2-3-2007

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Recommended Citation
Field, Alexander J. 2007. "The Origins of U.S. Total Factor Productivity Growth in the Golden Age." Cliometrica 1 (April): 63-90.

The final publication is available at Springer via https://doi.org/10.1007/s11698-007-0006-4

January 2007

The Origins of U.S. Total Factor Productivity Growth in the Golden Age

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*This paper is part of an ongoing project on the history of US technical change and productivity advance. For comments on earlier and related presentations, I am grateful to participants in seminars at Harvard, Dartmouth, Rutgers, UC Berkeley, Virginia, Indiana, Ohio State, Stanford, Yale, Michigan, UCLA, Columbia, and UC Riverside, as well as presentations at Humboldt, Carlos III Madrid, and Oxford universities and the London School of Economics. Presentations at the conference on "Understanding the 1990s: The Economy in Long Run Perspective" (Duke University, March 2004), the International Cliometrics conference (Venice, Italy, July 2004), the Economic History Association meetings (San Jose, California, September 2004), and ASSA meetings in Boston, Massachusetts (January 2006), and Chicago (January 2007) were also helpful. Special thanks to Jeremy Atack, Michael Edelstein and Tim Leunig for comments. Forthcoming in *Cliometrica*.

JEL Codes: N12, N71, O47

Keywords: Productivity, TFP, U.S. Macroeconomic History, Manufacturing, Transportation

ABSTRACT

A consideration of TFP growth in the United States during the golden age (1948-73) raises two related questions: on the one hand why was it so strong and on the other hand, why were TFP growth rates lower than they were during the Depression years (1929-41)? A continuing downward trend in TFP growth within manufacturing, and its declining share after World War II, help provide answers to the latter question. A persisting productivity windfall associated with the build out of the surface road infrastructure helps answer the former question. By adopting a longer historical perspective, we can move beyond understanding the golden age sui generis, and begin to see it instead as a period reflecting the persistence of trends and developments whose origins are to be found prior to the Second World War.

Introduction.

The quarter century running from 1948 through 1973 is generally recognized as the golden age of U.S. productivity growth. Over these years output per hour in the private nonfarm economy grew at a compound annual average rate of 2.88 percent per year. The distinctiveness of this achievement, and its implications for the U.S. material standard of living, is reflected in the fact that the long run growth rate of U.S. *output* for over a century has been approximately 3 percent per year.

Of this 2.88 percent, approximately 1 percentage point per year can be attributed to the effects of capital deepening associated with the revival of private sector physical capital accumulation following its cessation after 1929. Net private investment was negative during the Depression years, and although accumulation revived after 1941, it was only after the war that it could do so in a fashion less distorted by the demands of war. The remainder of growth in output per hour between 1948 and 1973, 1.90 percent per year, reflected an increase in total factor productivity.

The purpose of this paper is to examine the sources of this advance in the light of a revised narrative of twentieth century U.S. economic growth that places the Depression years in a more prominent position than they have heretofore occupied. Between 1929 and 1941 TFP in the private nonfarm economy grew at an unadjusted rate of 2.31 percent per year, the highest peak to peacetime peak rate of the century. If one makes a cyclical adjustment for the level of productivity in 1941, the TFP growth rate over this 12 year period rises to 2.78 percent per year. Output per hour grew more slowly than during the golden age because of the absence of net private sector capital deepening. But the difference comparing the two periods is remarkably small - only .45 percentage points per year using unadjusted 1941 data and barely two one hundreds of a percentage point using adjusted data.[1]

While unemployment remained at double digit levels until 1941, an expansion of potential output largely unrecognized at the time helps explains how the United States was able to wage an equipment intensive war, put over 12 million individuals in the active duty military, and, by some measures, increase consumption over Depression levels in spite of rationing and the unavailability of some goods during the war. Another way of understanding the magnitude of the increase in potential output is this. Between 1929 and 1941 the input of hours into the private nonfarm economy was basically unchanged; and the private capital stock actually declined. But output was 32 percent higher in 1941 (Kendrick, 1961). Thus *all* of the increase in output, and *all* of the growth in output per hour over this twelve year period, is attributable to the residual

This new emphasis on the Depression's contribution to growth of potential output is a prism through which the experiences of the rest of the century are refracted in new ways. It places the achievements of the 1920s and the 1990s in a different light. It overturns the conventional wisdom attributing achieved 1948 productivity levels principally to the war (Field, 2007b). And – the thesis of this paper -- the golden age (1948-73) no longer has to be understood sui generis, but can be seen as a period reflecting the extension and persistence of trends and technological foundations established during the interwar period.

What were these trends? The first was a continuing decline in the rate of advance of TFP within the manufacturing sector. The second was the persistence of high rates of

[1] Because total factor productivity growth was strongly procyclical between 1929 and 1941, the adjustment raises the estimated level of full employment TFP in 1941, and thus its rate of growth over the twelve year period. For details, see Field (2007b).

TFP growth in transportation, communication, public utilities, and trade. In both the 1930s and the golden age, these sectors benefited from complementary investments in government infrastructure. The 1930s saw a very high rate of street and highway expenditure, in which the paved highway network of the US caught up with the rapid expansion of automobile and truck production during the 1920s. This allowed the emergence of a transformed system of moving goods that involved an integration of rails for long haul and trucks for local and regional distribution. These changes underlay extremely high rates of TFP advance in trucking and warehousing and to a lesser degree railroads during the Depression years and the persistence of advance in these sectors during the postwar period (Field, 2006a).

Manufacturing

Much attention has been focused on the revolution in manufacturing productivity during the 1920s, and rightly so. Between 1919 and 1929, TFP in the sector grew at 5.12 percent continuously compounded, accounting for 84 percent of the growth of the residual in the entire private non-farm economy (Kendrick, 1961; Field, 2006a). If there was ever a period that warrants the sometimes excessive attention devoted to this sector by economists, the 1920s certainly qualifies.

The fundamental cause was a revolution in factory design and the distribution of power within it associated with a shift from steam (or in a few cases, still, water) power to electric power. Because of square – cube relationships involving cost savings associated with larger boilers and pistons, a single large steam engine as prime mover was almost always the economically attractive option for a fixed installation. In a steam powered factory motive force was generated centrally and distributed to work stations by means of a mechanical system of leather belts, pulleys, and rotating horizontal shafts. The economics of factory design required balancing the increased cost per square foot of multistory designs with the imperative to minimize the sum of runs from the prime mover to individual work stations, so as to keep a lid on the substantial power losses attributable to friction when mechanical transmission was used.

The fact that power driven factories in the nineteenth century were typically two, three, four, or five stories tall was not generally the result of high urban land values. This was obviously so in the case of water power, which dominated mechanized factories in the antebellum period. The early textile cities such as Lowell and Lawrence, Massachusetts or Manchester, New Hampshire were greenfield sites. Water held on tenaciously in New England (in 1900 over 35 percent of the horsepower in the region was still generated by these means), but steam came to predominate elsewhere in the country, a development facilitated by advances in high pressure engineering and the development of large, powerful, and energy efficient engines such as the Corliss (Atack, Bateman, and Weiss, 1980; Rosenberg and Trajtenberg, 2001). The prime mover in a steam powered factory was typically housed in its own room, with a leather belt, often several feet wide and several hundred feet long, connecting the flywheel to the main drive shaft. Although use of steam power allowed location of new factories closer to existing supplies of labor and transport facilities, the basic design of a plant remained fundamentally unchanged, and its height was driven by the same considerations involving the internal distribution of power as had dictated its profile in the age of water.

Thus for both water and steam powered plants, the multistory factory building of the nineteenth century was the result of a different economic imperative than that which pushed up the height of commercial office structures in central business districts. The most persuasive evidence for this is what happened in the twentieth century. With electrification, and the eventual elimination of the old internal system for distributing power, factories went predominantly single story, even though the population of the U.S. was larger and more concentrated, so in principle land was scarcer (more flexible surface transportation associated with the diffusion of the internal combustion engine and related infrastructure also played a role in this transition). To a very considerable degree, multistory factory construction in the nineteenth century reflected an engineering solution to the problem of distributing power mechanically from a central prime mover.

The first factory electrification (for power rather than illumination) involved simply replacing one large prime mover with another. The steam engine was removed and an electric engine substituted – but there were no changes in the mechanisms for distributing power mechanically within the factory. It took several decades for factory designers and electrical engineers fully to appreciate how, using a few large power generating plants and a multitude of smaller electric motors, they could dispense with the onsite prime mover <u>and</u> the apparatus for mechanically distributing power, replacing the latter with a network of relatively cheap and flexible electric wires. An intermediate step (group drive) involved use of medium sized motors to turn somewhat shorter drive shafts that in turn supplied power to groups of machines (Devine, 1983).

The change in the way in which power was distributed removed a straightjacket from factory design, allowing one story layouts and a reconfiguration of internal work flow that went hand in hand with the diffusion of assembly line techniques in such industries as transport equipment and electrical machinery. There are many features distinguishing twentieth century factory buildings from those constructed in the nineteenth, but the most salient is that the twentieth century structure, like Ford's River Rouge facility, is single storied, whereas the nineteenth century factory was not. Single storied buildings had lower construction costs per square foot, but there were other advantages, particularly in industries based on mechanical or electrical engineering that required the assembly of many parts. The best way to engineer an assembly line, except in the few instances where gravity can be harnessed to particularly good effect, it to keep it on a single level. A bonus was reduced risk of fire. Multistory factories with mechanical power distribution required openings between floors so that power could be transferred across drive shafts on different floors. These openings created natural avenues through which fire could spread, entailing higher fire insurance premiums and/or the costs of enclosures to mitigate the risk (Devine, 1983, p. 361).

Electrical internal power distribution and the use of small electric motors made all floor areas of the factory – not just those close to an overhead shaft – of roughly equivalent economic value. In the steam powered factory there was prime real estate near the overhead shafts and there were "dead" areas that could be used only for storage. Such areas could now also be used for stages of the manufacturing process. The dismantling or elimination of the mechanical system for distributing power internally, which had required brackets and rotating drive shafts hanging from the ceiling, made it much easier to install overhead cranes for moving subassemblies. The possibility of using portable tools powered by electricity was another contributor to productivity advance. Finally, new single storied buildings could utilize skylights for illumination and ventilation – a rare feature in a nineteenth century factory.

It was during the 1920s that much of this transition took place, and the decade is unique in the history of U.S. manufacturing. TFP growth rates in manufacturing were extremely high, and this was true across the board at the two digit level (Kendrick, 1961; Field, 2006a). The profits associated with this transition played a major role in fueling the stock market boom between 1925 and 1929.

As a result of this revolution in factory design, layout, and internal power distribution, the level of TFP in U.S. manufacturing was higher in all subsequent periods. But one of the lessons learned from analysis of the Solow model is that it is far easier to raise the trajectory of levels of productivity in a sector or economy than it is to permanently increase productivity growth rates. Of course, whenever levels increase there will be a transition in which the rate of growth will accelerate. But the higher rates, whether due to a rising saving rate or to the availability of new technologies, usually cannot be sustained.

And so it was in this case. U.S. manufacturing could not hope to sustain a rate of increase of TFP of over 5 percent per year in perpetuity from the electrification/ assembly line/ one story transition. Eventually, as old factories were reconfigured, and as new factories replaced old, there would be fewer and fewer opportunities to reap additional gains. As Devine shows, the transition from steam to electric power, which began around the turn of the century, and accelerated after the First World War, was largely complete by the end of the 1920s. By 1929, electricity was responsible for driving about 79 percent of total capacity within U.S. manufacturing (Devine, 1983, p. 349).

From this perspective, the puzzle is not so much why manufacturing TFP growth declined from 5.12 percent per year (1919-29) to 2.60 percent per year between 1929 and

1941 (Field, 2006a) as why it did not fall further. There are two considerations that help explain why. The first reflects the residual influences – the tail end -- of the electrification transition. In some cases, as Bresnahan and Raff have shown for the automobile industry, some older and less productive plants that had persisted in operation during the boom period of the 1920s simply shut down, as the economy went into recession between 1929 and 1933, and it was the remaining (and higher productivity) facilities that supplied output as the economy recovered (Bresnahan and Raff, 1991).

But the second and more important influence involved the maturing of a privately funded research and development system that had begun with Edison at Menlo Park and reached maturity during the 1930s. Both R and D employment and spending soared during the Depression years, and as Margo (1991) has shown, scientists and engineers were largely protected from the risk of unemployment that fell so heavily on other job groups.

Thus one must use a light touch in contextualizing trends in manufacturing TFP during the interwar period. In the two decades after 1929, TFP growth in manufacturing was substantially lower and less uniform across two digit industries than it had been in the 1920s. Nevertheless, by any standard of comparison other than that of the 1920s, TFP growth in manufacturing during the Depression years was world class.

The 1941-1948 period saw manufacturing TFP growth become negative. Above and beyond war related plants owned and operated by the government, the federal government paid for more than $10 billion of new capital, most of it in manufacturing and most of it equipment, located in Government Owned Privately Operated (GOPO) facilities. Although labor productivity rose modestly (.20 percent per year) as a consequence of this capital deepening, TFP in the sector fell at an annualized rate of -.52 percent per year (Field, 2007a)

In contrast with the 1920s, productivity advance during the Depression years and, to an even greater extent, the postwar period, cannot be explained by focusing almost exclusively on manufacturing. That said, prior advance in manufacturing helped set the stage for the golden age of U.S. productivity growth, a period of sustained growth in living standards that W. W. Rostow (1960) called the age of high mass consumption. To recapitulate: The revolution in factory layout, design, and internal power distribution resulted in manufacturing TFP that was two thirds higher in 1929 than it had been in 1919. The twelve Depression years (1929-41) saw a halving of the TFP growth rate in manufacturing, but this rate of advance was still far higher than rates obtained in any period of the twentieth century other than the 1920s. It was fueled in part by the final stages of the electrification transition and by the elimination, in some cases permanently, of low productivity plants as output fell. That by itself, however, would have been insufficient to produce 2.60 percent per year over twelve years. An increasingly important ingredient was rising spending on R and D and rapid advances in science based manufacturing, with which such spending was associated. During the war years the manufacturing sector benefited from, but was also bloated and distorted by, the increase in military procurement and the injection of GOPO capital.

American manufacturing emerged from the war in an unprecedented position of world dominance. Technical frontiers had been expanded by a host of new product and process innovations during the 1930s, and some of this potential had begun to be realized prior to the war. In other cases, such as television, all of the development work had been done pre-war and the product was poised for rapid exploitation with the ending of controls after V-J day. Another illustration: all of the combat aircraft placed in service during the Second World War by the United States were already on the drawing boards at its outset (Galbraith, 1971, p. 18).

With European and Japanese manufacturing hobbled by war damage, U.S. manufacturing faced extraordinary global opportunities in helping to rebuild foreign industries and in satisfying their domestic markets while this took place. Continued high levels of military spending during the Korean and Cold Wars meant a stream of direct orders for defense contractors and a stimulus to and stabilization of aggregate demand for the rest of the economy.

This was the environment in which the manufacturing corporations described in Galbraith's New Industrial State consolidated their distinguishing characteristics. Galbraith described them as islands of planned economy within an ostensibly market based system. Many corporations offered something equivalent to lifetime employment security. Through marketing and planned obsolescence, the disruptive force of technological change, what Schumpeter called creative destruction, had largely been domesticated, at least for a time. Whereas large corporations had funded research leading to a number of important innovations during the 1930s, many critics now argued that these behemoths had become obstacles to transformative innovation, too concerned about devaluing rent yielding income streams from existing technologies. Disruptions to the rank order of the largest U.S. industrial corporations during this quarter century were remarkably few. And the overall rate of TFP growth within manufacturing fell by more than a percentage point compared with the 1930s, and more than three and a half percentage points compared with the 1920s.

The view of the quarter century following 1948 as one of more moderate innovative advance within manufacturing is consistent with the enumerations of basic innovations by Alfred Kleinknecht, Jacob Schmookler, and Gerhard Mensch. All of these series show peaks in the 1930s, particularly its second half. Kleinknecht's analysis, which runs through 1969, shows a big peak in total and product innovations in the 1930s, although process innovations peak in the 1950s (Kleinknecht, 1969). Schmookler's data, which runs through 1959, shows a peak of 48 basic innovations in the 1935-39 period, dwindling to 0 in 1955-59 (Schmookler, 1966).

The most recently updated Bureau of Labor Statistics data show that the rate of increase of TFP in manufacturing falling to 1.49 percent per year between 1949 and 1973. Kendrick and Grossman (1980) report that the calculated TFP growth rate in manufacturing measuring from 1948 to 1973 was 1 percent less than measuring 1949 to 1973. Making an allowance for this difference, one can use 1.48 percent per year as a rough estimate of TFP growth in the sector between 1948 and 1973. This is 1.12 percentage points lower than the rate experienced in the Depression years, and 3.6 percentage points lower than the blistering pace realizing in the 1920s (see Field, 2006a). An important conclusion follows: The golden age of American labor productivity growth was a phenomenon associated with generally decelerating TFP advance within manufacturing. Since TFP growth in the private non-farm economy as a whole was 1.90 percent per year over this period, it is obvious that other sectors of the economy had to have been experiencing TFP growth substantially higher than was manufacturing.

Here is one way of considering manufacturing's diminishing contribution to TFP growth. On average manufacturing constituted about a third (.339) of the private nonfarm economy over this period (see Table 1 below). Suppose TFP growth in manufacturing had continued during the golden age at the same rates it had evidenced during the Depression years. Using this hypothetical growth rate of 2.60 percent per year and the actual share of output, manufacturing would have contributed .881 percentage points to PNE TFP growth (.339*2.60). In actuality, with TFP rising at 1.48 percent per year, it contributed .502 percentage points (.339*1.48), a difference of .38 percentage points. Everything else being equal, continued manufacturing sector TFP growth of 2.60 percent per year would have boosted PNE TFP growth to 2.28 percentage points per year (1.90+.38), just shy of the record (unadjusted) rate experienced during the Depression years (2.31 percent per year). Or, in other words, almost the entirety of the slowdown in PNE TFP growth, comparing the postwar period with the Depression years, can be attributed to the reduction in the growth rate in manufacturing.

We can also consider the effect of declining TFP advance in manufacturing by looking at the share of PNE TFP growth accounted for by the sector. Manufacturing accounted for only 26 percent of TFP advance in the PNE during the golden age (.502/1.90), as compared with 48 percent during the 1929-41 period (see Field 2006a). This decline was the result of a reduction in the sector's share of output and its TFP growth rate. Had the share but not the sector growth rate decreased, manufacturing's contribution would have fallen only from 48 percent to 39 percent of PNE TFP growth (.881/2.28).

However we parse manufacturing's contribution we are impelled to look elsewhere in the economy for a full understanding of trends and levels of productivity advance within the United States during the golden age. An obvious strategy is to examine sectoral TFP growth rates across the economy. Our analysis begins with two relatively solid numbers: TFP growth for manufacturing and for the PNE as a whole, both obtainable from the Bureau of Labor Statistics. Unfortunately, there is a large asymmetry in the attention government statistical agencies devote to manufacturing as compared with the rest of the economy, and this is particularly so for productivity data. The Bureau of Labor Statistics publishes detailed information down to the 2 digit level on the growth of total factor productivity in the manufacturing sector from 1949 onwards. The most detailed productivity data at the sectoral level are for manufacturing, and they show, as already noted, that between 1949 and 1973, TFP grew in the sector at a compound annual rate of 1.49 percent per year. As discussed above, I use 1.48 percent per year as the estimate for TFP growth in the sector between 1948 and 1973.

1.48 percent is substantially below the rate of advance of 1.90 percent per year calculated by the BLS for the entire private nonfarm economy. This means, as noted, that within the private nonfarm economy TFP advance outside of manufacturing had to be, on average, higher than it was within it. The large scale bureaucratic corporations that dominated manufacturing, and were described in Galbraith's <u>The New Industrial State</u>, generated rates of TFP advance that were historically modest by the standards of the 1920s or the 1930s.

As an approximation, the growth rate of overall TFP growth in the PNE will be a weighted average of sectoral TFP growth rates, the weights corresponding to the shares of the sectors in PNE value added. A good rule of thumb for the latter part of the twentieth century is that the PNE constituted three fourths of GDP. For TFP calculations applicable to the PNE, the BLS excludes from GDP the value added of agriculture, general government, government enterprises, nonprofit institutions, paid employees of private households, and the rental value of owner-occupied dwellings. (BLS Handbook of Methods, ch. 10). In Table 1 I sum the value added of agriculture, government, including government enterprises, educational institutions (almost all of which are private non-profit; government funded schools and universities would already be excluded because they are part of general government), social services, and 2/3 of non-farm housing services. These exclusions approximate a quarter of GDP in both 1948 and 1973, and in the calculations that follow, I will use 4/3, or 1.333, as the markup factor to convert a GDP share into a share of the PNE.

Table 1
GDP excluded from the Private Non-Farm Economy

	1948	1973
Agriculture	8.89	3.97
Government (incl. gov enterprises)	11.17	14.77
Educational Services	0.34	0.72
Social Services	0.05	0.27
2/3 of nonfarm housing services	3.03	4.67
Private Households	0.88	0.35
	24.36	24.75

Source, Bureau of Economic Analysis, Gross Product Originating by Industry
www.bea.gov

Manufacturing's share of value added was .278 in 1948 and .232 in 1973. Averaging these shares, we can conclude that manufacturing accounted for about a quarter of GDP (25.5 percent) in the golden age, and about a third of the private non farm economy (25.5*1.33 = 33.9 percent). Multiplying manufacturing's weight – about one third -- by the sectoral TFP growth rate (.339 * 1.48) yields the sectoral percentage point contribution of .502 to the total PNE TFP growth of 1.90 percent. Thus, as already noted, manufacturing was responsible for approximately 26 percent of PNE TFP growth (.502/1.90) during the golden age. This share can be compared with the 84 percent contributed between 1919 and 1929, and the 48 percent contribution between 1929 and 1941.

So, where is the remainder of TFP advance coming from during the golden age? Neither the BLS nor the BEA, unfortunately, readily provides detailed sectoral calculations outside of manufacturing. There are two published sources that do, although they are not based on the latest revisions to the national accounts. The first is by Kendrick and Grossman, published in 1980. The second is a study by the American Productivity Institute cited in a 1982 paper by Nordhaus. We will use these data (see Table 2) to examine relative productivity advance in the following subsectors of the PNE: Manufacturing, trade, public utilities, communication, transportation, construction, services, and FIRE (finance, insurance, and real estate), keeping in mind that the absolute rates of growth are somewhat higher than a complete reworking of the numbers based on current revisions to the national accounts would likely suggest. Both of these sets of estimates imply TFP growth in the PNE of about 2.2 percent per year, whereas the most recent BLS estimate has it at 1.90 percent.

If we sum the shares of the six subsectors with higher TFP growth rates than manufacturing, they account for 43.9 percent of PNE, in comparison with the 33.6

percent attributable to manufacturing. Using the Kendrick/Grossman data, a weighted average of the TFP growth rates of these six subsectors is 2.66, in comparison with 2.30 for manufacturing. Using the API data, the weighted average is 2.75, in comparison with 2.2 percent for manufacturing. A more definitive analysis awaits a full reworking of the sectoral estimates to bring them in line with the BLS's most recent estimates for manufacturing and the PNE as a whole. But if anything, this reworking should reinforce the point made here. That is because the current BLS numbers show an even larger differential between manufacturing TFP growth and the total for the PNE than do these two accountings.

Table 2
Sectoral TFP Growth Rates, United States, 1948-73

	Share PNE, 1948-73	TFP Growth, 48-73 Kendrick/Grossman	TFP Growth, 48-73 API/Nordhaus
Communication	.025	4.13	4.6
Public Utilities	.026	3.79	4.1
Transportation	.064	2.87	2.8
Real Estate	.063	2.74	2.8
Mining	.034	2.39	2.5
Trade	.227	2.33	2.4
Manufacturing	.336	2.30	2.2
Services	.122	1.70	1.8
Construction	.061	.91	1.2
Finance, Insurance	.042	.00	.2

Sources: Kendrick and Grossman, 1980; Nordhaus, 1982, p. 134.
Note: Share of PNE is based on average of share of value added in 1948 and 1973, divided by .7593, the share of PNE in total value added.

Most of the remainder of the discussion in this paper focuses on transportation and distribution, and particularly the implications of a several decades long transition from a surface system dominated by a rail/water division of labor, to one in which roads and to a lesser degree pipelines also played important roles. According to Table 2, transport accounted for an average of 6.4 percent of the PNE during the golden age. But the significance of technological and structural change in the sector is broader because changes within it contributed to the ability of distribution (trade) and real estate to enjoy TFP growth rates above those experienced within manufacturing. I have less to say here about the sectors generating the very highest rates of TFP growth: communications and public utilities, except that what is going on in these sectors also represented a continuation of trends already evident during the Depression years (see Field, 2003). Their direct contribution to TFP advance is smaller than that of transport or trade, because even though their rates of advance are higher, their shares in the economy are smaller.

In understanding what forces outside of manufacturing are responsible for achieved productivity gains during the Golden Age, it is helpful to go back to the Depression years and consider them in relation to what transpired during the 1920s. As previously noted, the TFP growth rate in manufacturing dropped by half, comparing 1919-29 with 1929-41. What picked up the slack and enabled the latter period to experience an unadjusted PNE TFP growth rate 15 percent higher than was registered in 1919-29? The answer is to be found principally in transportation, communications, and public utilities, and to a lesser degree in wholesale and retail distribution (Field, 2003, 2006a). Within this general area of non-manufacturing TFP advance, transportation was a standout. The very rapid build out of government funded highways during the Depression years played an important role in facilitating high TFP growth rates in such sectors as trucking and railroads (Field, 2007a).

Rails and Roads

Throughout the nineteenth century the construction and maintenance of roads had been, with a very few exceptions, a local responsibility. With the exception of expenditures for Post roads, and the construction of the National Road, the involvement of the Federal government in the construction or improvement of highways was minimal prior to the passage of the Federal Aid Road Act (sometimes known as the Federal Highway Act) of July 11, 1916. It was also in that year that the first trackage of the rail system reached its all time peak. Although turnpikes had been built in the antebellum period (some private, some state supported), the extension of the railway network killed off most of this activity, and resulted in an almost complete division of labor between the provision of local transport by horse powered wagons traveling over mostly dirt roads and that of regional or interstate transport by steam powered vehicles moving over rail and water. Aside from freight carried over water, longer distance and in particular interstate transport of both goods and passengers was conducted overwhelmingly by rail.

The condition of American roads in the first decades of the twentieth century did not reflect the state of the technological art. Other countries at comparable stages of development had intercity road networks that were far superior. France, for example, had consistently devoted public resources to roads as well as rail and canals, and had also invested in and benefited from the skills of a superb cadre of highway engineers, graduates of the Ecole des Ponts et Chaussées. In the early 1920s U.S. farmers paid 21 cents a ton mile to haul crops over dirt roads, whereas French farmers paid ten cents a ton mile to haul over paved roads. Proponents of highway spending in the United States referred to this as a “mud tax,” arguing that it cost US farmers over $500 million per year (Goddard, 1994, p. 59).

The 1920s experienced a continuing and growing disjuncture between U.S. vehicle production and its surface infrastructure. Because of very rapid advance in manufacturing productivity, (see the first part of this paper), U.S. production and marketing of vehicles surged ahead of what was taking place in Europe, even though most of the underlying automotive technology had been perfected there. By 1919, U.S. automobile registrations had already risen to 6.6 million, and there were 898 thousand trucks on the road. These vehicles were used, however, almost exclusively for local travel.

Trucks took advantage of the overburdened state of the railroads during the First World War to grab short haul business. Urban firms welcomed trucks, which delivered door to door, obviating the necessity of running a horse and buggy down to the depot to pick up or drop off freight. To the degree one could arrange point to point truck shipment thus bypassing the railroads entirely, businesses also found that breakage and wastage decreased because of the avoidance of intermodal transfer (Goddard, 1994, p. 87).

But for interstate travel trucks still faced daunting challenges. The state of the U.S. road network at the end of the First World War is reflected in the experience of a fleet of Army vehicles that attempted a cross country transit in 1919. It took them 62 days, averaging about 50 miles a day. If we assume they drove 10 hours a day, this is an average speed of about 5 miles an hour. West of Kansas City, the roads were mostly dirt. Local roads outside of towns weren't much better (Paxson, 1946, p. 244).[2]

During the 1920s the fleets of cars and trucks continued to expand as their costs of production declined. Between 1919 and 1929 automobile registrations more than tripled to 23.1 million, and truck registration surged by a factor of 4 to 3.5 million. Although the

[2] In 1915 Emily Post, considering a cross country car trip across the United States asked a friend who had done it many times what was the best route across the United States. Without hesitation the friend replied, The Union Pacific. See http://www.fhwa.dot.gov/infrastructure/not2.pdf.

states and counties labored mightily to respond to the growing political demand for taxpayer financed road improvement, and the federal government began some revenue sharing to this end, without an agreement on which state highways would be part of a national system, interstate freight and passenger travel would be slow and uncertain at best, moving over roads of widely varying quality and capacity.

Agreement among the states about which routes would be stitched together into a national system was brokered by the Federal government. The 1921 Highway Act pledged that paved roads should link every county seat (Goddard, 1994, p. 91), but more importantly, insisted that states identify which 7 percent of its roads should be linked together into a national system. The politics of doing so were contentious, however, and the list of US routes was not finalized until November 11, 1926. Although the Great Depression began less than three years later, its impact is scarcely evident in road construction figures. Indeed, if one looked only at a series on such expenditures during the 1920s and 1930s, one would have no idea that the country experienced a severe economic downturn during the latter decade.

Because of the lag between the surge in vehicle production in the 1920s and the catch up in infrastructure, it was primarily during the Depression years that the United States built its first national road network. The expenditures that made this possible, which included projects administered by the Public Works Administration (1933-39) and the Works Progress Administration, have generally been interpreted as motivated by a Keynesian make work rationale, and that is sometimes how they were justified politically after the fact. But these projects had very strong political support and a defensible economic rationale, and they probably would have been undertaken (with a supply side rather than a make work justification) had the economy not headed south.

In these respects they are somewhat analogous to the Bush administration tax cuts of 2001. Those changes, which flowed disproportionate reductions in taxes to upper income households, were justified initially as a saving enhancing growth oriented program, but then repackaged in essentially unchanged form as a consumption enhancing Keynesian stimulus package when the economy went into recession. The public road construction of the 1930s (an expenditure increasing rather than a tax reducing fiscal policy) had a less questionable supply side rationale. Given the political agreement on the national route structure at the end of 1926 and the continued overhang of millions of new car and truck registrations, the U.S. probably would have gone forward with this construction whether or not the Great Depression had happened.

During the twelve Depression years, the stock of street and highway capital in the country almost doubled (Field, 2003), and the interstate (small i) network whose outline had been agreed upon in 1926 was finished by the time the war began. As Frederic Paxson wrote in 1946, “when the attack at Pearl Harbor drew the United States again into war, the highways were a completed operating mechanism, needing at the last minute little more than a detail act for access and strategic roads” (1946, p. 238). The system of U.S. routes already enabled, prior to the Second World War, very substantial amounts of interstate ton mileage – almost 10 percent of the total - to be shipped by truck.

Road building then effectively ceased for six years, resuming again with a full head of steam in 1947. The Interstate Highway System, launched subsequently by President Eisenhower, significantly expanded the capacity of the system, and changed some of its qualities, but its routes were built alongside of or literally on top of those of an already completed US highway network. Interstate 95, for example, which runs from Maine to Florida, roughly parallels US 1 that followed the same route; sections of several interstates have replaced US 66 that, as the song says, ran from Chicago to LA. In 1956, the year in which ground was broken on the Interstate system, trucks already carried 18 percent of the ton mileage of interstate freight (up from 9.5 percent in 1940) (U.S. Statistical Abstract, 1964, p. 561). In 1973, almost twenty years later, trucking's share had risen by only another 5 percentage points.

The outlines of the eventual truck/rail division of labor in carrying freight were not readily discernible in 1929, when trucks were probably responsible for less than 2 percent of interstate ton mileage. But they were by 1941. Postwar developments in surface transportation took place along lines that had been mapped out and essentially completed during the Depression.[3]

At the end of the First World War virtually all interstate freight not carried over water moved by rail, and the rail/water division of labor that this reflected had been in place at least since the 1850s. Just as the reconfiguration of American manufacturing in the 1920s represented a major departure from patterns that had prevailed for decades, so too did the transition in interstate shipments from a rail/water system to one that involved rail, road, water, and pipelines. That shift took off during the Depression and continued during the Golden Age.[4]

[3] U.S. routes were, of course, built to substantially lower standards, with lower average speeds and capacities, than were the Interstates, controlled access divided highways that eschewed stop lights. But the 1941 system, essentially what the country had in 1956, represented an enormous improvement over what was in place in 1929.

[4] Public infastructural investment during the 1930s affected all four modes. The US internal water transportation system, for example, also received substantial upgrades. The Tennessee Valley Authority built dams which controlled floods and generated hydropower, but also improved river navigation.

This transition is part of the explanation for the high economy wide TFP growth rates that prevailed in the United States during the Depression years and the golden age. The growth of trucking's share of interstate shipments from virtually nothing as late as the end of the 1920s to 18 percent in 1956 was predicated both on infrastructural capital accumulation and on a number of important technical advances which included the pneumatic tire and (more arguably) the internal combustion engine. This complex of innovation and accumulation facilitated the development of a complementary and symbiotic relationship between a growing trucking industry and a pared down rail sector.

A very substantial portion of this transition had already occurred by the time the first concrete for the Interstate highway system was poured. That massive public works project helped extend the good times, at least for another decade. But the mechanisms and magnitude of productivity advance in the transport/distribution sector in the postwar period represented continuation of trends and processes begun during the Depression. Both road and rail transport also experienced healthy productivity advance after the war. Remarkably, between 1948 and 1966, rail productivity rose even faster than it had during the Depression, and faster than productivity in the rest of the transportation sector.

The shrinkage of the railway sector and the corresponding expansion of trucking in the golden age are vividly illustrated in the BEA's persons employed series. Railway employment dropped from 1.503 million to 565 thousand between 1948 and 1973, while employment in trucking expanded from 655 thousand to 1.303 million over the same period (www.bea.gov, Table 6.8B, accessed Oct 26, 2004). Between 1973 and 1989,

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Elsewhere in the country, The U.S. Army Corps of Engineers improved navigation channels. The 9 foot channel navigation project, for example, benefited river transport on 284 miles of the Upper Mississippi. Barge transport also benefited from the switch from tows to push barges. But, in contrast with trucking and warehousing or railroads, TFP growth within water transport was very low across the Depression years (see Field, 2006a, Table 5).

while persons employed in railways dropped further to 262 thousand, trucking expanded to 1.546 million. By 1989 there were as many people employed in trucking as there had been in railroads in 1948, but less than half as many people employed in railroads as there had been in trucking at the earlier date.

The role that highway construction played in influencing productivity in the U.S. rail industry is complex. There is no question that (along with air transport) improved surface roads ultimately killed most of the rail passenger business, and that roads (along with pipelines) did the same for much of its freight business. But it is also true that rail productivity increased sharply during the Depression years, in the presence of capital shallowing. It did so even more rapidly after the war in the context of capital deepening caused in part by a very rapid decline in labor input (see Kendrick and Grossman, 1980, p. 133). And for several decades railroads remained part of a political coalition demanding federal support for the expansion of roads.

Infrastructural investment during the Depression was an important contributor to TFP growth in the private economy (Field, 2006a,b; 2007a,b). Included here are investments in streets and highways, as well as the construction of tunnels and bridges particularly in such intermodal centers as the Bay Area and the New York metropolitan areas. The coincident increase in output per hour is not simply a result of failing to include in measures of relevant private sector capital deepening the increased investments in highways. The build out of the surface road network led to spillovers – network externalities and innovations in running rail systems and trucking operations – that boosted Depression era TFP growth, and continued to do so in the postwar period.

One might claim that the dominance of the 1929-41 period in TFP calculations is simply an accounting artifact resulting from the shift from privately owned rail permanent way to publicly owned streets and highways. But this hypothesis is inconsistent with the data in Table 3, which recalculates PNE TFP growth using a capital input series that adds to private sector capital the value of the stock of government owned streets and highways (the data are from the BEA's Fixed Asset Tables). It is true that adding in public capital growth makes a very significant difference in the growth of the augmented capital series between 1929 and 1941 – the largest difference of any of the periods examined. But the dominance of the Depression years in terms of TFP growth remains unchanged.

Table 3
Effect of Including Components of Government Infrastructure on Calculations of TFP Growth, United States, 1919-2000

	PNE TFP Growth	Change in Capital Contribution	Adjusted TFP Growth
1919-29	2.02	.17	1.85
1929-41	2.31	.29	2.01
1941-48	1.29	-.02	1.31
1948-73	1.90	.13	1.77
1973-89	.34	-.08	.42
1989-2000	.78	.02	.80

Sources: Sources: Field, 2006a, Table 1; BEA Fixed Assets Table 2.1, 2.2, 7.1, 7.2..
Note: Government Infrastructure includes streets and highways (federal and state and local) and other government structures, which includes electric and gas facilities, transit systems, and airports. Capital share used in calculating change in capital contribution =. 31. For 1919-1929, I compare growth of fixed asset stocks with and without government infrastructure between 1925 and 1929.

Road improvements contributed to productivity growth in the trucking industry in a number of easily understood ways. With paved roads stopping at the city's edge, as they generally did in 1919, trucks faced a tough go of it if they ventured beyond, particularly in the winter and during the spring thaw. Improved roads meant trucks could travel at higher average speeds and cover longer distances in a day. As routes got longer and trucking traffic grew, network externalities resulted in greater likelihoods that truckers could snag a backhaul, which increased capacity utilization and raised the productivity of both capital and labor.

Quality improvements in the reliability and durability of trucks complemented improvements in the roads. Perhaps the most important of these was the borrowing of the pneumatic tire from the bicycle industry. Indeed, one can make a case that the tire was a more important technological precondition for a successful truck industry than were advances in the internal combustion engine – since alternate power sources, such as steam, might have achieved comparable range and reliability had they received similar levels of research and development attention (Arthur, 1989).[5] In the absence of the pneumatic tire, however, vibrations and shocks made any but short distances and low speeds unbearable for the driver. Wear and tear on the vehicle as well as the driver was far greater, and there were higher costs in damaged freight and broken containers. The problem of absorbing shocks transmitted from the road surface was more serious for trucks than cars because of the greater weights involved. After more than a century, no serious alternative to the use of inflatable rubber tires for cushioning surface road transport has emerged.

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[5] A steam powered automobile one the first Los Angeles to Phoenix race in 1908 with an average speed of 17.5 mph. See http://www.fhwa.dot.gov/infrastructure/not2c.htm.

The pneumatic tire was first used on bicycles in 1889. Just as many automobile manufacturers benefited from their experience building bicycles, so to did political pressure from bicyclists for better paved roads lay the foundation for subsequent lobbying by automobile and truck interests towards the same end (Finch, 1992, pp. 24-25.). The emerging political coalition for "good roads" brought together automobile and bicycle enthusiasts and a growing trucking industry with automobile, truck, and tire manufacturers, road contractors, asphalt and cement producers, the petroleum industry, insurance companies and the motor lodging industry (Goddard, 1994, p. ix).

There is a rapidly growing literature on the impact of general purpose technologies on economic growth. Despite the efforts of Bresnahan and Trachtenberg (1995) and Lipsey, Bekar, and Carlaw (1998) to be more precise about its characteristics, there are good reasons for being skeptical that the concept adds a great deal to our toolkit (Field, 2006b), Nevertheless, there are clearly some innovations and innovation complexes that are more important than others. A number of writers (Gordon, 2000, David and Wright, 2003) have speculated about the "internal combustion engine" as a potential GPT. Careful consideration suggests that this new engine design was only part of a consequential innovation complex, and not necessarily its most important part. It is true that in the event the vast majority of vehicles on America's highways were powered by gasoline or diesel engines in which combustion took place within rather than outside of cylinders. But the particular design of the engine is not what was critical. It was the use of self propelled vehicles on rubber tires running over a paved and improved infrastructure that was the key contributor to the second wave of TFP advance identified here. Whether these vehicles were powered by external combustion (steam), or gasoline fueled internal combustion engines was a matter of secondary importance.

While it is clear how better roads benefited trucking, it is not so obvious that they promised and in fact yielded significant benefits to the rail industry. How did improving the surface road network lead to complementary improvements in productivity in the railroad sector? One important mechanism was by smoothing out seasonal fluctuations in the demand for freight cars. Rural Free Delivery had brought mail and mail order goods to millions of farm households, and the insistence by the Post Office that roads be minimally passable in order to institute the service had resulted in some improvements in local roads and bridges. But as late as the mid 1920s paved roads tended to end at the edges of towns and cities with the possible exception of major metropolitan centers on the two coasts. Consequently shipments to and from rural households dropped precipitously when the roads were bad, particularly during the winter months and the spring thaw. Prior to the railroad, freezing temperatures shut down interior commerce in much of the northeast and Midwest for as much as five months during which canals and rivers were impassable. Railroads were largely unaffected by changing weather conditions, but they still relied on trucks or horse and buggies for the trip from depots to farm households. These miles, dependent on a dirt roadbed, remained more vulnerable to the weather than had interregional canal and river traffic prior to the railroad.

The flip side of the collapse of shipments during winter and spring months was that shippers deluged the railroads with business during the dry season. Carriers had to balance the benefits of being able to meet this surge in demand with the costs of holding excess capacity the rest of the year. As one might expect, their solution represented a compromise, with the result that prior to road improvements and the growth of the trucking industry, railroad shipments were backlogged during four or five months while many freight cars ran close to empty during the remainder of the year (Goddard, 1994, p. 52).

In the 1920s railroads could not imagine trucks making runs of more than 20 miles a day and they anticipated that better roads would smooth their shipment flow and they would enjoy a symbiotic relationship with the trucking industry in which they (the railroads) would enjoy the role of senior partner. That was one reason for their support of the “good roads” movement for the better part of several decades. Another was their expectation that they could earn money by shipping construction materials – asphalt and concrete - for new roads. They cheerfully hauled the materials that would improve the highways, and they hauled the steel, glass, tires and subassemblies to Detroit, where the trucks and cars were built, and they hauled the completed trucks and cars from Midwest factories to retail markets around the country. Slowly, shipment by shipment, they contributed to the building of a competitive transport mode that eventually took away most of their passenger business and much of their freight traffic.

The railroad industry simply did not fully appreciate the extent to which the burgeoning trucking industry would eventually eat much of its lunch. Conventional wisdom for several decades was that trucks helped railroads, they were the servants of railroads, because they either delivered from the depot to the final destination (where railroads could not). Or, in cases where roads might parallel rails, the conventional wisdom was that trucks were suitable only for short hauls, on which railroads couldn’t make money anyway. But entrepreneurial truckers had other ideas, pushing the edge of the envelope to 50 miles, then 100, then even longer runs. Low barriers to entry and the lack of regulation prior to 1935[6] created an environment in which the industry could grow rapidly in response to burgeoning profit opportunities made possible by improvements to the roadbed and to the durability, reliability, and size of trucks.

The economics of trucking were fundamentally different from those of rail. Because railroad companies enjoyed decreasing average costs over much of their output range, the industry tended toward monopoly. Pricing at marginal cost might be allocatively efficient but could not hope to cover fixed costs. The consequence was a byzantine system of freight classes through which rail companies tried to price discriminate based on the value of the product being shipped rather than what it cost to move it. Charging what the market would bear was a practical necessity if bankruptcy was to be avoided, but was arbitrary and inherently discriminatory. Complaints about discrimination and political agitation against railroads led to the creation of the Interstate Commerce Commission and a system of regulated prices.

Truckers, who did not own their road bed or have to pay for it directly, had low fixed costs and faced cost structures more closely approximating the canonical competitive firm. They did not have to segregate their freight into categories. They charged by weight, and could respond to changing market condition by quickly adjusting rates, whereas railroads had to go through a complicated and time consuming administrative process to do so. That was one reason why truckers were running circles around railroads, literally and figuratively. Another was that trucking had much greater flexibility in terms of changing routes and batching jobs to deal with geographically dispersed pickup and delivery, so that while rails struggled with increasing numbers of

[6] The Federal Motor Carrier Act.

less then carload shipments, network externalities allowed truckers to increase their load factors. By 1940, 9.5 percent of interstate ton mileage was already carried by trucks. (Statistical Abstract, 1964, p. 561).

Nevertheless, there remained much that was defensible in the railroad's justification for supporting the construction of better roads. Both labor productivity and TFP went up in the railroad sector faster during the 1929-41 period faster than they had between 1919 and 1929, even though capital deepening occurred in the earlier period and capital shallowing (declines in the stock of both equipment and structures and declines in the overall ratio of capital to labor in the industry) took place during the Depression years (Field, 2003). The total mileage of the railroads reached its high water mark in 1916, the year of the first Federal highway bill, but the shrinkage of trackage was slow in the 1920s and began to accelerate only during the 1930s. Spurs to inactive mines were abandoned, and lightly used freight and passenger routes were increasingly abandoned as well. To the degree that the rail system shut down its least productive activities, productivity went up.

First track mileage operated for all reporting railways peaked at 266,381 miles at the end of 1916. By 1929 this had dropped only marginally to 262,546. By 1941, however, it had fallen to 245,240, about a 9 percent decline from the peak (US Statistical Abstract, 1942, p. 477.) In 1973 it had fallen to 216,000 miles (US Statistical Abstract, 1978, p. 660), as the industry continued to seek and receive permission to abandon unused or lightly used lines.

Between 1929 and 1941 TFP advance in trucking and warehousing was nothing short of phenomenal, growing at a compound annual rate of 13.6 percent. The sector was responsible for almost 10 percent of the entire PNE TFP growth during this period. TFP in railroads rose at 2.91 percent per year between 1929 and 1941. Even though this was only a fifth of the blistering pace in trucking and warehousing, the substantially larger weight of rails in the economy meant that railroads accounted for about 6.5 percent of the 2.31 percent per year TFP growth in the private nonfarm economy (again, this is in comparison with the 48 percent contributed by manufacturing; see Field 2006a for detailed calculations).

By 1941, then, a significant reconfiguration of the US surface transportation system had already taken place. The network of national routes that remains with us to this day, although subsequently expanded and paralleled by the Interstate system, was essentially complete. The key infrastructural components (bridges and tunnels) for the major East and West Coast port complexes had been built. Trucking was already responsible for close to 10 percent of interstate ton mileage, and the railroads had abandoned more than 20,000 miles of first track.

The historical trends that emerged during the Depression were temporarily interrupted by the Second World War, as the trucking sector shrank and railroads expanded in the face of wartime exigencies. It was a triumphant period for the U.S. rail system, which performed far better than it had during the First World War, when, jammed with shipments from the industrial Midwest to East Coast ports, a railroad sector beaten down by a hostile public and tough ICC rate regulation had been ignominiously taken over by the government. Trucking, on the other hand, had received something of a boost during the First World War. Even though the roads were terrible, the U.S. was still the world's largest petroleum producer and fuel availability was not a problem, so trucks were able, heroically in some instances, to come through where the bottlenecked rail system could not.

The situation was quite different during the Second World War. Petroleum was scarcer. Fuel was now needed for thousands of aircraft, tanks, jeeps, and other military vehicles, since the scale of mechanized warfare far exceeded what had been true in the earlier war. Truck tonnage shrunk, while rail tonnage expanded. Because the war was fought on both a Pacific and a European front, freight (and passengers) moved both East and West, a situation that benefited rail performance by attenuating the backhaul problem that had plagued the system in 1917-18. Both passenger and freight traffic hit record levels and the railroads made substantial profits, emerging from the war in better financial shape than they had enjoyed in more than two decades.

After the war trends from the 1930s reasserted themselves. Public infrastructural expenditure resumed, and, in conjunction with innovations such as piggybacking and containerization, continued to throw off spillovers in the transport and distribution sector. But it was now rail rather than trucking that experienced the highest rate of productivity growth. TFP in the shrinking rail sector more than doubled between 1948 and 1966, growing at a compound annual rate of over 4 percent per year (Kendrick and Grossman, 1980, p. 133).

A growing contributor to productivity advance in the transport sector in the postwar period was innovation in intermodal transfer, particularly piggybacking and containerization. Piggybacking involved placing the trailer part of a tractor trailer on a flatbed railcar, shipping it over long distances, and then reconnecting it a truck to be taken to its final destination. In 1958 about 1 percent of railway car loadings (278,081) were piggybacked trailers. By 1986 that share had risen to 15 percent (Duke et. al., 1992, pp. 52-53). Containerization, launched in 1956 in the ocean borne freight industry, expanded rapidly during the 1960s, and even more rapidly thereafter. The development of a standard sized container, carriers built to accommodate them, and transshipment facilities that could quickly handle them meant dramatically reduced labor and capital costs associated with transfers between water, road, and rail.

For the railroads and trucking industries, containerization represented a more flexible generalization of the principle of piggybacking. Some commodities, such as coal, oil, grain, or iron ore, remain best suited, whether shipped over water or rails, to specialized bulk carriers. And some other types of cargo continue to be shipped in the breakbulk portion of the industry.   But for a wide range of general freight, the innovation of a standard sized container (originally 20’ x 8.5’ x 8.5’; now usually 40 feet long) that could be stacked on a ship, a railcar, or the back of a tractor trailer, dramatically cut the costs and time required to effectuate transfers.

Containerization began in 1956 when the Sealand Corporation ran a modified tanker stuffed with containers from New York to Houston. It took off in the 1960s, as new port facilities were built in places such as Port Elizabeth, New Jersey, Oakland, California and, in Europe, Rotterdam. Although originally developed to reduce turnaround time and labor costs in loading and unloading ships, containerization rapidly evolved to the point where it could equally well facilitate road to rail transfers (or vice versa). Containerization and its predecessor, piggybacking, represented an important part of the evolving symbiosis between railways and the trucking industry.

As Wilfred Owen observed back in 1962, the innovation saved both labor and capital (Owen, 1962, p. 410). The labor saving was obvious: less hours required to break or transship cargo. And although containerization required investments in both structures and equipment, capital saving resulted from increases in the rate of throughput, meaning faster rates of inventory turn and higher utilization rates on fixed capital (see Field, 1987). In terms of its contribution to private nonfarm economy TFP growth during the golden age, containerization was probably more important than any single innovation coming out of the manufacturing sector during this period.

The End of the Golden Age

A full understanding of the post 1973 productivity slowdown, a global phenomenon, has eluded the best efforts of a large number of economists. But just as our understanding of economic growth in the golden age benefits from a study of its roots in the Depression years, so too does the study of the productivity slowdown after 1973 benefit from a search for the sources of advance in the golden age. Growth in TFP began to slow in many sectors after 1966 and dropped precipitously after 1973. The slowing in TFP growth, the major cause of the retardation in growth in output per hour, coincides with a tapering off of gains from a one time reconfiguration of the surface freight system in the United States. After declining sharply for decades, the share of rails in intercity ton mileage stabilized after 1973 in the 37 percent range, actually rising slightly in the 1990s (the 2000 figure was 41 percent). This stabilization, in turn, coincided roughly with the completion of the Interstate Highway system.

Productivity advance in transportation did not cease after 1973. Although progress was weak in all modes in the 1970s, it came back strongly in rail and air transport in the

1980s and 1990s. Rail productivity benefited from changes in work rules that eliminated cabooses and reduced manpower requirements. Crews on intercity trains dropped from four or five to two people. Electronic sensors rather than humans now warned of avalanche slides or highwater flows over bridges. Computer assisted dispatching combined with track sensors and other electronic devices reduced labor requirements in marshalling yards. The 1980 Staggers Rail Act made it easier for lines to abandon lightly used track and to merge. Mergers, in turn, allowed more intensive utilization of consolidated and shared facilities (Duke et al, 1992, pp. 52-53).

Railroads became highly specialized and highly productive “pipelines” for coal, grain, chemicals and even the movement of new vehicles, a business they now recaptured to a significant degree from trucks. They rounded out their portfolio with containerized shipments, which grew dramatically in the last third of the century. Railroads initially opposed containerization, but they ultimately appear to have benefited from it more than did trucking. One of trucking’s big early advantages over rails had been that it could offer point to point transit, without the need for breaks in cargo. Because the use of standardized containers reduced the cost and time required for transfers, rails could now recapture some of this business. Rails also benefited from periods of high energy costs, in a manner somewhat analogous to what had happened during the Second World War. Railroads are more energy efficient in carrying freight long distances; higher energy costs also increased the demand for coal shipments, rarely carried by truck.

Although productivity growth in trucking eventually revived after the doldrums of the 1970s, the glory days were behind it. The sector could no longer anticipate spillovers from infrastructure enhancement, as it had to such an extraordinary degree in the 1930s.

Just as the unprecedented TFP gains in manufacturing slowed as the share of electrified manufacturing approached 80 percent at the end of the 1920s, so too did the surface road spillovers within transportation slow as the capacity enhancements of the road net were completed in the early 1970s. After 1973, productivity growth in trucking slumped. Productivity growth in airlines and railways, on the other hand, revived at a strong pace during the 1980s (Baily and Gordon, 1988, p. 419).

Table 4
Sectoral TFP Growth Rates, United States, 1948-66 and 1966-73

	TFP Growth, 48-66 Kendrick/Grossman	TFP Growth, 66-73 Kendrick/Grossman	Share PNE, 1948-73
Communication	4.62	2.84	.025
Public Utilities	4.79	1.24	.026
Transportation	2.99	2.08	.064
Real Estate	3.32	1.26	.063
Mining	3.20	.32	.034
Trade	2.44	2.04	.227
Manufacturing	2.46	1.89	.336
Services	1.50	2.20	.122
Construction	2.46	-3.10	.061
Finance, Insurance	.40	-.88	.042

At least through the 1960s, highway construction was, on balance, beneficial to the U.S. standard of living. For several decades spillovers and network externalities outweighed any tendency toward diminishing returns. This does not mean, however, that such a result could necessarily continue indefinitely. There are grounds for questioning both the social and economic benefits of the final stages of the building of the Interstate system, which rammed freeways into the heart of central business districts, reducing the urban tax base as they destroyed often viable neighborhoods, and contributing to the decay of inner cities. These projects were extraordinarily expensive on a per mile basis, and improved road access to a core whose economic viability was simultaneously being eroded by the construction projects themselves. It has taken several decades to reconfigure urban areas to adjust to these shocks (in some cases more successfully than elsewhere), with renewed investments in mass transit and reintroduction of light rail technologies abandoned several decades earlier.

With the exception of services, there was an across the board decline in TFP growth rates, comparing 1966-1973 with 1948-1966, presaging decleration over the 1973-89 period, which experienced the worst (peak to peak) productivity growth in the twentieth century. Most students of the productivity slowdown (Abramovitz was an exception) dated it from 1973, but as the above data show, the deceleration began earlier. The emphasis on 1973 led to a lot of early work on the role of the oil shocks of 1973-74 and 1979, and oil retains appeal as the one obvious explanation for the global character of the slowdown. But real oil prices collapsed in the 1980s, and productivity growth remained slow through the remainder of the decade.

Within the United States, Vietnam and the malaise and discontent – as well as dislocations of the economy -- with which it was associated perhaps played a role. But a more concrete influence was the end of the era of large private sector spillovers from government funded highways programs. Whether higher levels of infrastructural spending following the completion of the interstate highway system could have forestalled lower productivity growth rates on this account, and if so, by how much, is an open and much debated question.

In accounting for the decline in PNE TFP growth following 1973, some attention should also be paid to the continued decline in TFP growth within manufacturing compared with the golden age. TFP growth in manufacturing dropped from 1.48 percent per year (1948-73) to .57 percent per year between 1973 and 1989 (BLS data). Over the same period TFP in the private nonfarm economy declined from 1.90 percent per year to .34 percent a year, a stunning drop of 1.56 percentage points. How much of this can be attributed to the slowed rate of growth of TFP in manufacturing? Manufacturing's share of value added declined after the Second World War, dramatically so after 1973.

Averaging beginning (.2324) and end point (.1843) share, we have a manufacturing share of .2084 of value added over the 1973-89 period, thus a manufacturing share of about .277 of the PNE. Had TFP growth within manufacturing persisted at the 1948-73 rate of 1.48 percent per year, we would have had a contribution from manufacturing to PNE TFP growth 1973-89 of .41 percentage points a year (.277*1.48), instead of the .16 percentage points (.277*.57) actually contributed. The difference represents manufacturing's contribution to the collapse of PNE TFP growth: .25 percentage points per year.

But since PNE TFP growth declined, comparing the two periods, by 1.56 percentage points, manufacturing can account for at best a sixth of the slowdown. As has been noted, there is a general and persistent downward trend in TFP growth within manufacturing from its peak during the 1920s. Some of the retardation, which is already evident in the last years of the golden age and continued during the 1973-89 period, may be associated with the slowdown in non defense R and D spending that is apparent starting in the 1960s and continuing in the 1970s (see Rosenberg and Mowery, 2001). But whatever its causes, only a small fraction of the slowdown in the economy as a whole after 1973 can be attributed directly to productivity slowdown within manufacturing.

The remainder has to be originating elsewhere, and a prime candidate is the retardation in productivity advance in transport/distribution coincident upon the exhaustion of the extraordinary productivity advances made possible by the shift from rail to truck that had begun in the late 1920s. The rough post-1973 stability of road/rail shares in intercity ton mileage, after four decades in which trucking had risen at the expense of rails, testifies powerfully to the coming to the end of a transition comparable in significance to the electrification of U.S. manufacturing.

Fernald (1999) provides data which supports this interpretation. He finds a close correlation between road construction and changes in productivity in vehicle intensive sectors, such as transportation and trade. Prior to 1973, productivity growth in those sectors was higher than the economy wide average. Subsequent to 1973, when the U.S. street and highway capital stock essentially stopped growing, the reverse was true. Fernald also finds that, at the margin, highway construction does not appear to be unusually productive. Thus he concludes that "Road building…explains much of the productivity slowdown through a one time, unrepeatable productivity boost in the 1950s and 1960s" (Fernald, 1999, p. 619). His argument supports my analysis, although because his statistical work is limited to the second half of the century, he is not able fully to appreciate the extent to which advances in the golden age represented a continuation of trends first manifested in the 1930s.

Jovanovic and Rousseau (2005) attribute the end of the golden age to the first stages of the IT revolution, arguing that when one has a transformative technology, productivity growth must first deteriorate before it can improve. The logic involves transition and the reality that users often don't initially know how best to take advantage of a new technology. But while their argument is theoretically coherent, it is empirically implausible.

In the late 1960s, when the slowdown began in the United States, the use of mainframe computers for accounting and billing and time shared systems for airline reservations were already well established, whereas the disruptive effects of personal computers and the internet were still decades away. In 1966 the current cost value of IT equipment and software was just 2.5 percent of private fixed assets and 3.1 percent of the total in 1973. Another perspective: The real stock of IT capital in 1966 stood at just 3.25 percent of its value in 2000 (the latter calculation is based on chain type quantity indexes of the net stock; see Bureau of Economic Analysis, Fixed Asset Tables 2.1 and 2.2).

At the time the productivity slowdown began, the uses of IT capital were limited, relatively well established, and concentrated in a few sectors. The slowdown in productivity advance was significantly broader. Without a more detailed explication of exactly how and where IT investments were responsible for the slowdown, it is difficult to give the hypothesis much credence. The exhaustion of the gains from the second transition emphasized in this paper – from a rail/water duopoly in surface transport to the new modality of road/rail/water/pipelines is a more promising candidate in helping us understand the decline in growth in both TFP and output per hour after 1973.

It should be emphasized that there is no inconsistency in arguing that government infrastructural investments in the four decades running from the late 1920s to the mid-1960s had important spillover effects that show up in economy wide PNE, and at the same time remaining agnostic or skeptical about whether additional infrastructural spending would have forestalled the decline. Thus it may be misleading to suggest that the slowdown after 1973 is principally attributable to the demonstrable decrease in such spending (Aschauer, 1989). It is more plausible to argue that the slowdown was a justified response to the reduced potential for incremental gains from additional investment. The logic here is similar to the argument made with respect to factory electrification/redesign. Another example. The 1930s were a great age of bridge, hydro, and tunnel construction. The Golden Gate, Oakland Bay, and George Washington bridges and Lincoln Tunnel are a few famous examples from the two coasts. The last major suspension bridge built in the United States crossed the Verrazanno Narrows, and was completed in 1964. But that does not mean that U.S. productivity growth would necessarily have been higher had bridge construction continued at the same rate into the 1970s and 1980s.

Conclusions

Students of the history of total factor productivity in the United States have noted that it grew fastest in a period spanning the fourth through seventh decades of the twentieth century (Abramovitz and David, 2001; Gordon 1999). Gordon has referred to this acceleration as “One Big Wave” although the analogy is not entirely apt, since it is an unusual wave that leaves the water level permanently higher after it has passed. Whatever we call it, the phenomenon is real and we would like to understand better what underlies it.

This paper can be thought of as tale of two transitions. The first involved the electrification and reconfiguration of the American factory, a development that had its roots in the 1880s but blossomed only in the 1920s, producing enormously high rates of TFP growth in manufacturing during that decade. Rates in that sector trended generally downward for the remainder of the century. The second transition, involving the movement of goods, peaked later. From the late 1920s to the early 1970s, trucking expanded its share of interstate ton mileage, while the rail sector shrunk, specializing as it did so.

Within the four decade period identified above, the strongest TFP growth occurs across the Depression years (1929-41), with performance in the quarter century after 1948 a runner up (Field, 2003). This paper has tried to explain both why TFP growth during the golden age was relatively strong and also why it was lower than it was during the Depression. The downward trend in TFP growth within manufacturing, and its declining share after World War II, provide some answers to the latter question, but also forces us to look further a field in answering the former.

As we step back from the subperiods, and consider the 1929-73 years as a long swing characterized by exceptionally high TFP growth, we should appreciate the extent to which developments in the postwar period – both the declining influence of advance within manufacturing (compared especially with the 1920s) and the significance of the continued transition within transport and distribution -- reflect the extension of trends already evident during the interwar years. In doing so, we can move beyond the inclination to treat the golden age sui generis, and see within it the unfolding of developments that, although temporarily disrupted by the war, had their origins in the interwar years.

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