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The Adversity/Hysteresis Effect: Depression Era Productivity Growth in the U.S. Railroad Sector

by

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Throughout its history the United States has endured cycles of financial boom and bust. Boom periods have been marked by weakened or absent regulation of the financial sector and a growing willingness on the part of households, nonfinancial businesses, and financial businesses to hold riskier assets and to finance these positions with higher leverage (higher debt to equity ratios). These twin engines fueled financial sector profits and remuneration so long as asset prices continued to appreciate, but they (especially the trend toward higher leverage) rendered the system vulnerable when asset bubbles burst. In the boom phase, as the financial system becomes more interconnected, with narrowing capital cushions and complex webs of rights to receive from and obligations to pay to, it becomes more fragile and vulnerable. The failure of one financial institution now has the potential to bring down others, like a row of dominoes, with the potential for severe impacts on the real economy as credit flows seize up.

This cycle was evident in the late 1920s (boom) going into the 1930s (bust), in the initial decade of the twenty first century, and in a number of lesser intervening cycles such as that associated with the Savings and Loan Crisis. In each of these instances, while the upswing of the cycle supercharged the accumulation of physical capital, particularly structures, its aftermath retarded it. The boom and bust cycle of physical accumulation has had predictable impacts on productivity growth in the short run. The upswing of the financial cycle lays the groundwork for a subsequent contraction in physical accumulation, which, amplified by multiplier effects and only partially counteracted by fiscal and monetary policy, contributes to the decline in aggregate demand that induces recession, which has historically produced a short run adverse effect on both labor productivity and TFP.

This adverse affect has been reflected in growth retardation and in many instances outright declines in productivity measures. Why? Slowdown in physical accumulation produces a growing output gap, the result of the reduction in spending on structures and equipment augmented by indirect multiplier effects. Between 1890 and 2004, an increase in the unemployment rate of one percentage point was statistically associated with a reduction in the TFP growth rate for the private nonfarm economy of about .9 percent. This short run cyclical effect persists through periods characterized by both high and low trend growth rates. A weaker procyclical influence on labor productivity growth can also be identified (Field, 2010a).

Initial reports from the Bureau of Labor Statistics suggested productivity growth after 2007 that seemed unusually strong for a recession period, indicating the possible disruption of a pattern that had prevailed for more than a century. But later reports raised doubts. The August 24, 2010 BLS release (see http://www.bls.govshowed that private nonfarm economy MFP (TFP) grew only .1 percent per year during 2008, its slowest rate of increase since 1995. MFp (TFP recovered somewhat in 2009, rising at a rate of about .8 percent per year, but this was still substantially below what took place in each of the of the years 2002, 2003, 2004, and 2005. And the September 2, 2010 release showed that although output per hour rose during 2009 after declining in 2008, it fell again between the first and second quarter of 2010. So there are grounds for believing that the historical pattern persisted through the 2007-2009 downturn:: recessions mean declines in productivity or at least growth retardation.

These issues, however, involve shorter run effects, since business cycles are, by their definition, shorter run phenomena. What long run effects, if any, might the financial cycle, and the cycle of physical accumulation to which it helps give rise, have on productivity growth? This requires consideration of potentially beneficial and adverse consequences of both boom and bust. The most obvious influences are clearly negative. In the later stages of a credit boom, as lending standards deteriorate, and as financial institutions push credit on borrowers rather than just responding to their demands for it, it becomes increasingly less likely that physical capital will be allocated to its best uses. The wrong types of capital goods may be produced, and they may be sold or leased to the wrong firms or installed or built in the wrong places. These problems are more easily remedied for equipment, because producer durables are physically moveable, and in any event, are relatively short lived.

Structures are longer lived and generally immobile and in their case a configuration decided upon in haste in the upswing may foreclose other infrastructural developmental paths. It is not always simply a problem of overbuilding, with an overhang that can be worked off in a few years. Some decisions about structural investment are irreversible, or reversible only at great cost. In growth models, more physical capital accumulation is generally better than less, but the reality is that in some cases the economy would have been better off (because of disposal and remediation costs) had poorly thought out prior investment not occurred at all.

Zoning and other types of planning and land use regulation can partially mitigate these effects. These were largely absent in the 1920s, and so the adverse effects on the revival of accumulation were more acute in the interwar period than they were in the 1980s or will likely be in the 2010s. During and after the Depression, and partly in response to it, and alongside the more well known apparatus of financial sector control, municipalities developed a locally administered system regulating the physical accumulation of structures (both government and privately owned). The regulation of land use and construction survived the deregulatory enthusiasms of the last quarter century more successfully than did the restraints on finance. Why this was so is an interesting story in itself. It had to do in part with the lower concentration of the real estate development industry, the fact that battles would have had to have been fought at the level of hundreds of local jurisdictions rather than primarily at the federal level, and the fact that land use regulation and local building codes, although sometimes perceived as an irritant, did not hinder the potential for private sector profit as much as did the legacies of New Deal regulation of the financial sector. Still, the real estate collapse that began in 2006 has been geographically specific in the severity of its impact, and it is possible some new construction may well end up evolving into blighted neighborhoods that will ultimately need to be razed.

The second adverse impact on potential output takes place during the downturn. In the bust phase of the cycle, as the financial crisis disrupts lending and other financial intermediation, physical accumulation slows down. Assuming that the speculative fever has broken, we can now expect the borrowing and lending that takes place to be more considered. But because both borrowers' and lenders' balance sheets are weaker, lending is perceived as riskier, and less of it takes place. So the bust imposes a purely quantitative loss to potential output in the form of accumulation not undertaken. On the expenditure side, a recession represents foregone opportunities for investment as well as consumption. Stilled productive capacity could have been used to add to the nation's physical capital stock but wasn't. Idle productive capacity (representing the unused service flows of both labor and capital) is like an unsold airplane seat or hotel room. The dated service flows represent potential gone forever if not utilized. And so some houses, warehouses, apartment buildings or producer durables are not acquired or built that could have been.

In sum, 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 the 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..

The question I now pose is whether there is 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 seems almost mystically to view 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 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...”

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). 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. Athough TFP for the private nonfarm economy grew at 1.46 percent per year between 1995 and 2005, it grew only .33 percent per year between 2005 and 2008 (BLS Series MPU491007, accessed 8/31/2010). As noted, advance was particularly weak between 2007 and 2008, after the recession began. In spite of suggestions by Robert Gordon (2010) that the historically inverse relationship between the output gap and productivity has gone away, there is increasing evidence that the recession will be associated with weak or negative TFP growth as it was between 1929 and 1933, and more generally throughout the entire period from 1890 to 2004 (see Field, 2010a).

We won't have good 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 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 build out of the surface road network, which boosted private sector productivity, particularly in transportation and wholesale and retail distribution (Field 2010b). The third influence, which 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 show up clearly 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. Both capital and labor inputs declined substantially.[1] Underutilized sections of track, for example, were decommissioned (see Figure 6),[2] and the net stocks of both railroad structures and railroad equipment declined (Figure 2) as did the number of employees (Figure 7). 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 both rolling stock and permanent way. More sections of the system were electrified.[3] Steam locomotives were replaced with diesel-electrics, which reduced or eliminated the need for refueling and eliminated the need for rewatering stops and made unnecessary the locomotive position of fireman. Passenger cars were increasingly made of light weight aluminum and alloys; streamlining became the aesthetic hallmark for both self propelled articulated (or single car) trains or locomotive pulled cars. Freight cars became larger.

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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).

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

Complementing these improvements in permanent way and equipment, logistical innovation helped enable railroads, despite 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 are some examples of these improvements? The most significant affected the movement of freight, and involved the development of agreements that permitted unlimited interchange of freight cars, so that a box car, for example, could move from one system to another without needing to break cargo, and when it reached its destination (even though outside of the system that owned it) could be reloaded rather than immediately sent back empty to its origin. Cooperation was enabled by a standardized schedule of car rental payments along with arrangements so that repairs and maintenance, if necessary, could be undertaken in yards owned by a railroad different from the one that owned the car.[4] All of this was facilitated by moves towards equipment standardization initiated during the Federal government's takeover of the railroads during the First World War (Longman, 2009), and pushed forward in the 1930s by the Association of American Railroads, formed in October 1934 through the merger of five industry trade groups. The AAR 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, which were and are published in its Manual of Standards and Recommended Practices. Because railroads are a highly interconnected network industry, failure of one small part of a system can have much larger deleterious consequences than say in trucking, and for this reason standardized

[4] The system eventually evolved to incorporate freight cars owned by third parties, so that today more than half of freight rolling stock is not owned by railroads (Richter, 2005, p. 35).

equipment and procedures takes plays a particularly important role in facilitating growth in efficiencies.

Kendrick's series for 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 US 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. We would like to have a sense of how much of this, if any, was the result of this adversity/hysteresis effect, relative to the other two tributaries.

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 (Figure 1), 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. Figure 2 brings together NIPA data on gross investment in railroad equipment and structures. Gross investment in railroad equipment peaks in 1923 and then moves fairly steadily downward to virtually nothing in 1933. It then revives somewhat, particularly after 1935 and the big increase in railroads in receivership. Investment in railroad structures peaks in 1926 but remains high through 1930 before declining to a trough in 1933 and then recovering modestly in the remainder of the Depression, although not as sharply as equipment investment. Using the data underlying theses 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.[5]

We can get further insight into trends in railroad accumulation by looking at detailed numbers on rolling stock (Figures 3-5; these data are in units, not dollars). 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 shrunk from 61,257 in 1929 to 44,375 in

[5]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.

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. A small but increasing number of the replacement engines were diesel electric. 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 (Figure 5). Numbers fell from 53,838 in 1929 to 38,344 in 1941.

Figure 6 is of particular interest. It reports miles of road constructed and abandoned, with abandonments taking a sharp jump to a higher level in 1932, and new construction tapering off to virtually nothing by 1934. On the labor input side (Figure 7), the number of railroad employees declined moderately in the 1920s, then precipitously in the 1930s (Figure 7). Bringing together all of these data on labor and capital inputs, we have a picture of a system undergoing wrenching rationalization, rationalization midwifed by the economic downturn and the threat or actuality of receivership.

Figures 8 and 10 provide data on freight car miles and millions of passenger miles. 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. Figures 8-10 include data on output over the war years. 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 a closer 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.

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

Figures 1 through 10 and Table 1 document at the aggregate level the productivity achievements of the U.S. railway sector across the Depression years. This last section of the paper examines the phenomenon at the level of individual railroads. The analysis involves comparing the labor productivity performance of 128 class I railroads in 1941 with their performance in 1929. Class I railroads were defined during the Depression as those with operating revenues greater than $1 million. Data are drawn from Statistics of Railways in the United States, a volume published annually by the Interstate Commerce Commission. The 1929 edition contains data on 167 class I railroads. These roads covered the vast majority of operations in the United States. Total employment in the sector for the year was 1,694,042 (see Figure 7); these 167 roads employed 1,662,095, or 98 percent of the total.

The 1941 ICC volume reported data for 135 class 1 railroads, which employed 1,139,129 out of total sector employment of 1,159,025 (again, 98 percent). Although the majority of railroads in existence in 1929 persisted to 1941, the total number of class I railroads did decline by 19 percent.[6] In order to make meaningful comparisons between 1941 and 1929, comparable operational units need to be identified. 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 need to be aggregated. Table 2 describes the linkages between railroads in the two years. Railroad history has attracteds considerable interest from professional historians as well as amateurs and there is a wealth of information available on the web including information on the history of firm consolidation and corporate structure. Using multiple searches, I have linked 43

[6] 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, $250 million (1993). Today the cutoff is $319.3 million. While there were 135 class I railroads operating in the U.S. in 1941, there are now only seven: l: Union Pacific, BNSF (Burlington Northern Santa Fe), CSX, Norfolk Southern, and Kansas City Southern and Canadian Pacific and, Canadian National.

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 (see table 2). Two other railroads, both small, drop out because they ceased operations during the interval.[7] For six other small railroads employing a total of 2,077 in 1929, I am not able to locate a successor.[8] Four small roads employing a total of 827 appear in 1941 but not 1929.[9] And I dropped two small lines, one, a small unit whose productivity numbers were an outlier, as well as a small railroad in Hawaii.[10] I end up making 1929 – 1941 comparisons for 128 linked units.

To compare labor productivity in the two years, we need to define an output measure. This requires agreement on appropriate metrics for freight and passenger operations, and on how to aggregate them. For freight output, I use revenue ton miles, and for passenger traffic, revenue passenger miles. To aggregate the two main types of output I calculate the ratio of passenger revenue per passenger mile to freight revenue per ton mile, and 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. This is similar to what Barger (1951) did 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.

[7] These two, with 1929 employment in parentheses, were Ft. Smith and Western (137), and Copper River and Northwestern (166).
[8] 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).
[9] 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).
[10] These two roads were New York Connecting (with 49 employees in 1929), and Oahu Railroad and Land Company (with 407 employees in 1929)..

The ICC grouped class I railroads into 8 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 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.

Turning now to analysis of changes between 1929 and 1941, I define the dependent variable 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 41FREIGHT% 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 the carried no passengers to a low of 51 percent for Staten Island Rapid Transit, 64 percent for the Florida East Coast Line, or 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, and 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 (%CHGEMPLOYhas 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.

The aggregate data show that rising labor productivity coincided with declining employment, but the firm level analysis provides stronger 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 .

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.

Conclusion

The Depression era history of the U.S. rail system provides a compelling example of the operation of the adversity/hysteresis effect. Faced with tough times in the form of radically changing demand conditions, crushing debt burdens, and lack of access to more capital, railroad organizations changed their operating procedures, introduced new technologies, and reduced their trackage, rolling stock and employees, in most cases quite dramatically. In the face of these cuts, output nonetheless grew modestly to the beginning of the war and rapidly during it. It is true that the sector faced tough times in the quarter century following the war as it struggled with the continued erosion of its passenger business and the reality that trucking also threatened its 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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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
Averrage 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

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.

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
41FREIGHT%	0.929605	2.677457
SOUTH	0.420113	4.983351
%CHGEMPLOY	-0.40371	-2.63621

n = 128 R^2 = .24

Data sources: see text.

Figure 1
Mileage of Railroads Under Receivership

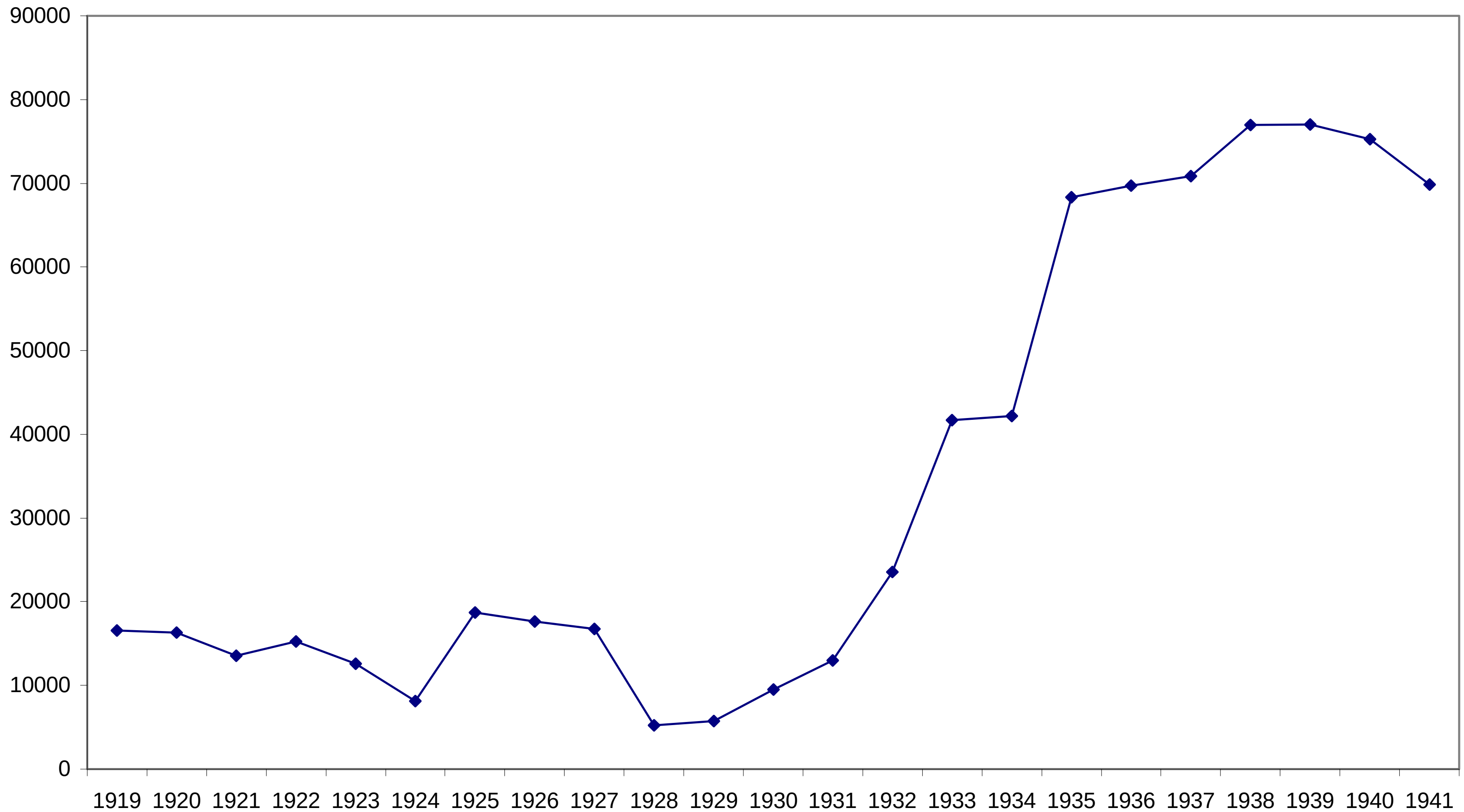


Figure 2
Gross Investment in Railroad Equipment and Structures

Figure 3
Locomotives Installed and Retired, 1919-41

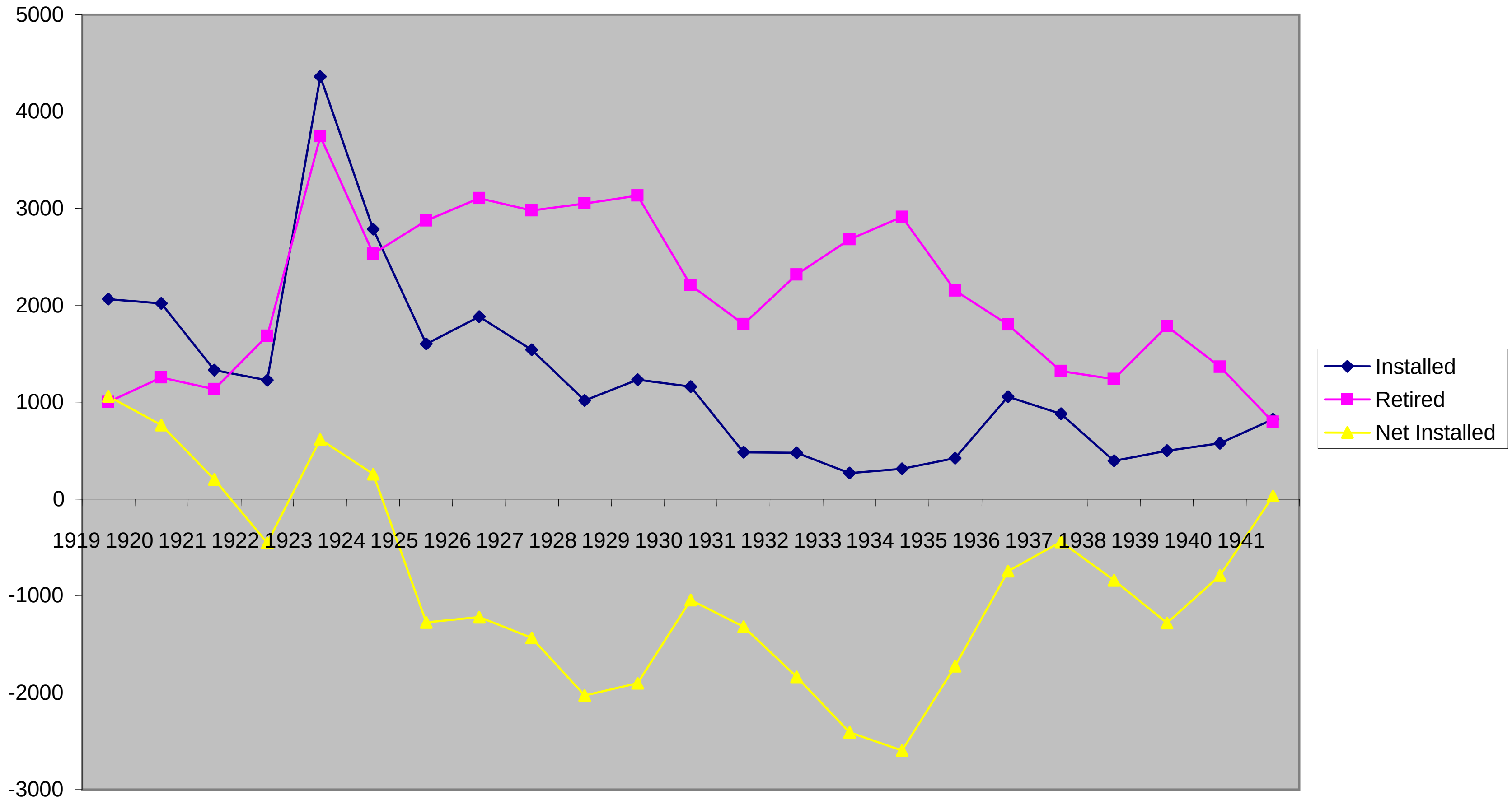


Figure 4
Freignt Cars Installed and Retired, 1919-41

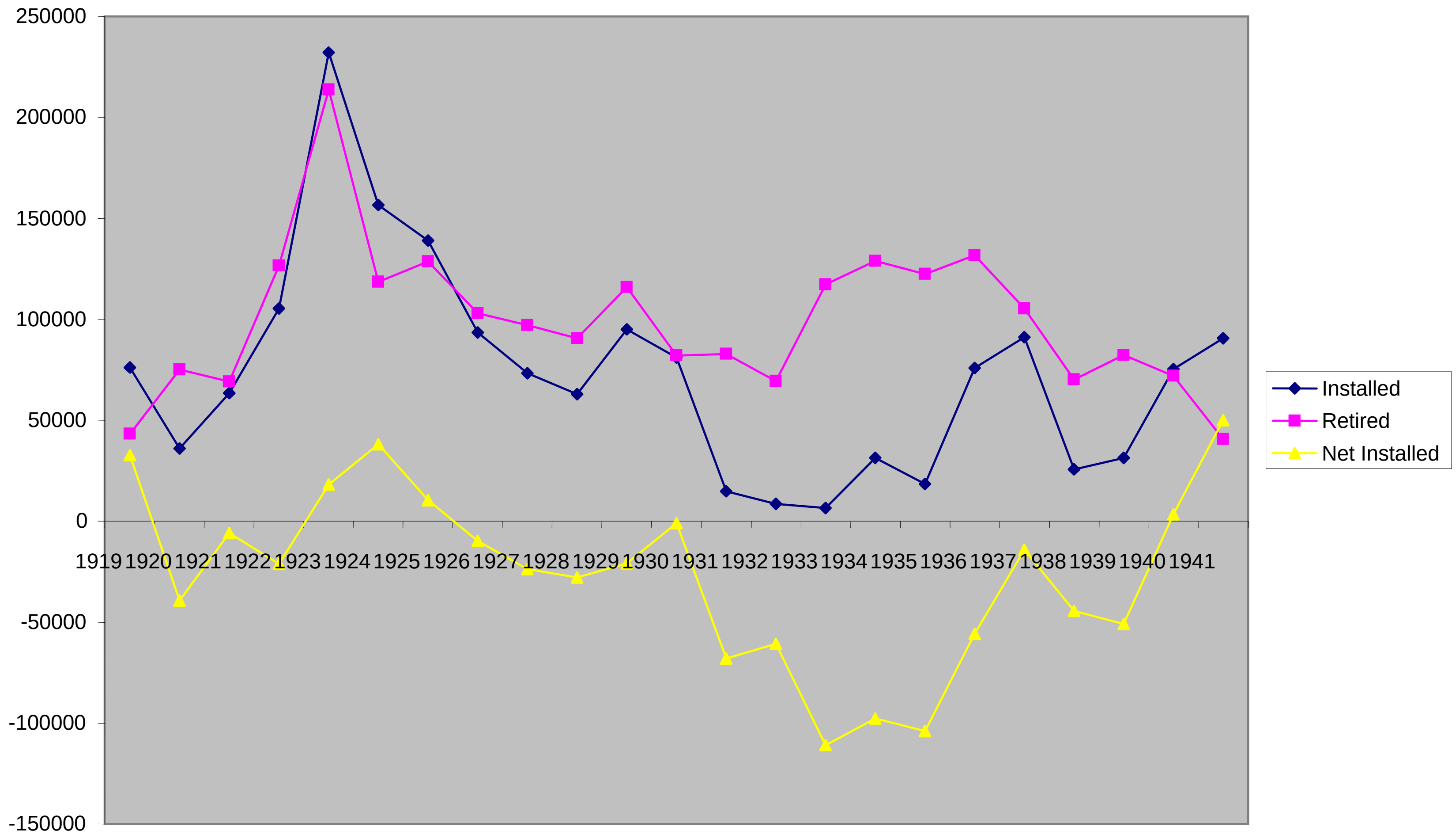


Figure 5
Railroad Passenger Cars Installed and Retired, 1919-41

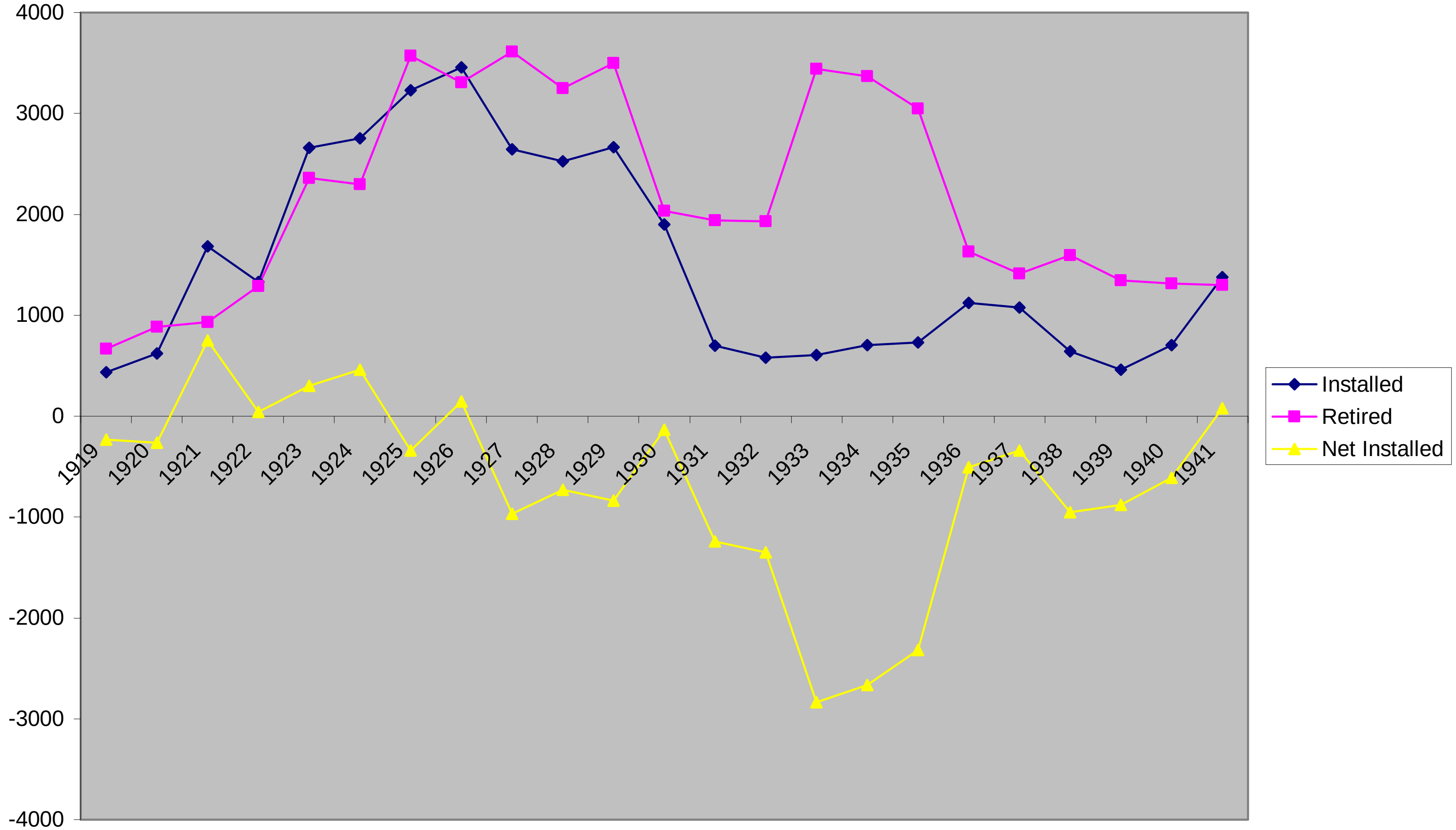
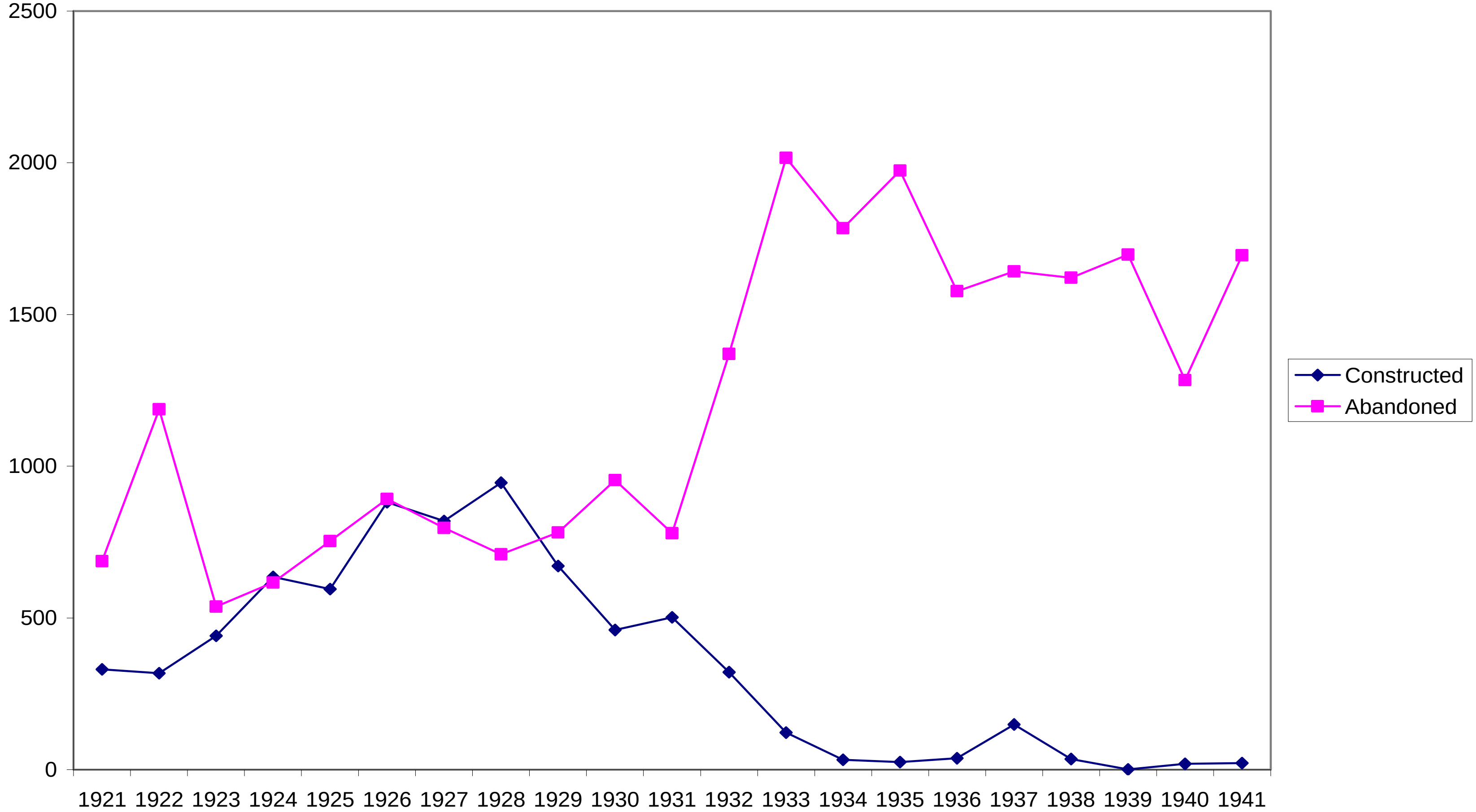


Figure 6
Miles of Road Constructed and Abandoned, All Line Haul Steam Railroads, 1921-1941



Source: Interstate Commerce Commission, Statistics of Railways in the United States, 1941. Washington: GPO, 1943, p. 14.

Figure 7
Railroad Employees, 1919-41

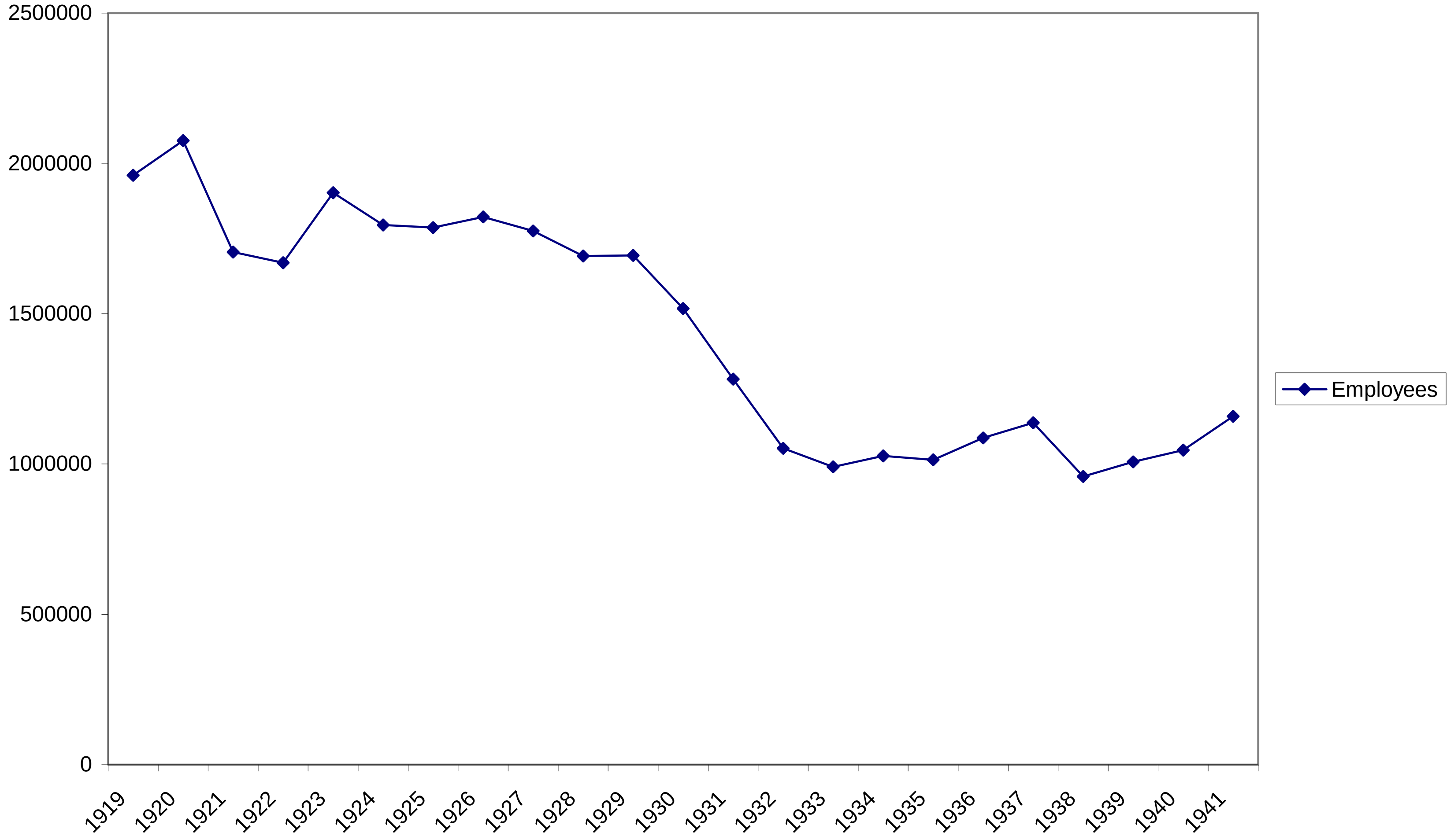


Figure 8
Railroad Freight Car miles, 1920-46

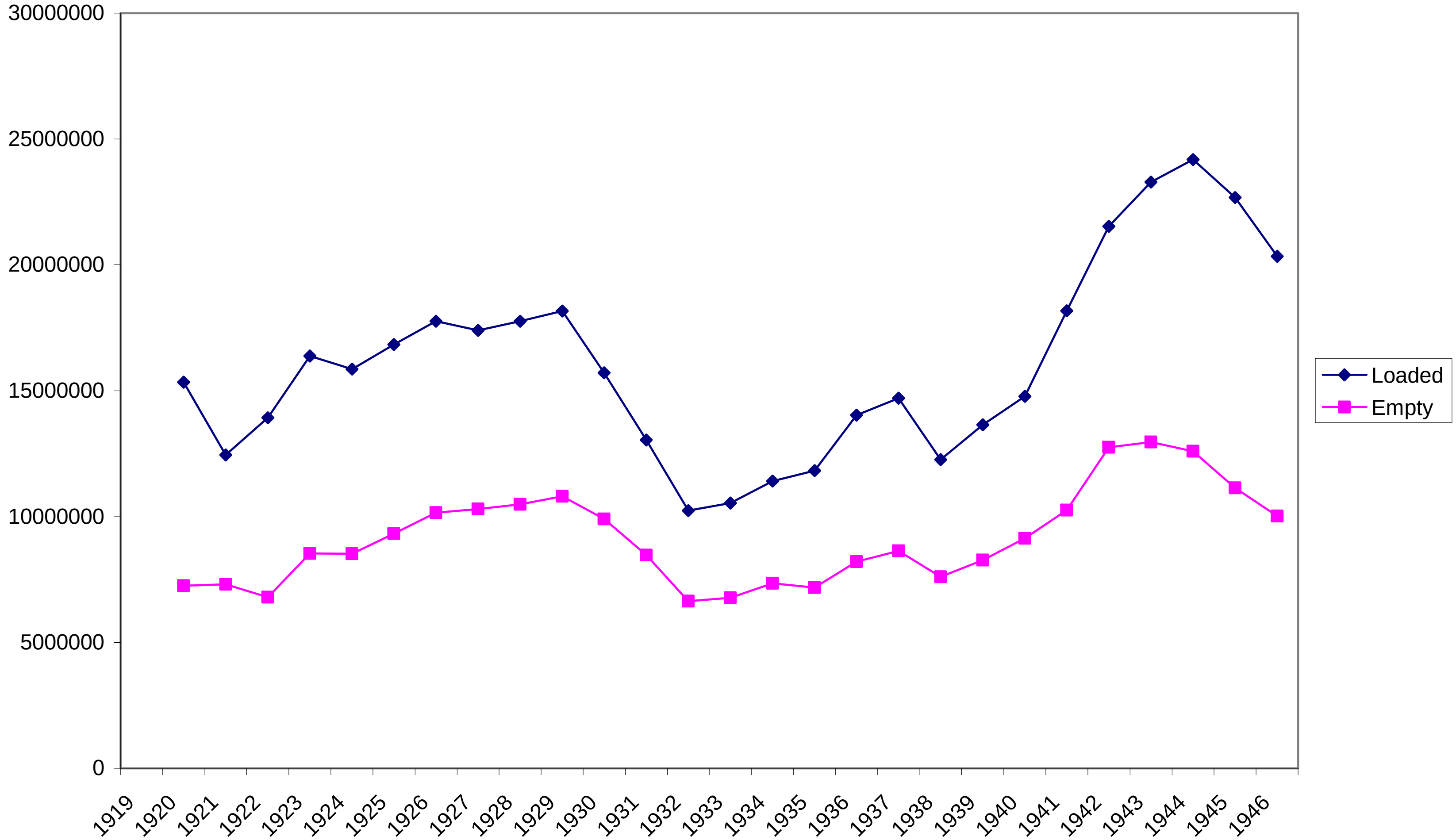


Figure 9
Freight Ton Miles, 1919-1946

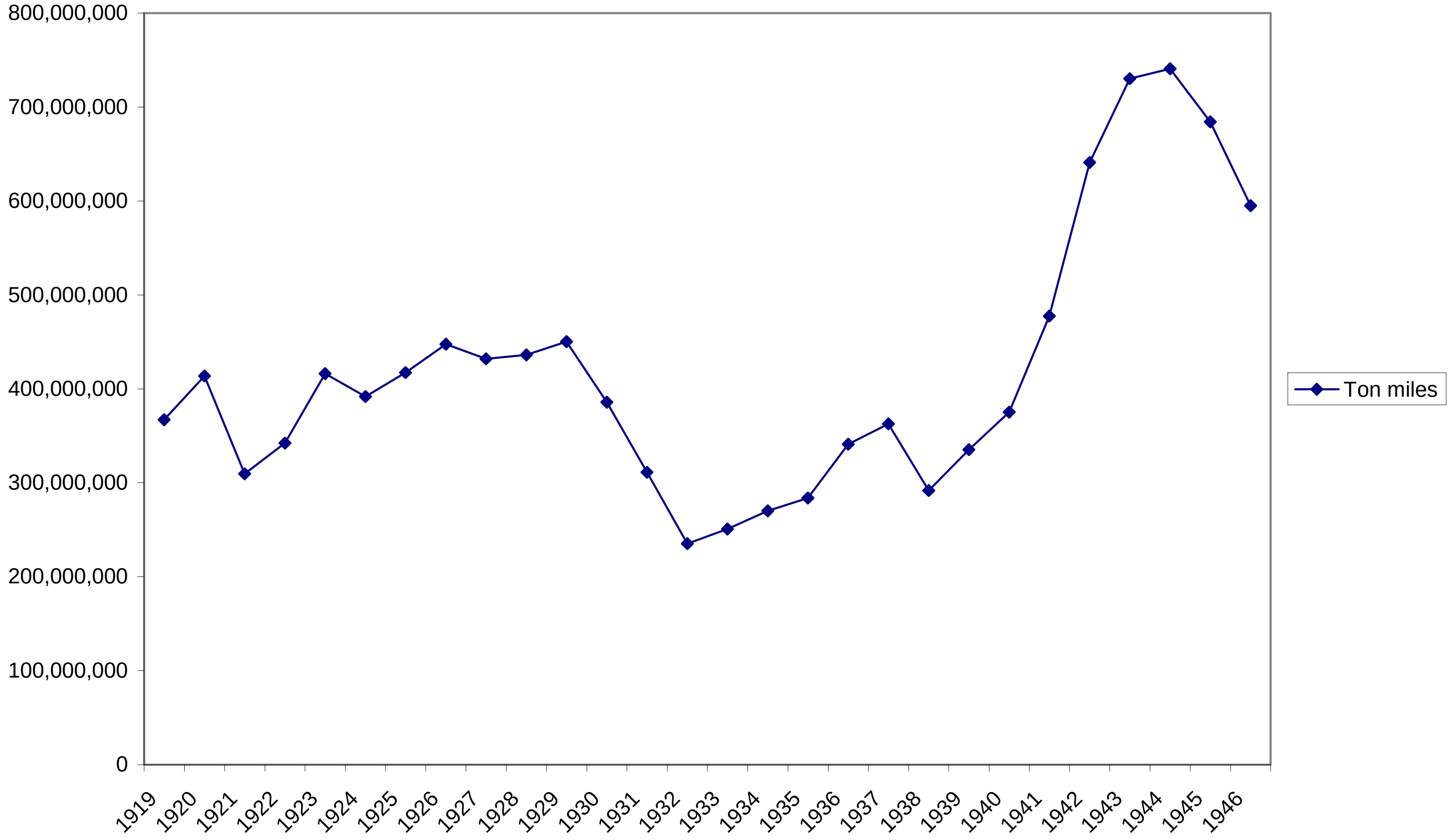


Figure 10
Railroad Passenger Miles, 1919-46