THE REINTERPRETATION OF AMERICAN ECONOMIC HISTORY

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14 RAILROADS AND AMERICAN ECONOMIC GROWTH

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To establish the proposition that railroads substantially altered the course of economic growth one must do more than provide information on the services of railroads. It must also be shown that substitutes for railroads could not (or would not) have performed essentially the same role. Writers who have held either that railroads were crucial to American economic growth or enormously accelerated this growth implicitly asserted that the economy of the nineteenth century lacked an effective alternative to the railroad and was incapable of producing one. This assertion is without empirical foundation; the range and potentiality of the supply of alternative opportunities is largely unexplored.

In the investigation of the incremental contribution of the railroad to economic growth it is useful to distinguish between the primary and the derived

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consequences of this innovation. The primary consequence of the railroad was its impact on the cost of transportation. If the cost of rail service had exceeded the cost of equivalent service by alternative forms of transportation over all routes and for all items, railroads would not have been built and all of the derived consequences would have been absent. The derived consequences or aspects of the innovation included changes in the spatial distribution of economic activity and in the mix of final products. They also included the demand for inputs, especially manufactured goods and human skills, required for railroad construction and operation as well as the effects of that construction and operation on human psychology, political power, and social organization. Those who have held that railroads were indispensable to American economic growth could have based their position either on the ground that the reduction in transportation costs attributable to railroads was large or on the ground that the derived consequences of railroads were crucial (even if the reduction in transportation costs were small) or on some combination of the two types of effects.

THE PRIMARY EFFECT OF RAILROADS

Summary of the Findings

In this study the investigation of the primary effect of railroads is limited to transportation costs connected with the distribution of agricultural products. Chapters II and III[1] discuss the increase in the production potential of the economy made possible by the availability of railroads for the transportation of such goods. The main conceptual device used in the analysis of this problem is the "social saving." The social saving in any given year is defined as the difference between the actual cost of shipping agricultural goods in that year and the alternative cost of shipping exactly the same collection of goods between exactly the same set of points without railroads.

This cost differential is in fact larger than the "true" social saving. Forcing the pattern of shipments in a nonrail situation to conform to the pattern that actually existed is equivalent to the imposition of a restraint on society's freedom to adjust to an alternative technological situation. If society had had to ship by water and wagon without the railroad it could have altered the geographical locus of agricultural production or shifted some productive factor out of agriculture altogether. Further, the sets of primary and secondary markets through which agricultural surpluses were distributed were surely influenced by conditions peculiar to rail transportation; in the absence of railroads some different cities would have entered these sets, and the relative importance of those remaining would have changed. Adjustments of this sort would have reduced the loss of national income occasioned by the absence of the railroad.

For analytical convenience the computation of the social saving is divided into two parts. Chapter II deals with the social saving in interregional distribution. In 1890 interregional distribution began with the farm surpluses concentrated in the eleven great primary markets of the Midwest. Over 80 per cent of the agricultural products that entered into interregional trade were shipped from the farms to these markets. The surpluses were then transshipped to some ninety secondary markets located in the East and South. After arriving in the secondary markets the commodities were distributed to retailers in the immediately surrounding territory or were exported.

The interregional social saving is computed for only one year—1890. The social saving per ton-mile was greater, however, in 1890 than in previous years; the tonnage of agricultural goods carried by railroads increased more rapidly than gross national product; and the average distance of an interregional haul increased over time. Hence both the absolute interregional social saving and that social saving relative to total national product was greater in 1890 than in previous years.

Only four commodities are included in the interregional computation, but these—wheat, corn, pork, and beef—accounted for over 90 per cent of the tonnage of interregional agricultural shipments. While it is possible to include all commodities in the computation, the increase in the accuracy of the estimate would not justify the effort required to do so.

Of the various forms of transportation in use in 1890, the most relevant alternative to railroads were waterways. All of the eleven primary markets were on navigable waterways.

[1] [This and subsequent references are to the book from which this selection is taken.—Editors' note.]

Lakes, canals, rivers, and coastal waters directly linked the primary markets with secondary markets receiving 90 per cent of the interregional shipments. Consequently it is possible to compute a first approximation to the interregional social saving by finding the difference between payments actually made by shippers of agricultural products and the payments they would have made to water carriers if shippers had sent the same commodities between the same points without railroads.

The total quantity of corn, wheat, pork, and beef shipped interregionally in 1890 was approximately equal to the local deficits of the trading regions of the East and South, plus net exports. The local net deficits of a trading area are computed by subtracting from the consumption requirements of the area its production and its changes in inventories. The average rail and water distances of an interregional shipment are estimated from a random sample of the routes (pairs of cities) that represent the population of connections between primary and secondary markets. The water and rail rates per ton-mile for the various commodities are based on representative rates that prevailed in 1890 over distances and routes approximating the average condition. The application of observed water rates to a tonnage greatly in excess of that actually carried by waterways is justified by evidence which indicates that water transportation was a constant or declining cost industry

These estimates of tonnages shipped, rates, and distances reveal that the actual cost of the interregional transportation of corn, wheat, pork, and beef in 1890 was $87,500,000 while the cost of transporting the same goods by water would have been only $49,200,000. In other words the first approximation of the interregional social saving is negative by about $38,000,000. This odd result is the consequence of the fact that direct payments to railroads included virtually all of the cost of interregional transportation, while direct payments to water carriers did not. In calculating the cost of shipping without the railroad one must account for six additional items of cost not included in payments to water carriers. These items are cargo losses in transit, transshipment costs, wagon haulage costs from water points to secondary markets not on waterways, capital costs not reflected in water rates, the cost resulting from the time lost when using a slow medium of transportation, and the cost of being unable to use water routes for five months out of the year.

The first four of the neglected costs can be estimated directly from available commercial data.

It is more difficult to determine the cost of the time lost in shipping by a slow medium of transportation and the cost of being unable to use water routes for about five months during each year. Such costs were not recorded in profit and loss statements, or publications of trade associations, or the decennial censuses, or any of the other normal sources of business information. Consequently they must be measured indirectly through a method that links the desired information to data which are available. The solution to the problem lies in the nexus between time and inventories. If entrepreneurs could replace goods the instant they were sold, they would, *ceteris paribus*, carry zero inventories. Inventories are necessary to bridge the gap of time required to deliver a commodity from its supply source to a given point. If, on the average, interregional shipments of agricultural commodities required a month more by water than by rail and if water routes were closed for five months out of each year, it would have been possible to compensate for the slowness of water transportation and the limited season of navigation by increasing inventories in secondary markets by an amount equal to one half of the annual receipts of these markets. Hence the cost of interruptions and time lost in water transportation is the 1890 cost of carrying such an inventory. The inventory cost comprises two elements: the foregone opportunity of investing the capital represented in the additional inventory (which is measured by the interest rate) and storage charges (which were published).

When account is taken of the neglected costs, the negative first approximation is transformed into a positive social saving of $73,000,000 (see Table 1). Since the actual

Table 1. The Social Saving in the Interregional Distribution of Agricultural Commodities

First approximation	$-38,000,000
Neglected cargo losses	6,000,000
Transshipping costs	16,000,000
Supplementary wagon haulage	23,000,000
Neglected capital costs	18,000,000
Additional inventory costs	48,000,000
Total	$ 73,000,000

1890 cost of shipping the specified commodities was approximately $88,000,000, the absence of the railroad would have almost doubled the cost of shipping agricultural commodities interregionally. It is therefore quite easy to see why the great bulk of agricultural commodities was actually sent to the East by rail, with water transportation used only over a few favorable routes.

While the interregional social saving is large compared to the actual transportation cost, it is quite small compared to annual output of the economy—just six tenths of one per cent of gross national product. Hence the computed social saving indicates that the availability of railroads for the interregional distribution of agricultural products represented only a relatively small addition to the production potential of the economy.

The estimation of the social saving is more complex in intraregional trade (movements from farms to primary markets) than in long-haul trade. Interregional transportation represented a movement between a relatively small number of points—eleven great collection centers in the Midwest and ninety secondary markets in the East and South. But intraregional transportation required the connection of an enormous number of locations. Considering each farm as a shipping point, there were not 11 but 4,565,000 interior shipping locations in 1890; the number of primary markets receiving farm commodities was well over a hundred. These points were not all connected by the railroad network, let alone by navigable waterways. The movement of commodities from farms to primary markets was never accomplished exclusively by water or by rail. Rather it involved a mixture of wagon and water or wagon and train services.

This is the crux of the intraregional problem. If the evaluation of the impact of interior railroads merely involved an analysis of the substitution of water for rail transportation, there would be no reason to expect a large social saving. Considered in isolation, boats were a relatively efficient substitute for the iron horse. However the absence of the railroad would have required greater utilization not only of water service but also of wagon service. It is the additional amount of very costly wagon transportation that would have been needed for the shipment of each ton of agricultural produce leaving the farm, which suggests that the social saving attributable to interior railroads probably exceeded the social saving of the more celebrated trunk lines.

The intraregional social saving—which covers twenty-seven commodities—is estimated in two ways. The first computation (estimate α) is a direct extension of the method used for long-distance shipments. It is the difference between the actual cost of shipping goods from farms to primary markets in 1890 and the cost of shipping in exactly the same pattern without the railroad. However in the intraregional case the assumption that pattern of shipments would have remained unchanged despite the absence of railroads implies that wagons would have carried certain agricultural commodities over distances in which wagon haulage costs greatly exceeded the market value of the produce. As a result estimate α introduces an upward bias that is too large to ignore.

It is possible to estimate the intraregional social saving by a method that reduces this upward bias. Without railroads the high cost of wagon transportation would have limited commercial agricultural production to areas of land lying within some unknown distance of navigable waterways. If the boundaries of this region of feasible commercial agriculture were known, the social saving could be broken into two parts: (1) the difference between the cost of shipping agricultural commodities from farms lying within the feasible region to primary markets with the railroad and the cost of shipping from the same region without the railroad (i.e., an α estimate for the feasible region), and (2) the loss in national product due to the decrease in the supply of agricultural land. The social saving estimated in this manner (estimate β) would be less than the previous measure since it allows for a partial adjustment to a nonrail situation. Moreover by disaggregating the social saving, estimate β provides additional information on the gestalt of the railroad's influence on the development of agriculture.

A first approximation of the α estimate can be computed on the basis of the relationship shown in equation 1:

$$\alpha = x\,[w(D_{fb} - D_{fr}) + (BD_{bp} - RD_{rp})] \quad (1)$$

where

x = the tonnage of agricultural produce shipped out of counties by rail
w = the average wagon rate per ton-mile
B = the average water rate per ton-mile

R = the average rail rate per ton-mile
D_{fb} = the average distance from a farm to a water shipping point
D_{fr} = the average distance from a farm to a rail shipping point
D_{bp} = the average distance from a water shipping point to a primary market
D_{rp} = the average distance from a rail shipping point to a primary market

The first term within the square bracket $w(D_{fb}—D_{fr})$ is the social saving per ton attributable to the reduction in wagon transportation; the second term $(BD_{bp} - RD_{rp})$ is the social saving per ton on payments to water and rail carriers. One of the surprising results is that only the first term is positive. In the absence of railroads wagon transportation costs would have increased by \$8.92 for each ton of agriculture produce that was shipped interregionally by rail. Payments to water carriers, however, would have been \$0.76 per ton less than the payments to railroads. In other words the entire first approximation of the α estimate of the social saving —which amounts to \$300,000,000—is attributable not to the fact that railroad charges were less than boat charges but to the fact that railroads reduced the amount of expensive wagon haulage that had to be combined with one of the low-cost forms of transportation.

To the \$300,000,000 obtained as the first approximation of α it is necessary to add certain indirect costs. In the long-haul case it was shown that the first approximation of the social saving omitted six charges of considerable importance. In the intraregional case, however, three of these items are covered by the first approximation. Wagon haulage costs are included in equation 1. Transshipment costs would have been no greater in the nonrail case than in the rail case. In both situations bulk would have been broken when the wagons reached the rail or water shipping points and no further transshipments would have been required between these points and the primary markets. Since all government expenditures on rivers and canals financed out of taxes rather than tolls were assigned to interregional agricultural shipments, their inclusion in the intraregional case would represent double counting.

Three indirect costs do have to be added to the first approximation of α. These are cargo losses, the cost of using a slow medium

Table 2. Preliminary α Estimate (In Millions of Dollars)

First approximation	300.2
Cargo losses	1.3
Cost of slow transportation	1.7
Cost of limited season of navigation	34.0
	337.2

of transportation, and the cost of the limited season of navigation. As is shown by Table 2 these neglected items amount to only \$37,000,000 which, when added to the first approximation, yields a preliminary α estimate of \$337,000,000 or 2.8 per cent of gross national product.

Execution of the β estimate requires a theoretical structure that will make it possible to infer the location of the boundary of feasible commercial agriculture from observed data. The theory of rent provides such a structure. The applicability of the theory of rent can be demonstrated by considering a hypothetical example. Suppose that Congress passed a law requiring all farmers in an area of land one mile wide and a hundred miles long, running westward from the Mississippi River through the state of Missouri along the 40th parallel, to send their products to market (St. Louis) by wagon and boat. Suppose that Congress also prohibited these farmers from responding to the law by changing the kinds or the proportions of the commodities that were produced for the market. Finally assume that the rate from all rail shipping points in the strip to St. Louis were exactly the same as Mississippi River rates from the 40th parallel to St. Louis.

Under these circumstances farms lying along the Mississippi would be unaffected by the law as would all farms that were just as far from the Mississippi River as from a rail shipping point. For all other farmers the law would result in a decline in the prices they received at the farm for their various commodities. Since the output of the farms in question is very small relative to total agricultural production, no output decisions on the part of these farmers could affect prices in primary markets. The reduction in prices paid at the farm and the corresponding fall in land values would be completely explained by the increased cost of transportation. The farther a farm was from the Mississippi, the greater would be the fall in the value of that farm land. At some distance from the

Mississippi the increase in the cost of wagon transportation would be such that land values would be zero. All land lying beyond this distance would have a negative price. Hence given the value of each plot of land prior to enactment, the quantities of agricultural commodities shipped to St. Louis from each of the farms, the wagon rates, and the distance from each farm to a rail shipping point, one could determine the boundary of feasible commercial agriculture after the enactment. The boundary would be located along a set of points at which the increase in the cost of transporting the market-bound output from a farm to a shipping point was exactly equal to the pre-enactment rental value of that land.

The hypothetical example indicates the basic procedure for establishing the boundaries of feasible commercial agriculture. There are, of course, differences between the hypothetical example and the actual problem. Thus transportation costs from rail and water shipping points to primary markets will not be the same for most farms. Since water costs were in fact generally less than rail costs, the boundary of feasible production is pushed out. Moreover when the whole country is considered, one cannot ignore the effect of the cessation of agricultural production in land beyond the feasible range on the level of prices in primary markets. Given the relative inelasticity of the demand for agricultural products, the reduction in production would have tended to raise prices in primary markets. The rise in prices would have led to a more intensive exploitation of agriculture within the feasible region, thus raising land values and increasing the burden of additional transportation costs that could have been borne by various farms. Hence calculation of the feasible range on the basis of the actual 1890 land values and shipment statistics tends to understate the limits of feasible commercial agriculture, and overstates the amount of land that would have remained unused in the absence of the railroad.

The theory of rent can also be used to estimate the loss in national income brought about by the decrease in the supply of land. The 1890 rental value of the lands lying beyond the region of feasible commercial agriculture represents the amount by which the annual product of labor and capital utilized on this territory exceeded the value of the product of the same amount of labor and capital when applied at the margin. If the land in the nonfeasible region had not been available, the labor and capital employed on it would have been utilized either at the intensive or extensive margin. Hence if the quantity of displaced factors had been small, the fall in the value of the output of these factors would have been equal to the annual rental value of the land they had previously occupied. This loss in national income could be estimated by decapitalizing the land values, i.e., multiplying land values by appropriate mortgage rates of interest. The amount of labor and capital employed on nonfeasible terrain, however, was quite large so that their displacement would have led to a fall in national income which exceeded the decapitalized value of the nonfeasible lands.

Unlike the α estimate, the β estimate of the social saving has downward as well as upward biases. While the upward biases may be stronger than the downward ones, these conflicting errors tend to cancel and make β a more acceptable approximation of the true social saving than α.

Data pertaining to the North Atlantic states indicate that in this region the boundary of feasible commercial agriculture would have been located between 40 and 50 airline miles from navigable waterways. The feasible boundary would probably have been closer to waterways in the North Atlantic region than in other sections of the nation. This is indicated by the fact that farm land values relative to outshipments were probably lower in this area than in all other areas except the Mountain states. At the same time the cost of wagon transportation was higher on the average in the North Atlantic region than outside it. Nevertheless in computing the β estimate it is assumed that in all regions of the country the boundary of feasible commercial agriculture fell 40 airline miles from a navigable waterway.

Table 3 shows that 76 per cent of all agricultural land by value was within 40 miles of natural waterways and canals actually in use in 1890 as well as abandoned canals that would have been in use in the absence of railroads. Table 3 shows also that the loss in national income due to the diminished supply of land would have been $154,000,000. The loss is not equally distributed. Close to three quarters of it is concentrated in the North Central states. Indeed more than half of the decline falls in just four states: Illinois, Iowa, Nebraska, and Kansas. This finding

Table 3. Loss in National Product Due to the Decrease in the Supply of Land (By Regions) (Thousands of Dollars)

	Value of Farm Land (1)	Value of Farm Land Beyond Feasible Region (2)	Col. 2 as a Per Cent of Col. 1 (3)	Loss in National Product (4)
North Atlantic	1,092,281	5,637	0.5	331
South Atlantic	557,399	117,866	21.1	8,452
North Central	4,931,607	1,441,952	29.2	110,476
South Central	738,333	158,866	21.5	14,191
Western	800,952	218,216	27.2	19,919
United States	8,120,572	1,942,537	23.9	153,572

does not support the frequently met contention that railroads were essential to the development of commercial agriculture in the prairies. Rather, the concentration of the loss in a compact space suggests that most of the productive agricultural land that fell outside of the feasible region could have been brought into it by a relatively small extension of the canal system.

Adding an α estimate for the feasible region to the loss in national income attributable to the diminished supply of land yields a first approximation of β amounting to $221,000,000 (see Table 4). The further addition of indirect charges of $27,000,000 results in a preliminary β estimate of $248,000,000 or 2.1 per cent of gross national product.

The preliminary estimates of the intraregional social saving are based on the severe assumption that in the absence of railroads all other aspects of technology would have been unaltered. It seems quite likely, however, that in the absence of railroads much of the capital and ingenuity that went into the perfection and spread of the railroad would have been turned toward the development of other cheap forms of land transportation. Under these circumstances it is possible that the internal combustion engine would have been developed years sooner than it actually was, thus permitting a reduction in transportation costs through the use of motor trucks.

Table 4. Preliminary β Estimates (In Millions of Dollars)

First approximation		220.9
Loss due to diminished supply of land	153.6	
α estimate for feasible region	67.3	
Cargo losses		1.0
Cost of slow transportation		0.7
Cost of the limited season of navigation		25.5
Total		248.1

While most such possibilities of a speed-up in the introduction and spread of alternative forms of transportation have not been sufficiently explored to permit meaningful quantification at the present time, there are two changes about which one can make fairly definitive statements. These are the extension of the existing systems of internal waterways and the improvement of common roads. Neither of these developments required new knowledge. They merely involved an extension of existing technology.

Figure 3.5 presents a system of canals that could have been built in the absence of railroads.[2] Although the thirty-seven canals and feeders proposed are only 5000 miles in length, their construction would have brought all but 7 per cent of agricultural land within 40 airline miles of a navigable waterway. Allowing for the projected waterways, the α estimate is reduced to $214,000,000 (1.8 per cent of gross national product) and the β estimate falls to $175,000,000 (1.5 per cent of gross national product).

Such an extension of internal water transportation is more than an historian's hallucination. The proposed canals would have been technologically, and, in the absence of railroads, economically, feasible.[3] Built across

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[2] [This map is on p. 93 of the book from which this selection is taken.—Editors' note.]

[3] Even if the amortization period of canals is put as low as twenty-five years, the reduction in β implies a social rate of return of 45 per cent on the investment in the proposed canals. If the reduction in the α estimate is used, the implied return is 76 per cent.

the highly favorable terrain of the North Central states and Texas, the average rise and fall per mile on the proposed system would have been 29 per cent less than the average rise and fall on those canals that were successful enough to survive railroad competition through 1890. The water supply along the routes would have been abundant. Even if worked at full capacity, no canal in the system would have required more than 65 per cent of the supply of water available to it. And in no case would the agricultural tonnage carried by a canal have exceeded one third of its capacity.

According to data published by the Bureau of Public Roads, the intraregional social saving could have been further reduced by the improvement of common roads. The Bureau estimated that improvements would have reduced the cost of wagon haulage to ten cents per ton-mile. This rate implies a boundary of feasible commercial agriculture located at an average of 80 airline miles from navigable waterways. The doubling of the distance of this boundary together with the construction of the proposed canals would have brought all but 4 per cent of agricultural land within the feasible region. Under these circumstances the value of α is \$141,000,000 or just 1.2 per cent of gross national product, while the value of β is \$117,000,000 or slightly less than one per cent of gross national product.

It thus appears that while railroads were more important in short-haul movements of agricultural products than in long-haul movements, the differences are not as great as is usually supposed. It is very likely that even in the absence of railroads the prairies would have been settled and exploited. Cheap transportation rather than railroads was the necessary condition for the emergence of the North Central states as the granary of the nation. The railroad was undoubtedly the most efficient form of transportation available to the farmers of the nation. But the combination of wagon and water transportation could have provided a relatively good substitute for the fabled iron horse.

Extension to all Commodities

Of course the social saving has been computed only for agricultural commodities. Ultimate conclusions regarding the significance of the primary effect of railroads must await the computation of the social saving on nonagricultural items. It has been suggested that one can obtain a reasonable estimate of the social saving in the transportation of all freight by multiplying the combined inter- and intraregional figures by four. The suggestion is rationalized on the ground that agricultural products probably accounted for about one fourth of the ton-miles of transportation services provided by railroads in 1890. The procedure implies a total social saving of 7.1 per cent of gross national product if the α estimate of the intraregional saving is used, (\$214,000,000 × 4)/\$12,000,000,000, or 6.3 per cent if the β estimate is used, (\$190,000,000 × 4)/\$12,000,000,000. Unfortunately this simple way of moving from the agricultural to the total social saving probably leads to so large an overestimate of the true total that the figure derived from the computation is useless for most purposes.

Data on the ton-miles of railroad service utilized in shipping nonagricultural commodities can hardly be classified as decisive information. As has been shown, comparisons of transportation costs based only on direct payments to railroad and water carriers for the ton-miles of service provided by each introduced negative components into the social saving in both the inter- and intraregional cases. The important elements in the agricultural social saving were the cost of supplementary wagon transportation, the cost of increasing inventories to compensate for interruptions in navigation, and other indirect charges. The cost of increasing inventories alone equaled 65 per cent of the interregional social saving, and supplementary wagon transportation similarly dominated the intraregional computation.

However there is no simple relationship between these all-important charges and the ton-miles of service actually provided by railroads. That is why it was not possible to estimate the intraregional social saving from the interregional one by extrapolating on the ton-miles of railroad service. Since intraregional shipments of agricultural products required only one half of the ton-miles of railroad service consumed by shipments between regions, such an extrapolation would have led to the erroneous conclusion that interior railroads were considerably less important than the trunk lines. The intraregional problem turned on the extent of the increase in supplementary wagon transportation that would have been required for each ton of freight shifted from railroads to boats. This increase could not have been derived from data on the amount of railroad service actually consumed.

Consequently no firm estimate of the social saving on nonagricultural items can be obtained without the detailed, protracted research required to determine such matters as: the geographic patterns of the production and consumption of nonagricultural goods, the extent to which the observed geographic patterns permitted the substitution of water for rail transportation, the amount of supplementary wagon transportation that would have been required in the nonrail case, the extent to which additions to the canal system would have permitted further reductions in the social saving through the substitution of water for wagon transportation, and the cost of the additional inventories of nonagricultural commodities required to compensate for the slowness and unavailability of water transportation during certain months of the year.

Such a study would probably reveal that the social saving per ton-mile of railroad service was lower for nonagricultural commodities than for agricultural commodities. This conclusion is suggested by the fact that products of mines dominated nonagricultural freight shipments in 1890. Coal alone accounted for 35 per cent of the nonagricultural tonnage. Iron and other ores brought the share to over 50 per cent.

Unlike agricultural commodities which were produced on farms occupying nearly a million square miles of land in over 2000 counties in every state of the nation, the production of coal was highly concentrated. Nine states accounted for about 90 per cent of all coal shipped from mines in 1890. And within these states production was further concentrated in a relative handful of counties. Forty-six counties shipped 76,000,000 tons —75 per cent of all the coal sent from the mines in the nine states. Moreover all of these counties were traversed by navigable rivers, canals actually constructed, or the proposed canals of Figure 3.5.[4] Consumption of coal was also geographically concentrated. Just fifteen cities—all on navigable waterways—received 43 per cent of all coal shipped from mines.

The production and consumption of iron ore were even more localized than coal. The *Report on Mineral Industries* prepared for the Eleventh Census reported that 73.11 per cent of the output of iron ore in 1890 was produced in four localities embracing a territory of barely 10,000 square miles (less than one third of 1 per cent of the territorial expanse of the United States). With respect to consumption, about 80 per cent of all iron ore was received by blast furnaces located in thirty-one counties.

Consequently the transportation pattern of minerals more nearly approximated the conditions of the *inter*regional than the *intra*-regional distribution of agricultural commodities. Products of mines were carried from a relatively small number of shipping locations to a similarly small number of receiving locations. Many of these shipping and receiving centers were directly linked to each other by waterways, and a limited extension of the canal system could have provided water connections for many of those points that did not already have them. It thus appears likely that only a small amount of additional wagon transportation would have been required for each ton of coal or ore shifted from railroads to waterways. Moreover the cost of increasing inventories to compensate for the slowness of and interruptions in water transportation would have been quite low. The total value of all products of mines in 1890 was well below the value of the agricultural commodities that entered intraregional trade. Hence the opportunity cost of the increased inventories of minerals would have been well below that found for agriculture. Additional storage costs, if any, would have been trivial. Minerals required neither very expensive cold storage facilities nor shelters. They were stored on open docks or fields.

Still another consideration militates against an extrapolation from the agricultural to the total social saving by use of data on the tons of goods carried by railroads or the ton-miles of service railroads provided. That is the fact that the $214,000,000 presented as the agricultural social saving already includes substantial elements of the social saving on nonagricultural items. Although all of the capital costs of the improvement of waterways were charged to agricultural commodities, most of this cost should be distributed among nonagricultural items. Similarly the wagon rates used in the computations assumed zero return hauls so that these rates cover most of the additional wagon cost that would have been incurred in shipping

[4] [See footnote 2.—Editors' note.]

nonagricultural commodities to farms. It is possible that as much as 35 per cent of the $214,000,000 should be assigned to the social saving induced by railroads in transporting products of mines, forests, and factories. If the "pure" agricultural social saving is about $140,000,000, then extrapolation to the total saving on the basis of ton-miles yields an α estimate of $560,000,000 or 4.7 per cent of gross national product. This result, taken together with the earlier comments on the upward bias of such an extrapolation, suggests that careful study will yield an α estimate for all commodities that is well below 5 per cent of gross national product.[5]

[5] For theoretical reasons previously discussed, the α concept of the social saving developed in chapter II can only provide an upper bound to the true social saving. Of course many upper bounds are possible; the task is to find the least upper bound compatible with theoretical and data limitations.

In applying the α concept of the social saving to all items carried by railroads in the year 1860, Albert Fishlow [*1*, chap. II] produced an estimate equal to about 5 per cent of gross national product. His estimate of the agricultural saving alone is about two and one-half per cent of gross national product. This result may seem to be in contradiction with the lower figures put forth here, especially since it is clear that the social saving increased over time.

The seeming contradiction is explained by the fact that in order to avoid the introduction of downward biases, Fishlow chose figures which, to quote him, made his estimate of the benefit of railroads "quite generous." Moreover, Fishlow did not take account of the reduction in water and wagon costs that could have been achieved by an extension of the canal system and improvements in common roads. Hence his computation of an α type estimate contains upward biases that put it well above a least upper bound.

Fishlow did attempt to compute an unbiased estimate of the social saving for agricultural commodities. This estimate is based on the assumption that the change in the value of agricultural land between 1850 and 1860 reflects the increase in national income attributable to railroads. If the circumstances of the situation examined by Fishlow approximated a partial equilibrium model, the assumption would be appropriate. (Cf. *2*, chap. IV) However when 10,000 miles of railroads are introduced and make supramarginal a land area equal to one third of that previously in use, conclusions derived from a partial equilibrium rent model do not apply. Under such conditions a general equilibrium model must be used. It can be shown that in a general equilibrium model the change in agricultural rent arising from a reduction in transport costs may be less than, greater than, or equal to the change in income originating in agriculture. Indeed it is entirely possible that the effect of railroads per se was to reduce land rents and that the observed rise is attributable entirely to the increase in capital and labor that took place between 1850 and 1860. Without information on elasticities of substitution one cannot disentangle the effect of the introduction of railroads from the effect of changes in other endowments.

Ultimate judgment of the primary effect of railroads on American economic growth must not only await the computation of the social saving on nonagricultural items; it must also await research on the likelihood that the existing scientific and technological knowledge would have allowed society to find more effective substitutes for the railroad than were examined here. The most interesting possibility is that in the absence of railroads, motor vehicles would have been introduced at an earlier date than they actually were. Another alternative is that inland navigation could have been kept open throughout the year. No less an engineer than R. H. Thurston pronounced as feasible a plan to keep the Erie Canal in operation during the winter by the application of artificially generated heat. He put the cost of such a scheme at $4800 per mile. At this rate a canal system of 10,000 miles could have been kept in operation throughout the year for less than two thirds of the inventory charges indicated for the compensation of interruptions in shipping agricultural products. The capacity of the economy to have adjusted to the absence of railroads cannot be fully ascertained without further research in the engineering and scientific literature of the nineteenth century.

THE DERIVED EFFECTS

To facilitate discussion the derived effects of railroads will be divided into two groups. The term "disembodied" will be applied to those consequences that followed from the saving in transportation costs per se and which would have been induced by any innovation that lowered transportation costs by approximately the amount attributed to railroads. The term "embodied" will be applied to those consequences that are attributable to the specific form in which railroads provided cheap transportation services.

The Relationship Between the Primary and Derived Effects

If it is assumed that the existence of railroads did not alter the stock of resources (e.g., the territory of the United States) then the combined inter- and intraregional (α) social saving of \$214,000,000 may be interpreted as an upper limit estimate of the amount by which railroads changed the production potential of the economy through a reduction in the cost of transporting agricultural products per se. As such, the social saving subsumes all of the disembodied effects of railroads. In particular, the social saving includes all of the increase in national income attributable to regional specialization in agriculture induced by the decline in shipping costs. Based as it is on actual outputs and shipments, the social saving represents the increased cost of transportation that the nation would have incurred if, in the absence of railroads, it attempted to maintain the pattern of production and distribution that actually existed in 1890. In other words by increasing its transportation bill on agricultural commodities by the amount of the social saving, the nation could have reaped all of the benefits of regional agricultural specialization and trade in the absence of railroads that it obtained with them. Hence the nation need not have been saddled with a geographic locus of production that reduced national income by more than the social saving.[6]

Of course the social saving may exclude some disembodied effects because the stock of resources was altered by the existence of railroads. It has been suggested that without railroads the nation's income potential would have fallen not merely because the rise in transportation costs would have diverted resources from other productive activities but also because the rise in costs would have reduced the rate of growth of population. A decline of potential income by \$214,000,000 with the 1890 population of 63,000,000 held constant implies a fall in per capita income of about \$3.40, i.e., a decline from about \$190 per capita to somewhat under \$187 per capita. The contention that the absence of railroads would have reduced population, then, is based on the hypothesis that the rate of growth of the American population was a positive function of the level of per capita income.

But the empirical support for this hypothesis is slender. The population of the United States grew at a higher rate between 1800 and 1850 than between 1850 and 1900, although both the level and rates of growth of per capita income were substantially higher in the latter period than in the former one. While the crude death rate fell during the nineteenth century, the crude birth rate fell even more rapidly. The consequence was a substantial decline in the American reproduction rate. Since the same pattern was evident in the industrialized countries of Europe, one might well argue that—at least with respect to natural reproduction—a decrease in per capita income induced by the absence of railroads would have increased rather than retarded the rate of population growth.

The exact relationship between the rate of immigration and the level of per capita income in both the United States and the countries of emigration has not yet been clearly established. Nevertheless even if it is granted that immigration into the United States was strongly and positively correlated with the differential in per capita income, it by no means follows that the absence of railroads would have reduced immigration. The social saving implies a fall in the average income level of the United States relative to the rest of the world because the social saving was computed on the assumption that only the United States would have been deprived of railroads. This assumption obviously biases the estimated social saving upward. Given the highly favorable situation of the United States with respect to navigable waterways, it is possible that in a situation in which all nations were deprived of railroads, income would have fallen less in the United States than in the rest of the world. Under these conditions the suggested relationship between migration and income levels implies that the absence of railroads would have increased American immigration. Indeed at this point one cannot rule out the possibility that in a world forced to rely on water and wagon

[6] The normal operation of the market would have generated forces that led the economy to a geographic distribution of agriculture consistent with the production frontier implied by the social saving. Whenever the exploitation of land became so intensive that the marginal product of labor and capital in the East fell below that in the West by more than the extra cost of transporting Western goods, the opportunity to increase profits would have directed resources to the more productive territories. As Kent Healy has pointed out, the shift of population into the West did not wait for the coming of the iron horse. By 1840 "before a single railroad had penetrated that area from the coast, some 40 per cent of the nation's people lived west of New York, Pennsylvania and the coastal states of the South" [*3*, pp. 130–131].

transportation, the American advantage would have been so great that the turn in its terms of trade with the rest of the world would have more than offset the increased cost of transportation.

It may be that the decisive feature of the railroad's contribution to economic growth was not that it allowed society to produce transportation service at a much lower cost than would otherwise have been possible but that it embodied low-cost service in a distinctive and uniquely important form. Although other mediums may also have been able to provide cheap transportation, the optimum geographic locus of activity in railroad and nonrailroad economies might have differed. In the absence of railroads the spatial distribution of population could have been altered in a manner unfavorable to economic growth. Under a changed dwelling pattern people given to extravagance might have received a larger share of the nation's income and thus retarded the accumulation of capital. Moreover changes in the climatic or physiographic environment of sections of the population could have altered the way in which they allocated their time between leisure and income-producing activities. Such embodied consequences would not be subsumed by the estimates of the social saving given above.

Leaving aside disputes regarding the role of climatic conditions in economic growth, the force of this line of argument is undermined by the findings of Chapter III. Chapter III reveals that in the absence of railroads, extensions of canals and improvements in wagon roads would have kept in use all but 4 per cent of the land actually worked in 1890. Such a limited reduction in the supply of land leaves scant scope for alterations in the geographic locus of economic activity—hardly enough scope to warrant the assumption that aggregate propensities for saving and leisure would have been significantly altered by railroad-induced changes in the physiographic or climatic environment of the population.

One could also argue that shifts in political circumstances and social institutions would have reduced the production potential of the economy beyond the level indicated by the social saving. Thus one might conjecture that railroads gave the North a crucial edge in the Civil War—that in the absence of railroads Northern generals would not have developed a strategy capable of defeating the insurrection. It might be further argued that a Southern victory would have saddled the nation with institutional arrangements—such as slavery—that inhibited the growth of productivity in agriculture and in other sectors of the economy. While the possibility of such a course of development may be worth investigating, the currently available evidence is too tenuous to make this conjecture an acceptable basis for believing that national income would have fallen by more than the social saving. In the light of current knowledge one could just as well argue that in the absence of railroads the West would have been more closely allied with the South and hence a military conflict would have been avoided. It could be further asserted that whatever the moral repugnance and inefficiencies of slavery, the consequences of its continuation would not have reduced economic growth as much as did the destruction of resources and the disruption of Southern agriculture caused by the Civil War. The axiom of indispensability cannot be resurrected on sociopolitical grounds without stronger evidence than is now available.

The "Take-Off" Thesis

Perhaps the most persuasive theory of embodied consequences is the one which holds that the inputs required for railroad construction induced the rise of industries, techniques, and skills essential to economic growth. According to Rostow [*4*] the growth of America's modern basic industrial sectors can be traced directly to the requirements for building and, especially, maintaining the railway system. Through their demand for coal, iron, machinery, and other manufactured goods railroads are supposed to have ushered the United States into a unique period of structural transformation that built modern growth into the economy. Rostow calls this period of radical transformation the "take-off into self-sustained growth." He holds that it occcurred between 1843 and 1860.

At first sight it might appear that available data support Rostow's contention that the eighteen years from 1843 through 1860 witnessed a unique structural transformation in the economy. According to data compiled by Robert Gallman the manufacturing share of commodity output increased from 21.1 per cent to 32.0 per cent over a period closely approximating the one singled out by Rostow

—1844 through 1859. While this shift towards manufacturing is impressive, averaging 3.6 percentage points per quinquennium, it is by no means unique. Gallman's series extends from 1839 to 1899. Of the 12 quinquennia included in the study, the manufacturing share increased by 3.0 points or more in half. However only one of these high-rate-of-change periods falls during Rostow's "take-off" years. Four belong to the epoch following the Civil War. Indeed the increase in the manufacturing share during the fifteen years from 1879 to 1894 exceeded that of 1844–1859 by 50 per cent.

Unfortunately there is no aggregate measure equivalent to Gallman's for the period prior to 1839. Available information indicates, however, that the decade of the 1820s may have witnessed a shift toward manufacturing comparable to that observed for the "take-off" years. This possibility is supported by the sharp decline in the home manufacture of consumer's goods and by the fact that urban population increased at twice the rate of the population as a whole. It is also buttressed by the rapid rise of the cotton textile and iron industries. The production of cotton cloth increased by over 500 per cent between 1820 and 1831. In the latter year the output of textiles was 40 per cent greater in America than it had been in Great Britain at the close of its "take-off." The growth of iron production outstripped that of cotton. The output of pig iron increased from 20,000 tons in 1820 to 192,000 tons in 1830, a rise of nearly 900 per cent. By 1830 iron, like textiles, was a substantial industry. In this branch of manufacture, too, American production in 1830 exceeded British production at the close of the era that Rostow designated as the British "take-off."

The development of cotton textiles and iron during the 1820s was so rapid that even if all other commodity-producing sectors grew no faster than the population, the manufacturing share of commodity output would have increased by 1.5 percentage points. And if manufacturing industries other than iron and cotton grew at three times the rate of population, the manufacturing share in commodity output would have risen by nearly 6 percentage points. Since the production of woolen textiles, carpets, paper, primary refined lead, sugar, and meat packing expanded from three to twenty-five times as rapidly as the population, the last alternative seems quite reasonable.

Available evidence thus tends to controvert the view that the period from 1843 to 1860 or any other eighteen-year period was one of unique structural change. Instead the data suggest a process of more or less continuous increase in the absolute and relative size of manufacturing extending from 1820—a good argument can be made for viewing 1807 as the starting date—through the end of the century.

The doubt attached to Rostow's dictum on the existence of very short periods of decisive structural transformation does not imply that historians must abandon the concept of "industrial revolution." One should not, however, require a revolution to have the swiftness of a coup d'etat. That manufacturing accounted for about 10 per cent of commodity production in 1820 and 48 per cent in 1889 is certainly evidence of a dramatic change in what was, by historical standards, hardly more than a moment of time. One need not arbitrarily abstract eighteen years out of a continuum to uphold the use of a venerable term.

If the growth of manufacturing during the two decades prior to the Civil War was not the crossing of the Rubicon pictured by Rostow, it was nonetheless large and impressive. The question of the relationship between this growth and the materials required for the construction and maintenance of railroads still remains.

The Iron Industry

Iron is the most frequently cited example of an industry whose rise was dominated by railroads. Hofstadter, Miller, and Aaron, for example, report that the railroad was "by far the biggest user of iron in the 1850s" and that by 1860 "more than half the iron produced annually in the United States went into rails" and associated items. Such reports, however, are not based on systematic measurements but on questionable inferences derived from isolated scraps of data. Casual procedures have led to the use of an index that grossly exaggerates the rail share, to the neglect of the rerolling process, and to a failure to consider the significance of the scrapping process.

The systematic reconstruction of the position of rails in the market for iron requires the development of a model of rail consumption that incorporates the largest number of available data fragments in an internally consistent manner. A model which meets this specification involves the following variables:

R_t = tons of rails consumed in year t
R_{dt} = tons of rails produced domestically in year t
R_{ft} = tons of rails imported in year t
R_{jt} = tons of worn rails scrapped in year t
M_t = track-miles of rails laid in year t; a track-mile of rails is defined as one half of the miles of rails in a mile of single track.
w_t = the average weight of rails in year t per track-mile of rails laid in year t; i.e., $w_t = R_t/M_t$
M_{st} = track-miles of rails used in the construction of new single track in year t
M_{et} = track-miles of rails used in the construction of new extra track in year t; extra track refers to second and third tracks on a given line, sidings, etc.
M_{rt} = track-miles of rails used in the replacement of worn out rails in year t
t = time measured in years

The model can be set forth as follows:

$$R_t = M_t w_t \tag{1}$$

$$R_{dt} = R_t - R_{ft} \tag{2}$$

$$M_t = M_{st} + M_{et} + M_{rt} \tag{3}$$

$$\frac{\sum_0^t M_{et}}{\sum_0^t M_{st}} = \alpha_t \tag{4}$$

$$M_{rt} = \beta_1 M_{t-1} + \beta_2 M_{t-2} + \dots + \beta_n M_{t-n} \quad \sum \beta_i = 1 \tag{5}$$

$$R_{jt} = \lambda_1 R_{t-1} + \lambda_2 R_{t-2} + \dots + \lambda_n R_{t-n} \tag{6}$$

Four of the variables in these equations, w_t, R_{ft}, M_{st}, and t, are determined exogenously. The first three equations are definitional identities. The fourth equation states that the ratio of total extra track to total single track increased linearly with time. The fifth and sixth equations state that the amount of rails replaced in any given year and the amount of scrap generated by the replacement process were functions of the rails laid in all previous years. The parameters of the fifth and sixth equations were in turn determined by the assumption that rail life was a stochastic process that could be described by a log-normal distribution with a mean of 10.5 years and a standard deviation of 3 years. This hypothesis is strongly supported by data on rail life published in the Tenth Census. Moreover the estimates produced by the model proved to be relatively insensitive to various other assumptions, consistent with the census data, regarding the parameters and form of the distribution of rail life.

Various tests indicate a high degree of conformity between estimates produced by the model and available data fragments. Thus the model is within one percentage point in predicting the iron industry's "rule-of-thumb" for the share of the track replaced during a year, within 8 per cent of the reported ratio of rails required for new consumption to total rail consumption for 1856, and within 3 per cent in predicting the average weight of rails on main track at the end of 1869. The estimates of rail consumption generated by the model for the years 1849 through 1869 are also consistent with the consumption series published by the American Iron and Steel Association.

The model does more than conform to alternative estimates. It reveals the substantial magnitude of two previously neglected processes. The first of these is replacements. The model shows that replacements became an important part of total rail consumption early in the 1840s. In fifteen of the thirty years following 1839 replacements represented more than 40 per cent of total rail requirements; in five of these years replacements accounted for more than two thirds of requirements. Moreover the variability of rail life acted like a moving average, smoothing the peaks and troughs of new construction to produce a fairly continuous and predictable increase in the amount of rails required for replacements. Hence the use of rails gave rise to a mechanism that made the demand for the product considerably more stable than it would have been if demand depended only on new construction.

The model also reveals that the scrap metal generated in the replacement process rapidly became a significant part of the supply of crude iron. The availability of scrap in turn spurred the development of the rerolling of old rails. As early as 1849 one fourth of all domestically produced rails were rerolled from discarded ones. By 1860 rerolling accounted for nearly 60 per cent of domestic production. Thus although replacements rapidly became a substantial part of total rail consumption, replacement demand had little effect on the growth of blast furnaces. Replacements generated their own supply of crude iron. And scrapped rails that were not rerolled supplanted pig iron as an input in the production of other products. Consequently the net addition to pig iron production required for rails between 1840 and 1860 amounted to less than 5 per cent of the output of blast furnaces.

The significance of railroads appears somewhat greater if account is taken of all forms of railroad consumption of iron from all sectors of the iron industry. On this basis railroads accounted for an average of 17 per cent of total iron production during the two decades in question. While it is true that the railroad share rose to 25 per cent in the final six years of the period, what is more germane to the evaluation of the Rostow thesis is the fact that during the quinquennium ending in 1849, railroad consumption of domestic crude iron was just 10 per cent of the total. Even if there had been no production of rails or railroad equipment whatsoever, the domestic crude iron consumed by the iron industry would have reached an average of 700,000 tons in the second quinquennium. The rise over the previous quinquennium would still have been 338,000 tons—an increase of 94 per cent as opposed to the 99 per cent rise that took place with the railroads. Clearly railroad consumption of iron had little effect on the rate of growth of the industry during the crucial first decade of Rostow's "take-off" period; the new high level of production attained by the iron industry during 1845–1849 did not depend on the railroad market.

The strongest statement that can be made in support of Rostow's thesis is that the demand for railroad iron played an increasingly important role during the fifties in maintaining the *previous* level of production when the demand for other items sagged. Otherwise one could just as well argue that nails rather than rails triggered the 1845–1849 leap in iron production. Indeed in 1849 the domestic production of nails probably exceeded that of rails by over 100 per cent.

Other Industries

The position of railroads in the market for the products of other industries designated by Rostow appears equally limited. In the case of coal, direct consumption during the two decades ending in 1860 was negligible. While the pace of experimentation increased in the fifties, few coal-burning locomotives were in regular service until the last two years of the decade. Wood was the fuel that powered the land leviathan. On the second stage of demand the picture changes slightly. The iron industry was a major consumer of coal. It required 8,300,000 tons of this fuel to manufacture all of the domestic rails produced during 1840–1860 and 4,300,000 tons to manufacture the iron required for rail fastenings, locomotives, and cars. All told, railroads consumed 12,600,000 tons of coal through their purchases of rails and other products made of iron. Over the same two-decade period total coal production was 211,700,000 tons. Thus coal consumed by railroads through consumption of iron products represented less than 6 per cent of the coal produced during the "take-off."

Railroads exercised a still more modest influence on the development of the modern lumber industry—this despite the huge quantities of wood consumed as fuel and in the construction of track. The paradox is partly explained by the fact that wood burned in the fire boxes of railroad engines was not lumber. A similar consideration is involved in connection with the railroads' consumption of cross ties. Throughout the nineteenth century railroad men believed that ties hewed by axe would resist decay better than sawed ties. Consequently lumber mills supplied ties amounting to only 450,000,000 feet B. M. during the "take-off" years. This was less than one half of one per cent of all lumber production. When the lumber required for car construction is included, the figure rises by half a point to 0.96 per cent. The modest position of railroads in the market for lumber products emphasizes the scale of lumber consumption by other sectors of the economy.

The share of the output of the transportation equipment industry purchased by railroads is also surprising. From 1850 through 1860 some 26,300 miles of new track were laid. During the same time, about 3,800 locomotives, 6,400 passenger and baggage cars, and 88,600 freight cars were constructed. Yet value added in the construction of railroad equipment in 1859 was only $12,000,000 or 25.4 per cent of value added by all transportation equipment. The output of vehicles drawn by animals was still almost twice as great as the output of equipment for the celebrated iron horse.

As for other types of machinery, railroads directly consumed less than 1 per cent. Again the situation does not change appreciably if indirect purchases at more remote levels of production are considered. When the share of machinery consumed by the lumber, iron, and machine industries attributable to the railroad is added to that of transportation equipment, the railroad still only accounts for about 6 per cent of machine production in 1859.

The transportation equipment, rolling mill, blast furnace, lumber, and machinery industries were the main suppliers of the manufactured goods purchased by railroads. Using value added as a measure, railroads purchased slightly less than 11 per cent of the combined output of the group in 1859. Since these industries accounted for 26 per cent of all manufacturing in that year, railroad purchases from them amounted to a mere 2.8 per cent of the total output of the manufacturing sector. Railroad purchases from all the other manufacturing industries raise the last figure to just 3.9 per cent. This amount hardly seems large enough to attribute the rapid growth of manufacturing during the last two ante-bellum decades to the "requirements for building and, especially, for maintaining substantial railway systems."

IMPLICATIONS FOR THE THEORY OF ECONOMIC GROWTH

The most important implication of this study is that no single innovation was vital for economic growth during the nineteenth century. Certainly if any innovation had title to such distinction it was the railroad. Yet despite its dramatically rapid and massive growth over a period of a half century, despite its eventual ubiquity in inland transportation, despite its devouring appetite for capital, despite its power to determine the outcome of commercial (and sometimes political) competition, the railroad did not make an overwhelming contribution to the production potential of the economy.

Economic growth was a consequence of the knowledge acquired in the course of the scientific revolution of the seventeenth, eighteenth, and nineteenth centuries. This knowledge provided the basis for a multiplicity of innovations that were applied to a broad spectrum of economic processes. The effectiveness of the new innovations was facilitated by political, geographic, and social rearrangements. All of these developments began before the birth of the railroad and the railroad was not needed for the transformation in economic life that followed from them.

The English Industrial Revolution did not wait for the coming of the iron horse. It was virtually completed before the first railroad was built. The millions that migrated to the American West before 1840 did not do so because they anticipated the windfall gains that the incipient competitor to waterways would bring. They moved to the West because even without railroads the growth of population and capital in Europe and the eastern portions of the United States made investments in the new lands more profitable than a comparable investment in the old ones. It was the heavy demand for nails, stoves, and various forms of cast iron rather than rails that elicited the leap in the American production of pig iron during the 1840s. The acceleration in urbanization that paralleled the rapid expansion of industry and commerce also preceded the railroads. And the large market for their products that Eastern textile firms found in upstate New York before 1835, and in territories further to the West before 1840, were reached by waterways and wagons.

The railroad—like the improvement of the steam engine, the mechanization of textile production, the development of refrigeration, or the introduction of the puddling and rolling process—was a part rather than a condition for the Industrial Revolution. Along with a series of other inventions, it emerged out of a widespread effort to apply scientific and technological knowledge to the improvement of products and the reduction of costs. This search for new methods was distinguished not only by the vigor with which it was pursued but also by the fact that it frequently yielded more than one solution. Arkwright and Hargreaves separately invented different spinning machines. Bessemer and the Siemens brothers found alternative ways of producing cheap steel. Watt relied on the sun and planet while Pickard used the crank and connecting rod to transform reciprocating into rotary motion. In transportation, too, the search for cheap sources of service yielded more than one solution.

If correct, this stress on the multiplicity of solutions along a wide front of production problems clashes with the notion that economic growth can be explained by leading sector concepts. Such concepts suggest that the search for, or discovery of, new solutions was limited to narrowly selected industries and that growth in other sectors had to wait for breakthroughs in the anointed ones. It is the hero theory of history applied to things rather than persons. In the American case virtually every two-digit manufacturing industry was experiencing rapid growth during the last two decades of the ante-bellum era. The observed growth was not induced by a single technological change that linked all manufacturing enterprises to the railroad, like a string of freight cars attached to a locomotive. Rather it was induced by a multiplicity of innovations in these industries coupled with a series of cost saving developments in transportation as well as developments on the demand side that served to expand markets (accelerated population growth in Europe, rapid urbanization, etc.).

This view makes growth the consequence not of one or a few lucky discoveries but of a broad supply of opportunity created by the body of knowledge accumulated over all preceding centuries. Luck may have determined which breakthroughs came first or which of the many possible solutions was seized by society. It may have affected the timing of particular innovations and the relative rates of growth of particular industries. Chance factors no doubt affected the precise path that growth followed. But chance operated within the set of opportunities created by the scientific revolution.

The theory of overwhelming, singular innovations has probably been fostered by the modus operandi of competitive economies. Under competition firms tend to choose the most efficient of the available methods of production. Alternatives that could perform the same functions at somewhat greater cost are discarded and escape public attention. The absence from view of slightly less efficient processes creates the illusion that no alternatives exist. This illusion is heightened by the fact that the chosen process has an optimal set of institutional arrangements, appurtenances, and personnel. Given the fact that the operation of the economy has adjusted to the selected process, business success will frequently depend on the speed and effectiveness with which firms adopt these supplementary arrangements. Thus accessories of the innovation become *conditionally* indispensable and add to the impression of the massive and overwhelming character of the basic selection. Yet these accessories—in the case of railroads they were such things as automatic coupling devices, block signals, fast freight services, time tables, types of rails, varieties of freight cars, geographic locations—usually make no independent contribution. They are merely the conditions under which the primary innovation operates and through which it imparts its contribution to economic growth.

Emphasis on the multiplicity of opportunities does not mean that the particular nature of the solutions society selects are without significance. Cheap inland transportation was a necessary condition for economic growth. Satisfaction of this condition did not entail a specific form of transportation. The form by which the condition was in fact satisfied did effect, however, particular features of the observed growth process. It determined the names of some of the chief decision makers, it added new products to the bill of output, and it modified the location of economic activity. Changes of this sort defined a particular path of economic growth, a path distinct from that which would have been followed if society had embraced some other solution. In other words the fact that the condition of cheap transportation was satisfied by one innovation rather than another determined, not whether growth would take place, but which of many possible growth paths would be followed.

REFERENCES

1. Albert Fishlow, *American Railroads and the Transformation of the Ante-Bellum Economy*, Cambridge, Harvard University Press, 1965.
2. Robert W. Fogel, *The Union Pacific Railroad: A Case in Premature Enterprise*, Baltimore, Johns Hopkins Press, 1960. (The chapter referred to is reprinted below as essay 31.)
3. Kent T. Healy, "American Transportation Before the Civil War," Harold F. Williamson, ed., *The Growth of the American Economy*, Englewood Cliffs, N.J., Prentice-Hall, 1951, pp. 116–132.
4. Walt Whitman Rostow, *The Stages of Economic Growth*, Cambridge, University Press, 1960.