Multifactor productivity in railroad transportation

Multifactor productivity growth in this industry averaged 3.5 percent per year between 1958 and 1989; consolidation of railroads into larger systems, particularly in the 1980's, generated operational efficiencies that, with technological changes, boosted productivity

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Labor productivity, as measured by output per employee hour, experienced substantial growth in railroad transportation between 1958 and 1989, averaging 5.2 percent per year.[1] Output increased 1.0 percent per year and employee hours dropped 4.0 percent annually. Annual productivity growth in this industry was considerably greater than the annual growth rate in the private business sector, which averaged 1.4 percent annually in the same period.

Changes in output per employee hour reflect a wide range of influences, including changes in technology, composition and skills of the work force, organization of production, and the amount of capital per employee hour and intermediate purchases per employee hour. Labor productivity should not be interpreted as solely representing labor's contribution to production. The multifactor productivity measure of railroad transportation presented in this article is intended as an extension of a labor productivity measure that the Bureau has published for many years.[2]

The multifactor productivity measure of railroad transportation relates output to the combined inputs of labor, capital, and intermediate purchases. It reflects many of the same influences as the labor productivity measure, but because both capital and intermediate purchases are included as inputs, it does not reflect the effect of these influences on the productivity residual.

Output per employee hour can be calculated as the sum of the effects of changes in capital and intermediate purchases inputs relative to labor, and the multifactor residual. The influence of capital on output per employee hour is referred to as the "capital effect" and is measured as the rate of change in the capital-labor ratio multiplied by the share of capital costs in the total cost of output. Similarly, the influence of intermediate purchases on output per employee hour is referred to as the "intermediate purchases effect" and is measured as the rate of change in the intermediate purchases-labor ratio multiplied by intermediate purchases' share of the cost of output. Multifactor productivity accounted for 3.5 percentage points of the 5.2-percent gain in output per hour, while the capital effect accounted for 0.5 percent and the intermediate purchases effect represented 1.2 percent. (See table 1.)

Multifactor productivity

The 3.5-percent average annual growth in multifactor productivity (or output per unit of combined

Table 1. **Average annual growth rates in output per employee hour, multifactor productivity, and related measures, railroad transportation industry, selected periods, 1958–89**

Measure	1958–89	1958–73	1973–89	1973–79	1979–89
Output per employee hour[1]	5.2	5.6	6.4	3.0	8.8
Multifactor productivity	3.5	4.2	3.8	1.6	5.5
Capital effect[2]	.5	.4	.7	.2	1.0
Intermediate purchases effect[3]	1.2	.9	1.8	1.2	2.1
Capital services	–1.6	–1.8	–1.5	–1.3	–1.9
Employee hours	–4.0	–3.3	–5.7	–2.3	–7.2
Capital per employee hour	2.5	1.5	4.4	1.0	5.8
Intermediate purchases	.0	.5	–.7	1.6	-1.6
Intermediate purchases per employee hour	4.1	3.9	5.3	4.0	6.1

[1]Output per employee hour equals multifactor productivity plus the capital effect plus the intermediate purchases effect. Each measure presented in this table is computed independently. Therefore, the three components may not sum exactly to output per employee hour due to rounding.

[2]The capital effect is the rate of change in the capital-labor ratio multiplied by the share of capital costs in the total cost of output.

[3]The intermediate purchases effect is the rate of change in the intermediate purchases-labor ratio multiplied by the share of intermediate purchases costs in the total cost of output.

inputs) reflected a 1.0-percent annual growth in output and a 2.4-percent decline in combined inputs.

The rate of growth in output per employee hour in railroad transportation did not decline after 1973, unlike many industries in the private business sector; instead, it increased slightly, from a 5.6-percent average annual growth rate in the 1958–73 period, to a 6.4-percent rate in the 1973–89 period.[3] (See table 2.) The rate of growth in output per employee hour in the private business sector, however, declined by 1.3 percent from an average annual growth rate of 2.1 percent in the 1958–73 period to 0.8 percent in the 1973–89 period. Labor productivity accelerated for railroad transportation despite a slight decline in the growth rate of multifactor productivity from an average annual gain of 4.2 percent in the 1958–73 period to 3.8 percent in the 1973–89 period, as the capital effect and intermediate purchases effect accelerated. The capital effect nearly doubled, from a 0.4-percent average annual rate of growth from 1958 to 1973 to 0.7 percent from 1973 to 1989. The intermediate purchases effect doubled, from a 0.9-percent rate in the first period to 1.8 percent in the following period.

The capital effect, which is the weighted change in the capital-labor ratio, can be analyzed by examining the movements in each of its components—capital services, employee hours and the capital share weight. The average annual decline in capital services was less rapid in the second period, falling at a rate of 1.5 percent relative to the 1958–73 decline of 1.8 percent. This contributed to the increase in the capital-labor ratio between the two periods, as employee hours fell from an average 3.3-percent drop annually to a 5.7-percent decline in the 1973–89 period. The capital-labor ratio therefore accelerated from an average annual gain of 1.5 percent in the first period to a 4.4-percent rate in the1973–89 period. This increase, weighted by capital's share in the cost of output, which fell from an average of 24 percent in the first period to 18 percent in the later period, caused the capital effect to rise from an average 0.4-percent annual rate of growth during the period 1958–73 to 0.7 percent in the 1973–89 period.

The intermediate purchases effect similarly can be broken down. The rate of growth in intermediate purchases fell from a 0.5-percent average annual rate of gain in the 1958–73 period to a decline of 0.7 percent in the 1973–89 period. The relatively steeper drop in employee hours mentioned above countered this decline.

Consequently, the growth rate of the intermediate purchases-labor ratio accelerated from a 3.9-percent average annual gain in the first period to a 5.3-percent rate in the latter period. This gain, weighted by the share of intermediate purchases in the total cost of output (which rose from about one-fourth to one-third), resulted in an increase in the intermediate purchases effect from a 0.9-percent average annual rate of growth in the 1958–73 period to a 1.8-percent rate in the second period.

It is necessary to examine the 1958–73 and 1973-89 periods when comparing productivity among industries because of the economy's well publicized productivity slowdown in the post-1973 period. But because evidence points to a rebound in productivity since the late 1970's and because of conditions pertinent only to railroads, two additional periods are analyzed—1973–79 and 1979–89. These periods are examined not only because 1979 marked a peak year in output for railroads, but also because it highlights the relative stagnation of railroads during the 1970's and the industry's revitalization in the 1980's.

This renaissance was due not only to the introduction and diffusion of technology throughout the industry, but also to the effects of the Staggers Rail Act of 1980. Key provisions of the Staggers Act helped improve efficiency in the industry by loosening regulations in ratemaking, liberalizing track abandonment procedures, and expediting merger proposals. The new terms allowed railroads to eliminate underutilized track and reduce employee hours when traffic levels fell, as demonstrated by the railroads' response to the 1982 recession contrasted to the 1975 recession.

In 1975, output in the railroad industry decreased 13.2 percent, while labor productivity decreased 4.8 percent and multifactor productivity fell 6.7 percent. In 1982, output decreased by a similar 11.9 percent, but multifactor productivity increased 1.3 percent and labor productivity rose 5.7 percent. The variations in labor productivity are due to a much larger decline in employee hours during the 1982 recession—16.6 percent—than during the 1975 recession—8.8 percent. Employee hours continued declining substantially after 1982, which contrasts with hiring practices in past recessions when companies furloughed workers and rehired them when traffic improved.[4]

The railroads also are abandoning tracks: Late 1970's estimates show that as much as 67 percent of freight transported by railroads moved over just 20 percent of the track.[5] Since the Staggers Act took effect, railroads increased abandonment of underutilized track by 40 percent during the 1979–87 period over the average for the 1969–78 period.[6] In addition, more efficient long-line railroads emerged from mergers. One rail official estimated that by the mid-1980's, 60 percent of all freight cars could travel from origin to destination on one railroad.[7] Railroad consolidation results in fewer interchanges where railroads interconnect, reducing transit time and labor requirements, and improving service.

A rapid acceleration in output per employee hour occurred between 1973–79 and 1979–89. While the average annual rate of growth was 6.4 percent during the 1973–89 period, output per employee hour grew at an average annual rate of 3.0 percent in the 1973–79 period, and surged to an average annual growth rate of 8.8 percent in the 1979–89 period. This was due primarily to a jump in multifactor productivity from an average annual rate of 1.6 percent in the period, 1973–79 to 5.5 percent in the following period, helped by increases in the capital effect and intermediate purchases effect. The capital effect accelerated from an average gain of 0.2 percent per year during the 1973–79 period to 1.0 percent in the 1979–89 period. The intermediate purchases effect jumped from an average annual increase of 1.2 percent in the former period to 2.1 percent in the latter.

Table 2. **Multifactor and related productivity indexes in the railroad transportation industry, 1958–89**

[1982=100]

Year	Multifactor productivity	Output per employee hour	Output per unit of capital	Output per unit of intermediate purchases
1958	48.6	34.1	56.7	88.2
1959	51.0	36.6	60.9	85.1
1960	51.4	37.7	61.2	81.8
1961	54.6	40.5	62.5	88.2
1962	58.4	43.5	68.1	91.3
1963	60.5	45.8	71.7	89.7
1964	63.8	48.7	77.2	90.6
1965	69.3	54.1	82.3	95.9
1966	73.3	58.1	87.1	98.1
1967	74.0	59.8	85.2	99.0
1968	77.9	62.8	89.4	104.6
1969	79.6	65.2	92.1	102.6
1970	76.2	62.1	90.0	97.5
1971	78.6	66.2	89.9	96.2
1972	85.2	72.3	96.0	104.4
1973	93.5	79.9	107.1	111.1
1974	92.2	78.2	107.1	110.0
1975	86.0	74.4	94.4	102.7
1976	91.2	80.5	103.2	103.6
1977	95.1	84.3	110.0	105.9
1978	98.2	88.6	113.7	106.0
1979	100.4	93.2	117.5	103.4
1980	99.0	93.8	113.5	100.1
1981	98.7	94.6	111.6	99.0
1982	100.0	100.0	100.0	100.0
1983	116.9	123.6	109.2	112.6
1984	125.9	134.0	122.2	117.5
1985	127.6	140.1	119.7	116.3
1986	132.8	153.2	120.7	115.3
1987	145.8	171.8	133.3	122.2
1988	154.6	186.1	143.3	124.7
1989	160.0	197.4	148.6	124.8
Average annual rates of change (percent)				
1958–89	3.5	5.2	2.6	1.0
1958–73	4.2	5.6	4.0	1.6
1973–89	3.8	6.4	1.9	1.0
1973–79	1.6	3.0	2.0	-0.9
1979–89	5.5	8.8	2.9	2.5

Related measures

Output. Output averaged an annual 1.0-percent increase during the 1958–89 period. (See table 3.) This gain masks a slowdown of 1.7 percent between the two major periods studied, as output grew at a 2.1-percent average annual rate in the 1958–73 period, but fell to a rate of 0.4 percent in the post-1973 period.

Freight transportation increased modestly in the 1958–89 period, but passenger transportation fell sharply. Passenger miles declined during the period at an average annual rate of 2.0 percent; total passenger miles fell from 23.3 billion in 1958 to 9.7 billion in 1982 and rose to 14.4 billion in 1989. Weighted freight ton-miles increased an average of 1.6 percent per year between 1958 and 1989.[8] These rates of change, combined with total expense weights for passenger miles and weighted

Table 3. **Output and input indexes in the railroad transportation industry, 1958–89**

[1982=100]

Year	Output	Combined inputs	Employee hours	Capital	Intermediate purchases
1958	84.7	174.3	248.4	149.3	96.0
1959	88.2	173.1	241.3	144.9	103.7
1960	86.2	167.7	228.7	140.8	105.4
1961	85.3	156.1	210.6	136.4	96.7
1962	89.9	154.0	206.8	132.1	98.5
1963	92.1	152.2	201.0	128.4	102.7
1964	97.1	152.3	199.4	125.7	107.2
1965	102.2	147.5	188.9	124.2	106.6
1966	107.7	146.9	185.3	123.6	109.8
1967	104.6	141.3	175.0	122.8	105.7
1968	108.1	138.7	172.1	120.9	103.3
1969	109.5	137.5	168.0	118.9	106.7
1970	105.4	138.3	169.8	117.1	108.1
1971	103.6	131.8	156.4	115.2	107.7
1972	108.6	127.4	150.2	113.1	104.0
1973	118.9	127.2	148.8	111.0	107.0
1974	116.8	126.7	149.3	109.1	106.2
1975	101.4	117.9	136.2	107.4	98.7
1976	109.1	119.6	135.5	105.7	105.3
1977	115.0	120.9	136.4	104.5	108.6
1978	117.7	119.9	132.9	103.5	111.0
1979	120.7	120.2	129.5	102.7	116.7
1980	116.2	117.4	123.9	102.4	116.1
1981	113.5	115.0	120.0	101.7	114.6
1982	100.0	100.0	100.0	100.0	100.0
1983	106.4	91.0	86.1	97.4	94.5
1984	116.2	92.3	86.7	95.1	98.9
1985	111.9	87.7	79.9	93.5	96.2
1986	110.9	83.5	72.4	91.9	96.2
1987	119.4	81.9	69.5	89.6	97.7
1988	125.4	81.1	67.4	87.5	100.6
1989	127.5	79.7	64.6	85.8	102.2
Average annual rates of change (percent)					
1958–89	1.0	–2.4	–4.0	–1.6	.0
1958–73	2.1	–2.0	–3.3	–1.8	.5
1973–89	.4	–3.3	–5.7	–1.5	–.7
1973–79	.7	–.9	–2.3	–1.3	1.6
1979–89	.9	–4.4	–7.2	–1.9	–1.6

freight ton-miles averaging 11 percent and 89 percent led to the 1.0 percent increase in output in the 1958–89 period.

Railroads operate most efficiently when carrying large volumes on long distance hauls. They carry commodities such as coal, grain, and other raw materials. But competition with truck, barge, and pipeline transport has influenced railroad transportation when it hauls other types of goods. In addition, the business cycles of the industries rail roads serve, and the partial deregulation of the industry and the mergers that followed, have influenced railroad transportation. More fundamentally, changes in the economy, particularly the shift from heavy manufacturing to service industries, reduced the growth rate in transportation of raw materials.[9]

Truck transportation and oil pipelines have challenged railroad transportation's dominance in freight ton-miles as a percentage of total volume of intercity freight transportation. The most rapid gains in the share of ton-miles occurred before the period studied here. Truck transportation's share of ton-miles more than quadrupled, from 5 percent in 1944 to 21 percent in 1958 as the share of transportation by oil pipeline increased from 12 percent to 17 percent. Railroad's share of transportation declined at the same time from 69 percent to 46 percent. Although its share further decreased to 38 percent by 1973, railroad transportation has since stabilized and maintained the largest share, averaging 37 percent of total intercity freight ton-miles for the 1973–1989 period. During the same period, truck transportation and oil pipelines each averaged about a 23-percent share.

Other forms of transportation have not challenged railroads' share of freight ton-miles to such a degree. Air transportation's share is less than 1 percent, while water transportation's share averaged approximately 12 percent since 1973.[10]

Railroads once received 20 percent of the Nation's freight dollars, but now command only 12 percent. Nevertheless, the industry still dominates coal, grain, and motor vehicle traffic, carrying two-thirds of the Nation's total and about half of the food products and household appliances.[11] The six largest commodity groups in 1989 as measured by carloadings were coal; grain; chemicals and allied products; motor vehicles and equipment; crushed stone, gravel and sand; and food and kindred products. Coal is by far the leading freight commodity, accounting for 39 percent of total tonnage for all commodities and 22 percent of total freight revenues in 1989.[12] Chemicals are the second largest source of revenue, accounting for 13 percent; transportation equipment is third, accounting for 11 percent of total freight revenue in 1989.

The output and transportation needs of these industries have greatly influenced the output of railroad transportation. Large increases in fuel prices in the mid-1970's and early 1980's helped push up demand for the transport of coal, as utilities and industry, domestic and foreign, switched to coal as an alternative fuel source. The high cost of fuel also helped railroads gain back some market share from truck transportation because fuel efficiency is two to four times greater for trains than for trucks.[13]

The increased use of piggyback traffic or intermodal transportation—containers and trailers on flat cars—has offered an opening into the market for moving merchandise and other freight that had traditionally been the domain of truck transportation. The number of cars loaded with highway trailers rose from 278,071 or nearly 1 percent of total rail carloadings in 1958 to 2,982,276, or 15 percent of total carloadings in 1986, the last year for which these data are available. Most of this gain in carloadings took place after 1973. In 1973, containers and trailers on flat cars accounted for 6 percent of car loadings, while coal accounted for 16 percent. By 1986, the shares of total carloadings had increased to 15 and 28 percent.[14]

On the contrary, railroad passenger-miles have experienced a drastic fall in their share of total public passenger transportation. Between 1944 and 1960, railroad passenger-miles fell from a 76-percent share of total public passenger-miles to a 29-percent share, as air transportation rose from less than 2 percent of the total to 42 percent. The share for air transportation has continued to rise dramatically and, as of 1988, accounted for 90 percent of total passenger-miles, while railroad transportation has fallen to 4 percent.[15]

Labor. Employment in the railroad industry declined from 840,575 employees in 1958 to 248,656 in 1989, a 70-percent decline. Employee hours dropped 74 percent during the same period, or at an average annual rate of 4.0 percent. Between 1958 and 1973, output increased at an average annual rate of 2.1 percent, and employee hours declined at an average rate of 3.3 percent per year; from 1973 to 1989, increases in output slowed to an average annual rate of 0.4 percent, and employee hours declined at a faster 5.7-percent annual rate. This obscures an even faster rate of decline within the latter period: employee hours decreased relatively slowly between 1973 and 1979, at an average annual rate of 2.3 percent; however, between 1979 and 1989, employee hours plunged at an average 7.2 percent per year.

Average hourly earnings in 1989 for railroad employees were nearly six and one-half times as high as in 1958. This is considerably larger than for the private nonfarm business sector in which average hourly earnings rose by a factor of five in the same period.[16] The difference was the result of several multiyear wage agreements, most notably an agreement in 1970 providing for a series of increases totaling about 42 percent over a 42-month period and one in 1973 providing for up to 36 percent in wage increases in a 3-year period.[17] A labor agreement that extended from 1978 through March 1981 led to a 35-percent increase in average hourly earnings, while earnings in the private nonfarm sector rose 27 percent. Since the early 1980's, wage increases have slackened.

Several factors have been responsible for the large reduction in employment in railroad transportation. Fewer trains in operation and work rule changes have decreased labor requirements for train and engine crews and for other activities such as maintenance and track operations. Deregulation has made possible the abandonment of unprofitable track and also has allowed mergers that eliminate duplicate facilities, resulting in the reduction of personnel. Advances in technology also have contributed to lower labor requirements.

Changes in employment varied among the different job classifications.[18] The executive category, which is the smallest employment category, declined the least (27 percent) over the study period, while the largest group—train and engine transportation—declined by more than 60 percent. Technological changes have reduced train and engine crews, which perform some of the most labor intensive functions.

These technological advances include electronic train parts that maintain the flow of air, water, and fuel at optimal settings, adjusting for changes in the environment such as altitude, grade, and outside temperature, while wheel sensors with computer-synthesized voices warn about overheating. Railroads have begun to use two-person locomotive crews for intercity runs instead of the typical four- or five-member crews. Some job classifications have been completely superseded by electronic devices. For example, rail fences that detect rock slides and set off warning lights in approaching locomotives have replaced track watchers who patrolled for avalanches. Similarly, high-water sensors that notify trains as they approach railroad bridges have replaced the rain riders who performed this duty.

At the same time, the "other transportation" employment category has undergone the largest decline—more than 85 percent. Within this category, yardmasters, telegraphers, station agents, and dispatchers have experienced the largest employment decreases due to technological advances. Computer systems that control train movements and provide information on trains and the contents of each car in the station yards have replaced yardmasters and assistants. Many telegraphers, station agents and dispatchers who control the movement of the train along the rail network have been superseded by centralized traffic control, particularly computer-assisted dispatching (CAD), which allows the monitoring of larger areas with a smaller number of local agents. At the same time, the number of stations has declined due to decreased traffic, abandonments and mergers.

Employment in maintenance of equipment has declined by more than 75 percent because the number of locomotives and cars declined with lower traffic levels, and because the cars are larger than they once were. At the same time, the number of railcars owned and maintained by shipping companies has increased.

Many recent advances in technology have led to an employment decline of 65 percent between

1958 and 1989 in maintenance of way and structures. As abandonment of rail lines continues, remaining track time availability becomes scarce, and machinery is necessary to minimize labor and time required on track to complete a given job. Some mechanization began in the 1950's, but most advances have occurred since the 1970's.

Among the three periods studied, employment declined the least or even increased slightly between 1973 and 1979. One reason was an increase in track and equipment maintenance, as output grew during this period.

Intermediate purchases. Intermediate purchases, which comprise materials, fuels, electricity, and purchased services, showed no average annual change in the 1958–89 period. From 1958 to 1973, intermediate purchases grew slowly at an average rate of 0.5 percent per year, and declined in the 1973–89 period at an average annual rate of 0.7 percent. Intermediate purchases productivity also experienced a small slowdown; it increased at an average rate of 1.6 percent per year in 1958–73 and dropped to 1.0 percent in the post-1973 period.

The shares of the various components in the total value of intermediate purchases in railroad transportation differ markedly from those of most manufacturing industries. For manufacturing industries studied,[19] the materials component accounts for an average of 81 percent of the total value of intermediate purchases, purchased services accounts for 15 percent, and energy (fuels and electricity), 4 percent. In the 1958–73 period, materials averaged 38 percent of the total value of intermediate purchases for railroad transportation; purchased services, 43 percent; fuels, 16 percent; and electricity, 2 percent. By the 1973–89 period, materials declined to a 26-percent average value share, fuels jumped to 27 percent, purchased services rose slightly to 45 percent, and electricity nudged forward to a 3-percent share.

For the entire 1958–89 period, total purchased services constituted the largest share of intermediate purchases, 43 percent. Of this, equipment rental accounted for 24 percent of intermediate purchases, while nonrent purchased services accounted for about 19 percent.

Fuels play an integral role in the delivery of railroad transportation services, which is not the case for manufactured goods production. The substantial increase in fuels' value share is due primarily to the oil price jumps of the 1973–74 and 1980–81 periods. Although freight ton-miles increased 19 percent since 1973, fuel used in freight service declined 22 percent. This resulted in an increase of 52 percent in freight ton-miles per gallon of fuel, from 210 ton-miles in 1973 to 320 in 1989. Most of the efforts by railroads to reduce fuel consumption have concentrated on the diesel-electric locomotive, which because of its economic and operational advantages, had replaced the steam locomotive by the early 1960's. Even the early diesel engines converted power into traction four times more efficiently than did steam engines. As railroads declined in use as passenger transportation, they replaced their first generation diesels with more powerful diesels. The modern diesel units now deliver twice as much power as early diesels.[21]

Capital. Capital plays a greater role in railroad transportation, compared with manufacturing, because of the industry's huge infrastructure. For railroads, capital accounted for about 21 percent of total costs on average over the period studied, compared with an average of about 13 percent in manufacturing industries.[22] Assets per employee in railroad transportation were four times the total manufacturing average in 1985. Yet the share in total costs comprised by capital is not much higher because railroad assets last for longer periods of time and therefore replacement costs per dollar of stocks, or depreciation, are lower than the manufacturing average. In addition, average investment per employee over the 1976–85 period for railroads was only twice as high as that for total manufacturing.

Between 1958 and 1989, the flow of services from the capital stock fell steadily at an average annual rate of 1.6 percent. By 1989, capital input fell 43 percent below the 1958 level. Capital input declined at an average annual rate of 1.8 percent in the 1958–73 period when output was rising; declined at a 1.3-percent average annual rate between 1973 and 1979 when output rose more slowly; and fell at an average rate of 1.9 percent in the 1979–89 period when output was falling slightly.

Railroad capital includes the services yielded by equipment, such as shop machinery and locomotives, freight cars, and passenger cars, structures (track, signals, and buildings), land owned by railroads, and railroad inventories of materials and supplies (including fuels). Rates of growth and decline varied in these categories of capital input—equipment, structures, land, and inventories. When capital input fell at an average rate of 1.8 percent per year between 1958 and 1973, equipment grew slowly, at 0.7 percent, but structures, inventories, and land fell more rapidly, at 3.2, 2.5, and 3.0 percent. In the 1973–89 period when capital input fell at 1.5 percent per year, capital input of structures fell at a slower rate of 0.8 percent annually, while capital input of equipment, inventories, and land fell more quickly at average annual rates of 2.4, 4.4, and 2.0 percent.

Technological change

Although railroads were a vital force that played an important role in the economy during the first three decades of this century, their position eroded greatly after World War II due to increasing competition from truck and oil pipeline transportation. By the 1970's, the industry was faced with a declining share of total transportation revenue, an inability to meet costs, and an increasing number of bankruptcies. But in the 1980's, the industry rebounded considerably, due to factors such as deregulation and resulting changes in management techniques and technological improvements.

Many problems that have plagued the railroad transportation industry are the result of an aging system, portions of which have been in place since the 19th century. Some problems resulted from declining demand for the services of the industry, while other problems were due to restrictive regulatory practices that hampered the railroads' ability to adapt to changing economic and competitive conditions in the industry.

Railroad transportation has grown much more slowly than the transportation sector as a whole since the 1920's. As a consequence, railroads' share of total transportation services has diminished considerably, particularly in the last 60-65 years.

Railroads have lost considerable ground since 1929 to motor freight, oil pipelines, and water carriers, which have become increasingly popular for moving higher valued commodities and manufactured goods such as chemicals, food, and electronics. Railroads' share of passenger service also declined tremendously since its heyday as travelers turned increasingly to private cars and airlines.

The shift from railroad transportation occurred for a variety of reasons, including the impact of regulation; large scale public investment in nonrail transportation; the relative movement from agriculture, lumber, and mining in favor of small manufacturing and services; and the increasing decentralization of economic activity, as manufacturers and other businesses moved from the old railroad hubs to areas not convenient to railroad lines.

While the composition and location of economic activity were changing rapidly, the fixed nature of the railroad infrastructure presented a disadvantage to the industry.

By 1920, the Nation's rail system was at its peak with more than 250,000 miles of roads. In 1958, railroads owned about 215,000 miles of road, and in 1989, the industry owned 124,000 miles of road, representing a 50-percent drop from 1920 and 42 percent from 1958. Despite these declines, much of the basic configuration of 60 years ago still characterizes today's network. Maintenance and replacement of the aging capital present a continuing challenge to the railroad industry.

Other problems facing railroads over the years were the result of restrictive regulation of the industry. Passage of the Staggers Rail Act of 1980 addressed many of these problems. The creation of Conrail by the federally-funded U.S. Railway Association in the mid-1970's, which incorporated portions of seven bankrupt railroads into a more efficient system, was a precursor to the mergers allowed by this deregulatory legislation. But before this legislation was enacted, most railroads were faced with an aging infrastructure and very low, highly regulated rates of return, and were unable to generate sufficient income to meet the requirements of plant maintenance and rehabilitation. Much-needed maintenance was postponed from year to year, resulting in widespread deterioration of much of the railroads' physical plant. In addition, regulatory practices made it difficult for railroads to abandon old and uneconomic lines or merge with other railroad companies, which resulted in excess capacity in the form of redundant facilities and excess competition. New technological innovations such as piggybacking and containerization were not introduced quickly until after the consolidation that occurred in the mid-1970's.

The Staggers Act called for a partial deregulation of the industry, allowing railroads greater flexibility in adjusting shipping rates to meet costs; this made railroads less susceptible to economic downturns. In addition, the legislation promoted greater restructuring of the industry with greater freedom for railroads to arrange mergers and acquisitions; form new, smaller railroads; abandon unprofitable sections of track; and coordinate transportation with other carriers, such as trucking and bargelines. The proliferation of small feeder lines, with which the larger railroads often subcontract for labor-intensive operations such as cargo pickup and delivery, is another result of the Staggers Act that has helped increase the efficiency of the industry. Deregulation brought about by the Staggers Act permitted contracts for the first time between railroads and shippers. Conditions could be specified in these contracts to allow railroads to schedule their resources more efficiently.

By emphasizing cooperative operations in which freight in trailers and containers is moved by rail, truck, and water transportation, railway companies have overcome the disadvantages of their fixed plant and increased their share of the freight hauling market. This is made possible in large part by the increased use of piggyback trains that carry trailers and containers on flat cars. New intermodal terminals can load and unload hundreds of these trailers and containers daily, using overhead cranes and sideloading equipment. Double stacking containers on a single flat car is an additional improvement in efficiency that has grown recently.

Changing technology also has helped the performance of the industry while at the same time changing skill requirements of jobs. Improvements in centralized traffic control have allowed railroads to move trains more efficiently over large portions of track from a single control station. Computer-aided dispatching, where the initial routing is done by computer, has been particularly helpful in reducing costs and delays. In addition, computers are used to provide switching instructions and handle car orders.

Computers also are used in many locomotives to direct control systems such as propulsion and braking, and regulate power flow to auxiliary operations. These computers have greatly reduced power needs, and have allowed for quicker diagnosing and repair of defects, which reduce downtime.

Centralized traffic control and computerized recordkeeping, with reduced labor requirements, have made an additional improvement in railroad transportation: the emergence of the "cabooseless" train. The elimination of cabooses from freight trains has reduced fuel needs and the costs of maintenance, service, and replacement of the cabooses.

Technological change also has had an effect on the size, durability, and mobility of freight cars. Modern freight cars are larger and more durable than in the past, leading to an increase in average freight car capacity from 67 tons in 1970 to 88 tons in 1989. Soaring fuel prices in the 1970's caused railroads to focus on energy conservation, resulting in the use of lighter weight materials in car construction, improved wheel suspensions, and better aerodynamics. For example, newer cars use roller bearings and journal pads rather than cotton waste to provide for improved wheel lubrication. As a result, they have fewer cases of overheated axles and thus cause fewer freight train derailments than the older freight cars.

Changes in technology also are increasing the efficiency of operation of modern classification yards where trains are disassembled and reassembled for different destinations. Improvements in yard design allow for faster joining of cars, and the increased use of computers in yard operations allows for automatic switching and centralized control of humping; braking and switching operations; inventory; origin and destination; and scheduling.

Maintenance of way operations also have experienced increased efficiency due to changing technology. Changes in rail design and maintenance equipment have reduced labor requirements in this area. For example, the increased use of continuous welded rail has reduced track smoothing requirements and cross tie replacements. More highly mechanized maintenance equipment, such as self-propelled machines that replace ties or those that tamp down track ballast also have reduced labor requirements. Computers also are used in maintenance operations to establish data banks for planning, managing, and monitoring track systems.[23]

Summary

Output per employee hour in the railroad industry grew at an average annual rate of 5.2 percent over the 1958–89 period. Multifactor productivity accounted for 3.5 percent of this gain, while the intermediate purchases effect accounted for 1.2 percent and the capital effect accounted for 0.5 percent.

Between the two periods of 1958–73 and 1973–89, the average annual rate of growth for output per employee hour increased slightly, from 5.6 percent to 6.4 percent. This relatively small rise obscures a substantial jump during the latter period when output per employee hour grew at an average annual rate of 3.0 percent in the 1973–79 period and surged to 8.8 percent between 1979 and 1989. This was due primarily to a jump in multifactor productivity from an average annual rate of 1.6 percent in the period 1973–79 to 5.5 percent in the following period, helped by increases in the capital effect and intermediate purchases effect.

Less regulation resulting from the Staggers Act and advances in technology are among the many factors contributing to this increase in multifactor productivity. Railroads have proven to be an efficient high volume long-haul mode of transportation, while the economy's shift from heavy manufacturing to service industries has led to a reduction in the transportation of raw materials.

In addition, the proximity of manufacturers to large urban markets has reduced the distances between the points of production and consumption that has allowed trucks, pipelines, and barges to make inroads for short and medium hauls in intercity freight ton-miles once dominated by railroads. Yet railroads still command the largest share, capturing 37 percent of ton-miles in 1989, and have regained some losses with innovative techniques such as piggyback service, and computer-assisted dispatching, traffic control, and recordkeeping, which have improved service and reliability and reduced costs. □

Footnotes

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[1] All average annual rates of growth presented in this article are based on the least squares trend of the logarithms of the index numbers.

[2] Railroad transportation in this study consists of Class I establishments engaged in line-haul railroad passenger and freight operations classified as industry number 4011 in the *1987 Standard Industrial Classification Manual.* In 1989, Class I railroad systems were defined by the Interstate Commerce Commission as railroads with at least $93.5 million in annual operating revenues. Switching and terminal companies are excluded. Excluding Amtrak, Class I railroads accounted for approximately 91 percent of industry revenues.

[3] The 1958–73 and 1973–89 periods are used to analyze the post-1973 productivity slowdown in the overall economy. For additional discussion of the economy-wide slowdown, see Edwin Dean and Kent Kunze, "Recent changes in the growth of U.S. multifactor productivity," *Monthly Labor Review,* May 1988, pp. 14–22..

[4] "Rail Traffic is Back on a Fast Track," *Business Week,* July 25, 1983, p. 31.

[5] David Pauly, "Green Light on the Rails," *Newsweek,* February 25, 1980, p. 63.

[6] *Annual Report to Congress,* Interstate Commerce Commission, various years.

[7] "Can the Rails Stay Lean and Profitable?" *Business Week,* May 7, 1984, p. 76.

[8] For the years between 1958 and 1984, freight ton-miles are adjusted for commodity mix with an index constructed using data from the Association of American Railroads publication, *Freight Commodity Statistics.* From 1984 on, proportions of ton-miles and revenue by length of haul and commodity are computed with Waybill sample data from the U.S. Interstate Commerce Commission and applied to total ton-miles and revenue from the *AAR Yearbook* to estimate universe data for 400 categories, grouped by four length-of-haul ranges, 50 commodity types and two shipping modes; the estimated ton-miles are aggregated with revenue shares to yield an index of weighted freight ton-miles.

[9] *Improving Railroad Productivity,* Final Report of the Task Force on Railroad Productivity to the National Commission on Productivity and the Council of Economic Advisers (Washington, DC), November 1973, p. 7.

[10] "Volume of U.S. Intercity Freight and Passenger Traffic," *Railroad Facts,* various editions.

[11] Jerry Flint, "Here Come the Truck Busters," *Forbes,* June 30, 1986.

[12] Data are from *Railroad Facts,* 1988 edition, Association of American Railroads.

[13] David Pauly, "The Railroads are Rolling Again," *Newsweek,* May 10, 1982, pp. 69–70.

[14] Data are from *Railroad Facts,* Association of American Railroads, various years.

[15] *Ibid.*

[16] *Employment, Hours and Earnings, United States, 1909-84,* Bulletin 1312-12 (Bureau of Labor Statistics, 1985) and *Supplement to Employment and Earnings* (Bureau of Labor Statistics, 1989).

[17] *Railroad Facts,* Association of American Railroads, 1972 and 1976 editions.

[18] Data are from "Statement A-300, Wage Statistics of Class I Freight Railroads in the United States," U.S. Interstate Commerce Commission, various years.

[19] This average is calculated from BLS multifactor productivity studies for manufacturing industries at the two-digit level for 1958 to 1988, the last year available.

[20] Data are from *Railroad Facts,* Association of American Railroads, various years.

[21] Tom Shedd, "The Little Engine that Does," *Technology Review,* February/March 1984, pp. 60-69.

[22] See footnote 19.

[23] For further examination of the changes in the technology of the railroad transportation industry, see "Railroad Transportation," *Technological Change and its Labor Impact in Four Industries,* Bulletin 2316 (Bureau of Labor Statistics, 1988).

APPENDIX: Multifactor productivity measurement

Methodology and data definitions

The following is a brief summary of the methods and data underlying the multifactor productivity measure for the railroad transportation industry. A technical note, describing the procedures and data in more detail, is available from the authors at the Office of Productivity and Technology, Bureau of Labor Statistics, Washington, DC 20212.

Output. The output measure for railroad transportation is based on a Tornqvist aggregation of weighted freight ton-miles and total passenger miles using operating expense data as weights. The sources for these data were the U.S. Interstate Commerce Commission and Association of American Railroads. For the period 1958–84, freight ton-miles were first adjusted for commodity mix. For 1984 on, a Tornqvist aggregate of freight ton-miles was first computed, as described in footnote 8.

For multifactor measures for individual industries, output is defined as total production, rather than the alternative of value added. For a value added measure, intermediate inputs are subtracted from total production. Consequently, an important difference between the multifactor productivity indexes BLS publishes for individual industries and for aggregate sectors of the economy is that the latter measures are constructed in a value-added framework. Intermediate transactions tend to cancel out for the major sectors of the economy. Intermediate inputs are much more important in production at the industry level.

Labor. Employee hour indexes, which represent the labor input, measure the aggregate number of employee hours. These hours are the sum of supervisory and nonsupervisory workers and were derived from data from the Interstate Commerce Commission and the Association of American Railroads. The labor input data are the same as data used in the previously published BLS output per hour series, but contain an adjustment to remove capitalized labor hours.

Capital. A broad definition of capital input, including equipment, structures, land, and inventories, is used to measure the flow of services derived from the stock of physical assets. Capitalized labor costs are included in capital input because labor time contributes to the production of output over a period of years, not just the current year. Financial assets are not included.

For productivity measurement, the appropriate concept of capital is "productive" capital stock, which represents the stock used to produce the capital services used in current production. To measure the productive stock, it is necessary, for each type of asset, to take account of the loss of efficiency of the asset as it ages. That is, assets of different vintages have to be aggregated. For the measures in this article, a concave form of the age/efficiency pattern (slower declining efficiency during the earlier years) is chosen.

In combining the various types of capital stock, the weights applied are implicit rental prices of each type of asset. They reflect the implicit rate of return to capital, the rate of depreciation, capital gains, and taxes. (For an extensive discussion of capital measurement, see *Trends in Multifactor Productivity*, 1948–81, Bulletin 2178, Bureau of Labor Statistics, 1983.)

Intermediate purchases. Intermediate purchases primarily include materials, fuels, electricity, and services the railroad industry purchased and consumed. Materials measured in real terms refer to items consumed or put into service during the year.

The cost of purchased services also are required for multifactor productivity measurement in a total output framework. Purchased services include equipment rental; intra-sectoral equipment rental is removed from the measure. Some examples of services are legal services, communications services, and machinery repair services.

Factor cost shares. Weights are needed to combine the indexes of the major inputs into a combined input measure. The weights for this industry are derived in two steps. First, an estimate of cost in current dollars for each input is derived, and the cost of each input is divided by the total cost of all inputs.

Conceptual framework

The multifactor productivity measure presented in this article is computed by dividing an index of output by an index of combined inputs of capital, labor, and intermediate purchases. The framework for measurement is a production function describing the relation of output and inputs and an index formula consistent with this production function.

The general form of the production function underlying the multifactor productivity measures is postulated as:

$$(1) \qquad Q(t) = Q\,(K(t), L(t), M(t), t)$$

where $Q(t)$ is total output, $K(t)$ is input of capital services, $L(t)$ is input of labor services, $M(t)$ is input of intermediate purchases, and t is time.

Differentiating equation (1) with respect to time and with some algebraic manipulations, the sources of growth equation is:

$$(2) \qquad \frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + w_k\frac{\dot{K}}{K} + w_l\frac{\dot{L}}{L} + w_m\frac{\dot{M}}{M}$$

where $\dot{A}/A$ is the rate of change of multifactor productivity, w_k is output elasticity (percentage change in output due to a 1-percent change in input) with respect to the capital input, w_l is output elasticity with respect to the labor input, and w_m is output elasticity with respect to the intermediate purchases input (the dot over a variable indicating the derivative of the variable with respect to time).

Equation (2) shows the rate of change of output as the sum of the rate of change of multifactor productivity and a weighted average of rates of change of capital, labor, and intermediate purchases inputs. Now, if competitive input and output markets are assumed, then each input is paid the value of its marginal product. The output elasticities in equation (2) can be replaced by factor income shares:

$$w_k = \frac{P_k K}{P_q Q}, \quad w_l = \frac{P_l L}{P_q Q}, \quad w_m = \frac{P_m M}{P_q Q}$$

where P_q is the price of output, and P_k, P_l, and P_m are the prices paid for the capital, labor, and intermediate purchases inputs. Furthermore, if constant returns to scale are assumed, then $w_k + w_l + w_m = 1$.

Equation (2) can be rewritten as:

$$(3) \qquad \frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - w_k\frac{\dot{K}}{K} - w_l\frac{\dot{L}}{L} - w_m\frac{\dot{M}}{M}$$

In this expression, the growth of multifactor productivity can be seen as a measure of economic progress; it measures the increase in output over and above the gain due to increases in inputs.

Equation (2) also can be transformed into the contribution equation that allows for an analysis of the change in output per hour. First subtract $\dot{L}/L$ from both sides of equation (2). Because the weights sum to one, apply the term $(w_k + w_l + w_m)$ to the $\dot{L}/L$ term inserted on the right hand side. Next, gather the terms with the same weight and derive the following equation:

$$(4) \qquad \frac{\dot{Q}}{Q} - \frac{\dot{L}}{L} = w_k\left[\frac{\dot{K}}{K} - \frac{\dot{L}}{L}\right] + w_m\left[\frac{\dot{M}}{M} - \frac{\dot{L}}{L}\right] + \frac{\dot{A}}{A}$$

The left side of equation (4) is the growth rate of output per hour. The terms in brackets are the rates of change in the capital-labor ratio and intermediate purchases-labor ratio. Thus, the rate of growth in output per hour can be decomposed into the weighted sums of changes in these ratios plus the change in multifactor productivity.

Equations (2), (3), and (4) describe aggregation in continuous form. The BLS multifactor indexes are constructed according to a Tornqvist formula that represents aggregation at discrete points in time and is consistent with a transcendental logarithmic production function. The rate of change in output or an input is calculated as the difference from one period to the next in the natural logarithms of the variables. For example, $\dot{Q}/Q$ is calculated as $\ln Q(t) - \ln Q(t\text{-}1)$. Indexes are constructed from the antilogarithms of this differential. The weights w_k, w_l, and w_m are calculated as the arithmetic averages of the respective shares in time periods t and t-1.