raised, since they have fallen steadily in recent decades through both deficit and surplus periods. And, 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. 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 principally to the forces of thrift rather than the specific availability op the IT innovations. In the absence of IT, saving flows would have been congealed in a set of not quite as good capital goods. The contribution of capital deepening to labor productivity growth might not have been noticeably different.

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.

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[29] 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.

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, something most economists think is a good thing. As an example, in the Bureau of Economic Analysis's Fixed Asset Tables, for example, 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 may be true, but if so*, we will pick up this effect in MFP growth within the IT using sectors.*

Another manifestation 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.

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 (I compare here my estimate of .15 percent per year for the railroad with the .80 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 there is no "great man" technological history of the 1930s to 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.[30] Recent history does not necessarily validate the GPT's usefulness as a tool for analyzing the broad sweep of economic history. The end of century productivity revival needs to be understood on its own terms. We should give the IT revolution its due, but be wary of giving it more than its due.

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

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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

	1929	1941	CAAGR
Output			
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

	1929	1940	CAAGR
Output			
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.