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Depression Era Productivity Growth in U.S. Railroads

by

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ABSTRACT

Financial boom/bust cycles misallocate capital in an upswing. And the downswing deprives an economy of capital accumulation that might have taken place. These are both negative influences on the trend growth rate of productivity. But can there be a "silver lining", a compensatory beneficial effect? The answer is nuanced. Like individuals, firms and sectors exhibit a diversity of response to adversity. Some become moribund and ultimately fail. Others are spurred to technological and organizational innovation, with persisting long run consequences. Railroads during the Great Depression were one such sector. Between 1929 and 1941, the number of employees, locomotives, and rolling stock dropped by about a third, but freight ton miles increased and passenger miles were within 6 percent of 1929 levels. This paper considers the innovations that enabled this and uses firm level Interstate Commerce Commission data to explore the contours and determinants of labor, capital, and total factor productivity growth between 1929 and 1941.

Introduction

A financial boom/bust cycle misallocates physical capital in an upswing, in some cases with irreversible or expensively reversible adverse consequences. And the downswing deprives an economy of capital formation that might have taken place in the absence of the recession. In contrast with an imagined world in which accumulation took place at steadier rates, both of these effects on aggregate supply have to be entered on the negative side in an accounting of the effect on the trend growth rate of productivity of the boom/bust financial cycle and the closely related cycle of physical capital accumulation..

But is there some compensatory effect during a recession – some positive impact on the long run growth of potential output? In other words, is there a silver lining to depression? A subterranean theme in some economic commentary views depression as a purifying experience, not only purging balance sheets of bad investments and excessive leverage, but also refocusing economic energies on what is truly important, and perhaps stimulating creative juices in a way that expands the supply of useful innovations. This style of argument is reflected in Richard Posner (2009) in a chapter entitled "A Silver Lining?" and it echoes Treasury Secretary Andrew Mellon's approving depression era encouragement to "Liquidate labor, liquidate stocks, liquidate the farmers, liquidate real estate….It will purge the rottenness out of the system. …People will work harder, live a more moral life..." (Hoover, 1952, p. 30).

Is it possible for a diet of feast then famine to toughen up the economic patient, ultimately allowing the economy to grow more rapidly, compensating for the effect on potential output of misallocated capital in the boom and foregone accumulation in the trough? The years of the Great Depression (1929-41) were the most prolonged period in U.S. economic history in which output remained substantially below potential. That period was also the most technologically progressive of any comparable period in U.S. economic history (Field, 2003, 2008, 2011). Is there a connection? It is natural to ask whether there was and whether, because the Depression experienced such pronounced advance in this regard, we could expect some boost to longer run growth as a direct consequence of our current recession.

With respect to recent economic history, Bureau of Labor Statistics productivity data show that the decade long IT productivity boom ran out of steam in 2005. Although TFP for the private nonfarm economy grew at 1.57 percent per year between 1995 and 2005, it declined slightly between 2005 and 2009, although preliminary data indicate revival of growth in 2010 (BLS Series MPU491007, accessed 7/31/2011). We won't have definitive evidence on the longer run trajectory of TFP in the 2010s for some time, since trend growth in my view can only be reliably measured between business cycle peaks. Thus we will need to await the closing of the output gap and the economy's return to potential to get a good reading. Even then there will be a question – as there is in the case of the Depression – as to how much of the advance would have taken place anyway. Still, the issue of whether we can expect a "recession boost" to potential output is obviously an important one, and it is natural to turn to the Depression experience for possible indications as to whether this is likely. That long run trajectory bears on a number of major policy issues, including the adequacy of Social Security funding, our ability to address escalating health costs, and the more general question of what will happen to our material standard of living.

I offer a nuanced response to the question of whether 1929-41 bred productivity improvements that might foreshadow what will happen over the next decade. The issue is best approached by thinking of TFP growth across the 1930s as resulting from the confluence of three tributaries. The first was the continuing high rate of TFP growth within manufacturing, the result of the maturing of a privately funded research and development system. The second was associated with spillovers from the buildout of the surface road network, which boosted private sector productivity, particularly in transportation and wholesale and retail distribution (Field 2011). The third influence, what I call the adversity/hysteresis effect, reflects the ways in which crisis sometimes leads to new and innovative solutions with persistent effects. It is another name for what adherents of the silver lining thesis describe, and it is a mechanism reflected in the folk wisdom that necessity is the mother of invention.

In the absence of the economic downturn, we would probably have gotten roughly the same contribution from the first two tributaries. That is, certain scientific and technological opportunities, perhaps an unusually high number of them, were ripe for development in the 1930s, and they would have been pursued at about the same rate even in circumstances of full employment. With or without the depression Wallace Carothers would have invented nylon; Donald Douglass would have brought forth the DC3. Similarly, by the end of the 1920s, automobile and truck production and registrations had outrun the capabilities of the surface road infrastructure. Strong political alliances in favor of building more and improved roads had been formed, and issues regarding the layout of a national route system had been hashed out by the end of 1927. It is highly probable that the build out of the surface road network would have continued at roughly the same pace in the absence of the Depression. So it is the third effect, the kick in the rear of unemployment and financial meltdown, that is most relevant in terms of a possible causal association between depression and productivity advance.

The adversity/hysteresis mechanism is familiar to households unexpectedly faced with the loss of a wage earner or suddenly cut off from easy access to credit which had been formerly available. Under such circumstances, successful families inventory their assets and focus on how they can get more out of what they already have, not just how they can get more.

Adversity does cause some people to work harder, just as it causes some people to take more risks: these are people for whom the income or wealth effects of adversity dominate the substitution effects. For others, the substitution effect leads to withdrawal from the labor force, or discouragement. In more severe forms this is evident in a variety of mental and physical disorders that may show up in aggregate statistics on alcoholism, depression, suicide, and divorce. The overall effect on innovation, work effort and risk taking is not easy to predict, given that, in economic terms, both income and substitution effects are operative, and that they pull in opposite directions (blanket opposition to tax increases based on their effects on aggregate supply typically focuses only on substitution effects). There is merit in the adage that what doesn't kill you makes you stronger. It's just that sometimes it kills you. Not all families or firms are resilient, and in some instances adversity destroys them. So I am skeptical overall that we can take an unqualified optimistic view of the effects of economic adversity on innovation and creativity.

These qualifications aside, there is one important sector which appears to have benefited from the silver lining effect during the Depression, and that is railroads. Railroads confronted multiple challenges. They faced adverse demand conditions specific to the industry that would have continued to plague firms with or without the Depression. The automobile was already eroding passenger traffic in the 1920s, and trucking was changing the freight business by providing strong competition in the short haul sector. For an industry faced with these challenges and characterized by heavy fixed costs, the downturn in aggregate economic activity was particularly devastating, and pushed many railroads into receivership. Access to capital was disrupted, although some ailing roads received loans from the Reconstruction Finance Corporation and, paradoxically, bankrupt rails, no longer required to meet obligations to their original creditors, could obtain credit, especially short term financing for equipment purchases, with greater ease than lines which had not gone bankrupt. But access to cheap fifty year mortgage money – widely available in the 1920s -- was pretty much gone (Schiffman 2003). Railroads responsible for roughly a third of U.S. track mileage were in receivership by the late 1930s, and had their financing constraints somewhat relaxed. A corollary, however, is that railroads responsible for the remaining two thirds were not in receivership. With generally weak balance sheets, they faced limited access to credit.

Confronted with these challenges, both labor and management took a hard look at what they had, and worked to use their hours and capital resources more effectively. The result was a substantial increase in the rate of total factor productivity growth, due to innovations in equipment, structures, and logistics. Both capital and labor inputs declined substantially.[1] Underutilized sections of track, for example, were decommissioned [2] and the net stocks of both railroad structures and railroad equipment declined as did the number of employees. Rolling stock went down by a third, and the number of employees declined by almost that percentage.

Superimposed on this overall rationalization of the rail system were improvements in locomotives, rolling stock, and permanent way. Steam locomotives (and even some of the early electrics) began to be replaced with diesel-electrics, an almost unambiguously superior technology, particularly in comparison with steam. Diesel-electrics did not require an hour for "firing up" to deliver full power, did away with the need for rewatering stops (to replenish the boiler's source of steam), reduced or eliminated the need for refueling, and made unnecessary the locomotive position of fireman. If properly equipped, diesel-electrics could operate on both electrified or non-electrified portions of a system, drawing power from overhead wires where available or generating their own when it was not, which made them considerably more flexible than pure electric locomotives.[3] Overall, diesel electrics had much lower maintenance costs, produced less wear and tear on tracks, and had fuel efficiency that was at least three times that of steam locomotives (Stover, 1997, p. 213). Although diesel electrics still represented a small fraction of the total locomotive stock in 1941, their introduction and development is

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[1] Posner captures the silver lining hypothesis insofar as it applies to productivity in these words: "A depression increases the efficiency with which both labor and capital inputs are used by businesses, because it creates an occasion and an imperative for reducing slack…. When a depression ends, a firm motivated by the recession to reduce slack in its operations will have lower average costs than before…" (2009, pp. 222-3)

[2] First track mileage operated was roughly unchanged from 1919 to 1929 (263, 707, declining to 262,546). But between 1929 and 1941, it dropped 5.9 percent (262,546 to 245,240) (Statistical Abstract, 1945, table 521, p. 470). As first track mileage declined, however, the relative importance of secondary trackage increased (see Stover, 1997, pp. 182-83).

[3] Contrary to some misconceptions, a diesel electric does not use a diesel motor directly to power the locomotive. The diesel engine drives a generator, the electrical output of which drives an electric motor that powers the engine. It is thus closer in design philosophy to what the new Chevrolet Volt is attempting than say, the Toyota Prius.

testimony to the engineering advances that were being pushed forward during the Depression years.

Passenger cars also improved, with more of them constructed from light weight aluminum and alloys; streamlining became the aesthetic hallmark for both locomotive pulled cars and self propelled articulated or single car (such as the Budd car) trains. Freight cars became larger. The introduction of electro-pneumatic retarders improved the efficiency of gravity switching yards. Without them "it would have been a virtual impossibility to handle war traffic through major centers" (Parmalee, 1950, p. 43).

Complementing these improvements in equipment, investments in permanent way along with logistical innovation enabled railroads, in spite of substantial reductions in the numbers of locomotives, rolling stock, and employees, to record slightly more revenue ton miles of freight and book almost as many passenger miles in 1941 as they had in 1929. What were some of these improvements? First, more sections of the system were electrified.[4] Second, centralized traffic control systems allowed more intensive use of trackage without jeopardizing safety. Centralized traffic control was a refinement of block signaling in which the operation of trains could be monitored and controlled by a single dispatcher, who scanned a central display board providing real time location information for all trains in a division. Track mileage operated using this system increased more than six fold between 1929 and 1941, from 341 to 2,163 miles, and then more than tripled during the war years (Stover, 1997, p. 184). The innovation was particularly important in heavily used portions of the rail network, since it allowed substantial increases in utilization without compromising safety.

[4] The most important Depression era project was electrification of the Pennsylvania Railroad from New York to Washington and beyond.

The most far-reaching and significant organizational innovation, however, was the negotiation and implementation of unlimited freight interchange. Agreements worked out during the Depression allowed the free movement of freight cars among different systems, so that, for example, a box car could move from one road to another without needing to break cargo. And when it reached its destination (even though outside of the system that owned it) the car could be reloaded rather than sent back empty to territory controlled by the originating road.[5] Cooperation was enabled by a standard schedule of rental payments along with agreements so that repairs and maintenance, if necessary, could be undertaken in yards owned by a railroad different from the one that owned the car.[6]

Unlimited interchange resulted in large reductions in the transactions costs associated with moving freight long distances. It was facilitated by moves towards equipment standardization initiated during the Federal government's takeover of the railroads during the First World War (Stover, 1997, p. 175; Longman, 2009), and pushed forward in the 1930s by the Association of American Railroads. The AAR, formed in October 1934 through the merger of five industry trade groups, vetted and approved, from the standpoint of both safety and efficiency, changes in freight car design, and took the lead in developing and promulgating industry standards for operations, interchange, and ultimately interoperability. These were and are published in its Manual of Standards

[5] In the first half of the twentieth century most transcontinental rail passengers had to change in Chicago. As one writer put it, the city was "a phantom Chinese wall that splits America in half." After the Second World War the President of the Chesapeake and Ohio published advertisements announcing provocatively that "a hog could travel across the United States without changing cars but a human could not." The ads were intended to jumpstart flagging passenger traffic by showcasing the removal of Chicago as an "invisible barrier." But the copy is indirect testimony to what unlimited freight interchange had achieved during the 1930s (Stover, 1997, pp. 216-217).

[6] The system eventually evolved to incorporate freight cars owned by third parties, so that today more than half of freight rolling stock is owned by entities other than railroads (Richter, 2005, p. 35).

and Recommended Practices. Because railroads are a highly interconnected network industry, standard setting takes on more importance in facilitating efficiency improvement than is the case for example in trucking, because failure of one small part of a system can have much larger deleterious consequences.

During the Depression railroads faced strained financial circumstances, lack of easy access to financial capital, and reduced investment flows. These conditions arguably created a particular incentive to search for and implement logistical improvements, disembodied change which shows up largely in the TFP residual. If this is so, the adversity of these years can be seen as having influenced not just the rate of productivity change but also its character or direction.

The results of these and other changes were significant improvements in productivity over the course of the Depression. Kendrick's series for railroad sector output, drawn from Barger (1951), shows overall output (a weighted average of freight and passenger traffic) 5.5 percent higher in 1941 than it was in 1929. Given the big declines in inputs, this was a very impressive achievement. Other factors, largely independent of the business cycle, certainly contributed to the strong productivity performance of railroads during the Depression. For example, the build out of the surface road network facilitated a growing complementarity between trucking and rails. But some of the productivity improvement resulted from responses internal to organizations. And whereas in households it is sometimes argued that memories are short and there is little permanent carryover of behavioral changes when times improve, institutional learning and memory particular to the corporate form probably allowed some hysteresis. Beneficial organizational innovations when times were poor persisted when times improved, and contributed to permanently higher levels of TFP, and the far superior performance of the U.S. rail system in the Second World War as compared with the First.

In exploring this question, we need to keep the larger context in mind. If we compare total GDP in 1929 and 1941 using the Bureau of Economic Analysis's chained index number methodology, we see from the latest revisions that the aggregate grew at a continuously compounded growth rate of 2.8 percent per year over that twelve year period (NIPA Table 1.1.6). This is close to the 3 percent per year often viewed as the long run "speed limit" for the U.S. economy. GDP surpassed its 1929 level in 1936, and was 40 percent above its 1929 level by 1941. Because private sector labor and capital inputs increased hardly at all over that period (hours were flat and net fixed assets increased at only .3 percent per year (FAT Table 1.2)), virtually all of this was TFP growth. Productivity growth in transportation and distribution complemented still strong TFP growth in manufacturing in producing this result

If the adversity/hysteresis mechanism has some empirical punch to it, then it is possible that the storm clouds of recession/depression can have something of a silver lining. The disruption of credit availability and an increase in the cost of equity finance were both central features of the 1930s, just as its easy accessibility and cheap cost through most of the 1920s had been a feature of that decade. The boom/bust cycle was associated with declining physical capital accumulation and productivity, particularly between 1929 and 1933. At least in the case of railroads, however, there appear to have been longer run benefits to the downswing phase of the financial cycle and the closely related cycle of physical accumulation in the form of technical innovation within the context of effective organizational responses.

Railroads and the Silver Lining

In the last part of the nineteenth century, railroads dominated the U.S. economy in a way no other economic organization ever had or ever has again. They remained a formidable presence in the 1930s, although beset with challenges from several sides. What differentiated railroads from other parts of the private economy was the scale of their enterprise, particularly the size and value of the physical capital they owned, capital whose acquisition was financed largely by borrowing. Coming out of the 1920s, railroads had huge fixed nominal debt service obligations. They didn't necessarily have to worry about rolling over short term debt, since much of their borrowing was in the form of long term mortgages, but they still had to meet mandated payments. In the face of an economic downturn and wrenching changes in market opportunities associated with the growth of trucking and the automobile, railroads were the poster child for Irving Fisher's debt-deflation thesis. By 1935, railroads responsible for more than 30 percent of first track mileage were in receivership, and this remained so for the remainder of the Depression. But the problems for the sector as a whole were in a sense less those of the roads in receivership, and more the challenges faced by those who weren't. The former were actually less cash strapped than the latter. Railroad organizations were under enormous stress during the Depression, and so their productivity performance over this period is all the more remarkable.

If we ignore variations in income shares – which are relatively stable over time, a TFP growth rate calculation is basically a function of three numbers: the rate of growth of labor input, the rate of growth of capital input, and the rate of growth of output. Kendrick's series for railroad output are drawn from Barger (1951) and are based on data for both freight and passenger traffic, with a larger weight on freight. It shows output 5.5 percent higher in 1941 than it was in 1929. Kendrick's labor input series are also from Barger and are identical to those that continue to be listed on the BEA website (NIPA Table 6.8A, line 39). Between 1929 and 1941, the number of employees declined 30.4 percent, employee hours 31.4 percent. Kendrick's railway capital series is taken from Ulmer (1960), and shows a 1941 decline of 5.5 percent between 1929 and 1941. Putting these altogether, Kendrick has railway TFP rising at 2.91 percent per year over the twelve years of the Depression.

It's not possible given currently available data to do better than Kendrick for output and labor input. But the BEA's revised Fixed Asset Tables do give us an opportunity to update capital input. Gross investment in railroad equipment peaked in 1923 and then moved fairly steadily downward to virtually nothing in 1933. It then revived somewhat, particularly after 1935 and the big increase in railroads in receivership. Investment in railroad structures peaked in 1926 but remained high through 1930 before declining to a trough in 1933 and then recovering modestly during the remainder of the Depression, although not as sharply as equipment investment. Using the data underlying these series, I calculate that between 1929 and 1941, the real net stock of railroad structures declined from $27 billion to $25.65 billion, and railroad equipment from $6.5 billion to $4.77 billion. Overall, then, the real net capital stock declined 9.2 percent over the twelve year period, while Kendrick has it declining only 5.5 percent. (Kendrick, 1961, Table G-III, p. 545). A more rapid decline in capital input (.69 percent per year rather than .47 percent per year) would boost TFP growth in railways between 1929 and 1941 from 2.91 to 2.97 percent per year.[7]

We can get further insight into trends in railroad accumulation by looking at detailed numbers on rolling stock. The locomotive numbers show decumulation in 1922 and then again starting in 1925. The number of locomotives then shrinks continuously until 1941. Some of this reflects replacement of locomotives with larger, more powerful engines, but the overall trend is unmistakable. The total number of locomotives shrank from 61,257 in 1929 to 44,375 in 1941. A small but growing number of replacement engines were diesel-electric; the count of such locomotives rose from 621 in 1929 to 895 in 1941 (1944 Statistical Abstract, table 525, p. 473), while the average tractive power of the remaining steam engines increased from 44,801 to 51,217 pounds.

Annual freight car data show continuous decumulation from 1920 through 1939, with the exception of 1924-26. Over the same period, aggregate freight car capacity in kilotons shrank from 105,411 to 85,682 (1937 Statistical Abstract, table 427, p. 372; 1944 Statistical Abstract, table 523, p. 472). (The replacement cars were however somewhat larger; average capacity rose from 46.3 to 50.3 tons between 1929 and 1941). Passenger car decumulation was modest through 1930, then increased dramatically through 1933. There was some recovery to lower rates of decumulation, particularly after 1935, but the number of passenger cars did not grow again until 1941. Numbers fell from 53,838 in 1929 to 38,344 in 1941.

As far as railroad permanent way, abandonments took a sharp jump to a higher level in 1932, and new construction tapered off to virtually nothing by 1934. On the labor input

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[7]The difference between Kendrick's capital input decline rate of .47 and the rate of decline based on the latest BEA data (.69) is .22 percent per year, which, with a .25 weight on capital in the growth accounting equation, would add .055 percent per year to the sector's TFP growth rate.

side, the number of railroad employees declined moderately in the 1920s, then precipitously in the 1930. These data on labor and capital inputs paint a picture of a system undergoing wrenching rationalization, rationalization midwifed by the economic downturn and the threat or actuality of receivership.

Despite a net stock of structures that had fallen 6 percent since its peak in 1931, in spite of a labor force that was 30 percent smaller than it had been in 1929, and in spite of the fact that the real stock of railroad capital was a full one third lower than it had been in 1929, revenue ton miles were 6 percent greater in 1941 than 1929.

The data on passenger miles show steadily declining output by this measure throughout the 1920s, testimony to the growing threat to passenger traffic posed by the automobile, and a sharp drop to 1933. But 1941 passenger miles were within 6 percent of carriage in 1929. It is clear that since more freight was carried with many fewer freight cars, a substantial portion of the railway sector's productivity gains came from increases in freight car capacity utilization rates, which generated big increases in capital productivity. The ability to carry more freight and about the name number of passengers with much reduced numbers of locomotives, freight cars and passenger cars also reduced the demand for railway structures: maintenance sheds, sidings, roundhouses, etc., which was serendipitous since the financing for expanding the stock of structures was not readily available. The U.S. railroad system was able in 1941 to carry more freight and almost as many passengers as it had in 1929 with substantially lower inputs of labor and capital. That meant, as a matter of definition, big increases in both labor productivity and TFP. By the end of the Depression, the U.S. rail system was in much better shape than it had been at the start of the First World War, and was able to cope with huge increases in both passenger and freight traffic during the Second World War. If one measures from 1929 through 1942, using Kendrick's data, TFP in the sector grows by 4.48 percent per year.

Table 1 allows an examination of trends in and contributors to productivity increase. It shows the percent change in a variety of input, output, and physical productivity measures between 1919 and 1929, 1929 and 1941, and 1929 and 1942. It also reports the underlying data, as well as aggregate economic data for 1929, 1941, and 1942. 1942 is the first year of full scale war mobilization, and one can see in the aggregate data the partial crowding out of consumption and investment as a result of the doubling of government expenditure. Still, civilian unemployment averaged 4.7 percent for the year, and the distortions for the economy were not as extreme as in 1943 and 1944. Therefore, there is some merit in calculating productivity growth in railroads between 1929 and 1942 as well as 1941, since the output gap in 1942 is closer to what it was in percentage terms in 1929. Also, since we are examining physical productivity measures, the distortions in pricing and valuation associated with wartime are somewhat less of a concern.

What these data show is that, overall, in spite of or perhaps in part because of the trying times, railroad productivity growth was significantly stronger across the Depression years than it had been in the 1920s. An important measure of physical productivity is revenue ton miles per freight car, which grew 28.1 percent between 1919 and 1929, 42.3 percent from 1929 to 1941, and 86.5 percent between 1929 and 1942. Let's look more closely at what underlay the Depression era increases. The total number of miles traversed by loaded freight cars in 1941 was approximately the same as it had been in 1929. The big driver of productivity improvement was that the number of cars had declined 25.6 percent. The average capacity of each car was somewhat greater – it had grown from 46.3 to 50.3 tons, making it easier to achieve a 6.1 percent increase in tons of revenue freight per loaded car. Overall, we can deduce that the average speed of each freight car, (a function of average time stopped and average speed while in motion) had increased, since if it had remained the same as it had been in 1929, the 25.6 percent decline in the number of cars would have reduced total freight car miles by a comparable percentage. We also know that the number of freight car loadings in thousands declined from 52,828 in 1929 to 42,352 in 1941; freight traveled on average a longer distance, reflecting the inroads of trucking in shorter hauls.

In contrast, between 1919 and 1929, the number of cars stayed about the same, but total miles traversed by freight cars rose. Note, however, that miles booked by empty cars increased much faster than loaded miles during the 1920s, whereas between 1929 and 1941, while the total number of loaded miles remained unchanged, unloaded miles dropped. This decline is another reflection of logistical improvement in railroad operations.

An alternate measure of the physical productivity of freight haulage is ton miles per mile of first track. This grew more strongly in the 1920s than during the Depression years, although if one measures to 1942 the reverse is true. Ton miles per employee, a rough measure of labor productivity in freight haulage, grew 41.9 percent during the 1920s, but 55.1 percent during the Depression, 86.8 percent if one measures to 1942.

Table 1
Percent Change in Inputs, Outputs, and Productivity, US Railroad Sector.

					Percent Change		
	1919	1929	1941	1942	1919-29	1929-41	1929-42
Inputs							
Employees	1,960,439	1,694,042	1,159,025	1,291,000	-13.6	-31.6	-24.8
Locomotives	68,977	61,257	44,375	44,671	-11.2	-27.6	-27.1
Freight Cars	2,426,889	2,323,683	1,732,673	1,773,735	-4.3	-25.5	-23.7
Passenger Cars	56,920	53,888	38,334	38,445	-5.3	-28.9	-28.7
Miles of first Track	263,707	262,546	245,240	242,744	-0.4	-6.6	-7.5
Outputs							
Revenue Ton Miles (millions)	367,161	450,189	477,576	640,992	22.6	6.1	42.4
Freight Car miles (loaded) (thousands)	14,273,422	18,169,012	18,171,979	21,535,673	27.3	0.0	18.5
Freight Car miles (unloaded) (thousands)	6,531,570	10,805,302	10,251,079	12,755,362	65.4	-5.1	18.0
Passenger Miles (millions)	40,838	31,165	29,406	53,747	-23.7	-5.6	72.5
Physical Productivity Measures	1919	1929	1941				
Ton Miles per Freight Car	0.151	0.194	0.276	0.361	28.1	42.3	86.5
Tons of Revenue Freight per loaded car	25.72	24.78	26.28	29.76	-3.7	6.1	20.1
Average Miles per car per day	23.0	32.3	40.6	46.3	40.4	25.7	43.3
Average Freight Car capacity (tons)	41.9	46.3	50.3	50.5	10.5	8.6	9.1
Average Freight car speed (mph)	0.979	1.459	1.920	2.263	49.1	31.6	55.0
Number of freight car loadings (thousands)	41,832	52,828	42,352	42,771	26.3	-19.8	-19.0
Average haul, revenue freight (miles)	309	317	369	428	2.8	16.2	34.9
Ton Miles Per Mile of First Track	1.392	1.715	1.947	2.641	23.2	13.6	54.0
Passenger Miles per Passenger car	0.717	0.578	0.767	1.398	-19.4	32.6	141.7
Ton Miles per Employee	0.187	0.266	0.412	0.497	41.9	55.1	86.8

Passenger Miles per Employee	0.021	0.018	0.025	0.042	-11.7	37.9	126.3
Aggregate Economic Indicators							
Unemployment rate		3.2	9.9	4.7			
Real GDP (billions of chained 1937 dollars)		87.2	122.1	144.7		40.0	65.9
Real Gross Private Domestic Investment		12.2	17.6	9.3		44.3	-23.8
Real Government Consumption and Investment		9.2	25.6	60.3		178.3	555.4
Real Consumption		63.0	78.2	76.5		24.3	21.4

Sources: Statistical Abstract of the United States, 1937, 1944, 1947; NIPA Table 1.1.6A.

Table 2
1929-1941 Linkage, Class I Railroads, United States

Column in 1941 ICC Volume	1941 Railroad	Column in 1929 ICC Volume	1929 Railroads
18	Erie Railway Company	17	Chicago and Erie Railway
		18	Erie Railway Company
		19	New Jersey and New York Railway
26	New York Central Railway Company	27	Michigan Central
		28	New York Central
		35	Ulster and Delaware Railway Company
		51	Cincinnati Northern
		52	Cleveland, Cincinnati, Chicago and St. Louis
		53	Evansville, Indianapolis & Terre Haute
35	Baltimore & Ohio Railway Company	11	Buffalo, Rochester and Pittsburgh
		39	Baltimore & Ohio Railway Company
		42	Buffalo and Susquehanna
47	Pennsylvania-Reading Seashore Lines	56	Pennsylvania System: West Jersey and Seashore Lines
		57	Reading System: Atlantic City Railroad
52	Chesapeake and Ohio	43	Chesapeake and Ohio System: Hocking Vallkey RR
		62	Chesapeake and Ohio RR
62	Atlantic Coast Line System: Louisville and Nashville RR	72	ACLS: Louisville and Nashville
		73	ACLS: Louisville, Henderson & St. Louis
68	Gulf, Mobile and Ohio	79	Gulf, Mobile & Northern
		85	New Orleans Great Northern
		91	Mobile & Ohio

92	Duluth, Missabe, and Iron Range	104	Duluth and Iron Range
		105	Duluth, Missabe & Northern
99	Atchison, Topeka and Santa Fe and Affiliated Companies	125	Santa Fe: Atchison, Topeka and Santa Fe
		126	Santa Fe: Panhandle and Sant Fe
		138	Frisco: Ft. Worth and Rio Grande
		160	Santa Fe: Gulf, Colorado and Santa Fe
		161	Santa Fe; Kansas City, Mexico and Orient
		162	Santa Fe: Kansas City, Mexico, and Orient Co of Texas
104	Chicago, Rock Island and Pacific	122	Chicago, Rock Island and Gulf
		123	Chicago, Rock Island and Pacific
112	Union Pacific Railroad Co Including its leased lines	112	UP: Oregon Washington RR & Navigation
		130	UP: Los Angeles and Salt Lake
		131	UP: Oregon Short Line
		132	UP: St. Joseph and Grand Island
		133	UP: Union Pacific
118	Kansas City Southern Railway Co and controlled companies	141	KS Southern: Kansas City Southern
		142	KS: Texarkana and Fort Smith
		145	Louisiana Railway and Navigation Co. of Texas
123	Missouri Kansas Texas Railroad Co and controlled companies	148	MKT Lines: Missouri Kansas Texas
		149	MKT Lines; Missouri Kansas Texas Co of Texas
133	St. Louis Southwestern Railway Co and affiliated companies	158	SLSW: St Louis Southwestern
		159	SLSW: St Louis Southwestern Co of Texas

Passenger miles per passenger car declined 19.6 percent during the 1920s, but rose sharply across the Depression years – 32.6 percent measuring to 1941, 141.7 percent measuring to 1942. Finally, passenger miles per employee, which declined almost twelve percent during the 1920s, rose 37.9 percent across the Depression years, 126.3 percent measuring through 1942.

Firm Level Analysis

The previous section documented and discussed the productivity achievements of the U.S. railway sector during the Depression years at the sectoral level. These next sections examine the phenomenon at the level of individual railroads. I begin by comparing the labor productivity of 128 class I railroads in 1941 with their performance in 1929. I then go on to explore capital productivity in both freight and passenger operations and finally examine the total factor productivity growth of individual lines. Data are from Statistics of Railways in the United States, a volume published annually by the Interstate Commerce Commission. During the Depression a Class I railroad was one with operating revenues greater than $1 million. The 1929 edition has data on 167 class I railroads, covering the vast majority of operations in the United States. Total 1929 employment in the sector was 1,694,042; these 167 roads employed 1,662,095, or 98 percent of the total.

The 1941 ICC volume has data for 135 class 1 railroads, employing 1,139,129 out of total sector employment of 1,159,025 (again, 98 percent). Although most railroads in existence in 1929 persisted through 1941, the total number of class I railroads did decline by about a fifth (19 percent).[8] In order to make meaningful comparisons between 1941 and 1929, we need to aggregate the data for some 1929 roads so that operational units are comparable to those existing in 1941. Where a number of railroads listed separately in 1929 merged or were otherwise consolidated during the Depression years, the data for the multiple 1929 operational units are pooled. Table 2 describes the linkages made between the railroad data in the two years. Railroad history attracts interest from both professional and amateur historians and there is a wealth of information available on the web on the history of firm consolidation and corporate structure at different points in time. Using multiple searches, I have linked 43 roads reporting in 1929 to 14 roads in 1941, resulting on this account in a reduction of 29 in the total number of class I railroads between the two years (see table 2). Two other railroads, both small, drop out because they ceased operations during the interval.[9] For six other small railroads employing a total of 2,077 in 1929, I am not able to locate a successor.[10] Four small roads employing a total of 827 appear in 1941 but not 1929.[11] And I dropped two small lines, one, a small unit whose productivity numbers were an outlier, as well as a small railroad in Hawaii.[12] I end up making 1929 – 1941 comparisons for 128 linked units.

[8] The threshold to be considered a class I railroad rose with inflation, to $3 million in 1956, $5 million in 1965, $10 million n 1976, $50 million in 1978, and $250 million in 1993. Today the cutoff is $319.3 million. Whereas there were 135 class I railroads operating in the U.S. in 1941, there are now only seven: Union Pacific, BNSF (Burlington Northern Santa Fe), CSX, Norfolk Southern, Kansas City Southern, Canadian Pacific, and Canadian National.

[9] These two, with 1929 employment in parentheses, were Ft. Smith and Western (137), and Copper River and Northwestern (166).

[10] These six, with their 1929 employment in parentheses, are Northern Alabama (412), Binghman and Garfield (256), Quincy, Omaha and Kansas City (306), San Diego and Pacific (471), Wichita Valley (322) and Wichita Falls and Southern (310).

[11] These four, with their 1941 employment in parentheses, are Cambria and Indiana (141), Spokane International (206), Colorado and Wyoming (413), and Oklahoma City, Ada, and Atoka (67).

[12] These two roads were New York Connecting (with 49 employees in 1929), and Oahu Railroad and Land Company (with 407 employees in 1929)..

Labor Productivity

To compare labor productivity in the two years, we need a combined output measure, which requires agreement on appropriate metrics for freight and passenger operations, and on how to aggregate them. For freight output, I use revenue ton miles; for passenger traffic, revenue passenger miles. I first calculate the ratio of passenger revenue per passenger mile to freight revenue per ton mile, then use this ratio to convert passenger miles into "equivalent" freight ton miles. Adding this to freight ton miles yields, for each railroad, the output measure.

We have two basic types of output: passenger miles and the freight ton miles. If cents per ton mile and per passenger mile were the same for a railroad, then passenger miles would simply be added to freight ton miles for a combined output measure. If a railroad was earning 2 cents for a passenger mile vs. 1 cent for a freight ton mile, then a passenger mile for that road would be converted to a freight ton equivalent at a ratio of 2:1. This procedure is similar to what Barger (1951) used for aggregate data. In cases where consolidation took place between 1929 and 1941, I divided the total equivalent freight ton miles for the multiple 1929 units by the total employment of the 1929 roads to create a 1929 equivalent ton miles per employee that could then be compared with the 1941 measure.

The ICC grouped class I railroads into eight regions: New England (NE), Great Lakes (GL), Central Eastern (CE), Pocahontas (PO), Southern (SO), Northwestern (NW), Central Western (CW), and Southwestern SW). I begin by exploring regional variation in productivity levels in 1929 by regressing ton miles equivalents per employee on eight regional dummies (no constant), which essentially returns the average productivity level for railroads in each region (table 3).

Setting aside the Pocahontas region, which had assigned to it only four railroads, we note that in 1929 roads in the Central Eastern region tended to have somewhat higher output per employee, whereas the reverse was true for roads in the South. If we now fast forward to 1941, we see that productivity grew quite substantially in every region. There had also been some convergence, with particularly rapid growth among Southern railroads and slower growth in the Central Eastern region. Still, the basic message conveyed by these data is that the productivity improvement in the railroad sector was a national phenomenon and aggregate advance was not driven, for example, by progress by a small number of large roads with disproportionate weight. In fact, an important negative result emerges from the statistical analysis: there is no statistically significant or economically meaningful relationship between the size of a railroad as measured by the number of its employees and its productivity level in either 1929 or 1941.

Table 3
Regional Output per Employee, U.S. Class I Railroads, 1929 and 1941

	1929	1941	% Increase
NE	238,300	374,094	57.0
GL	320,279	469,096	46.5
CE	336,080	404,979	20.5
PO	573,978	903,237	57.4
SO	242,728	465,672	91.8
NW	298,608	437,729	46.6
CW	301,645	441,389	46.3
SW	279,799	498,331	78.1

Source: See text.

Turning now to analysis of changes between 1929 and 1941, the results are somewhat different. I define the dependent variable here as the percentage increase in output per employee between 1929 and 1941. The average increase in labor productivity over the course of the Depression for the 128 railroad sample was 56 percent, but there was substantial variation, with a standard deviation of 43 percentage points. Within the context of the general sectoral improvement, what factors particularly influenced whether a railroad performed relatively well or poorly on this dimension?

The following regression establishes several important relationships. The first right hand side variable demonstrates that productivity improvements across the Depression years involved predominantly the movement of freight. The variable %FREIGHT1941 is the share of 1941 operating revenues originating from freight. The average for all roads was 92.6 percent, with a relatively low standard deviation of 9.8 percentage points. The measure varied from a high of 100 percent for railroads that carried no passengers to lows of 51 percent for Staten Island Rapid Transit, 64 percent for the Florida East Coast Line, and 69 percent for the New York, New Haven, and Hartford Railroad. What the positive coefficient on this variable shows is that, ceteris paribus, the greater the proportion of revenues from freight in 1941, the greater the percentage increase in productivity between 1929 and 1941. All else equal, a road with a ten percentage point higher share of its operating revenues from freight traffic could expect a 9.2 percentage point higher increase in output per employee over the Depression. These numbers are consistent with the view that passenger carriage for American railroads was a mature business by the 1930s. Although it would experience its finest hour during the Second World War, it was already poised for decline. It was the freight, not the passenger side of business that was being transformed.

The second variable is a dummy for location of the railroad in the South. As table 3 shows, southern railroads achieved a particularly large increase in output per employee over the Depression. This reflected catch up from the relative backwardness of the region in 1929, midwifed by such New Deal programs as the Tennessee Valley Authority, as well as the more general influence of continued road building during the Depression (complementarity with the expansion of trucking, which benefited from improved roads, was a key feature in railroad productivity improvement throughout the country). The coefficient on this variable shows that, all else equal, a railroad in the South experienced a 41 percentage point higher increase in output per employee compared to a road with similar characteristics elsewhere in the country

Finally, although the size of the railroad as measured by the number of its employees is irrelevant in accounting for levels of productivity in 1929 or 1941, the *change* in employment (ΔEMPLOYMENT) has a statistically significant and economically important influence on how much productivity grew for that railroad over the twelve year period. The relationship was inverse: the greater the percentage decline in employment, the higher the increase in output per employee. The average reduction in employment across the 128 units was 30.4 percent, almost exactly the decline in the aggregate numbers used by Barger and Kendrick. But there was substantial variation: the standard deviation across the roads was 22 percentage points.

This result is by no means obvious, necessary, or tautological. If cutting employment in an organization were an automatic route to higher labor productivity, the road to economic progress would be a lot less obstructed. The facts are that simply firing employees or reducing employee rolls by attrition can easily cause output to fall as fast or faster than employment. After all, there was a reason the employees were hired in the first place. The trick was and is to reduce employment in a well thought out fashion that is coordinated with changes in equipment, structures and logistics and allows output to be sustained, or at least to decline at a slower rate than employment.

Table 4
OLS Regression: Percent Increase in Output per Employee,
Class I Railroads, United States, 1941 over 1929

	coefficient	t statistic
Intercept	-0.50626	-1.51248
%FREIGHT1941	0.929605	2.677457
SOUTH	0.420113	4.983351
ΔEMPLOYMENT	-0.40371	-2.63621

n = 128 R^2 = .24

Data sources: see text.

The aggregate data show that rising labor productivity coincided with declining employment. The firm level analysis provides evidence indicative of a behavioral relationship. As noted, the average decline in employment was 30.4 percent. According to the regression results, a railroad for which employment declined an additional ten percentage points would have enjoyed, over the twelve years of the Depression, a four percentage point larger increase in output per worker.

But what interpretation can we give to this result? A labor historian might say that it simply reflected speed up – the lines had become better at extracting more labor from each individual. That may have been true to some degree. But I believe we can also give it a broader and more positive spin. The ability to shrink payrolls by margins this large while at the same time sustaining and in many cases increasing output required logistical and technological innovation, not just a more effective managerial use of the whip.

Many aspects of the story suggested by the aggregate data are consistent with what the firm level analysis tells us. Productivity improvement was a national phenomenon, affecting railroads both large and small. Innovations involved principally the logistics of moving freight, not passengers. Southern railroads, laggards on average in 1929, experienced the largest regional productivity improvements. And at the level of individual railroads, those with higher percentage declines in employment over the twelve years of the Depression reaped correspondingly higher increases in output per employee.

Capital Productivity

We turn now to discussion of levels and increases in capital productivity in both freight and passenger operations for individual railroads during the Depression. The measure of capital productivity in freight operations is freight ton miles per ton of freight car capacity. I do not attempt to adjust for changes in the mix of different types of freight cars (data are available for box cars, flat cars, stock cars, coal cars, tank cars, refrigerator cars, and other). Nor am I including data on locomotives or permanent way, both of which can be used in both passenger and freight operations. I am reasonably confident that more sophisticated and refined measures would be highly correlated with what I have used.

Because some railroads had consolidated or merged between 1929 and 1941 (see table 2) and because not all railroads had freight operations (and reported data) in both 1929 and 1941, it is possible to make comparisons of capital productivity in freight operations for at most 119 railroads (see table 5). For these railroads, freight ton miles grew from 407.96 billion in 1929 to 472.03 billion in 1941, an increase of 15.7 percent. At the same time, freight capacity in tons fell from 98.1 million to 85.4 million, a decline of 13 percent. Putting these numbers together, freight ton miles per ton of freight capacity rose from 4,158 in 1929 to 5,525 in 1941, an increase of 32.9 percent. If one calculates the increase in freight ton miles per ton of capacity for each of the 119 lines, however, the average of the individual increases comes to 90 percent. The average of the increases of the individual lines is higher than the increases as measured using the aggregates because the smaller lines had larger increases in capital productivity in the freight business than did the larger lines. If we use 1929 employment as a measure of scale, the correlation with the increase in capital productivity in freight is -.17. Since the average of the individual lines's increases is unweighted, the smaller lines contribute disproportionately to the average.

Table 5:
119 U.S. Railroads with Freight Operations in 1929 and 1941

NE	
1	Bangor and Aroostock
2	Boston and Maine
5	CPS: CPS lines in Maine
7	Maine Central
8	New York, New Haven and Hartford
10	Rutland RR
GL	
12	CNS: Grand Trunk Western
13	Delaware and Hudson
14	Delaware, Lackawanna, &Western
15	Detroit and Mackinnac
16	Detroit and Toledo Shore Line
18	Erie: Erie
20	NY, Susquehanna & Western
21	Lehigh and Hudson River
22	Lehigh and New England
23	Lehigh Valley

25 Montour
26 New Haven System: NY, Ontario & Western
28 NYC: New York Central
29 NYC: Pittsburgh and Lake Erie
30 NY, Chicago and St. Louis RR
31 Pere Marquette
32 Pittsburgh and Shawmut
33 Pittsburgh and WVA
34 Pittsburgh, Shawmut & Northern
36 Wabash: Ann Arbor
37 Wabash: Wabash
CE
38 Akron, Canton & Youngstown
39 B & O: Baltimore and Ohio
41 Bessemer and Lake Erie
44 Chicago and Eastern Illinois
45 Chicago and Illinois Midland
46 Chicago, Indianapolis and Louisville
47 Detroit, Toledo and Ironton
48 Elgin, Joliet and Eastern
49 Illinois Terminal
50 Missouri Pacific: Missouri Illinois
54 Penn =: Long Island RR
55 Penn: Pennsylvania RR
58 Reading: Central RR of NJ
59 Reading: Reading
60 Western Md
61 Wheeling and Lake Erie
PC
62 Chesapeake and Ohio
63 Norfolk and Western
64 Richmond, Fredericksburg and Potomac
65 Virginian
SO
66 ACLS: Atlanta and West Point
67 ACLS: Atlanta, Birmingham and Coast
68 ACLS: Atlantic Coast Line
69 ACLS: Charleston & Western Carolina
70 ACLS: Clinchfield
71 ACLS: Georgia RR
72 ACLS: Louisville and Nashville
74 ALCS: Nashville, Chattanooga & St. Louis
75 ACLS: Western RR of Alabama
76 Columbus and Greenville
77 Florida East Coast RR
78 Georgia and Florida RR
79 Gulf, Mobile & Northern
80 IC: Central of Georgia
81 IC: Gulf and Ship Island
82 IC: Illinois Central

83 IC: Yazoo and Miss Valley
84 Miss Central
86 Norfolk Southern
87 Seaboard Air Line
88 Southern: Alabama Great Southern
89 Southern: Cincinnati, New Orleans and Texas Pacific
90 Southern: Georgia Southern and Florida
92 Southern: New Orleans & Northeastern
94 Southern: Southern
95 Tennessee Central

NW

96 CNS: Duluth, Winnipeg and Pacific
97 CPS: Duluth, South Shore and Atlantic
98 CPS: Minneapolis, St Paul & Sault St Marie
99 CPS: Spokane International
100 C and NW: Chicago and Northwestern
101 C and Nw: Chicago, St. Paul, Minneapolis and Omaha
102 Chicago Great Western
103 Chicago, Milwaukee, St. Paul & Pacific
104 Duluth and Iron Range
106 Great Northern
107 Green Bay and Western
108 Lake Superior & Ishpeming
109 Minneapolis and St. Louis
110 Northern Pacific
111 Spokane, Portland & Seattle

CW

114 Burl: Chicago, Burlington and Quincy
115 Burl: Colorado and Southern
116 Burl; Ft. Worth and Denver City
118 Chicago & Alton
119 Denver and Rio Grande Westetrn
120 Denver and Salt Lake
121 Nevada Northern
123 Rock Is: Chicago, Rock Island and Pacific
125 Santa Fe: Atchison, Topeka and Santa Fe
127 SP: Northwestern Pacific
128 SP: Southern Pacific
129 Toledo, Peoria and Western
133 UP: Union Pacific
134 Utah
135 Western Pacific

SW

139 Frisco: St. Louis SF
141 KS Southern: Kansas City Southern
143 Kansas, Oklahoma and Gulf
144 Louisiana and Arkansas
146 Midland Valley
147 Missouri and North Arkansas

148 MKT Lines: Missouri Kansas Texas
151 MP: International - Great Northern
152 MP: Missouri Pacific
153 MP: New Orleans, Texas and Mexico
154 MP: St. Louis, Brownsville & Mexico
156 MP: Texas and Pacific
157 Nat RR of Mexico: Texas Mexico
158 SLSW: St Louis Southwestern
163 SP: Texas and New Orleans
164 Trinity and Brazos Valley/Burlington Rock Island

Let's begin however with a discussion of levels. If we regress 1929 and 1941 levels of freight ton miles per ton of freight capacity on regional dummies, we get these regional averages:

Table 6
Capital Productivity in Freight Operations in 119 U.S. Class 1 Railroads, 1929 and 1941

	1929	1941	1941/1929
NE	4998	6823	1.37
GL	5577	9843	1.76
CE	4883	6229	1.28
PC	6433	8839	1.37
SO	6194	10826	1.75
NW	5177	9901	1.91
CW	7054	11602	1.64
SW	9423	33798	3.59

Capital productivity in freight operations in 1929 was lowest in the Northeast, highest in the Central Western and Southwestern regions. Performing the same operation for the 1941 levels, we have roughly the same regional rankings, although the Great Lakes region moves up in rank. New England remains in the cellar, and the highest levels of capital productivity in freight operations remain in the Southwestern, Central Western and Southern regions. The final column on the right showing the ratio of capital productivity in freight operations in 1941 relative to 1929 is calculated by dividing the second column in Table 6 by the first column, and shows that capital productivity in the Southern, Great Lakes, Central Western, Northwestern and Southwestern region registered the biggest gains, with those in the Southwestern region being particularly strong.

Now looking more directly at the ratios of capital productivity in freight operations for *individual railroads*, regressing the 1941-1929 individual railroad relative on the regional dummies, one gets a slightly different picture, although the significance of capital productivity growth in freight operations in the Southwestern, Southern, Northwestern, and Central Western Regions remains apparent.

Table 7
Capital Productivity in Freight Operations in 119 U.S. Class 1 Railroads, Regressing 1941/1929 Relative on Individual Dummies

Region	1941/1929 Relative
NE	1.29
GL	1.68
CE	1.55
PC	1.32
SO	2.04
NW	1.76
CW	1.74
SW	2.98

As was the case for labor productivity, capital productivity in freight operations grew most dramatically in the South and Southwest. But for capital productivity in freight operations, the Southwest was king, whereas for labor productivity, the Southern roads led in growth. As far as laggard regions, the Northeast was at the bottom in terms of capital productivity growth in freight operations, whereas the Central Eastern region was at the bottom in terms of labor productivity growth.

For labor productivity growth, we found a strong negative relationship between the change in employment between 1929 and 1941 and the change in labor productivity. It turns out there is a similar relationship for capital productivity in freight operations. The lower the ratio of freight capacity in 1941 to freight capacity in 1929, the higher the growth in capital productivity in freight operations (see table 8). Again, this conclusion is not oxymoronic. Mindlessly getting rid of freight cars and freight capacity would not necessarily be a route to increased capital productivity as measured by freight ton miles per ton of freight capacity. It had to be combined with operational changes that increased both the velocity of the freight cars, and their average load factors.

Table 8
Capital Productivity in Freight Operations in 119 U.S. Class 1 Railroads,
Regressing 1941/1929 Relatives on Regional Dummies and Ratio of Freight Capacity in 1941 to Freight Capacity in 1929

		S.E.	T stat
NE	2.275	0.576	3.951
GL	2.459	0.329	7.471
CE	2.602	0.394	6.596
PC	2.503	0.704	3.555
SO	3.025	0.329	9.206
NW	2.788	0.400	6.964
CW	2.597	0.384	6.766
SW	3.695	0.361	10.223
Freight Capacity Ratio 41/29	-1.115	0.227	-4.904

R^2= .26; n=119

It is also interesting to examine the influence of scale factors on capital productivity growth in freight operations. Using levels of employment in 1929 and in 1941 as rough measures of scale, we find (as already noted) that there is a negative relationship with 1929 employment - "large" railroads experienced slower productivity growth in freight operations over the subsequent 12 year period. But, controlling for this, there is a positive relationship with employment levels in 1941. My interpretation of this is that railroads that were smaller in 1929 had faster productivity growth during the Depression. But in order to reap these logistical gains roads had to hire more skilled managers.

Table 9
Capital Productivity in Freight Operations in 119 U.S. Class 1 Railroads, Including Scale Variables

		S.E.	T stat
NE	2.53850	0.57139	4.44270
GL	2.64640	0.33045	8.00860
CE	2.93782	0.40698	7.21855
PC	2.80254	0.69748	4.01812
SO	3.29010	0.33654	9.77640
NW	3.07778	0.40594	7.58190
CW	2.76572	0.38588	7.16730
SW	3.89767	0.36131	10.78752
Employ 41	0.00007	0.00003	2.11875
Employ 29	-0.00007	0.00003	-2.39677
Freight Capacity Ratio 4129	-1.23731	0.23011	-5.37708

R^2=30.8; n=119

We now turn to capital productivity in passenger service by measuring passenger revenue miles per passenger car. This does not take into account increases in the average size of such vehicles, to the extent they occurred. The subset of railroads is slightly different from the 119 lines used in the freight productivity calculations. 14 of those lines had no passenger operations and were thus excluded, leaving a remainder of 105. Five lines were passenger only ore had inadequate data on freight operations and were thus added to the lines used for the freight calculations, leaving a total of 110 with passenger operations and data reporting for both 1929 and 1941. Table 10 summarizes the additions and subtractions from the subset described in Table 6.

For these 110 lines revenue passenger miles increased only slightly between 1929 and 1941, from 28.974 billion to 29.216 billion, or .86 percent. The number of passenger cars, however, fell sharply, from 49,134 to 37,962, or 23 percent. Putting these numbers together, we find that passenger revenue miles per passenger car rose from 589,708 in 1929 to 775,117 in 1941, an increase of 31.4 percent. Looking at the average increase in capital productivity in passenger service for the individual lines, we find that it is 29 percent, roughly the same as the increase in the aggregate. This is reflective of the lack of correlation between the scale of passenger service and the increases in capital productivity in passenger service garnered between 1929 and 1941. This is of course in contrast with what we found for capital productivity in freight operations, which increase more between 1929 and 1941 for railroads that were smaller in 1929.

Table 10
Additions and Subtractions from Table 6 to form Subset Used in Calculating Caital Productivity in Passenger Operations, 110 U.S. Class 1 Railroads, 1929-1941.

Added: Mostly passenger:

CNS: Central Vermont
Monongahela
B& O: Staten Island Rapid Transit
Penn: West Jersey & Seashore
MP: Beaumont, Sour Lake & Western

Subtracted: All Freight:

CPS: CPS lines in Maine
Detroit and Toledo Shore Line
Lehigh and Hudson River
Lehigh and New England
Montour
Pittsburgh and Shawmut
Pittsburgh and WVA
Pittsburgh, Shawmut & Northern
Elgin, Joliet and Eastern
Wheeling and Lake Erie
CNS: Duluth, Winnipeg and Pacific
Toledo, Peoria and Western
Utah
Kansas, Oklahoma and Gulf

Performing analysis similar to what we did for capital productivity in freight services, we begin by regressing levels of capital productivity in passenger service for 1929 and 1941 on regional dummies.

Table 11
Capital Productivity in Passenger Operations in 110 U.S. Class 1 Railroads, 1929 and 1941

	1929	1941	1941/1929 relative
NE	415322	483119	1.16
GL	557092	430317	0.77
CE	429943	510372	1.19
PC	338765	709106	2.09
SO	594918	943161	1.59
NW	385359	498479	1.29
CW	477332	619051	1.30
SW	1551717	678883	0.44

If we regress the passenger productivity 1941/1929 relatives of *individual lines* on regional dummies, we get the following regional averages for increases in passenger service capital productivity. If added, scale variables (employment in 1929 and 1941) and the relative passenger car capacity for 1941 and 1929 are insignificant and result in only minor changes in the coefficients on the regional dummies. These regressions are not reported.

These results are broadly consistent with my interpretation of the data for labor productivity: passenger service was a mature business and the big overall driver of productivity improvement in the Depression was in freight service.

Table 12
Capital Productivity in Passenger Operations in 110 U.S. Class 1 Railroads,
Regressing 1941/1929 Relatives on Regional Dummies

NE	1.10
GL	0.91
CE	1.02
PC	2.14
SO	1.60
NW	1.13
CW	1.33
SW	1.42

TFP Calculations

Finally, using the data on labor and capital productivity growth, I calculate rates of capital productivity increase for individual railroads. We have five lines with passenger but no freight operations in both years and fourteen lines with freight but no passenger operations in both years (see table 10). For these the capital productivity calculations are straightforward. For the other 105 lines, the capital productivity 1941-1929 relatives for freight and passenger traffic are weighted according to the average of the share of freight revenue in total revenue in 1929 and in 1941. Thus we have capital productivity growth data and labor productivity growth data for 123 lines.

These relatives, along with the labor productivity relatives, are then converted into continuously compounded rates of growth over the twelve year period 1929-41 The rate of growth of TFP can also be shown to be arithmetically equivalent to a weighted average of the growth rates of capital productivity and labor productivity, the weights corresponding again to the respective shares of these factors in national income.

To demonstrate this, start with the expression in (3),

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

which is our now familiar equation decomposing labor productivity growth into the influences of technological change and capital deepening. Rearranging, we have

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

Multiplying out,

$$a = y - n - \beta k + \beta n.$$

Adding βy and $-\beta y$ to the right-hand-side of this equation and rearranging, we have

$$a = \beta y - \beta k + y - n - \beta y + \beta n.$$

Factoring out yields

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

which puts into mathematics what the previous paragraph says in words: $(y-k)$ is the growth of capital productivity (Y/K), and $y-n$ is the growth of labor productivity (Y/N); TFP growth (a) is a weighted average of the two. Note that capital productivity (Y/K) is the inverse of the more familiar capital-output ratio.

TFP growth rates for individual lines can thus be calculated as a weighted average of capital and labor productivity growth rates, with the weights corresponding to shares of national income. Using an assumed capital share of .25, we arrive at TFP growth rates for 123 individual lines. Regressing these TFP rates on regional dummies, we get the following results:

Table 13
TFP Growth rates for 123 Class 1 Railroads

NE	0.0272
GL	0.0299
CE	0.0134
PC	0.0357
SO	0.0508
NW	0.0312
CW	0.0343
SW	0.0460

They show the highest rates of total factor productivity growth in Southern and Southwestern roads, with the lowest in Central Eastern and Northeastern roads. The correlation between labor and capital productivity growth in the individual railroads is positive (.31) and the average share of TFP growth contributed by capital productivity growth is about 30 percent, with about 70 percent coming from labor productivity growth. Most of the increases in capital productivity – an average of 88 percent – came from freight operations, confirming the hypothesis advanced in this paper that freight, not passenger operations, were those undergoing the most significant transformation. The average TFP growth for these 123 individual railroads -- 3.5 percent per year -- are broadly consistent with the 2.91 percent TFP growth reported for the sector by Kendrick (1961, pp. 590-591), which we adjusted to 2.97 percent per year earlier in the paper.

Conclusion

Faced with tough times in the form of radically changing demand conditions, crushing debt burdens, and lack of access to more capital, railroad organizations reduced their main trackage, rolling stock and employees, in most cases quite dramatically. At the same time, they introduced upgraded locomotives and rolling stock as they were replaced, built more secondary trackage, changing their operating procedures as they introduced new systems for logistical control and freight interchange. In spite of these cuts, output nonetheless grew modestly to the beginning of the war and rapidly during it.

This paper has extended analysis of sectoral data by bringing together data on individual rail lines that can be used to calculate labor productivity, capital productivity, and total factor productivity. In addition to studying regional variation in levels for 1929 and 1941, the paper looks at the effect of region, scale, and the rate of reduction of key inputs on growth rates of labor and capital productivity. It finds that labor productivity in individual lines grew pasted in southern roads, in those with a large share of revenues deriving from freight operations, and in those in which the number of employees was cut substantially between 1929 and 1941. For capital productivity in freight operations, the largest increases occurred in Southern and Southwestern railroads, and in roads that had decreased their freight capacity in tons. The growth rate of capital productivity in passenger operations was lower, and was not systematically related to reductions in key inputs. Most of the increases in capital productivity can be attributed to freight operations, providing support for the hypothesis advanced in this paper that.The total factor productivity growth rates for individual lines that emerge from this analysis are broadly consistent with rates of TFP growth for the sector calculated using more aggregated data.

In spite of their remarkable productivity performance during the Depression and Second World War, railroads faced tough times in the third quarter of the twentieth century, as they struggled with the continued erosion of passenger business and the reality that trucking also threatened long haul freight revenues. But, after sloughing off commuter lines to state agencies and the remaining intercity passenger business to government owned Amtrak, it emerged by the last decades of the twentieth century in relatively good shape, displaying strong productivity growth, testimony once again to the railroad sector's ability to reenergize and reinvigorate itself in the face of adversity.

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