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STUDIES IN INVESTMENT BEHAVIOR*

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1 GENERAL ASPECTS OF INVESTMENT

The rate of change in the stock of real fixed capital is one of the less satisfactorily explained processes in present economic thinking. Investment shows extreme fluctuations over time and, to a great extent, fluctuations that do not fit into a simple theoretical framework. In addition there are difficulties in concept and measurement. One of the prime tasks ahead, however, seems to be to pry into the actual investment process from a largely empirical point of view. We must learn more facts about investment and try to use them to establish a sound theory of investment among the embarrassing number of candidates.

As a practical matter in business cycle control, it has often proved more satisfactory for the state to adopt counter-cyclical measures to maintain an even flow of investment rather than an even flow of consumption, speaking roughly of the two as exhausting national production. In many cases it is not politically feasible or desirable to try to influence personal, household expenditures in a predetermined fashion, but direct state investment or state support of private investment is a workable alternative only if public authorities know such things as the correct timing of their action, the correct magnitudes involved, and the underlying factors that determine investment decisions. Those among us who would attempt to minimize the amount of direct state influence in economic activities must concentrate on the last mentioned item, the underlying factors, in order that they can recommend the appropriate indirect state action to influence investment.

A popular modern view of economic life holds that patterns of investment behavior are volatile as compared with other types of economic behavior, especially household consumption and savings. The factual evidence of the interwar period gives strong support to this hypothesis, but some would interpret the postwar patterns of consumer spending and saving as evidence that contradicts the assumption of relative stability in the household sector of the economy. While we must recognize the postwar spending spree as evidence, we may very well reserve judgment on the

* The author is indebted to Arlene Shapiro for research assistance and computational work on this study and to H. Irving Forman for the preparation of the charts.

basis that we have observed a very temporary and special event that can be explained in terms of war abstinence, war finance, demobilization, and other factors that tend to disappear as normalcy is approached. On the other hand, normalcy may have little effect on the volatility of investment behavior because of the nature of the decision-making process.

The carrying out of an investment act takes time, in many cases several months or even years, and contracts or other types of commitment are often involved. For these reasons, and others, it has become popular for the government and some private agencies to conduct investment surveys, asking entrepreneurs, in advance, the volume of their intended investment expenditures during a specific period. Potentially, these surveys could be scientifically organized so as to throw some light on the reasons for investment decisions and thus enable the government to forecast the effect of some of its manifold economic policies upon investment. Unfortunately, this type of material is not yet available on a satisfactory basis. But the state surveys of investment intentions are so organized as to throw some light on the timing and magnitude of forthcoming investment.

The surveys in this country, carried out by the Securities and Exchange Commission and the Department of Commerce, ask a sample of business firms how much they intend to spend (gross) on capital goods one quarter in advance and two quarters in advance. It is evident that there are two forecasts of each quarter, 3 months in advance and 6 months in advance. From the fourth quarter of 1945 through the first quarter of 1949, the average absolute value of the percentage error between forecast and observation was 9.3 per cent for the first estimate (two quarters ahead) of total investment, and from the third quarter of 1945 through the first quarter of 1949, it was 5.5 per cent for the second estimate (one quarter ahead). If total investment is split into categories (manufacturing and mining, railroads, electric and gas utilities, other transportation, commercial, and miscellaneous) the errors become much larger and maintain the same property that the second estimate is more accurate than the first.

	ERROR OF	
	First Estimate	Second Estimate
Manufacturing and mining	10.8%	7.1%
Railroads	26.7	19.5
Electric and gas utilities	7.9	7.0
Other transportation, commercial and miscellaneous	15.7	12.4
Total	9.3	5.5

Source: Press releases of the Securities and Exchange Commission.

The surveys have yet to weather a major cyclical turn.[1] Add to this their

[1] The mild downturn in investment from the fourth quarter of 1948 to the first quarter of 1949 was, however, reflected in both the first and second forecasts. See the table in the text below.

recorded performance in the contagious postwar boom and it does not become certain that they will serve as a solution, in their present form, to the forecasting problem. The above figures do show something also about the extreme volatility of investment.

The size of the error is substantial. The error may be a random variable that is part of the structure of the economic system; then we can do little more than recognize it in forecasting and try to measure its probable variability. This view fits in with much of modern business cycle theory. On the other hand, the error may have some nonrandom, systematic components which, if discovered, would enable forecasters to reduce its size. An analysis of the time series of the quarterly errors since 1945 does reveal some nonrandom behavior. The great preponderance of ratios of estimates to observation are less than unity. There also appear to be some systematic differences among the errors for the several industrial sectors.

INVESTMENT IN PLANT AND EQUIPMENT, SURVEYS OF THE SEC AND USDC (millions of current dollars)

Year and Quarter	First Estimate Z_1	Second Estimate Z_2	Observation Z_3	$\frac{Z_1}{Z_3}$	$\frac{Z_2}{Z_3}$
1945					
III		1,640	1,650		0.99
IV	1,780	1,870	2,300	0.77	0.81
1946					
I	2,090	2,120	2,200	0.95	0.96
II	2,390	2,890	2,790	0.86	1.04
III	3,200	3,300	3,310	0.97	1.00
IV	3,400	3,650	3,730	0.91	0.98
1947					
I	3,640	3,440	3,160	1.15	1.09
II	3,560	3,670	3,940	0.90	0.93
III	3,770	4,070	4,140	0.91	0.98
IV	4,020	4,440	4,940	0.81	0.90
1948					
I	4,100	4,480	4,170	0.98	1.07
II	4,780	4,690	4,820	0.99	0.97
III	4,570	4,950	4,830	0.95	1.02
IV	4,690	5,010	5,410	0.87	0.93
1949					
I	4,390	4,680	4,460	0.98	1.05

It may be that a single quarter is too short a period in which to forecast anything as lumpy and discontinuous as the average investment outlay. The surveys are conducted also on an annual basis, asking business firms about their prospective capital expenditures during a future calendar year. This procedure has the advantage, in terms of accuracy of realization, of evening out expenditures over a longer time span and the disadvantage of taking a look further into the future. The 1947 annual forecast for all sectors covered was \$14 billion; the 1948 annual forecast, \$18.7 billion.

These are to be compared with realized expenditures of $16.2 billion in 1947 and $19.2 billion in 1948; thus the errors were of the order of 14 and 3 per cent respectively.[2]

The Canadian government conducts an annual investment survey. In the closing months of a year it asks business firms to state their intended outlays for plant and equipment during the following twelve months. Canadian survey estimates of capital expenditures for manufacturing, primary industry, and utilities were 75.1 per cent of realized expenditures in 1946; survey estimates for the same industries, plus construction, commercial, merchandising, and service industries were 99.4 per cent of realized expenditures in 1947; and survey estimates for the same industries as in 1947 were 94.9 per cent of realized expenditures in 1948. The Canadian surveys are not small samples, but cover firms spending more than 60 per cent of the outlays for private capital formation.[3] In the conditions of the postwar boom, the Canadian government wisely carried out another survey on the production of basic and building materials as a check upon the supply side of the investment market. A combination of the two surveys was much more helpful than a survey of investment intentions alone in formulating government policy.

The two latest Canadian surveys, in contrast to the first, show some promise for forecasting investment, but they have not yet had the experience of a sizable turning point in economic activity and show wider errors in industry components than in national totals. Like the United States surveys, they do not answer the 'whys?' associated with investment decisions.

It is the purpose of this paper to attempt to go more deeply into the nature of investment decisions and to describe the results of empirical investigations the author has recently carried out. In the remainder of this section we shall dwell on the general theory of investment and some of the empirical studies already published.

In terms of the accounting records of business firms, we must first distinguish between those expenditures on real property that are wholly charged to current operating expenses appearing on the profit and loss or income statement, and those expenditures on real property that are only partly charged to current operating expenses. The first category is usually recorded as maintenance and repair expenditures, the second as capital expenditures. The portion of capital expenditures that is written off against

[2] See Melville J. Ulmer, Plant and Equipment Programs and Sales Expectations in 1949, *Survey of Current Business,* April 1949, pp. 9-13.

[3] For documentation see Department of Reconstruction and Supply: *Forecast of 1947 Investment by Canadian Business* and *Private and Public Investment in Canada;* Department of Trade and Commerce: *Private and Public Investment in Canada* (Ottawa, 1947, 1948, and 1949 respectively).

the revenues of a single accounting period is usually called depreciation expense. Our task is to provide an explanation of capital expenditures in terms of underlying motivational factors.

The most sophisticated and general view of economic activity presents a single, multivariate process that accounts simultaneously for such diverse things as capital expenditures, maintenance expenses, wage payments, raw material expenditures, and even household expenditures. At an early stage of scientific work, however, there are certain advantages in introducing a dichotomy between short-run and long-run decisions. In following this approach, we shall assume that entrepreneurs make two types of decisions, one type involving short-run, day to day fluctuations in variables associated with current expense (maintenance, manpower, raw materials, etc.); and another type involving longer-run fluctuations in variables associated with capital expenditures (durable equipment and plant). The short-run problem for the business firm may be viewed as the organization of the currently variable factors of production in the most profitable combination for the existing capital structure. The longer-run problem may be viewed as the choice of the most profitable capital structure. The entrepreneur, contemplating a capital expenditure, will in principle forecast future expenses arising from an economical combination of short-run factors of production applied to the new capital goods over the expected lifetime of the latter. Expected future receipts minus expected future expenses, properly discounted to the present, will show the expected future gain to be realized on the contemplated capital expenditure. The decision to make the capital outlay or not will hinge upon a comparison between the size of the outlay and the expected gain. This very general approach can be empirically described by a variety of mathematical expressions. Moreover, several refinements and elaborations can be introduced; some variables are involved that are not available in the factual records; and there are many 'irrational' types of investment decisions. In case the discounting factor for the expected future gain includes a pure interest rate as well as compensation for risk, interest charges should not enter as a cost item subtracted from anticipated receipts. In terms of accounting conventions, the expected future gain is identified with expected future 'operating profits'. If the discount factor is composed solely of subjective risk and interest charges are not subtracted from anticipated receipts, we may compare the ratio between expected incremental operating profits and the outlay with the interest rate for new capital. When the discounted future rate of return exceeds the interest rate, the entrepreneur should invest. The same phenomena can be expressed in other forms.

A simple profit calculus may be quite inadequate to express an entrepreneur's investment decision. He may be interested in other things besides profit; e.g., the size of his firm, its leadership position in the industry or wider circles, or its modern character. Thus the size, age, and composition of the present capital structure may also be important variables in investment planning. The size of the present capital stock may also enter in another way. The rate of return on old (existing) capital as well as that on new capital should be compared with the interest rate. In many cases it may seem unnecessary to embark upon new capital creating ventures because the same rate of return can be obtained from the existing capital stock. The rate of return on existing capital may enter in yet another way as one of the least unreliable indicators of the expected gain on new capital. Often an investor knows little about the real performance of new capital, and the expected profit calculus is subject to an extremely large error, rendering this calculus inadequate for explaining motivations in situations of uncertainty.

The purely rational profit calculus deals with marginal expected profits, marginal with respect to the variation of the capital stock. Marginal profit is not easily estimated, except for some individual investment decisions, and objective calculations of this variable are available, if at all, only in the internal records of business firms. Our best substitute for marginal profit is current profit on existing capital. The time-rate-of-change and acceleration of realized profits also may be important in judging the future course of profits. In addition to operating profit and its past history, such variables as interest rates, the stock of capital, and the age of capital may determine investment according to the above considerations.

The 'perfectly rational' business man operating in a smoothly functioning capital market should, in principle, have no preference for using his own rather than borrowed capital funds, but in actual experience probably will; thus we frequently encounter the view today that entrepreneurs prefer to use internal funds for investment. This is undoubtedly conditioned to a large extent by the institutional environment. To the extent that a preference for internal financing of investment exists, it should strengthen the role of currently realized profits in determining investment decisions. Other funds such as past accumulations of working capital, current nonoperating profits, and the deferment of current dividends also may have some importance. Accordingly, the influence of interest rates may be lessened.

Many cost items — wages, raw materials, maintenance (nonwage), etc. — affect operating profits. When the unit costs of noncapital items (labor and raw materials) become large relative to the unit costs of capital items (maintaining plant and equipment), it pays the entrepreneur to consider investment in capital instruments. The expected marginal profit calculus should, of course, bring out all such cost-saving potentialities, but the empirical investigator, working with realized profits, may find it useful to consider relative unit costs as a further important variable showing the desirability of substituting capital for other factors of production. This and other reasons may cause investment to depend on technological change.

Among past empirical studies of investment behavior, three are chosen for comment in order to give some indication of the existing state of knowledge on the subject. The pioneering econometric study of Tinbergen[4] is one of the most comprehensive and, in many respects, has stood the test of time. It covers the United Kingdom, France, Germany, Sweden, the United States; pre- and post-World War I data; and such diverse magnitudes as aggregate investment, housing, and railroad investment. In a broad sense more recent econometric studies are merely refinements as to methods of statistical inference, form of the mathematical relationships, and estimation of the basic series. Tinbergen's study is based entirely upon classical multiple correlation techniques whereby each relationship of an equation system is considered from a statistical point of view in isolation. Since there are definite lags between his explanatory variables and investment expenditures, his statistical techniques may not be as unsuitable for the study of investment as for other types of economic behavior. However, for aggregate investment, the lags may not be longer than the accounting period of observation of the variables in the analysis; therefore some simultaneous interaction probably exists among the several variables in Tinbergen's investment equations. To be very specific, Tinbergen believes that the lag between 12-month investment outlays and 12-month profits is a fraction of one year; hence a portion of his 'explanatory' profit variable coincides in time with his (annual) investment variable. In his study of investment in railway rolling stock, he is able to make direct observations on the lag between orders and deliveries and finds that the basic lag between profit and investment should be at least one year, in the pre-World War I period. For aggregate investment no material is available from which to estimate the lag independently, and it is highly probable that there is a bias in his estimate of the lag by multiple correlation techniques. I have found that the average lag between net investment and nonwage income changes if one uses an 'equation system' method instead of the 'single equation least-square' approach. The former method takes account of the simultaneous interaction between profits and investment, but the latter wrongly assumes that profits influence investment without being influenced by investment. However, the estimate of the sum of the coefficients of lagged and current nonwage income terms remains about the same for various methods of estimation.[5]

[4] Jan Tinbergen, *Statistical Testing of Business-Cycle Theories,* I, *A Method and Its Application to Investment Activity* (League of Nations, Geneva, 1939).

[5] See L. R. Klein, *Economic Fluctuations in the United States, 1921-1941* (Wiley, 1950).

Tinbergen correlates United States investment with several variables – corporate profits, share yields, unit profit margins, short-term interest rates, pig iron prices, first differences in the cost of living index, first differences in consumer goods production. Some different variables appear in the analyses of the other countries. One criticism of his method is that it is an inefficient use of information within the framework of multiple correlation analysis. Corporate profits, share yields, and unit profit margins reflect the same phenomena and thus play overlapping roles in determining investment activity. Profits are presumably taken after interest charges, then interest is introduced as a separate variable. This point has been explicitly criticized by T. Haavelmo.[6] The reader should not get the impression, though, that Tinbergen was, at any time, unaware of these difficulties, for they are specifically mentioned in his volume.

It would be wrong to criticize Tinbergen for using data that do not follow, precisely, the concepts he uses. Iron and steel consumption was undoubtedly one of the best indicators he could obtain for English and German investment before World War I. Similarly, the price of pig iron may have been the best available index of capital goods prices. The original empirical work of this paper is limited to periods for which direct estimates of the relevant variables are available. A remarkable feature of its findings and of other studies based on superior, recent data is the extent to which many of Tinbergen's results are confirmed.

The principal finding of Tinbergen's investigation is that profit is the main determinant of investment activity. This result is not surprising, but it is valuable, particularly because the magnitudes are estimated. The other variables studied such as pig iron prices and interest rates show results that are not always statistically significant or that contradict *a priori* ideas on the direction of influence. There is no uniformity among countries for these other variables. The United States data, 1919-33, show a strong influence of share yields as well as profits. I suspect the general validity of this result because Tinbergen's observations covered a period that is unlike its successor in the importance given to the share market in economic life. In separate studies of housing and railroad equipment, Tinbergen finds that variables peculiar to these special markets play a strong role in investment activity: rent, construction costs, interest rates, stock of houses, and nonwage income or corporate profits are used in the housing study; railroad profits, traffic and its rate of change, iron prices, and interest rates, in the railroad study. As would be expected, interest rates play a stronger role in these two special areas of investment, where capital goods have high durability. More detailed comments on the relation

[6] The Effect of the Rate of Interest on Investment: A Note, *Review of Economic Statistics*, February 1941, pp. 49-52.

between Tinbergen's results for railway rolling stock and our own results from more recent data, covering both road and equipment, will be presented in the following section. The housing equations of Tinbergen are not seriously contradicted by my own studies except for the relative orders of importance of some variables and the explicit treatment of family formation, an important demographic variable not satisfactorily dealt with in Tinbergen's volume.

In previous studies I have attempted to estimate the parameters of investment equations formulated on the basis of a rather general theory of the firm.[7] This approach leads to an equation that relates net investment (constant prices) to current and lagged nonwage income (constant prices) and the existing stock of real capital. The parameters are jointly estimated along with those in other equations of a system taken to represent the United States in the interwar period. In another model the demand for new producers' plant and equipment is treated as a function of the stock of real producers' plant and equipment, and current and lagged real production multiplied by the ratio of the output price to the capital goods price. Housing as a function of rents, construction costs, family formation, income, and bond yields is treated in separate equations within the model. Inventories are similarly split off from the rest of investment. There are differences of detail between this work and Tinbergen's, but the general approaches are more alike than different. The statistical estimation methods are different; share yields are important in Tinbergen's 1919-33 analysis; the stock of real capital is not used in Tinbergen's aggregate investment function; family formation is not a variable in Tinbergen's housing equation; etc. However, it is not the function of this paper to go into all these details.

A third study of investment, prepared for the TNEC,[8] is worthy of mention here, not because of its concrete contributions to the problems confronting us, but because of one aspect of its technique. In two industries, oil and steel, the intercompany variations between investment and profits are analyzed. The cross-section samples give new information about investment behavior that is not contained in the time series of industry or national aggregates.

The percentage change in property accounts for individual companies is correlated with the rate of return on invested capital. The validity of the book value data used is subject to question, but certain plausible findings stand out. The statistical significance of the relations in many of the indi-

[7] See L. R. Klein, *op. cit.*, Ch. II; and Notes on the Theory of Investment, *Kyklos,* II, 1948, 21.

[8] TNEC Monograph 12, *Profits, Productive Activities and New Investment,* by Martin Taitel (Washington, 1941).

vidual years studied is, indeed, weak, but there is definitely a stronger relation when the investment and profits for individual companies are computed for two to five years rather than for a single year. It is entirely possible that the anatomy of investment decisions will become clear only from data taken from periods longer than one year. Two variables, in addition to profits are cited in this study as being determinants of investment, the rate of capacity utilization and technology. The rate of capacity utilization is related to the stock of real capital which has proved to be of some statistical importance in time series studies. The TNEC study does not give a rigorous statistical justification for singling out capacity and technology as investment-determining variables; they are cited on the basis of a rough inspection of the investment-profits scatter diagrams.

2 RAILROAD INVESTMENT IN THE UNITED STATES

There are severe limits to the amount of information contained in annual time series of total United States investment for time spans of 20-30 years or even longer. This type of material has been examined many times over, and decreasing returns will accrue to research workers who do not adopt some new lines of approach. Tremendous advantages are to be gained by studying refined industrial sectors, for then a whole corpus of institutional knowledge will be available for getting a better picture of the investment process in the real world.

Within selected industries there is a great deal of homogeneity among the several firms because all are producing the same goods or services and often use similar production techniques. The homogeneity makes it possible to study cross-section data as well as time series on investment. Identical variables are likely to have widely differing quantitative influences on investment in different industries. Some variables need not be taken into account in some industries and are important in others. There may even be industrial differences in the direction of influence of some variables.

All these should be sufficient reasons for the study of investment in separate industries. Here we are concerned solely with United States railroad investment. It may be looked upon as a pilot study that could be extended to other sectors of the economy in order to put investment behavior on an established empirical basis. The railroad industry is selected as a starting point because it is a major component of aggregate investment; it has a great wealth of statistical data, especially cross-section material; its regulation aspects simplify some matters; and it may shed light on the significance of the interest rate in investment decisions.

The profits derived from railroad operations accrue to privately owned corporations that make the investment decisions. Investment, like other variables in the industry, is regulated in many ways, however, by the

Interstate Commerce Commission. The construction of new lines cannot be undertaken unless authorized by the ICC and likewise for the abandonment of old lines (disinvestment). Many safety devices, calling for substantial investment outlays, are required by the ICC. The railroads, being classified as a public service industry, are required to accept traffic as offered by shippers. In the short run, individual roads can do little to influence their output and must maintain their capital goods so as to meet the forthcoming volume of traffic. This has led some authors to invoke the 'acceleration principle' in explaining railroad investment. We shall consider this point below. ICC regulation extends also to such matters as the corporate structure of the industry, the determination of transportation rates (perhaps, the most widely discussed), and accounting procedures. We must always try to keep the institutional knowledge of the regulatory aspects of the industry in the back of our minds as we study the facts concerning the private investment decisions.

Another important fact concerning this country's railroads is that they comprise a relatively mature sector of the economy. The era of youthful expansion of railroads occurred in the previous century. For the past two or three decades or even longer there has been a declining amount of investment in new lines. Although investment in roadway and structures was as large as investment in equipment until the middle 1930's, the capital expenditures for such things as track have been to a large extent for an improved type of track, or extra track, rather than for track to serve new areas. One of the main reasons why we may now look upon railroading as mature is that newer forms of transportation are growing up and displacing rail service. From November 1920 to December 31, 1943, the ICC authorized the abandonment of 29,012 miles of railroad line in 1,971 proceedings.[9] Highway (truck and automobile) competition was cited as the principal factor responsible for the abandonment of 58 per cent of the total abandoned mileage. Other leading causes were exhaustion of natural resources, 19 per cent, and rationalization (elimination of duplicate railroad service, etc.), 10 per cent. Abandonments are also more frequent in areas of relative population decline.

A completely mature, stationary industry can supply the prevailing volume of output with the existing stock of capital. In this steady-state situation gross investment just equals depreciation expenses. In a relatively mature industry such as United States railroads, a changing volume of traffic, substitution of capital for labor under economic pressure, technological change, intercompany competition, and other factors maintain a level of net investment that is positive except in extremely depressed

[9] *Railroad Abandonments, 1920-1943,* ICC, Bureau of Transport Economics and Statistics (Washington, D. C., January 1945).

periods.[10] The change from a roadway of light rails and ties and no ballast in the last century to the modern heavy railed, ballasted road which accommodates high speed trains is a technological change that involved much investment. Rails have been improved progressively, and ties are now treated so that their life is effectively doubled as compared with nontreated ties still in existence. Diesel engines were introduced in switching service in the '20's and Diesel electric locomotives have been the object of large scale investment since 1934. The steam locomotive is also being improved to save fuel, increase speeds, and increase tractive power. Technological change in locomotives necessitated changes in tracks and roadbed, which are now real limiting factors. Until the latter part of the 19th century the average capacity of freight cars was 10 tons;[11] modern cars have a capacity of more than 50 tons. Readers are only too well aware of the changes in passenger equipment during the past two decades. Other less obvious technological improvements include automatic signal systems, automatic train control devices, automatic couplers, shock absorption devices, braking devices, car retarders, and numerous other devices. Some of these improvements are interrelated, one requiring the other. We can only expect that these changes will continue into the future, possibly even at an intensified pace; therefore the maturity status of the industry does not rule out large scale investment. Caution should be taken, however, against romanticizing the investment process in this or other industries as some economists are prone to do. Entrepreneurs are not always frantically searching for an innovation in which to invest or copying another's recent innovation. A great proportion of investment decisions are routine, and much of the investment in new types of capital goods represents replacement of worn out capital with the latest, improved variety. In the latter case, technological change is not responsible for the investment, but it would be pointless for an entrepreneur not to replace his facilities with the best available. It is difficult to estimate the net effect of technological change on investment because the changes have been occurring simultaneously with so many other things such as the need for replacement and profitability, but we may get some indication from a questionnaire survey of Class I roads conducted by the ICC. The roads were asked, "How much should be expended annually during the 3 years, 1939-1941 for additions, betterments, and extensions over and above the total shown for deferred maintenance . . .

[10] Appendix Table 1, columns 1, 3, 4, presents annual gross investment, recorded and unrecorded depreciation. Without making the refinement of revaluing depreciation charges to replacement costs, we find that net investment was positive in 1921-41, except in 1931-36 and 1938-39.

[11] This figure is taken from P. Harvey Middleton, *Railways and the Equipment and Supply Industry* (Railway Business Association, 1941). The earliest ICC figure is for fiscal 1903, showing an average capacity of 29.4 tons.

to enable respondent to handle more cheaply or expeditiously a volume of traffic equal to that actually handled in 1937?"[12] The replies totaled $495,757,106 for three years' capital outlays designed to handle a given traffic volume more cheaply or expeditiously. A large part of this outlay may perhaps be regarded as going into technological improvements. Gross capital expenditures for 1937 alone were estimated by the ICC to be $541 million and were at an average annual level of $521 million during the entire interwar period. This is by no means a perfect experimental situation, but it does give some indication of the magnitudes involved.

The effective life of railroad rolling stock varies from 20 to 40 years depending upon the nature of the equipment. Major items of road and structures depreciate at even slower rates. Treated ties now last about 25 years and new rail about 19 years. Some equipment for maintenance and other purposes lasts a much shorter period, say less than 10 years. But, for the most part, railroads must try to look ahead 20 years or more for large scale investment projects, and they are not allowed to write off assets in a shorter period than their known service lives. For investments of this type we can expect that interest calculations would be much more decisive than in manufacturing industries where equipment is required to pay for itself in less than five years.[13]

After World War I, and particularly in the great depression, railroads found access to the capital market difficult. It was not easy for them to sell stocks or ordinary long term bonds at favorable prices.[14] Equipment trust certificates were the one type of security that remained open to them at low interest rates. Equipment trusts are peculiar to this industry and now provide funds for financing equipment investments at 2.0-2.5 per cent. The railroads have shown an extremely good record in meeting interest payments on these securities.

It is well known that many railroads failed to meet their interest charges during the 1930's and were declared bankrupt. The large bankrupt companies continued operation under receivership or trusteeship, during which time their whole asset-liability structure was overhauled through court action. The most important reorganization decisions reduced the heavy interest payments on borrowed capital which had grown to unwieldy proportions. Reorganization plans approved by or proposed to the ICC as of

[12] *Financial Requirements of Railways* (Summary of returns on statistical series circular No. 26), ICC, Bureau of Statistics (March 1939).

[13] See George Terborgh, *Dynamic Equipment Policy* (McGraw-Hill, 1949), Ch. XII.

[14] See Irwin Friend, Business Financing in the Postwar Period, *Survey of Current Business,* March 1948, pp. 10-6, for statistics on new stock and bond issues for railroads, 1919-47. After 1930 there have been no new stock issues except for a small amount in 1945.

October 31, 1941[15] showed the accompanying alterations. For some

Debt before reorganization	$3,993,901,463
Debt after reorganization	1,729,134,094
Annual fixed charges before reorganization	142,191,942
Annual fixed charges after reorganization	41,043,119

roads,[16] the approved plans showed a much greater percentage reduction in annual fixed charges to figures less than 25 per cent of the original. Such large reductions of interest charges could be expected to figure importantly in investment behavior. During reorganization proceedings a road can argue that it needs a greater reduction in fixed charges to enable it to modernize and thus provide transportation on a profitable basis in the future. As will be seen below, this institutional phenomenon had profound effect on investment in the years after the depression trough of 1932. During the recent war many roads earned sufficient profits to pay off outstanding debts and emerge from receivership; therefore investment in the near future may be less influenced by reorganization.

Before we examine the investment records it may be useful to consider briefly an expository cost calculation by the Pennsylvania Railroad Company concerning an expenditure for machinery to be used for laying rail.[17] The cost of one outfit was put at $34,273. The costs of laying one unit of rail by machinery and by hand are compared in the accompanying table.

PENNSYLVANIA RAILROAD COMPANY
Daily Costs of Laying 300 39 ft. Rails per Day
(1.1 miles of track and 228 tons of rail)

	By Machine	By Hand
Labor cost	$875.81	$1,189.05
Interest	38.94	42.12
Depreciation	48.70	39.91
Annual overhaul	44.41	29.32
Running repairs	36.82	15.94
Supplies	165.67	230.74
Total	1,210.35	1,547.08

In a working period of eight months — 160 days — the Pennsylvania Railroad Company would save $53,876.80 as a result of introducing machinery to lay rail, more than the cost of one outfit. The actual calculations have

[15] *Changes in Capitalization under Plans of Reorganization Approved by the Commission or Proposed by Examiners for Railroads in Reorganization Proceedings before the Commission,* ICC, Bureau of Finance (October 31, 1941).

[16] Chicago and Northwestern Railway Co.; Chicago, Rock Island and Pacific Railway Co.; St. Louis-San Francisco Railway Co.; Western Pacific R.R. Co.

[17] Taken from *Exhibit Filed on Behalf of the Carriers before the Railroad Carrier Industry Committee (Committee No. 9) under Provisions of the Fair Labor Standards Act of 1938* (Washington, D. C., February 1940).

been summarized and aggregated here. Different types of labor earning different wage rates, the costs of work trains, the costs of camp trains, and other elements of cost were all considered in minute detail before arriving at the final figures.[18] On the Pennsylvania Railroad, workers were receiving an average basic rate of about 48 cents per hour at the time of the calculation. Other roads with lower wage rates would enjoy a smaller reduction in costs. At 40 cents per hour, it would be approximately $47,407 per year; at 35 cents per hour, $41,912 per year; and at 30 cents per hour, $36,416 per year. Under all circumstances, cost considerations show that the proposed investment is profitable. The interesting thing about this calculation is not the particular set of figures presented but the rationality of the approach. In my opinion, the typical theoretical scheme for investment found in economic literature is not essentially different.

Many more examples are provided in the same exhibit of calculations based on other types of mechanization such as weed burner, scarifier and ballast leveler, rail power drill, portable track nutter, and burro crane. But one must not get the impression that all railroad investment is based on precise engineering reports of incremental profits. In many instances the cost calculations depend on the expected level of traffic, which is much less certain over the expected lifetime of capital goods. Some computations directly involve incremental revenue as well as incremental cost; these are subject to greater error. Personal judgment about the future, even 'irrationality', or institutional practices may be the dominant considerations for many investments. Some investments have been made in this industry for the stated purpose of meeting competition. An example is the case of one road that spent funds improving a line serving an area where it was rumored that a competitor was considering the construction of new track. The established road wanted to show the ICC that there was no need for more service in the area and that construction should not be authorized for the incoming road. This is one among many ways in which investment may be carried out to meet competition or in which considerations other than cost reports of engineers serve to determine capital outlays.

The first set of empirical results on railroad investment to be described in these pages were obtained from an analysis of time series of industry aggregates during the interwar period. Were it not for the fortuitous occurrence of substantial lags in the equation describing railroad investment behavior, we would have to begin by formulating a complete model of several equations describing many activities besides investment. Our model would have to 'explain' both investment and profits in terms of predetermined variables, but the presence of lags in our relationship enables us to

[18] The reason for larger interest charges under the hand operation is that more camp train equipment would be needed.

assume that past profits influence current investment and that current investment does not influence past profits. This point repeats the remarks made concerning Tinbergen's techniques for studying investment behavior.

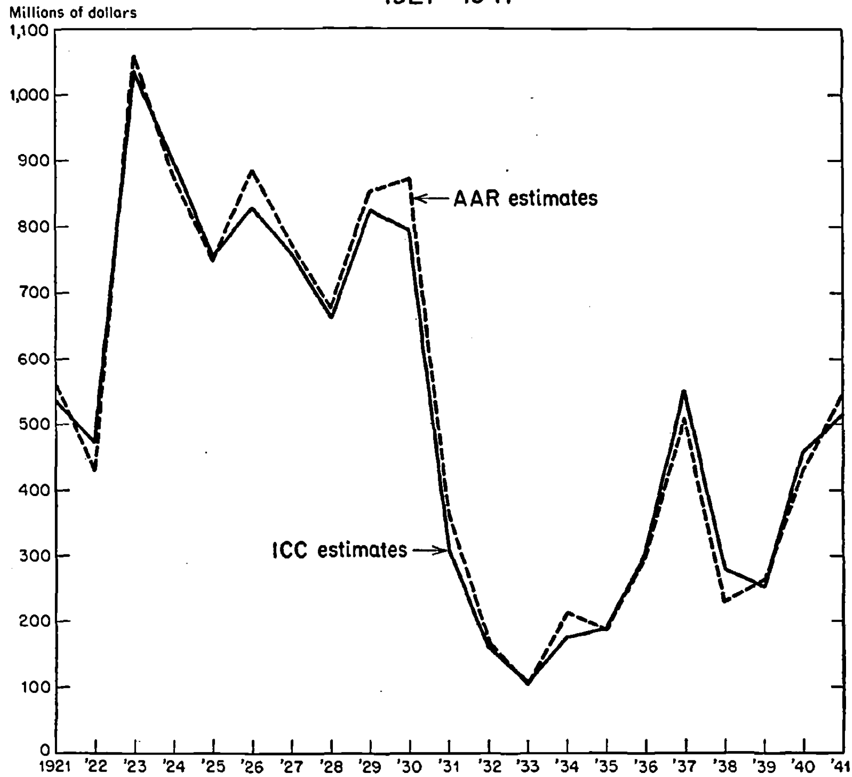
The reader is reminded that our statistics on investment are for expenditures that are generally recorded on the books of the railroads at the time of installation.[19] In a wartime memorandum of the War Production Board,[20] the average prewar lead time for procuring freight cars is 26 weeks; for passenger cars, 39 weeks; for Diesel electric locomotives, 26 weeks; for steam locomotives, 39 weeks; and for a miscellaneous category including maintenance equipment, signals, and track parts, 8-13 weeks. Calculations in the files of the National Bureau of Economic Research on the interval between the date of order of equipment and the contemplated date of delivery in 1937 confirm the WPB estimates. The National Bureau estimates of the average intervals for steam locomotives, electric locomotives, passenger cars and freight cars vary from 6 to 8 months for the four types of equipment. The interval for Diesel electric locomotives is only 2.42 months in 1937. For equipment there is this technical lag which must be put at more than a half year. Investment in road and structures will tend to lengthen the average lag for all capital formation, and we must add the further lag between the original formulations of the investment decision and the placing of orders for capital goods. For the sake of simplicity in estimation we have assumed a lag of one year between annual earnings and annual investment. In view of the information on orders and deliveries, this does not seem unreasonable when considered as an average for the whole industry and neglecting dispersion among the individual companies.

The earnings figure used is net railway operating income before depreciation. The reasons we use operating income instead of net income are twofold. First, we want to exclude fixed interest charges as a cost item and introduce the average interest rate as a separate variable. It may seem arbitrary to treat any single cost component in this way and the others as subtractions from receipts, but we want to attempt to single out the influence of interest rates on investment. Interest rates are subject to govern-

[19] In the cross-section studies the data on investment are taken directly from the accounting reports of the individual roads to the ICC. As may be seen in the Appendix, the time series for investment are taken from a special ICC study in which the data are called "gross capital expenditures", but the distinction between out of pocket expenditures and installations is not mentioned. In Chart 1 the time series estimated by the ICC is compared with estimates of out of pocket expenditures prepared by the Association of American Railroads. The chart shows little systematic difference between the two series, and they exhibit essentially the same type of movement.

[20] *Time Lag for Procurement of Selected Items,* WPB, Office of Operations Vice Chairman, October 1945.

Chart 1
Class I Steam Railroads, Gross Capital Expenditures
1921 - 1941



ment influence through the central banking system and the Treasury and thereby play a key role in business cycle discussions. The choice between monetary and fiscal policies to smooth out cycles depends to some extent on the role of interest rates in investment behavior. Second, we want to approximate, in a very rough fashion, the calculations that underlie individual investment outlays as illustrated above in the Pennsylvania Railroad Company example. The most recent rate of return from operations with existing facilities is taken as an indicator of the rate of return expected on new operations. The net income from nonrailway operations, excluding fixed interest charges, may also influence investment, and we shall take this possibility into account, although we begin by considering only net railway operating income before depreciation. If all the gross investment expenditures were for a new type of capital good based on a marginal profitability calculation it would perhaps be more correct to regard annual depreciation as an expense item in deriving operating income. But such a large part of gross expenditures represents routine replacement of capital that operating profits after depreciation would understate the expenditure potential. We have adopted the simplification of looking upon gross operating profits as a main determinant of gross investment expenditures.

In the first approximation we shall take the yield on new railroad bond issues (the price of new capital funds) and the existing stock of fixed capital used in operations as additional variables in the investment equation. The whole set of variables are

I = gross expenditures on road and equipment in 1910-14 prices

π = net railway operating income before depreciation deflated by a railroad construction cost index, 1910-14:1.00

K = end of year stock of fixed capital in road and equipment in 1910-14 prices

i = average yield on new railroad bonds

The statistics cover Class I railroads during 1922-41.[21] The actual observations and sources are listed in the Appendix. I, π, and K are in millions of dollars; i is in percentages. The least-squares estimates of the parameters are

$$(1) \qquad I = 1596 + \underset{(0.08)}{0.75\pi_{-1}} - \underset{(18)}{51i} - \underset{(0.02)}{0.14K_{-1}} + u$$

$$\bar{R} = 0.95 \qquad \bar{S} = \$51 \text{ million} \qquad \frac{\delta^2}{S^2} = 2.18$$

$\bar{R}$ is the multiple correlation coefficient and $\bar{S}$ is the standard error of estimate, both adjusted for degrees of freedom. The standard errors are given in parentheses below the corresponding estimates of parameters, and the statistic $\frac{\delta^2}{S^2}$ is a measure of the autocorrelation of u, the estimate of the random perturbation. It is the ratio of the mean square successive difference to the variance of the estimates of the random error. The value of 2.18 indicates that the hypothesis of randomness in time is not rejected by the data.

In equation (1) the average bond yield is not lagged as is the profit variable. It is assumed that investment decisions are in the first instance based on the profit outlook which carries a high degree of uncertainty, then corrected for the availability of loan funds, which is indicated with much less uncertainty by prevailing bond yields. However, calculations have been carried out in alternative ways with the average bond yield lagged and not lagged. The results differ little.

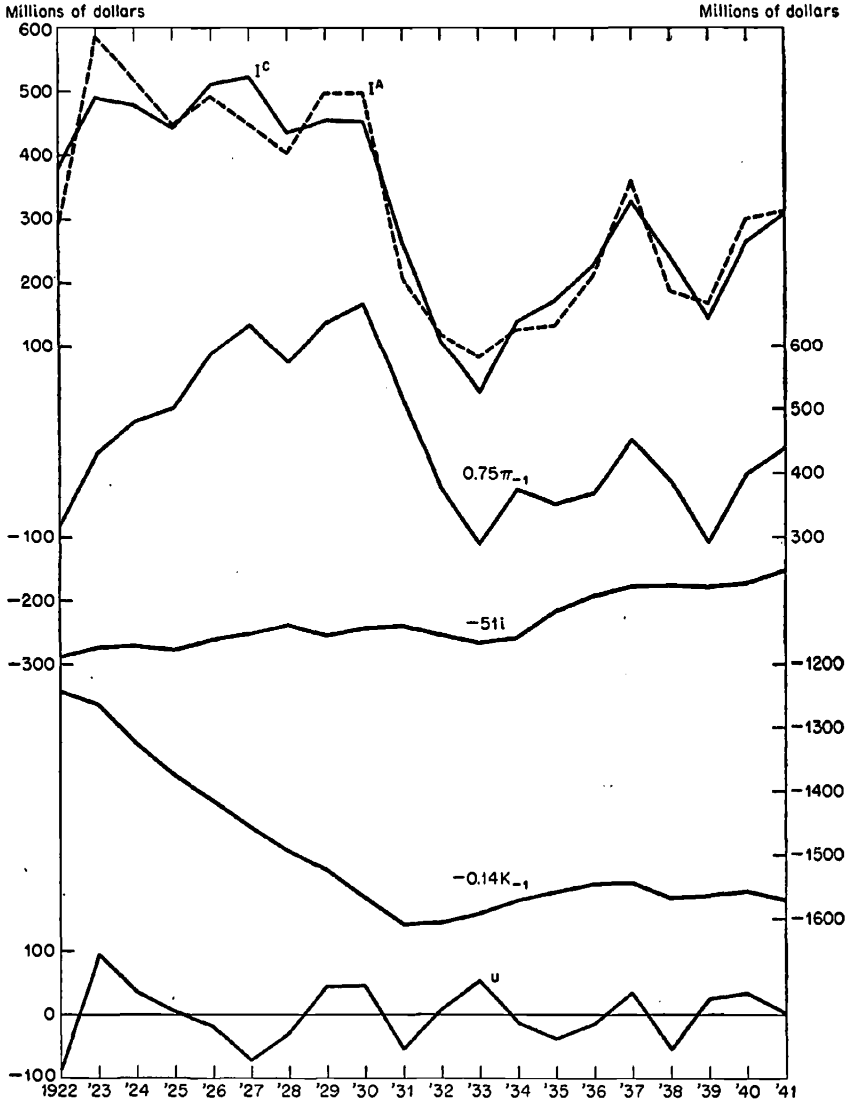
Profits are a dominating variable, but the yield on new bonds is also significant. The stock of capital, K, serves as a specific trend influence. If this variable were omitted, the coefficient of i would change sign. However,

[21] The beginning year is selected as 1922 in order to avoid using data taken from records during which the roads were under government operation.

Chart 2

Class I Railways, 1922–1941

(1) $I = 1596 + 0.75\pi_{-1} - 51i - 0.14K_{-1} + u$



K does not differ completely from an arbitrary trend variable. It is introduced for specific theoretical reasons mentioned above, but it may cover up some other general trend influences. If a linear trend is introduced as a fifth variable in equation (1), the coefficient of *i* is changed to a positive value, and the trend coefficient is itself positive, an unlikely event in a mature industry. My previous studies of investment behavior have used statistics of *net* investment in relation to profits and the stock of capital. The present study is noteworthy in that the investment variable is defined as *gross* investment throughout, and the stock of capital plays approximately the same role as in the previous work. But on the basis of the time series study alone, we cannot come to a definite conclusion concerning the influence of the stock of capital because of its intercorrelation with a general trend variable. An interesting feature of equation (1) is the quantitative influence of bond yields. The interest elasticity of gross investment, calculated at the point of means of the relevant variables, is about —0.73. There is, of course, a sampling error associated with this figure, but it shows, in any case, that although interest definitely influences investment, the influence is very limited. This conclusion is especially important because we are dealing here with an industry in which the interest rate is expected on *a priori* grounds to be more decisive than in other sectors of the economy. We are also dealing with an industry that accounts for a large but declining fraction of total interest payments. At the turn of the century, interest payments on railroad securities were 33.5 per cent of the total and steadily declined so that just prior to the recent war they were 17.4 per cent of the total.[22]

The relation between the average bond yield and investment in equation (1) measures the effect of interest on investment, not of investment on interest. We make this claim because of the nature of the market we are dealing with. Supply relationships in the capital market are very complex and do not take the form of the demand relationship represented by (1). The supply of funds for capital investment is not earmarked for any particular industry. The supply gets channeled into particular industries as a result of a consideration of a whole complex of interest rates and other variables in several industries. It is as meaningless to speak of the supply of funds to a particular industry as to speak of the supply of unskilled labor to a particular industry. Equation (1) has been written entirely in terms of variables that are specific to the railroad industry and is thereby identified as distinct from the relationships describing the supply of capital funds to several industries. Moreover, railroads seek loan funds for purposes other than real capital formation. Since our equation deals specifically with variables affected by the use of loan funds for real capital formation it is even more separable from the relationship between the total supply of funds and bond yields.

In judging the quantitative significance of the influence of K on I, one

[22] *Analysis of Steam Railway Dividends, 1890-1941*, ICC, Bureau of Transport Economics and Statistics (November 1943).

should remember that K does not vary in the short run (one year, for example) by more than a few percentage points. A final remark about (1) is that the estimated time series of u, in addition to being nonautocorrelated, does not show any marked relationship to the business cycle pattern or any other obvious economic series. There is, for example, practically no relationship observable in a scatter diagram of u and the Federal Reserve production index.

Equation (1) is, on statistical grounds, an acceptable explanation of investment behavior in the railroad industry, but our empirical results from a study of alternative hypotheses are worth presenting also. A. F. Burns has suggested the introduction of the price index of railway capital goods as a separate variable in addition to those already contained in (1).[23] Let us denote this price index by q, and set it equal to unity in the base period 1910-14. The resulting equation is

$$(2)\qquad I = 2647 + \underset{(0.09)}{0.88\pi_{-1}} - \underset{(0.02)}{0.20K_{-1}} - \underset{(15)}{69i_{-1}} - \underset{(128)}{301q_{-1}} + u$$

$$\bar{R} = 0.97 \qquad \bar{S} = \$39 \text{ million} \qquad \frac{\delta^2}{S^2} = 1.99$$

In equation (2) the bond yield is arbitrarily lagged to show that the results are not appreciably different from those of (1). The interest elasticity of investment is, however, raised slightly, to —1.03 at the point of sample means. The price elasticity of investment is —1.48 at the point of means.

On statistical grounds equation (2) is as satisfactory as (1). The former, however, deviates from a principle that is observed in all the other time series estimates: that all variables be independent of absolute prices.

Another reasonable hypothesis is that nonoperating income, exclusive of interest charges, can influence investment. Nonoperating income may have a positive effect because it represents a source of funds for capital expenditures. On the other hand, it may have a negative effect on investment in road and equipment through its indication of earning power of nonoperating assets. Our investment variable excludes expenditures on assets not used in railway operations.

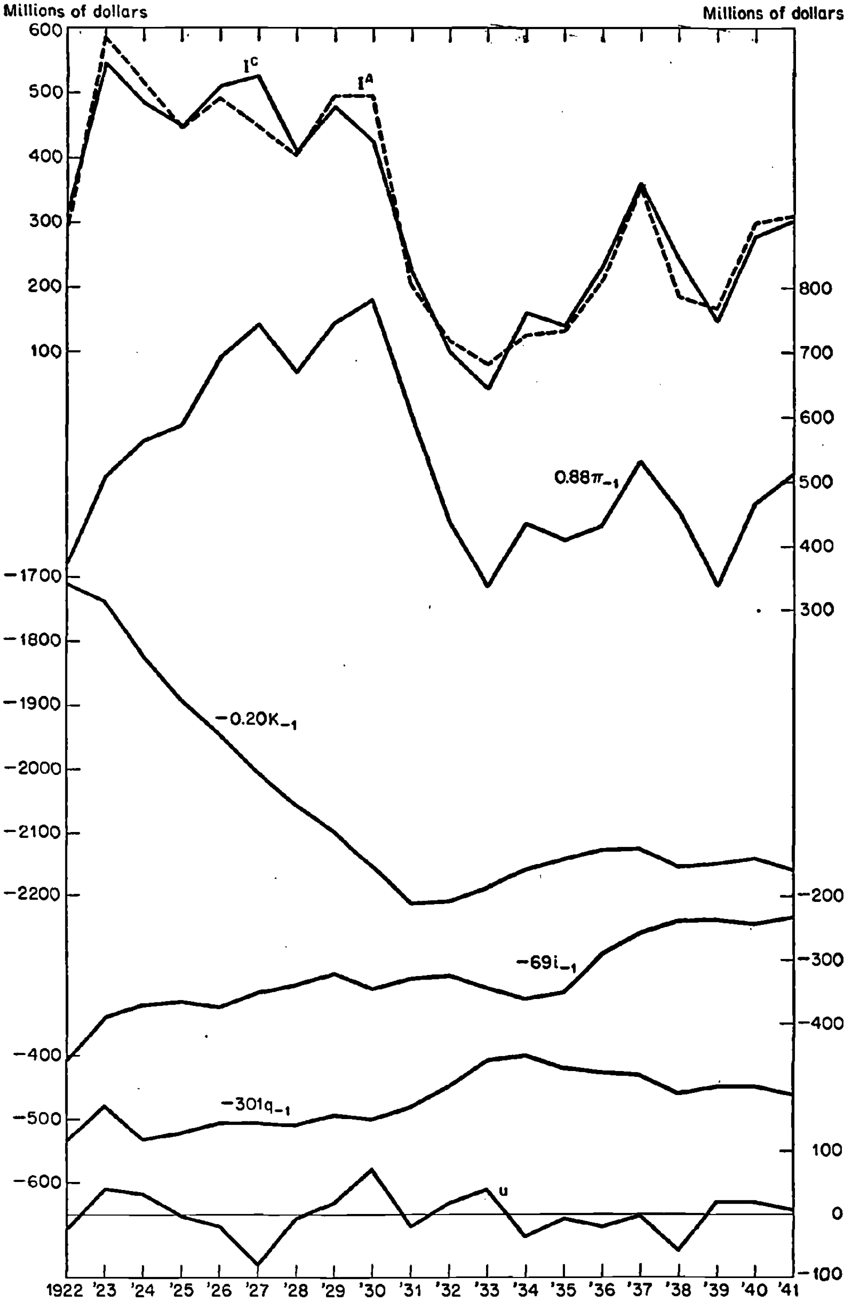
Another possibility is that the dividend policies of railroad corporations may influence investment in the sense that dividend payments represent funds that are specifically not available for capital expansion. We have not introduced lagged dividends as a separate variable, however, since it is correlated with past earnings. Tinbergen, in his second business cycle volume, presents the interesting result that dividends are a function of

[23] This same price index enters (1) in a limited way as the deflator used in putting I, π, K in constant prices.

Chart 3

Class I Railways, 1922 - 1941

$$(2) \quad I = 2647 + 0.88\pi_{-1} - 0.20\bar{K}_{-1} - 69i_{-1} - 301q_{-1} + u$$



corporate earnings and of surplus (cumulated retained earnings).[24] Thus the surplus account gives a good indication of the ability to pay dividends in such a way as not to impair the investment of earnings.

Let π' = net nonoperating income, deflated by a railroad construction cost index, 1910-14:1.00.

W = end of year unappropriated surplus deflated by a railroad construction cost index, 1910-14:1.00.

A new estimate of our investment equation is given by

$$(3) \qquad I = 1537 + \underset{(0.06)}{0.80}\pi_{-1} - \underset{(43)}{32}i - \underset{(0.04)}{0.14}K_{-1} - \underset{(0.65)}{0.90}\pi'_{-1} + \underset{(0.07)}{0.03}W_{-1} + u$$

$$\bar{R} = 0.95 \qquad \bar{S} = \$51 \text{ million}$$

The coefficients of all variables except π_{-1} and K_{-1} are unreliable. Twenty annual observations are actually not enough to enable one to estimate six parameters with much confidence.

Another revision of equation (1) that was considered was to add a variable showing the liquidity position of the railroads. We used working capital less materials and supplies to measure liquidity. The definitions of current assets and current liabilities in the accounts reported to the ICC, however, are not entirely satisfactory. Without getting more detailed information than was at our disposal, we were not able to include accrued tax liabilities with current liabilities for all years during 1922-41. Furthermore, the ICC statistics on current liabilities included during the period of our investigation a questionable item, principal of funded debt matured but unpaid. During the period of large receiverships this item is substantial. We have simply used working capital as defined in the ICC accounts minus materials and supplies. The final figure was deflated by the railroad construction cost index. If working capital, so defined, is introduced as a separate variable in equation (1), the other coefficients remain practically unchanged and working capital, defined in the same units as investment, carries the negligible estimate of —0.006. During a great part of the period, working capital is not even a positive quantity. The institutional framework of railroad finance and investment should lead one to conclude, in any case, that the current liquidity position is not as important for railroad investment as it may be in other industries.

Offhand remarks about the substitution of capital for labor in railroading are commonly heard, but sound empirical investigations to check on

[24] In *Corporate Income Retention, 1915-43* (to be published by the NBER) S. Dobrovolsky shows that time series of a sample of large manufacturing corporations, 1916-43, produce a reliable estimate of the influence of surplus on corporate savings. He obtains the same result in a cross-section study of the sample for 1940-41. However, a cross-section study for 1925-26 shows an insignificant influence of surplus on corporate savings or dividends.

the reliability of such remarks are few. The interesting study mentioned in note 17, however, shows the following results. During the interwar period there was a strong upward trend for investment in maintenance of way machinery and equipment per mile of main track. Cyclical fluctuations about the trend were noticeable but slight. Average straight time hourly earnings for track labor had a simultaneous upward trend since 1932. This variable changed little from 1925 to 1931. There was also a great fall in man-hours of track labor per mile of main track during the interwar period. These concomitant events must not be considered in isolation from other variables such as profits and traffic but they are suggestive. However, roads that paid straight time hourly earnings for track labor at a level above 33 cents for the whole period show a much more strongly rising investment (maintenance of way machinery and equipment) trend than do roads paying less than 33 cents per hour for the whole period. The great depression had a greater retarding effect on the investment of the latter group. Both groups of roads experienced a decrease in man-hours of track labor during this period, but a much greater fraction of the decrease is attributed to mechanization in the case of the high wage roads. They were also the largest and most profitable roads; consequently, mechanization may have occurred without the wage-cost stimulus.

We tried to compute a ratio of two unit costs that would show the overall desirability of substitution of capital for labor. Unit wage costs are taken to be represented by average hourly earnings, and unit capital costs by nonwage maintenance expenditures per car mile. Capital depreciation is included in the maintenance accounts. Letting r = unit capital costs (cents per car mile) and w = unit wage costs (dollars per hour), we obtain the estimates

$$(4) \qquad I = 803 + \underset{(0.08)}{0.73}\pi_{-1} - \underset{(19)}{60}i - \underset{(0.05)}{0.08}K_{-1} + \underset{(38)}{48}\frac{r}{w} + u$$

$$\bar{R} = 0.95 \qquad \bar{S} = \$50 \text{ million}$$

The estimated coefficient of $\frac{r}{w}$ is unreliable and has a sign opposite to what would be expected on the basis of substitution of capital for labor.

Equation (4) was reconsidered with a different series for the stock of capital. Instead of the total stock of capital, we used the ratio of the stock of capital to the number of car-miles. This gives us a measure of excess capacity rather than of total capacity. The calculations now show

$$(5) \qquad I = -30 + \underset{(0.16)}{0.60}\pi_{-1} - \underset{(21)}{61}i - \underset{(0.36)}{0.28}K_{-1}^{*} + \underset{(18)}{95}\frac{r}{w} + u$$

$$\bar{R} = 0.94 \qquad \bar{S} = \$53 \text{ million}$$

where K^* = stock of fixed capital (road and equipment) per car-mile.

Again the sign of the estimated coefficient of $\frac{r}{w}$ contradicts the hypothesis of mechanization through labor saving devices.

One might consider dropping $\frac{r}{w}$ as a variable from (5) and using the resulting equation as an alternative to (1). In this case the results are not entirely satisfactory because the estimated coefficient of i has a positive sign. Equations (1) and (2) are the only formulations that are satisfactory in all respects, economic and statistical. Equation (3) is a plausible alternative, but wide margins of error surround some of the estimated parameters of (3).

The basic sources of data for the time series studies are the official reports of the railroads to the ICC. The ICC combines the individual reports into tables of industry aggregates which it publishes annually in *Statistics of Railways.* In many cases, however, adjustments and special calculations must be made. Gross capital expenditures are taken from a special ICC study,[25] since they cannot be obtained in any simple way from published balance sheets. Net railway operating income (before or after recorded depreciation charges) and nonoperating income are readily obtained from the income statements to the ICC. The stock of fixed capital (road and equipment) as of January 1, 1940 *valued at cost of reproduction* is taken from a special report, by the ICC Bureau of Valuation.[26] Balance sheet figures would not be desirable for this calculation. Annual net investment is calculated from gross investment and depreciation, then used to obtain a time series of capital stock starting out from the January 1940 base value. Book value depreciation includes only equipment depreciation and voluntary road depreciation. As a consequence there is a substantial amount of unrecorded road depreciation that must be used in estimating annual net investment, although this figure is not needed for estimating net railway operating income before depreciation. A series on unrecorded road depreciation can be obtained from another special study by an ICC bureau.[27] The construction cost index used for putting the investment and capital variables in a constant price system is one prepared regularly by the ICC Bureau of Valuation, and covers all cost items entering into expenditures for road and equipment. In calculating real net investment, we should use separate deflators for gross investment and for depreciation; instead we have used the deflator appropriate for gross investment in the deflation of depreciation. The bond yield data represent

[25] *Postwar Capital Expenditures of the Railroads,* ICC, Bureau of Transport Economics and Statistics (March 1947).

[26] Ex Parte No. 148, *Exhibit No. A 11* (December 1942).

[27] *Analysis of Steam Railway Dividends, 1890-1941,* ICC, Bureau of Transport Economics and Statistics (November 1943).

an average of the yields on practically all new long-term issues. The yield for each new issue is weighted by the amount floated in that issue. We did not use the average yield on outstanding issues in the time series study. The yield data are regularly prepared by Moody's Investors Service. The other variables used in this study so far were compiled from *Statistics of Railways.*

The results of our time series study do not conflict seriously with Tinbergen's investigation, although they are not identical. Tinbergen covered only the period before World War I, 1896-1913, for this country, while we covered only the following period. There is great need for a study of the past 50-75 years, but we did not feel that the investment data were yet in a form to be used for such a long run study. Total railroad investment considered as one component of gross capital formation in accounts like those of the Department of Commerce is not yet available for years before 1919. Purchases of rolling stock are known for a longer period, but there are theoretical difficulties in studying equipment purchases, in the manner of Tinbergen, without studying road investment at the same time. Since we conclude in this study that railroads tend to invest most of their profits, the movement of any component of railroad investment in relation to profits may be compensated by the movement of the other components in relation to profits. If this is the case, an accurate picture can be obtained only by considering all investment together. Tinbergen's study of equipment investment attaches some importance to the rate of change of past profits as well as to the level of past profits. It shows a higher elasticity for the interest rate (average yield from a sample of 60 issues from all industries), but he concludes on the basis of studies in other countries that the postwar elasticity may be substantially lower, reflecting a changed approach in the financing of railroad investment. He does not consider the stock of capital explicitly in his railway study.

Tinbergen concludes that United States railroad investment in the past depended more on profits, interest, and prices of capital goods than on the technical acceleration principle — stock of capital proportional to traffic and investment proportional to the rate of increase of traffic. European countries seemed to differ in this respect. The acceleration principle is not a very satisfactory explanation of investment behavior. It implies a special production function, one that can be written in terms of output and stock of capital alone. The present writer's statistical studies of an econometric model for short-run railroad production decisions contradicts this assumption flatly. One has only to call to mind the phenomenal traffic increases of World War II with a practically unexpanded stock of fixed capital to realize that the relations imposed by the acceleration principle are not generally valid. It is possible that decade or other long-term investment rather than annual investment can be more readily explained in terms of the acceleration principle. This possibility needs empirical study, however, before we can judge its acceptability.

The basic data used for the study of investment carry us only to the end of the interwar period in 1941. The ICC study cited in note 25 is helpful for checking our findings in a rough way against more recent information. In the middle of 1945 roads were requested to assume their 1941 net railway operating income and to estimate, on the basis of this assumption, their proposed capital expenditures in the first three postwar years. It is interesting to note that the question was asked and answered in this form; it corresponds closely to our estimated investment function, although we may suggest that other control variables should have been introduced also. The actual expenditures in fiscal 1947 were $790 million as compared with a survey estimate of $625 million for the first postwar year. In the SEC — Department of Commerce surveys, the replies of railroads have consistently overestimated actual expenditures, but in these surveys there is no income assumption.

During the war, facilities were used intensively with a minimum of replacement and repair. The percentages of locomotives, freight cars, and passenger cars over 25 years old were much greater in 1945 than in 1941. At the end of 1945 the railroads embarked on a program of capital expansion that had some of its roots in the poor state of the existing stock of capital. According to the ICC survey, the intentions were to spend 38.2 per cent of the 3-year total in the first year, 32.7 per cent in the second year, and 29.1 per cent in the third year. With a growing stock of capital and a fixed operating profit, capital expenditures were expected to decline. The same result would follow from equation (1) or (2). Most capital outlays were intended for modernization to cut costs or permit higher speeds and to provide greater safety. There was not much investment proposed to enlarge over-all capacity except in so far as modernization automatically does so. This reflects the maturity of the industry.

Working capital, minus materials and supplies, went up from $511 million in November 1941 to $1,320 million in August 1945, yet only $125 million of the expected investment funds were to come from this source. The schedule of capital financing showed 7.7 per cent from prior accumulations, 62.6 per cent from current accumulations, and 27.7 per cent from indebtedness. In our equation (1) principal considerations are lagged profits (current accumulations) and bond yields (indebtedness). None of the postwar investment was expected to be financed by issues of capital stock and most of the indebtedness was expected to be from the issuance of equipment trust certificates. This represents a projection of prewar capital market conditions directly into the postwar situation.

Statistics are available for an estimate of 1948 investment from equation (1).[28] The estimate can then be compared with realized investment in 1948. The following data are used in the calculation:
net railway operating income in 1947 = \$781 million
depreciation charges in 1947 (road and equipment) = \$353 million
construction cost index in 1947 = 2.57
construction cost index in 1948 = 2.81
cost of reproduction of fixed capital, January 1, 1948 = \$23,108 million
average yield on new railroad bond issues in 1948 = 3.64 per cent.
From equation (1), we obtain

$$I = 1596 + 0.75\,\frac{781 + 353}{2.57} - 51(3.64) - 0.14\,\frac{23{,}108}{2.57} = 483$$

Actual expenditures in current prices were estimated at \$1,273 million by the Association of American Railroads. When deflated by the construction cost index, they become \$453 million, a not unfavorable comparison with 483. There is some doubt about the comparability of the January 1, 1948 ICC estimate of the cost of reproduction of fixed capital and the estimates used in the time series study. The recent figure is lower than that which would be derived by attempting to cumulate annual net investment forward from the January 1, 1940 estimate of the cost of reproduction. As mentioned in note 28, however, some problems are raised by the accelerated depreciation applied to wartime facilities and the revaluation of current book value depreciation charges in checking on the comparability of the two estimates. If the deflated cost of reproduction of fixed capital were raised from the level of \$8,991 million, the estimated capital expenditures for 1948 would be reduced.

Equation (1) has also been extrapolated to 1947 by estimating the value of K_{-1} from data on gross investment, depreciation, and the price of capital goods in 1947. The estimated value of I as shown by (1) is \$500 million, which does not compare favorably with \$337 million, the deflated value of the actual expenditures estimated by the Association of American Railroads. This overestimate resembles that shown by the railroad component of the SEC-USDC surveys in 1947. Equation (2) does

[28] Difficulties arise in extrapolating (1) to 1946 or 1947. The prewar estimate of the stock of capital cannot easily be carried forward to 1946 or 1947 by cumulating the net investment of the intervening years, because of a substantial amount of special depreciation on the wartime investment. The definition of π_{-1} for an extrapolation to 1946 is obscure for the same reason. The January 1, 1948 estimate of the cost of reproduction of fixed capital by the ICC cannot be satisfactorily carried back to 1947 or 1946 by subtracting net investment because the problem of revaluing depreciation charges has become more urgent with the great postwar increase in prices of capital goods. We have selected 1948 as the first 'normal' postwar year for which reasonably adequate data are available on all series in equation (1).

not extrapolate as well as (1) to 1948. Substitution of the observed values of π_{-1}, K_{-1}, i_{-1}, q_{-1} into the equation shows an estimated investment expenditure of only $225 million.

The time series for some variables relevant to our problem do not exist for periods as far distant as 1919-22; there is not a sufficiently long period of observation of the available variables to study the behavior of 2- or 3-year investment expenditures; finally, some questions simply cannot be well answered from time series. For these reasons, we now turn to an examination of intercompany or spatial variations (cross-section data) to see whether some new light can be thrown on the problem of railroad investment.

Twenty annual observations provide samples that are too small to treat many variables simultaneously or to test explicitly the assumptions made in statistical theory concerning the distribution of the random error, u, in the stochastic equations. For individual interwar years, we have grouped Class I railroads into systems of common ownership, and end up with approximately 80-90 independent statistical observations for each grouping. Details are given in the Appendix. This procedure yields far more degrees of freedom than 20 annual observations. In a separate study of expenditures for fuel, current capital items, and manpower together with a production function, we found that practically all the observations can be used on a homogeneous basis for estimating the parameters of the model. The relationships studied are stable and not too many variables are needed to account for the most important systematic differences among the roads. However, the situation is not quite as favorable with regard to investment. Here the intercompany differences appear to be much greater and the behavior pattern is undoubtedly less uniform or stable. Bankrupt railroads invest according to a pattern that differs markedly from other railroads. Small roads are much more erratic in their investment decisions than large roads. Some variables are not available for all companies. The result is that we can make our best cross-section studies with 35-40 independent observations, many more than were used in the time series study but many less than were used in the cross-section production study. The samples are unfortunately not large enough to make accurate tests of the underlying distributional hypotheses.

The general theory of the treatment of economic data obtained from cross-section samples is not as highly developed as time series analysis. For this reason we should discuss a few general principles that are involved in cross-section analysis. We must devote a few lines also to the difficult problems of comparing estimates made independently from cross-section and time series data.

Cross-section data refer directly to individual units; i.e., they are a part of micro-economic analysis. In many problems this is important in singling out directions of cause and effect among the several factors involved, for there are many variables that are given to the individual but are not given for aggregative market demand and supply. In economic theory individual units are assumed to adapt their behavior to market prices, wages, and interest rates, but aggregates of individual units affect these market variables as well as being affected by them. In the present case of the analysis of investment behavior these particular points are less important because of the substantial lag of investment behind the causal factors, and because of the nature of the capital market as discussed above in connection with equation (1).

The cross-section analyses based on family budget inquiries have usually assumed that market variables such as prices are held constant throughout the sample. This assumption seems questionable; prices paid do vary geographically, by income level, and by other characteristics. Some, but not all, of the price variation can be accounted for by the fact that the individual units in the cross-section sample purchase different commodities. In the cross-section sample of railroads many prices and unit costs are not held constant. One of the central problems in our cross-section studies is whether market interest rates are held constant in the samples used. The actual bond yields calculated for the individual carriers show substantial variation in 1936, reflecting the differences in risks attached to each road looked upon as a debtor. If all the companies appeared equally risky to lenders, 'pure' interest charges might not vary in the sample, but we do not claim to measure the effect of 'pure' interest, a subjective concept, on investment. Instead we are attempting to measure the effect of the objectively calculated market interest rates on investment. The bond yields that are used as variables in the analysis include charges for pure interest and risk. For our purposes this does not mean that observed bond yields are indicators of the cost of different commodities. We view them as costs of a dollar of loan funds, each dollar being a homogeneous commodity for each carrier. Only when a road becomes bankrupt, is forced to pay virtually infinite interest rates for capital funds, and is required to submit its properties to court reorganization do we recognize a difference in kind.

The explanatory variables introduced in time series analysis are used to account for the differences in some other variables from one period to another. We may say, in a sense, that the explanatory variables attempt to put the different periods on a homogeneous basis with regard to the other variables. A similar thing must be done in the cross-section analysis. Explanatory variables must be introduced to account for the differences in investment among the several roads. Many variables may be required to put the different companies on a homogeneous basis in regard to their investment outlays. In the cross-section studies from family budget data, rarely are more than two or three variables considered simultaneously, yet a larger number of variables would seem to be needed to account for the differences among individual units. A fundamental point to be kept in mind for cross-section analysis is that many variables must be treated simultaneously.

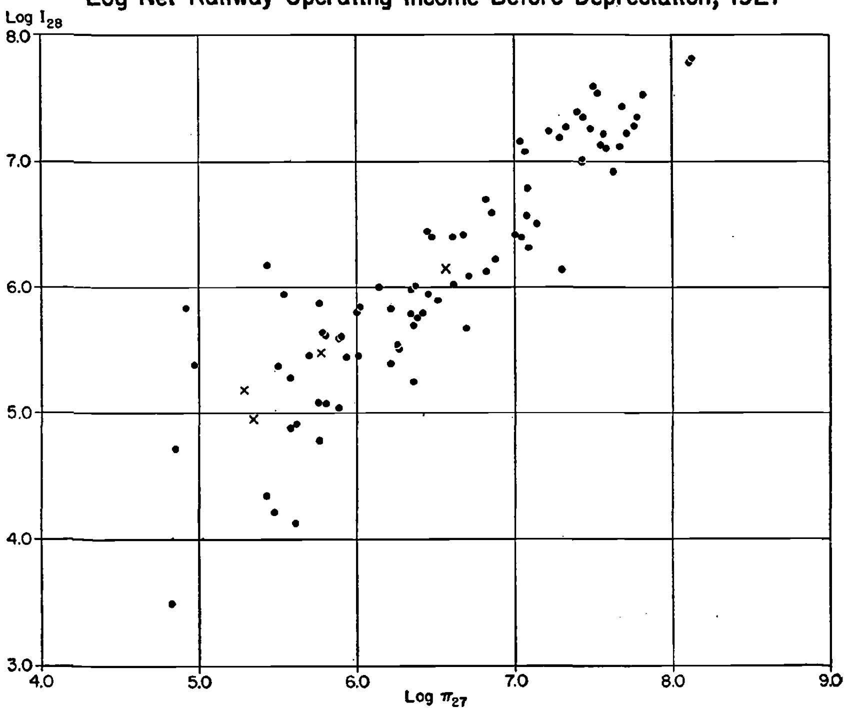
Suppose that each road invests according to some pattern that can be expressed as an equation containing a manageable number of parameters. The parameters need not be the same for each unit. It can be shown, in the linear case, that the time series aggregates for the whole industry are linearly related in terms of parameters that are averages of the parameters of the individual relations.[29] Similarly, it can be shown that the relation estimated from a cross-section sample is an average of the individual relations, and that the parameters of the former relation are averages of the individual parameters. The interesting thing is that the averages in cross-section and time series analysis have different weighting systems and different components in general. When comparing time series estimates with cross-section estimates one must keep this possible source of divergence in mind. To get the same results from both methods the problem is to introduce enough correct variables to put the different individual units and periods on as homogeneous a basis as possible. This procedure should make the parameters of the individual relations as alike as possible and will tend to minimize the differences between the average parameters estimated from time series and from cross-section data.

The data used for individual roads come from balance sheets, income statements, or operating reports published in *Statistics of Railways;* special studies by ICC bureaus; schedules in the original reports of the roads to the ICC; reports issued by associations in the industry; and the files of the National Bureau of Economic Research. Statistics on net railway operating income, recorded depreciation, nonoperating income, unappropriated surplus, working capital, dividends, train-hours, and car-miles are readily found in *Statistics of Railways.* The reproduction costs of the stock of capital in road and equipment as of certain dates are taken from special studies by the ICC Bureau of Valuation. Data on the age distribution of railway cars are published by the American Railway Car Institute, and bond yields on individual railroad securities are computed by the Financial Research Project from material prepared by W. B. Hickman of the National Bureau of Economic Research, Financial Research Project. The principal variable of the analysis, gross capital expenditures, is the most difficult to obtain and requires the most detailed discussion.

[29] See L. R. Klein, 'The Use of Cross-Section Data in Econometrics' (NBER, 1949; mimeographed).

Railroad accounting procedures are such that the difference between two successive, year-end balance sheet figures for the undepreciated road and equipment accounts does not give a good estimate of gross capital expenditures. This difference is closer to gross expenditures (at the installation stage) minus retirements, and the latter item can be very large for individual companies in individual years. In a separate schedule of the reports to the ICC, debits to the road and equipment asset accounts are separated from retirements but the sum of the net debit items does not quite meet our specifications on the definition of gross investment in property used for transportation. It includes accounting adjustments that may have little to do with current investment outlays. The adjustments may be corrections of previous accounting errors, or may be pure transfers between the road and equipment asset accounts and other asset accounts. In case freight cars are retired from the service of carrying goods and used as work train equipment, there is a credit to retirements and a debit to expenditures for additions and betterments. There is often no way of recognizing this debit item, and it gets included with the total net debits to the road and

Chart 4
Log Investment, 1928
Log Net Railway Operating Income Before Depreciation, 1927



equipment asset accounts (exclusive of retirement credits). Accounting adjustments over $50,000 must be described in the reports; therefore it is usually possible to tell whether an entry represents an actual expenditure, an account transfer, or some other accounting adjustment. The larger roads are more likely to describe their adjustments than the small companies who do not have many individual transactions in these accounts over $50,000. For this reason the data are probably more accurate for the larger roads.

The gross investment concept for an industry or a whole economy excludes many intercompany transactions, but in dealing with individual firms we must regard the purchase of a durable asset of one company by another as an act of investment by the latter. One disturbing type of entry in the schedule of investment expenditures in the railroad reports is that which comes under the heading 'cost of road purchased'. The valuations are sometimes spurious in this subaccount, and the treatment of mergers is questionable. We have followed the practice of omitting companies involved in mergers or attempting to exclude the merger valuations from investment expenditures. The latter step is logical when the merger is between a Class I road and a company outside this class and therefore outside our analysis.

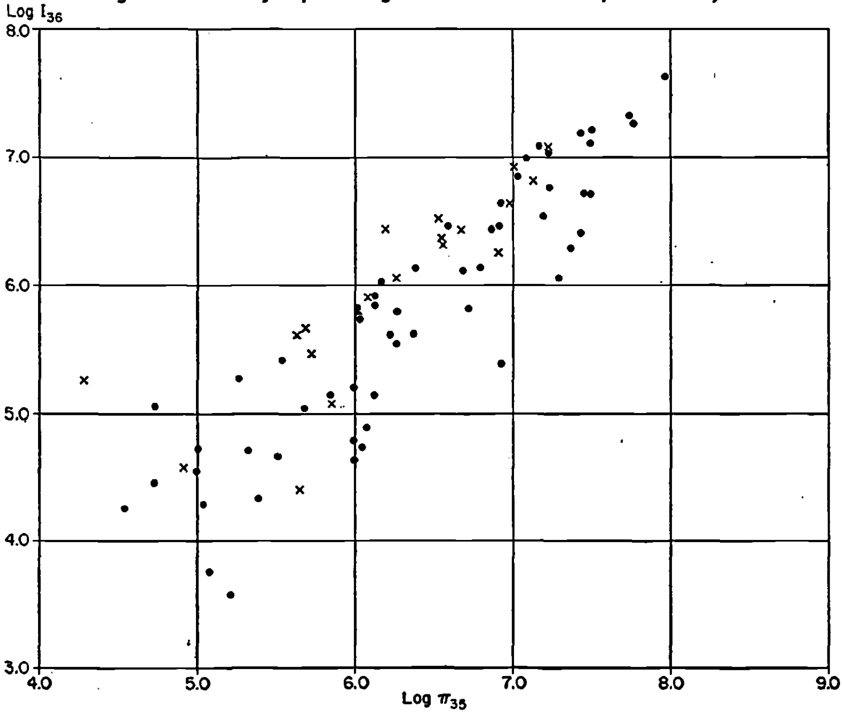
The Association of American Railroads receives special reports from the individual companies on their out of pocket capital outlays for road and equipment. These data would be far more suitable for our purposes but unfortunately are not made available to the public except as an annual aggregate for all firms. The time series of annual aggregates is presented in Chart 1.

A rough sketch, subject to many qualifications, of the intercompany investment-profit pattern can be seen from the logarithmic Charts 4-7. Investment and profits are plotted for four periods, with the logarithm of gross investment on the vertical axis and the logarithm of the preceding year's net railway operating income before depreciation on the horizontal axis. Naturally, the few roads with negative net railway operating income before depreciation are excluded.[30] Roads in receivership or trusteeship are marked x.

In a cross-section study there is an important variable which may not show up as significantly in a time series study, namely, the size of the unit. Large roads make large profits and large investments; small roads make small profits and small investments; hence it is difficult to get a true picture of the investment-profit relation from the charts. The logarithmic transfor-

[30] These roads are usually either jointly owned by two major systems, each making relatively large positive operating profits, or companies making negligible investment outlays.

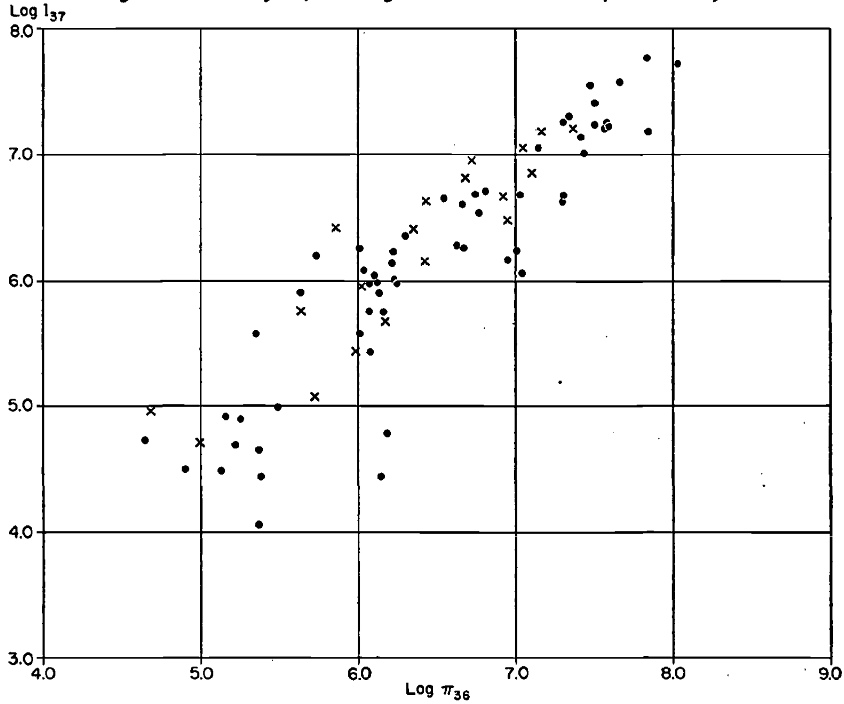
Chart 5
Log Investment, 1936
Log Net Railway Operating Income Before Depreciation, 1935



mation does make a correction for size, but it is a monotonic transformation, leaving the correction incomplete. However, one striking feature of the four charts must be taken into account for the ensuing analysis. During periods of large scale bankruptcies, 1935-36, 1936-37, and 1939-40, the charts show that receivership or trusteeship companies invest at a higher rate for a given profit status than do solvent companies, on the average.[31] The institutional background of this observation was discussed previously, and if the reader combines this discussion with the patterns exhibited in the charts, he will see that at least one point is illustrated — *access to the*

[31] A few statistics on Chart 5 may serve to reassure the reader on this point. Residuals from the least-squares line, $\log I_{36} = -0.054 + 0.938 \log \pi_{35}$, have a zero mean and standard error of estimate, $\bar{S} = 0.417$. The mean residual of the 19 observations for companies in receivership or trusteeship is $+0.232$. Assuming all residual observations to come from a population with a common variance, we can test whether the calculated mean of $+0.232$ is significantly greater than the mean of the other 70 residuals, -0.232. If the estimate of the population standard deviation is 0.417, the sampling error of the difference in means is 0.108, indicating clearly a significant difference.

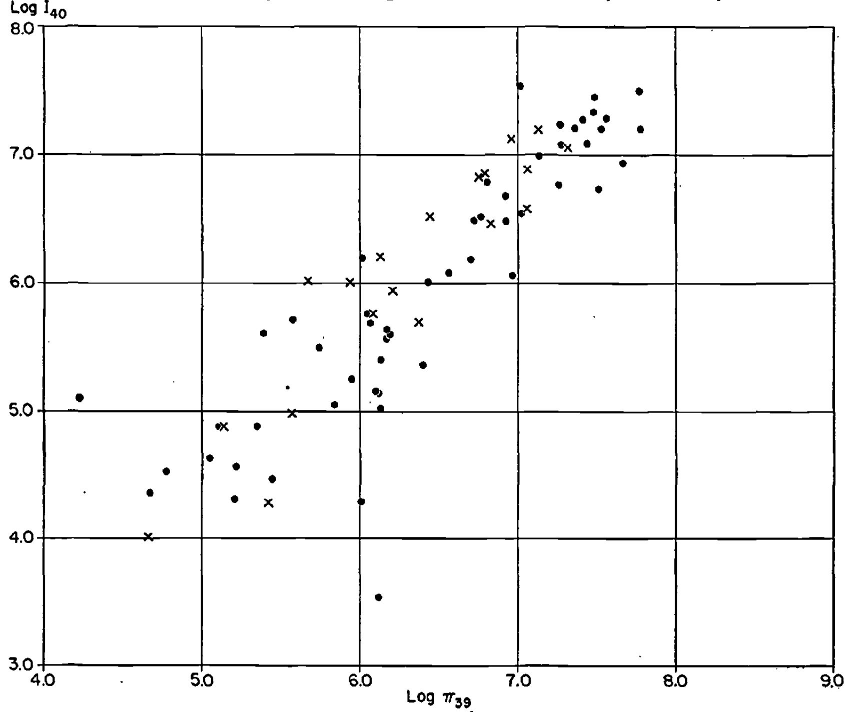
Chart 6
Log Investment, 1937
Log Net Railway Operating Income Before Depreciation, 1936



capital market is an important consideration in railroad investment. Roads in reorganization proceedings can, as pointed out above, argue for added reductions in fixed charges in order to modernize and put operations on a profitable basis once again. This means that they have a ready source of funds for capital outlays. Furthermore, a reorganized road can offer very attractive securities to the market. Since much of the old debt structure is canceled, the reorganized companies can offer first mortgage bonds to prospective lenders.

The profit elasticity of investment, as estimated by the slopes of the simple log-log regressions, varies approximately from 0.8 to 1.0, while the mean elasticity of equation (1) in the time series study is approximately 1.4. The two types of estimate differ significantly. If one proceeds, at the next stage, to introduce some of the same variables as were used in the time series study, difficulties immediately arise. The stock of capital, measured by the reproduction cost of road and equipment, is so highly intercorrelated with the profit variable that no reliable results can be obtained. The capital-profit correlation is even higher than the investment-profit

Chart 7
Log Investment, 1940
Log Net Railway Operating Income Before Depreciation, 1939



correlation; hence the two former variables cannot be considered as independent. If we arbitrarily fix the estimate of the profit elasticity in the logarithmic cross-section study at 1.4 to agree with the time series estimate, and correlate $\log I_{37} - 1.4 \log \pi_{36}$ with $\log K_{36}$, the least-squares estimate of the coefficient of the latter variable is negative, though less absolutely than the mean capital elasticity of the time series study. In the cross-section study the stock of capital plays a dual role: it exerts a positive effect on investment through its measure of the investing unit, and a negative effect through its measure of capital accumulation and existing capacity. Many alternative formulations in the logarithmic cross-section study have been computed with as many as eight variables simultaneously, but we have been able to get little more information from them than is contained in the charts.

However, one additional calculation with the logarithmic cross-section data does show an interesting result concerning the choice of variables to be contained in our investment equation. It often happens in econometric investigations that several hypotheses are consistent with the same set of observations. In such cases one might investigate independent samples or use information such as that provided by *a priori* economic knowledge in order to make a final choice of hypotheses. At a very early stage of our study, it was obvious that investment would be as highly correlated with total traffic (output) as with operating income; thus it appeared that the data would not enable us to distinguish between two hypotheses. This result showed up in both the cross-section and the time series data. Traffic and operating income are closely related, the latter variable being defined as traffic revenues minus operating costs (both in constant prices). One immediate reason for attempting to develop relations using operating income rather than traffic as a variable was that the former variable is more general than the latter since it includes traffic and other variables that influence investment decisions. Operating income is a concept that provides an extremely useful summary of many items, all of which affect investment, and does so with a minimum loss of degrees of freedom in estimating the parameters of the desired relationship.

In the cross-section study there are more observations in the sample; hence the problem of avoiding a loss of degrees of freedom is not as urgent as in the time series study. We have carried out a calculation in which the logarithm of revenues and the logarithm of costs are introduced as separate variables to see whether revenues, revenues and costs individually, or operating income would give the best statistical relationship. This calculation must be described at some length because it, at the same time, involves an attempt to integrate a separate study of the production of railroad services with the study of investment behavior. We shall not assume a lag between investment, revenues, and costs; therefore revenues and costs have to be simultaneously explained in terms of other variables that are not influenced by current investment. Revenues actually are not explained in terms of predetermined variables because it is assumed that an individual carrier passively adjusts its current operations to the given volume of traffic. However, in making this adjustment the carriers do have to decide about the current levels of input factors, which are the components of operating costs.

From the production study we adopt the following model estimated from cross-section data of 1936. Let

x_1 = net ton-miles of freight
x_2 = net passenger-miles
n = man-hours
c = tons of fuel (coal equivalents)
d = train-hours
z_1 = average length of haul
z_2 = percentage of freight carried in the form of products of mines

w = average hourly earnings
q = average price of fuel per ton
r = nonwage maintenance per train-hour

(6) $$x_1 = 5.62 x_2^{-0.16} n^{0.89} c^{0.12} d^{0.28} z_1^{0.34} z_2^{0.25}$$

(7) $$\frac{qc}{wn} = 0.1349$$

(8) $$\frac{rd}{wn} = 0.3124$$

Equation (6) is a production function (joint output) and (7)-(8) are conditions of cost minimization. Equations (7) and (8) are formally derived by minimizing $wn + qc + rd$ subject to (6), with x_1, x_2, w, q, r, z_1, z_2 assumed to be given variables to which the individual roads adapt n, c, d. The observations of the variables for all individual Class I steam railways in 1936 fit this model except for deviations that fit a trivariate logarithmic normal distribution. For each road in 1936 $n = n°$ was computed by substituting the observed values of x_1, x_2, w, q, r, z_1, z_2 into (6)-(8). Since operating costs are given by $wn + qc + rd = wn\ (1 + 0.1349 + 0.3124)$, estimated costs for each road are taken as proportional to $wn°$.[32] We next estimate the equation

(9) $$\log I_{36} = -1.81 + \underset{(0.91)}{2.12} \log (p_1 x_1 + p_2 x_2)_{36} - \underset{(0.88)}{1.10} \log (wn°)_{36} - \underset{(0.023)}{0.012} i_{36} + u$$

$$\bar{R} = 0.92 \qquad \bar{S} = 0.33$$

where $p_1 x_1 + p_2 x_2$ = dollars of operating revenue
i = average yield on outstanding bonds, excluding equipment trust certificates, measured in percentages.

For this calculation there are 43 observations — as many companies as are contained in the National Bureau of Economic Research sample of railroad bond yields. The sample consists mainly of large solvent carriers.

We come now to the interpretation of this statistical result. First, revenues carry a positive coefficient and costs a negative coefficient, as one would expect; however, both estimates are subject to large sampling errors, primarily because of the close intercorrelation between revenues and costs. But the coefficient of revenues just meets a statistical significance test at the 5 per cent level. None of the variables show strong enough statistical significance to account for the high correlation. The sum of the coefficients of $\log (p_1 x_1 + p_2 x_2)$ and $\log wn°$ $(2.12 - 1.10 = 1.02)$ is of special importance to us, and is highly significant in the statistical sense. The sampling error of the sum depends on the variance of each individual coefficient and their covariance. It is estimated to be 0.08.

[32] This would make $\log wn°$ differ from the logarithm of estimated costs by a constant.

There is no unique mathematical relation between the logarithm of (positive) profits and the logarithm of revenues and the logarithm of costs, although they do roughly provide the same information. In other words, there is no unique relation between profits and the ratio of revenues to costs. There is, however, a basic property of a profit variable that we may expect our analogue in ratio form to possess. If unit receipts and unit costs all change in any given proportion, profits also change in that same proportion. We say that profits have homogeneity of degree unity in prices and unit costs. If receipts and costs are expressed in ratio form, and if this ratio is to have the same homogeneity property, the exponent of the numerator must be larger by unity than the exponent of the denominator. In the symbols of our equation, we write

$$\frac{(p_1x_1 + p_2x_2)^{1+\alpha}}{(wn^\circ)^\alpha} \text{ or } (1 + \alpha) \log (p_1x_1 + p_2x_2) - \alpha \log (wn^\circ)$$

as a profit variable in our investment equation. This is analogous also to the ordinary profit variable in that it requires only one parameter to relate it to investment. We find in the calculation for equation (9), where log $(p_1x_1 + p_2x_2)$ and log (wn°) are introduced as separate variables, that their coefficients add up to unity (significantly), as would be expected in case profits were the relevant variable. The parameter α is not reliably estimated in equation (9), largely because of the high intercorrelation involved; we try to correct for this by considering the relation between log I and log π in the preceding charts.

To summarize: Both the logarithm of revenues and the logarithm of operating income show strong empirical relations with the logarithm of investment. When the logarithms of revenues and of costs are introduced as separate variables, they exhibit a relation to the logarithm of investment that suggests operating income as the relevant variable. We prefer the evidence obtained from the last mentioned relation because it is a more general relation than the other two, even though the high intercorrelation between revenues and costs prohibits its being used for the final result in estimating all parameters.

An essentially different approach has been investigated in treating the sample of cross-section data. Since it is evident that a size variable is correlated with other independent variables, we have corrected for size by means of a deflation process and used a size correction that is not the same thing as the stock of capital. For 1937 we selected train-hours, a measure of the *flow* of capital services, as a divisor of all size influenced variables.

I = gross investment measured in dollars per train-hour

π = net railway operating income before depreciation measured in dollars per train-hour

K = reproduction cost of road and equipment measured in dollars per train-hour

a = percentage of freight and passenger cars less than 20 years old

i = average yield on outstanding bonds, excluding equipment trust certificates, measured in percentages

π' = net nonoperating income, excluding fixed charges, measured in dollars per train-hour

W = unappropriated surplus measured in dollars per train-hour

Subscripts attached to I, i, π, and π' indicate the year during which they occur; subscripts attached to K, a, and W, the year-end date at which they occur. Hickman's sample of bond yields is more complete for every fourth year, of which 1936 is one. The yield data refer to the first quarter of the year.

An equation similar to (1) of the time series study is

$$(10) \qquad I_{37} = 19.13 + \underset{(0.14)}{0.53}\pi_{36} - \underset{(1.19)}{0.08}i_{36} - \underset{(0.02)}{0.02}K_{36} - \underset{(0.11)}{0.15}a_{36} + u$$

$$\bar{R} = 0.55 \qquad \bar{S} = \$11.6 \text{ per train-hour}$$

In this calculation there are 37 observations, including all roads with bond issue quotations in Hickman's sample except those in receivership or trusteeship, those operated as parts of foreign systems, and those failing to report the age of their equipment. The resulting sample covers all the major railways not in bankruptcy.

We have modified equation (1) by introducing the age as well as the size of the capital stock. Our particular age variable excludes locomotives and road property, yet it is indicative of the state of a major part of equipment. Time series for this variable do not exist for very long periods. The only variable which has definite statistical significance is π. This is true in all the cross-section samples of this study. The upper range of a 95 per cent confidence interval surrounding the estimate of the coefficient of π covers at least the lower range of the corresponding interval of the time series study. In this respect there is no contradiction. The estimate of the coefficient of i is very uncertain and provides neither confirmation nor contradiction of our previous result. It must be remembered, though, that i is measured in the same units in both studies, while the mean value of investment per train hour is about 16.1 as compared with a mean in the time series study of 319.0. After correction for units of measurement 95 per cent confidence intervals from the two studies overlap, but this finding is not particularly meaningful in view of the uncertainty involved in the cross-section study. Bond yields range from 2.9 to 13.4 in the sample during 1936 so that the insignificant estimate cannot be attributed to a lack of intercompany variation in this particular year. In equation (10), i has a different meaning than in equation (1), being the yield on outstanding rather than new issues. The estimate of the coefficient of K_{36} carries uncertainty also, but much less than in the case of i_{36}. The extreme upper range, 95 per cent, of the estimate of the coefficient of K_{36} does not even overlap with the extreme lower range, 95 per cent, of the same coefficient in (1). It is not expected that cross-section estimates will agree with time series estimates in every pair of samples, but there are some specific reasons why we may get the discrepancy noted here. The influence of capital stock, as an indicator of capacity and capital accumulation, on investment may be fundamentally different on an individual and on an aggregative basis. In the latter case, the stock of capital of the whole industry influences the investment of the whole industry. In the former case, both the firm and the industry (or regional) stock of capital may influence the investment of the single firm. This is the point made in the TNEC cross-section studies referred to above (see note 8). The reason for this is that the existing capacity of several competitors, in addition to a carrier's own capacity, may affect the need for capital expansion and thus influence individual investment decisions. In dealing with industry totals, these effects get mixed. The time series relation may be looked upon as an aggregation of individual time relationships in which the coefficient of the capital stock represents two separate effects on investment — the influence of each individual's capacity on his investment and the influence of the industry's (or competitor's) capacity on his investment. In a cross-section sample industry variables are held constant, and we are measuring only a part of the effect of capital on investment. Another point in the reconciliation with the time series results is that the estimate of the coefficient of K_{36} is not independent of the estimate of the coefficient of a_{36}. Both variables tend to show some of the same phenomena, although their empirical correlation is a small negative value in this sample. The age distribution of capital does make for separate intercompany differences and should not be left out of the cross-section study, however. The intercorrelation between π_{36} and K_{36} that upset the logarithmic relation is not as significant in the size deflated formulation. In the present sample, $r_{\pi_{36}K_{36}} = 0.39$, while the multiple correlation in (10) is as large as 0.55.

The interest rate has a negligible effect in all formulations of the cross-section relations. Dropping i_{36} and adding π'_{36} and W_{36}, we get:

$$(11) \qquad I_{37} = 22.83 + \underset{(0.14)}{0.45}\pi_{36} - \underset{(0.02)}{0.03}K_{36} - \underset{(0.10)}{0.17}a_{36} - \underset{(0.60)}{0.62}\pi'_{36} + \underset{(0.03)}{0.04}W_{36} + u$$

$$\bar{R} = 0.56 \qquad \bar{S} = \$11.4 \text{ per train-hour}$$

These results look similar to those of equation (3) in the time series study, and the statistical significance of π'_{36} and W_{36} remains doubtful.

The residual variation of (11), u, is estimated in the accompanying distribution. There are not enough degrees of freedom in the sample to test this distribution for normality.

Investment per train-hour	No. of cases
\$22.5 to \$30.78	2
13.5 to 22.49	2
4.5 to 13.49	5
−4.5 to 4.49	14
−13.5 to −4.49	11
−22.5 to −13.49	3
	37

Two years' observations on I, π, and π' in conjunction with the same values for K, a, W, and i lead to more stable estimates for some variables.

$$(12) \qquad I_{36+37} = 32.27 + \underset{(0.10)}{0.38}\pi_{35+36} - \underset{(0.03)}{0.04}K_{36} - \underset{(0.15)}{0.27}a_{36} - \underset{(0.52)}{0.44}\pi'_{35+36} + \underset{(0.06)}{0.08}W_{36} - \underset{(1.93)}{0.19}i_{36} + u$$

$$\bar{R} = 0.60 \qquad \bar{S} = \$15.90 \text{ per train-hour}$$

There are only 36 observations in this sample because the 1936 investment figure for the Missouri-Kansas-Texas Railroad Company contains some doubtful adjustments. The 2-year analogue of (11), excluding i_{36} from (12), is given by

$$(13) \qquad I_{36+37} = 31.05 + \underset{(0.12)}{0.38}\pi_{35+36} - \underset{(0.03)}{0.04}K_{36} - \underset{(0.15)}{0.27}a_{36} - \underset{(0.51)}{0.44}\pi'_{35+36} + \underset{(0.05)}{0.09}W_{36} + u$$

$$\bar{R} = 0.62 \qquad \bar{S} = \$15.64 \text{ per train-hour}$$

Comparison of (12) and (13) shows the insensitivity of the estimates to the inclusion or exclusion of i. In the 2-year study the over-all correlation goes up and some variables show more statistical significance. We have not investigated the further possibilities of 3-5 year, cross-section investment samples. A further interesting property of the 2-year analysis is that the distribution of residuals becomes even more symmetric and 'normal' in appearance. This is important and should not be made secondary to high correlation as econometricians have tended to do in the past. The new distribution is

Investment per train-hour	No. of cases
\$22.5 to \$52.43	1
13.5 to 22.49	3
4.5 to 13.49	5
−4.5 to 4.49	16
−13.5 to −4.49	6
−22.5 to −13.49	4
−36.99 to −22.49	1
	36

We have tried to check some of our findings by examining a year of the

1920's during which there was substantial investment. Our choice is 1928 because this is a year in which quadrennial data on bond yields are available, although we could have selected 1929 as well and used a lag for this variable as was done in 1937. We are not able to obtain estimates of all the same data in 1928 as in 1936-37. There are no cost of reproduction data for which to measure K_{27} for most roads. The age distribution of freight and passenger cars is not available in the same form. We have been forced to use instead the following approximation to a_{27}: the ratio of installations during the seven years 1921-27 to freight and passenger equipment owned on December 31, 1927. Car-miles were used to measure size in place of train-hours. The latter are not available in 1928.

Bond yields, as estimated from the National Bureau sample, show extremely small dispersion in 1928. There are 52 observations between 4.2 and 5.8 per cent, and 3 scattered observations at 6.2, 6.9, and 7.6 per cent. For all practical purposes we may consider this variable as fixed in the 1928 cross-section sample. In this year there are yield quotations for more of the smaller roads, and if we take again, as a sample of analysis, all roads reporting bond yields, we find that the small roads have such erratic investment patterns that any general relationship is obscured. In multiple and simple correlation computations, no variable shows any statistically significant relation to investment. If, however, we limit the sample to the 39 largest roads, all having more than 100,000,000 car-miles, some of the familiar patterns emerge.

The most significant variables in 1927-28 are π_{27} and a_{27}. The estimated relation is

$$(14) \qquad I_{28} = 0.0055 + \underset{(0.15)}{0.46}\pi_{27} - \underset{(0.011)}{0.008}a_{27} + u$$

$$\bar{R} = 0.41 \qquad \bar{S} = 0.013 \text{ tens of dollars per car-mile}$$

The coefficient of a_{27} cannot be readily compared with that of a_{36} because of the differences in definitions. The mean value of I_{28} is 0.0202.

The results in (14) are not appreciably affected by the inclusion of π'_{27} and W_{27} in the analysis, but these two variables have coefficients opposite in sign from those obtained for π'_{36} and W_{36} and the corresponding variables in the time series analysis. The estimates are subject to sufficiently large errors so that the signs are not significant. If we use book values for the stock of capital as a substitute for estimates of reproduction cost we get contradictory results, a small positive coefficient subject to an error less than one-half the estimate. We do not accept the book value data as reliable, however.

A final check upon the 1936-37 cross-section results has been made from a study of 1939-40 data. This period was chosen because estimates of reproduction cost of road and equipment are available as of January 1,

1940. The only point that is unequivocally made in this final check is a confirmation of the profits-investment relation. An equation like (14) for the more recent period is estimated as

$$(15) \qquad I_{40} = -1.54 + \underset{(0.09)}{0.57\pi_{39}} - \underset{(0.06)}{0.02a_{39}} + u$$

$$\bar{R} = 0.72 \qquad \bar{S} = \$9.31 \text{ per train-hour}$$

In this calculation roads in receivership or trusteeship were excluded, and of the remainder, the 37 largest systems, all having more than 31,000 train hours, were used. The variable a_{39} measures the percentage of freight cars less than 20 years old on January 1, 1940. Roads not reporting such data are also excluded. The estimate of the coefficient of a_{39} is unreliable, and nothing definite can be said about the effect of this variable in 1940.

A similar result holds for other variables such as K_{39}, W_{39}, and π'_{39}. This can be seen immediately from

$$(16) \qquad I_{40} = -3.57 + \underset{(0.13)}{0.58\pi_{39}} + \underset{(0.017)}{0.003K_{39}} - \underset{(0.08)}{0.01a_{39}} + \underset{(0.69)}{0.09\pi'_{39}} - \underset{(0.010)}{0.005W_{39}} + u$$

$$\bar{R} = 0.69 \qquad \bar{S} = \$9.71 \text{ per train-hour}$$

The estimates in (16) tell us little; they neither confirm nor contradict the results of the 1936-37 investigation or the time series analysis. There is some non-negligible intercorrelation among the variables in (16). The correlation between π_{39} and K_{39} is as large as 0.51. The results of (16) are not affected in any essential way if net railway operating income after depreciation is used as a measure of π_{39} in (16). These values of π_{39} are smaller than those used in (16) and, of course, take a larger coefficient in a linear equation.

While we must remain in doubt about some matters, interesting conclusions can be drawn from all the pieces of information. First, there can be no doubt about the influence of profit on investment. This effect shows up clearly in both the time series and cross-section data. Second, lower interest charges stimulate investment. Bond yields show a definite effect in the time series study, although the absolute value of the interest elasticity is low. Bond yields do not show a statistically significant effect in the cross-section data, and in one case this may be partly attributed to a small variance in the sample. The high investment of bankrupt companies seen in the cross-section data is additional evidence of the influence of interest charges on investment. Third, the stock of capital appears to have depressing effect on investment. This shows up in the time series calculation, but we cannot be certain that its effect is not confused with that of other trend variables. It is interesting, however, that the statistical significance shows up in this study where gross investment is the main variable. Previously, the stock of capital had been studied in relation to net investment. The cross-section data are ambiguous on its influence. This variable has some limited influence in the 1936-37 data but it is not significant at the 5 per cent level. The data are not satisfactory for 1927-28, and the estimates are quite unreliable for 1939-40. The age of capital (related to the size) shows more definite influence in 1936-37, less in 1927-28, and still less in 1939-40. All in all, there is substantial but inconclusive evidence that capital accumulation has a depressing effect on further investment. Fourth, the investment pattern seems to be somewhat more stable on a 2- than on a 1-year basis. The stability was tested only from the cross-section data, all of which imply that investment behavior patterns have a large erratic component which varies inversely with the size of the investing unit. Finally, the systematic role of other variables in railway investment decisions remains dubious. Nonoperating income and surplus are not statistically significant in any of the samples. The directions of their influence vary from sample to sample. At various stages of the research work giving rise to this paper several other variables were considered, but none show any statistical significance.

3 ELECTRIC LIGHT AND POWER INVESTMENT IN THE UNITED STATES

One peculiarity of the railroad industry, as pointed out above, is its maturity relative to other industries of the United States economy. It is an interesting question to ask whether our statistical results are sufficiently general to extend to growing youthful industries. A logical choice for empirical study and comparison is the electric light and power industry. It is certainly a growing industry, and it is comparable with railroads because of its public service and regulatory nature. A further likeness to railroading is that electric light and power companies invest in highly durable goods for which interest considerations could be of some importance.

We have not made a detailed study of the electric utility industry as we did for railroads; consequently our knowledge of its institutional characteristics is very limited. We have merely attempted to assemble a usable set of time series for the interwar period and estimate the parameters of an equation taking the same form as (1). The quality of the data is distinctly inferior to that of the railroad statistics. For the period since 1926 we used statistics compiled by the Edison Electric Institute on net operating income and depreciation. The income data were extrapolated to 1919 on the basis of the industry estimates of Simon Kuznets.[33] A defect of his estimates, for our purposes, is that they include some nonoperating income. The Census of Electrical Industries provides estimates of the value of plant

[33] *National Income and Its Composition, 1919-1938* (NBER, 1941), pp. 659-713.

and equipment in central electric light and power establishments in 1917, 1922, and 1927. We assumed that depreciation in 1917 and in 1922 was in the same ratio to the physical asset valuation as in 1927. Intervening years are estimated by linear interpolation. Gross investment, 1921-36, is taken from the well known study of George Terborgh,[34] and extended to 1937-41 from estimates published in the *Survey of Current Business*, May 1949. A price index for electric utility plant and equipment expenditures is published regularly in the *Engineering News-Record*. Other construction cost indexes are available for public utilities. We merely selected an index that covers both plant and equipment items and is widely used in the electric light and power industry. We did not use a special index for the revaluation of depreciation charges. An initial value for the stock of capital was not used in this time series study because there is no basic revaluation study converting book values into costs of reproduction. Instead, we include the initial stock of capital in the constant term of our linear equation and use cumulations of net investment from a zero origin as a measure of the capital stock. All parameters except the constant term are unaffected by this procedure. Finally, yields on new issues of utility bonds are estimated by Moody's Investors Service.

The notation will be exactly the same as that used in the railroad study, but all variables now refer to the electric light and power industry. The estimated equation, 1921-41, is

$$(17) \qquad I = 1054 + \underset{(0.43)}{2.03}\pi_{-1} - \underset{(37)}{146}i - \underset{(0.07)}{0.37}K_{-1} + u$$

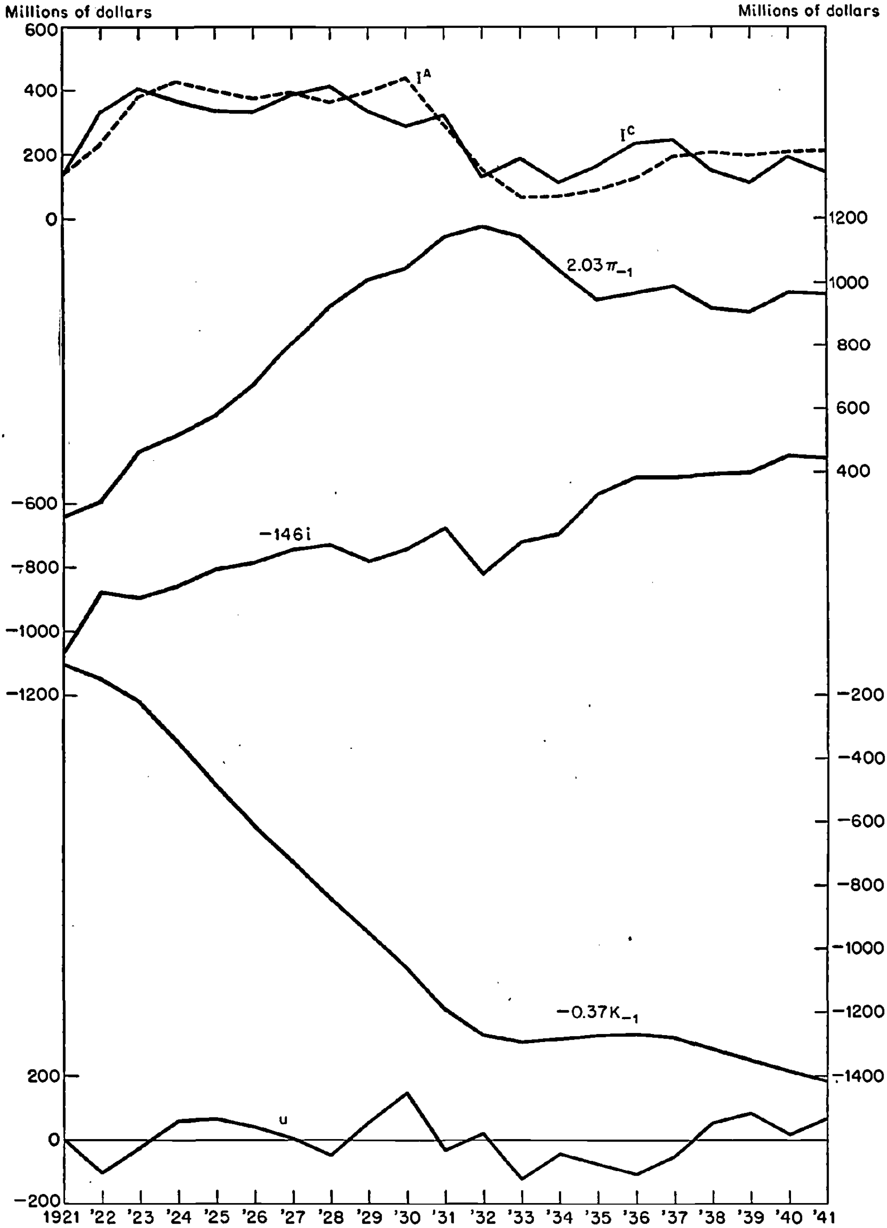
$$\bar{R} = 0.79 \qquad \bar{S} = \$77.23 \text{ million (1911 prices)} \qquad \frac{\delta^2}{S^2} = 1.40$$

The correlation is not especially high, but this is in keeping with our views on both the accuracy of the data used and the volatility of investment, particularly in a growing industry where investment decisions are not routine. The nonautocorrelation of the residual variation is acceptable at a 5 per cent level of significance, but the time shape of the residuals does leave something to be desired. They seem to contain a wavelike movement, and more intensive analysis of the industry's investment process is called for. There is some suggestion in the residual pattern that our profit-investment lag is not entirely suitable. Perhaps both current and past gross operating income should be variables in the investment equation for the electric light and power industry. We have not extended our calculations to this case, however, because the introduction of current operating income into the equation raises the problem of constructing a larger model to explain this variable as well as investment. Such further work would carry us too far afield.

[34] Estimated Expenditures for New Durable Goods, 1919-1938, *Federal Reserve Bulletin*, September 1939, p. 732.

Chart 8
Electric Light and Power, 1921 – 1941

(17) $I = 1054 + 2.03\pi_{-1} - 146i - 0.37K_{-1} + u$



The coefficients in (17) are all large in absolute value as compared with the estimates in (1). Although profit is an important variable in (17), it does not show the same stability with respect to investment as in the railroad study. In the present case the estimate of the profit coefficient is sensitive to the omission or inclusion of i and K_{-1}. The gross correlation between π_{-1} and I is negative. There is no *a priori* reason why the marginal propensity to invest out of gross operating profits should be less than unity, but I feel uncomfortable about the size of the estimate of this parameter in (17). The interest-elasticity of investment at the point of means is 2.79. In this industry, there appears to be a statistically significant relation between interest and investment which is not negligible in magnitude. This is a likely event in a growing industry. Equation (17) provides another example of the depressing effect of capital accumulation on investment.

In equation (17) there is high intercorrelation between gross operating income and the stock of capital. This relation is probably induced by regulations limiting profits in the industry to a 'fair' rate of return. Throughout the 1920's there is a very strong linear relation between π and K, then all the observations fall below the line of relationship, as though the depression conditions of the 1930's cut profits below a 'normal' or 'fair' return.

A slight revision of (17) was computed by introducing the lagged price of capital goods as a separate variable, thus casting the equation into the form of an analogue of (2) above. However, in this industry prices show a statistically significant positive effect instead of the expected negative effect. We reject this formulation. Another alternative has also been considered. Utilities are known to have had greater access than railroads to the market for equity capital;[35] so we replace gross operating income by an average yield on utility shares. The latter variable shows jointly the influence of profitability and of availability of equity funds on investment. At the same time we lag the bond yield variable (for the sake of variety) and use another measure of the existing stock of capital, total generating capacity measured in kilowatts. Capacity may be a superior measure as compared with the stock of capital in the sense that it takes account of both price and quality changes. Share yields are taken from Alfred Cowles' *Common Stock Indexes* for 1921-38 and from Moody's Investors Service for 1939-40. The Edison Electric Institute prepares statistics of generating capacity. The estimated equation, 1922-41, is

$$(18) \qquad I = 1459 - \underset{(9)}{50s_{-1}} - \underset{(21)}{58i_{-1}} - \underset{(3)}{24C_{-1}} + u$$

$$\bar{R} = 0.89 \qquad \bar{S} = \$57.54 \text{ million (1911 prices)} \qquad \frac{\delta^2}{S^2} = 1.38$$

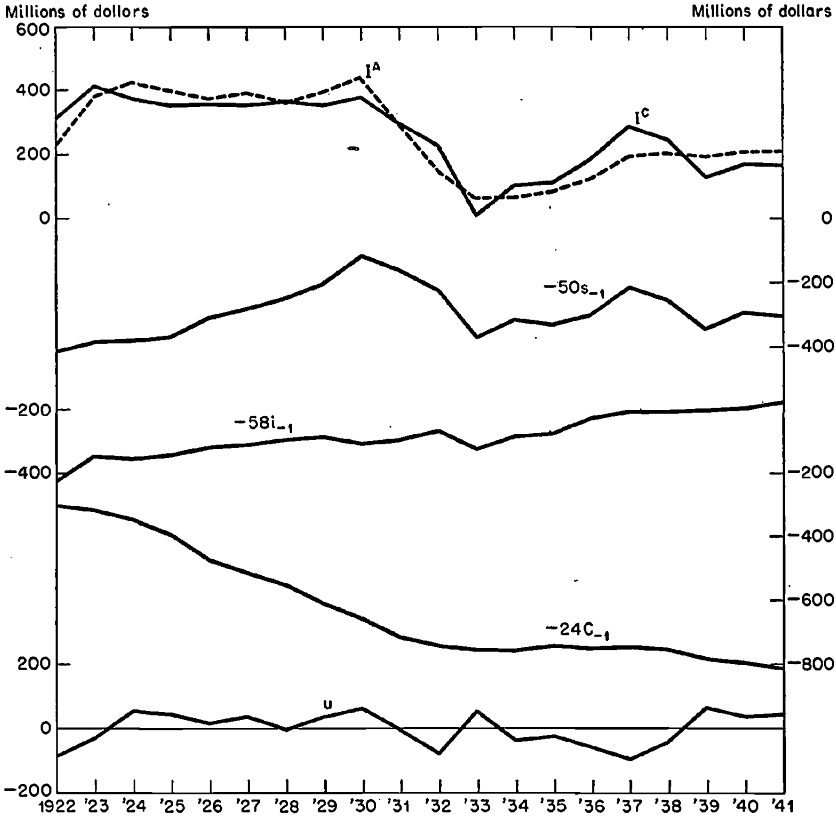
where s = share yield in percentages, and C = generating capacity in millions of kilowatts. This is not a definitive result because the residual varia-

[35] See Irwin Friend, *op. cit.*

Chart 9

Electric Light and Power, 1922 – 1941

(18) $I = 1459 - 50s_{-1} - 58i_{-1} - 24C_{-1} + u$



tion, while passing a significance test for lack of serial correlation, does not appear to be entirely random. These results are on a par with those in (17). Bond yields have a smaller influence in (18), yet remain statistically significant. It is interesting to see the effect of share yields on investment in the electric utility industry.

One should not draw a hasty generalization from the studies of railway and electric utility investment that interest rates affect investment in other highly durable producer goods in the same way. Railroads and electric utilities are in a sheltered position that enable them to plan over a long horizon. There is no compelling reason for them to amortize capital expenditures over 5-10 years when the service lives of goods are much longer. In other industries the effective horizon may be much shorter than the life of the capital goods purchased, and working capital or other internal funds may be more important for the financing of capital outlays.

Appendix Table 1

DATA FOR CLASS I STEAM RAILWAYS, 1921-1941

	Gross Capital Expenditures (thousands of dollars) (1)	Net Railway Operating Income (thousands of dollars) (2)	Depreciation Recorded (thousands of dollars) (3)	Depreciation Unrecorded (thousands of dollars) (4)	Construction Index 1910-14:1.00 (5)	Yield on New Bonds (percentage) (6)	Unappropriated Surplus (thousands of dollars) (7)	Net Non-operating Income (thousands of dollars) (8)	Maintenance Expenditures (thousands of dollars) (9)	Maintenance Wages (thousands of dollars) (10)	% of Wages Charged to Operating Expense (11)	Car-Miles (000) (12)	Av. Hourly Earnings ($) (13)
1921	534,952	600,937	149,873	98,701	1.77		1,921,328	330,633	2,007,893		93.65	23,995,012	0.667
1922	470,661	760,187	152,246	99,992	1.59	5.68	2,041,191	239,518	1,981,181	1,127,663	93.48	24,946,626	0.613
1923	1,035,703	961,955	166,249	100,494	1.77	5.38	2,253,427	234,015	2,278,845	1,349,279	92.71	29,432,500	0.610
1924	896,206	973,837	181,165	101,645	1.74	5.34	2,457,138	250,688	2,052,698	1,221,316	92.88	28,889,085	0.623
1925	750,885	1,121,076	194,169	102,655	1.68	5.45	2,734,881	244,449	2,076,278	1,222,654	92.49	30,785,543	0.631
1926	828,593	1,213,090	202,342	103,457	1.68	5.12	3,055,827	275,324	2,149,911	1,262,574	92.24	32,666,043	0.631
1927	757,053	1,067,985	213,663	102,959	1.69	4.94	3,163,641	290,874	2,087,633	1,232,626	92.45	32,462,179	0.644
1928	662,259	1,172,864	215,407	105,891	1.64	4.68	3,514,107	296,907	2,004,848	1,169,811	93.04	32,994,940	0.655
1929	825,399	1,251,698	219,672	107,238	1.66	5.02	3,885,105	337,767	2,058,267	1,213,891	92.32	33,828,943	0.666
1930	795,277	868,879	224,707	108,658	1.60	4.79	3,553,747	338,104	1,724,736	1,026,614	92.78	30,177,596	0.678
1931	308,181	525,628	214,450	110,094	1.49	4.73	3,272,305	281,363	1,347,566	793,328	93.81	25,608,792	0.689
1932	158,984	326,298	194,460	112,252	1.36	5.00	2,970,656	200,567	970,120	538,648	94.98	20,350,867	0.636
1933	105,803	474,296	184,626	114,492	1.33	5.24	2,772,516	197,527	920,996	507,314	95.18	20,597,254	0.629
1934	176,331	462,652	187,289	115,675	1.40	5.09	2,556,032	185,563	1,003,205	575,028	94.90	22,179,787	0.635
1935	189,296	499,819	193,221	117,016	1.42	4.25	2,307,272	168,646	1,075,854	619,110	94.54	22,512,343	0.686
1936	302,230	667,347	192,073	118,012	1.43	3.76	2,152,125	163,330	1,237,810	720,714	94.02	25,588,229	0.691
1937	550,801	590,204	194,851	115,596	1.53	3.49	1,948,460	149,596	1,322,303	780,882	93.96	26,848,097	0.709
1938	275,596	372,874	201,825	114,789	1.49	3.47	1,627,968	130,607	1,096,654	632,012	95.08	23,141,532	0.750
1939	250,674	588,829	201,853	113,757	1.49	3.52	1,283,301	135,964	1,232,766	708,982	95.57	25,258,741	0.749
1940	458,594	682,134	205,860	113,192	1.53	3.39	1,165,419	141,403	1,316,007	756,694	94.48	27,330,844	0.751
1941	512,897	998,256	233,340	105,417	1.65	3.03			1,595,701	931,856	94.27	32,147,389	0.780

COLUMN

1 *Postwar Capital Expenditures of the Railroads*, ICC, Bureau of Transport Economics and Statistics, Washington, D.C., March 1947, p. 35.

2 *Statistics of Railways.*

3 Same as 2.

4 *Analysis of Steam Railway Dividends, 1890-1941,* ICC, Bureau of Transport Economics and Statistics, November 1943, p. 95.

5 *Railroad Construction Indices,* ICC, Bureau of Valuation, August 1, 1942.

6 *Moody's, Railroads, 1946,* Moody's Investors Service, p. a49.

7 Profit and loss balance, *Statistics of Railways.*

8 Other income minus miscellaneous deductions, *Statistics of Railways.*

9 Same as 2.

10 Same as 2.

11 Thor Hultgren, *American Transportation in Prosperity and Depression* (NBER, 1948), p. 184

12 Same as 2.

13 Same as 2.

Variables Used in Time Series Estimates

$$I = \frac{(1)}{(5)};\ \pi = \frac{(2) + (3)}{(5)};\ i = (6) \qquad q = (5)$$

$$K_t = 10{,}924{,}943 + \sum_{i=1940}^{t} \left[\frac{(1) - (3) - (4)}{(5)}\right]_i, \qquad t > 1939$$

$$K_t = 10{,}924{,}943 \qquad , \qquad t = 1939$$

$$K_t = 10{,}924{,}943 - \sum_{i=t+1}^{1939} \left[\frac{(1) - (3) - (4)}{(5)}\right]_i, \qquad t < 1939$$

$$10{,}924{,}943 = \frac{16{,}278{,}165}{1.49}$$

16,278,165 = Cost of reproduction of fixed property excluding land. Ex Parte No. 148, *Exhibit No. A 11,* ICC, Bureau of Valuation (December 1942).

1.49 = construction cost index, 1939.

$$W = \frac{(7)}{(5)};\ \pi' = \frac{(8)}{(5)};\ r = \frac{(9) - \frac{(10)\ (11)}{100}}{(12)}\ 100;\ w = (13)$$

Class I Steam Railways, 1928

1 Bangor and Aroostook R.R. Co.
2 Boston and Maine R.R.
3 Canadian National System
- a Chicago, Detroit and Canada Grand Trunk Junction R.R. Co.
- b Atlantic and St. Lawrence R.R. Co.
- c Central Vermont Railway Co.
- d Detroit, Grand Haven and Milwaukee Railway Co.
- e Grand Trunk Western Railway Co.
- f Duluth, Winnipeg and Pacific Railway Co.

4 Canadian Pacific System
- a Canadian Pacific Lines in Maine
- b Canadian Pacific Lines in Vermont
- c Duluth, South Shore and Atlantic Railway Co.
- d Minneapolis, St. Paul and Sault Ste. Marie Railway Co.
- e Spokane International Railway Co.

5 Maine Central R.R. Co.
6 New Haven System
- a New York, New Haven and Hartford R.R. Co.
- b New York, Ontario and Western Railway Co.

7 New York Connecting R.R. Co.
8 Rutland R.R. Co.
9 Buffalo, Rochester and Pittsburgh Railway Co.
10 Delaware and Hudson Co.
11 Delaware, Lackawanna and Western R.R. Co.
12 Detroit and Mackinac Railway Co.
13 Detroit and Toledo Shore Line R.R. Co.
14 Erie System
- a Chicago and Erie R.R. Co.
- b Erie R.R. Co.
- c New Jersey and New York R.R. Co.
- d New York, Susquehanna and Western R.R. Co.

15 Lehigh and Hudson River Railway Co.
16 Lehigh and New England R.R. Co.
17 Lehigh Valley R.R. Co.
18 Monongahela Railway Co.
19 Montour R.R. Co.
20 New York Central Lines
- a Michigan Central R.R. Co.
- b New York Central R.R. Co.
- c Pittsburgh and Lake Erie R.R. Co.
- d Cincinnati Northern R.R. Co.
- e Cleveland, Cincinnati, Chicago and St. Louis Railway Co.
- f Evansville, Indianapolis and Terre Haute Railway Co.

21 New York, Chicago and St. Louis R.R. Co.
22 Pere Marquette Railway Co.
23 Pittsburgh and Shawmut R.R. Co.
24 Pittsburgh and West Virginia Railway Co.
25 Pittsburgh, Shawmut and Northern R.R. Co.[R]
26 Ulster and Delaware R.R. Co.
27 Duluth and Iron Range R.R. Co.
28 Great Northern Railway Co.
29 Green Bay and Western R.R. Co.
30 Lake Superior and Ishpeming R.R. Co.

31 Minneapolis and St. Louis R.R. Co.[R]
32 Northern Pacific Railway Co.
33 Spokane, Portland and Seattle Railway Co.
34 Union Pacific System
- a Oregon Short Line R.R. Co.
- b Oregon-Washington R.R. and Navigation Co.
- c Los Angeles and Salt Lake R.R. Co.
- d Union Pacific R.R. Co.
- e St. Joseph and Grand Island Railway Co.

35 Bingham and Garfield Railway Co.
36 Burlington Route
- a Wichita Valley Railway Co.
- b Chicago, Burlington and Quincy R.R. Co.
- c Colorado and Southern Railway Co.
- d Fort Worth and Denver City Railway Co.
- e Quincy, Omaha and Kansas City R.R. Co.

37 Chicago and Alton R.R. Co.[R]
38 Denver and Rio Grande Western R.R. Co.
39 Denver and Salt Lake Railway Co.
40 Nevada Northern Railway Co.
41 Northwestern Pacific R.R. Co.
42 Rock Island System
- a Chicago, Rock Island and Gulf Railway Co.
- b Chicago, Rock Island and Pacific Railway Co.

43 San Diego and Arizona Railway Co.
Note: Half owned by Southern Pacific Co. and half by Spreckles Securities Co.
44 Wabash Railway Co.
- a Ann Arbor R.R. Co.
- b Wabash Railway Co.

45 Akron, Canton and Youngstown Railway Co.
46 Baltimore and Ohio System
- a Baltimore and Ohio R.R. Co.
- b Staten Island Rapid Transit Co.

47 Bessemer and Lake Erie R.R. Co.
48 Buffalo and Susquehanna R.R. Corporation
49 Chesapeake and Ohio System
- a Hocking Valley Railway Co.
- b Chesapeake and Ohio Railway Co.

50 Chicago and Eastern Illinois Railway Co.
51 Chicago and Illinois Midland Railway Co.
52 Chicago, Indianapolis and Louisville Railway Co.
53 Detroit, Toledo and Ironton R.R. Co.
54 Elgin, Joliet and Eastern Railway Co.
55 Illinois Terminal Co.
56 Pennsylvania System
- a Baltimore, Chesapeake and Atlantic Railway Co.
- b Long Island R.R. Co.
- c Pennsylvania R.R. Co.
- d West Jersey and Seashore R.R. Co.

57 Reading System
- a Atlantic City R.R. Co.
- b Central R.R. Co. of N.J.
- c Perkiomen R.R. Co.
- d Port Reading R.R. Co.

e Reading Co.
58 Western Maryland Railway Co.
59 Wheeling and Lake Erie Railway Co.
60 Norfolk and Western Railway Co.
61 Richmond, Fredericksburg and Potomac R.R. Co.
62 Virginian Railway Co.
63 Atlantic Coast Line System
a Atlanta and West Point R.R. Co.
b Atlanta Birmingham and Coast R.R. Co.
c Atlantic Coast Line R.R.
d Charleston and Western Carolina Railway Co.
e Clinchfield R.R. Co.
f Georgia R.R., Lessee organization
g Louisville and Nashville R.R. Co.
h Louisville, Henderson and St. Louis Railway Co.
i Nashville, Chattanooga and St. Louis Railway
j Western Railway of Alabama
64 Columbus and Greenville Railway Co.
65 Florida East Coast Railway
66 Georgia and Florida R.R.
67 Gulf, Mobile and Northern R.R. Co.
68 Illinois Central System
a Central of Georgia Railway Co.
b Gulf and Ship Island R.R. Co.
c Illinois Central R.R. Co.
d Yazoo and Mississippi Valley R.R. Co.
69 Mississippi Central R.R. Co.
70 New Orleans Great Northern R.R. Co.
71 Norfolk Southern R.R. Co.
72 Seaboard Air Line Railway Co.
73 Southern System
a Alabama Great Southern R.R. Co.
b Cincinnati, New Orleans and Texas Pacific Railway Co.
c Georgia Southern and Florida Railway Co.
d Mobile and Ohio R.R. Co.
e New Orleans and Northeastern R.R. Co.
f Northern Alabama Railway Co.
g Southern Railway Co.
74 Tennessee Central Railway Co.
75 Chicago and North Western System
a Chicago and North Western Railway Co.
b Chicago, St. Paul, Minneapolis and Omaha Railway Co.
76 Chicago Great Western R.R. Co.
77 Chicago, Milwaukee, St. Paul and Pacific R.R.
78 Duluth, Missabe and Northern Railway Co.
79 Santa Fe System
a Atchison, Topeka and Santa Fe Railway Co.
b Panhandle and Santa Fe Railway Co.
c Gulf, Colorado and Santa Fe Railway Co.
d Kansas City, Mexico and Orient Railway Co. of Texas
e Kansas City, Mexico and Orient Railway Co.
80 Southern Pacific System
a Southern Pacific Co.
b Texas and New Orleans R.R. Co.
81 Toledo, Peoria and Western R.R.

82 Utah Railway Co.
83 Western Pacific R.R. Co.
84 Fort Smith and Western Railway Co.
85 Frisco Lines
   a Fort Worth and Rio Grande Railway Co.
   b St. Louis-San Francisco Railway Co.
   c St. Louis, San Francisco and Texas Railway Co.
86 Kansas City Southern System
   a Kansas City Southern Railway Co.
   b Texarkana and Fort Smith Railway Co.
87 Kansas, Oklahoma and Gulf Railway Co.
88 Louisiana and Arkansas Railway Co.
89 Louisiana Railway and Navigation Co.
90 Louisiana Railway and Navigation Co. of Texas
91 Midland Valley R.R. Co.
92 Missouri and North Arkansas Railway Co.[R]
93 Missouri-Kansas-Texas Lines
   a Missouri-Kansas-Texas R.R. Co.
   b Missouri-Kansas-Texas R.R. Co. of Texas
94 Missouri-Pacific System
   a Beaumont, Sour Lake and Western Railway Co.
   b International-Great Northern R.R. Co.
   c Missouri Pacific R.R. Co.
   d New Orleans, Texas and Mexico Railway Co.
   e St. Louis, Brownsville and Mexico Railway Co.
   f San Antonio, Uvalde and Gulf R.R. Co.
   g Texas and Pacific Railway Co.
95 Texas Mexican Railway Co.
96 St. Louis Southwestern Lines
   a St. Louis Southwestern Railway Co.
   b St. Louis Southwestern Railway Co. of Texas
97 Trinity and Brazos Valley Railway Co.[R]
98 Wichita Falls and Southern R.R. Co.
99 Copper River and Northwestern Railway Co.
100 Oahu Railway and Land Co.

Class I Steam Railways, 1936

1 Bangor and Aroostook R.R. Co.
2 Boston and Maine R.R.
3 Canadian National System
   a Canadian National Lines in New England
   b Central Vermont Railway, Inc.
   c Grand Trunk Western R.R. Co. (including Muskegon Railway and Navigation Co.)
   d Duluth, Winnipeg and Pacific Railway Co. (including Duluth, Rainy Lake and Winnipeg Railway Co.)
4 Canadian Pacific System
   a Canadian Pacific Lines in Vermont
   b International Railway Co. of Maine
   c Duluth, South Shore and Atlantic Railway Co.
   d Minneapolis, St. Paul and Sault Ste. Marie Railway Co.
   e Spokane International Railway Co.[T]
5 Maine Central R.R. Co.

6 New Haven System
a New York, New Haven and Hartford R.R. Co.[T]
b New York, Ontario and Western Railway Co.
7 New York Connecting R.R. Co.
8 Rutland Railroad Co.
9 Cambria and Indiana R.R. Co.
10 Delaware and Hudson R.R. Corporation
11 Delaware Lackawanna and Western R.R. Co.
12 Detroit and Mackinac Railway Co.
13 Detroit and Toledo Shore Line R.R. Co.
14 Erie System
a Erie R.R. Co. (including Chicago and Erie R.R. Co.)
b New Jersey and New York R.R. Co.
c New York, Susquehanna and Western R.R. Co. (including Wilkes-Barre and Eastern R.R. Co.)
15 Lehigh and Hudson River Railway Co.
16 Lehigh and New England R.R. Co.
17 Lehigh Valley R.R. Co.
18 Monongahela Railway Co.
19 Montour R.R. Co.
20 New York Central Lines
a New York Central R.R. Co.
b Pittsburgh and Lake Erie R.R. Co.
21 New York, Chicago and St. Louis R.R. Co.
22 Chesapeake and Ohio Railway
a Pere Marquette Railway Co.
b Chesapeake and Ohio Railway Co.
23 Pittsburgh and Shawmut R.R. Co.
24 The Pennroad Corporation
a Pittsburgh and West Virginia Railway Co.
b Detroit, Toledo and Ironton R.R. Co.
25 Pittsburgh, Shawmut and Northern R.R. Co.[R]
26 Wabash System[R]
a Ann Arbor R.R. Co.
b Wabash Railway Co.
27 Akron, Canton and Youngstown Railway Co.[T]
28 Baltimore and Ohio System
a Baltimore and Ohio R.R. Co.
b Staten Island Rapid Transit Co.
c Alton R.R. Co.
29 U. S. Steel Corporation
a Bessemer and Lake Erie R.R. Co.
b Elgin, Joliet and Eastern Railway Co.
c Duluth, Missabe and Northern Railway Co.
Duluth, Missabe and Iron Range as of July 1, 1937
30 Chicago and Eastern Illinois Railway Co.[T]
31 Chicago and Illinois Midland Railway Co.
32 Chicago, Indianapolis and Louisville Railway Co.[T]
33 Illinois Terminal Co.
Illinois Terminal Railroad Co. as of January 1, 1937
34 Pennsylvania System
a Long Island R.R. Co.
b Pennsylvania R.R. Co.
35 Pennsylvania-Reading Seashore Lines

36 Reading System
 a Central R.R. Co. of New Jersey
 b Reading Co.
37 Western Maryland Railway Co.
38 Wheeling and Lake Erie Railway Co.
39 Norfolk and Western Railway Co.
40 Richmond, Fredericksburg and Potomac R.R. Co.
41 Virginian Railway Co.
42 Columbus and Greenville Railway Co.
43 Florida East Coast Railway Co.[R]
44 Georgia and Florida R.R. (including Statesboro Northern Railway)[R]
45 Atlantic Coast Line System
 a Atlanta and West Point R.R. Co.
 b Atlanta, Birmingham and Coast R.R. Co.
 c Atlantic Coast Line R.R. Co.
 d Charleston and Western Carolina Railway Co.
 e Clinchfield R.R. Co.
 f Georgia R.R., Lessee organization
 g Louisville and Nashville R.R. Co.
 h Nashville, Chattanooga and St. Louis Railway
 i Western Railway of Alabama
46 Gulf, Mobile and Northern R.R. Co.
47 Illinois Central System
 a Central of Georgia Railway Co.[R]
 b Gulf and Ship Island R.R. Co.
 c Illinois Central R.R. Co.
 d Yazoo and Mississippi Valley R.R. Co.
48 Mississippi Central R.R. Co.
49 Norfolk Southern R.R. Co.[R]
50 Seaboard Air Line Railway Co.[R]
51 Southern System
 a Southern Railway Co.
 b Alabama Great Southern R.R. Co.
 c Cincinnati, New Orleans and Texas Pacific Railway Co.
 d Georgia Southern and Florida Railway Co.
 e Mobile and Ohio R.R. Co.[R]
 f New Orleans and Northeastern R.R. Co.
 g Northern Alabama Railway Co.
52 Tennessee Central Railway Co.
53 Chicago and North Western System
 a Chicago and North Western Railway Co.[T]
 b Chicago, St. Paul, Minneapolis and Omaha Railway Co.
54 Chicago Great Western R.R. Co.[T]
55 Chicago, Milwaukee, St. Paul and Pacific R.R. Co.[T]
56 Great Northern Railway Co.
57 Green Bay and Western R.R. Co.
58 Lake Superior and Ishpeming R.R. Co.
59 Minneapolis and St. Louis R.R. Co.[R]
60 Northern Pacific Railway Co.
61 Spokane, Portland and Seattle Railway Co. and affiliated companies
62 Atchison, Topeka and Santa Fe Railway Co. and affiliated companies
63 Burlington Route
 a Chicago, Burlington and Quincy R.R. Co.
 b Colorado and Southern Railway Co.
 c Fort Worth and Denver City Railway Co.

64 Denver and Rio Grande Western R.R. Co.[T]
65 Denver and Salt Lake Railway Co.
66 Rock Island System[T]
  a Chicago, Rock Island & Gulf Railway Co.
  b Chicago, Rock Island & Pacific Railway Co.
67 Southern Pacific System
  a St. Louis Southwestern Railway Co. and affiliated companies[T]
  b Northwestern Pacific R.R. Co.
  c Southern Pacific Co.
  d Texas and New Orleans R.R. Co.
68 Toledo, Peoria and Western R.R.
69 Union Pacific R.R. Co.
70 Utah Railway Co.
71 Western Pacific R.R. Co.[T]
72 Burlington-Rock Island R.R. Co.
73 Fort Smith and Western Railway Co.[R]
74 Frisco Lines
  a Fort Worth and Rio Grande Railway Co.
  b St. Louis-San Francisco Railway Co.[T]
  c St. Louis, San Francisco and Texas Railway Co.
75 Kansas City Southern Railway Co.
76 Muskogee Co.
  a Kansas, Oklahoma and Gulf Railway Co.
  b Midland Valley R.R. Co.
  c Oklahoma City-Ada-Atoka Railway Co.
77 Louisiana and Arkansas Railway Co.
78 Louisiana, Arkansas and Texas Railway Co.
79 Missouri and Arkansas Railway Co.
80 Missouri-Kansas-Texas R.R. Co. and controlled companies
81 Missouri-Pacific System[T]
  a Missouri-Illinois R.R. Co.
  b Beaumont, Sour Lake and Western Railway Co.
  c International-Great Northern R.R. Co.
  d Missouri Pacific R.R. Co.
  e New Orleans, Texas and Mexico Railway Co.
  f St. Louis, Brownsville and Mexico Railway Co.
  g San Antonio, Uvalde and Gulf R.R. Co.
  h Texas and Pacific Railway Co.
82 Texas Mexican Railway Co.
83 Wichita Falls and Southern R.R. Co.
84 Kennecott Copper Corporation
  a Nevada Northern Railway Co.
  b Copper River and Northwestern Railway Co.
85 Oahu Railway and Land Co.

Class I Steam Railways, 1940

1 Bangor and Aroostook R.R. Co.
2 Boston and Maine R.R.
3 Canadian National System
  a Canadian National Lines in New England
  b Central Vermont Railway, Inc.
  c Grand Trunk Western R.R. Co. (including Muskegon Railway and Navigation Co.)

d Duluth, Winnipeg and Pacific Railway Co. (including Duluth, Rainy Lake and Winnipeg Railway Co.)
4 Canadian Pacific System
a Canadian Pacific Lines in Vermont
b International Railway Co. of Maine
c Duluth, South Shore and Atlantic Railway Co.[T]
d Minneapolis, St. Paul and Sault Ste. Marie Railway Co.[T]
e Spokane International Railway Co.[T]
5 Maine Central R.R. Co.
6 New Haven System[T]
a New York, New Haven and Hartford R.R. Co.
b New York, Ontario and Western Railway Co.
7 New York Connecting R.R. Co.
8 Rutland Railroad Co.[R]
9 Cambria and Indiana R.R. Co.
10 Delaware and Hudson R.R. Corporation
11 Delaware Lackawanna and Western R.R. Co.
12 Detroit and Mackinac Railway Co.
13 Detroit and Toledo Shore Line R.R. Co.
15 Lehigh and Hudson River Railway Co.
16 Lehigh and New England R.R. Co.
17 Lehigh Valley R.R. Co.
18 Monongahela Railway Co.
19 Montour R.R. Co.
20 New York Central Lines
a New York Central R.R. Co.
b Pittsburgh and Lake Erie R.R. Co.
23 Pittsburgh and Shawmut R.R. Co.
24 The Pennroad Corporation
a Pittsburgh and West Virginia Railway Co.
b Detroit, Toledo and Ironton R.R. Co.
25 Pittsburgh, Shawmut and Northern R.R. Co.[R]
26 Wabash System[R]
a Ann Arbor R.R. Co.
b Wabash Railway Co.
27 Akron, Canton and Youngstown Railway Co.[T]
28 Baltimore and Ohio System
a Baltimore and Ohio R.R. Co.
b Staten Island Rapid Transit Co.
c Alton R.R. Co.
29 U. S. Steel Corporation
a Bessemer and Lake Erie R.R. Co.
b Elgin, Joliet and Eastern Railway Co.
c Duluth, Missabe and Iron Range Railway Co.
30 Chicago and Eastern Illinois Railway Co.[T]
31 Chicago and Illinois Midland Railway Co.
32 Chicago, Indianapolis and Louisville Railway Co.[T]
33 Illinois Terminal R.R. Co.
34 Pennsylvania System
a Long Island R.R. Co.
b Pennsylvania R.R. Co.
35 Pennsylvania-Reading Seashore Lines
36 Reading System
a Central R.R. Co. of New Jersey[T]
b Reading Co.

37 Western Maryland Railway Co.
38 Wheeling and Lake Erie Railway Co.
39 Norfolk and Western Railway Co.
40 Richmond, Fredericksburg and Potomac R.R. Co.
41 Virginian Railway Co.
42 Columbus and Greenville Railway Co.
43 Florida East Coast Railway Co.[R]
44 Georgia and Florida R.R. (including Statesboro Northern Railway)[R]
45 Atlantic Coast Line System
  a Atlanta and West Point R.R. Co.
  b Atlanta, Birmingham and Coast R.R. Co.
  c Atlantic Coast Line R.R. Co.
  d Charleston and Western Carolina Railway Co.
  e Clinchfield R.R. Co.
  f Georgia R.R., Lessee Organization
  g Louisville and Nashville R.R. Co.
  h Nashville, Chattanooga and St. Louis Railway
  i Western Railway of Alabama
46 Gulf, Mobile and Ohio
  Successor to Gulf, Mobile and Northern R.R. Co. and Mobile and Ohio R.R. Co. (July 31, 1940)
47 Illinois Central System
  a Central of Georgia Railway Co.[T]
  b Gulf and Ship Island R.R. Co.
  c Illinois Central R.R. Co.
  d Yazoo and Mississippi Valley R.R. Co.
48 Mississippi Central R.R. Co.
49 Norfolk Southern R.R. Co.[R]
50 Seaboard Air Line Railway Co.[R]
51 Southern System
  a Southern Railway Co.
  b Alabama Great Southern R.R. Co.
  c Cincinnati, New Orleans and Texas Pacific Railway Co.
  d Georgia Southern and Florida Railway Co.
  e New Orleans and Northeastern R.R. Co.
52 Tennessee Central Railway Co.
53 Chicago and North Western System
  a Chicago and North Western Railway Co.[T]
  b Chicago, St. Paul, Minneapolis and Omaha Railway Co.
54 Chicago Great Western R.R. Co.[T]
55 Chicago, Milwaukee, St. Paul and Pacific R.R. Co.[T]
56 Great Northern Railway Co.
57 Green Bay and Western R.R. Co.
58 Lake Superior and Ishpeming R.R. Co.
59 Minneapolis and St. Louis R.R. Co.[R]
60 Northern Pacific Railway Co.
61 Spokane, Portland and Seattle Railway Co. and affiliated companies
62 Atchison, Topeka and Santa Fe Railway Co. and affiliated companies
63 Burlington Route
  a Chicago, Burlington and Quincy R.R. Co.
  b Colorado and Southern Railway Co.
  c Fort Worth and Denver City Railway Co.
64 Denver and Rio Grande Western R.R. Co.[T]
65 Denver and Salt Lake Railway Co.
66 Chicago, Rock Island and Pacific Railway Co.[T]

67 Southern Pacific System
- a St. Louis Southwestern Railway Co. and affiliated companies[T]
- b Northwestern Pacific R.R. Co.
- c Southern Pacific Co.
- d Texas and New Orleans R.R. Co.

68 Toledo, Peoria and Western R.R.
69 Union Pacific R.R. Co., including its leased lines
70 Utah Railway Co.
71 Western Pacific R.R. Co.[T]
72 Burlington-Rock Island R.R. Co.
74 Frisco Lines
- a St. Louis-San Francisco Railway Co.[T]
- b St. Louis, San Francisco and Texas Railway Co.

76 Muskogee Co.
- a Kansas, Oklahoma and Gulf Railway Co.
- b Midland Valley R.R. Co.
- c Oklahoma City-Ada-Atoka Railway Co.

79 Missouri and Arkansas Railway Co.
80 Missouri-Kansas-Texas R.R. Co. and controlled companies
81 Missouri-Pacific System[T]
- a Missouri-Illinois R.R. Co.
- b Beaumont, Sour Lake and Western Railway Co.
- c International-Great Northern R.R. Co.
- d Missouri Pacific R.R. Co.
- e New Orleans, Texas and Mexico Railway Co.
- f St. Louis, Brownsville and Mexico Railway Co.
- g San Antonio, Uvalde and Gulf R.R. Co.
- h Texas and Pacific Railway Co.

82 Texas Mexican Railway Co.
84 Nevada Northern Railway Co.
85 Chesapeake and Ohio System
- a Erie Railroad Company (including Chicago and Erie R.R. Co.)[T]
- b New York, Chicago and St. Louis R.R. Co.
- c New York, Susquehanna and Western R.R. Co.[T]
- d Pere Marquette Railway Co.
- e Chesapeake and Ohio Railway Co.

86 Kansas City Southern System
- a Kansas City Southern Railway Co. and controlled companies
- b Louisiana and Arkansas Railway Co. (including Louisiana, Arkansas and Texas Railway Co.)

[R] Receivership [T] Trusteeship

Appendix Table 2: DATA FOR CLASS I STEAM RAILWAYS, 1928

Road No. (1)	Capital Expenditures 1928 (2)	Net Railway Operating Income before Depreciation 1927 (3)	Percentage Ratio of Cars Installed 1921-27 to Cars Owned 12/31/27 (4)	Investment in Road & Equipment Less Accrued Depreciation 12/31/27 (5)	Unappropriated Surplus 12/31/27 (6)	Net Non-operating Income 1927 (7)	Bond Yield 1928 % (8)	Car-Miles 1927 (9)
1	$1,004,191	$2,339,390	48.09	$30,808,601	$3,351,174		4.8	27,024,056
2	14,648,951	11,009,106	7.28	199,549,269	2,627,462	$1,730,694	5.0	272,185,733
5	2,562,281	3,000,285	46.69	40,539,265	4,252,790		4.9	81,117,264
6	18,325,335	30,882,467	30.66	388,609,900	12,635,011	5,620,241	5.0	435,886,364
8	434,197	611,301	31.66	24,009,321	5,355,749			28,599,566
9	564,726	2,425,839	1.19	55,477,930	3,129,190		4.8	95,714,743
10	1,669,822	7,591,560	0.36	79,081,532	31,091,144	1,975,002	4.4	208,508,205
11	1,362,591	20,078,726	24.48	79,942,998	72,018,374	5,294,953	4.2	368,176,540
12	237,376	318,284	4.66	6,908,132	−620,276			7,572,021
13	699,688	1,046,917	1.54	7,020,185	2,895,926			16,904,000
14	17,510,764	16,692,828	41.93	359,220,452	24,400,992	4,848,556	4.7	777,520,097
15	117,916	638,338	2.43	6,030,677	2,408,974			21,419,338
16	249,621	1,649,836	13.54	17,040,975	2,707,878			16,512,015
17	2,036,178	12,501,336	9.27	87,610,579	63,127,706	719,929	4.4	371,308,544
18	494,492	2,320,867	90.00	17,369,077	3,974,607			25,195,685
19	747,418	580,980	60.26	7,027,486	1,823,743			2,582,254
20	60,668,371	131,703,755	46.12	1,307,150,233	400,531,631	45,795,450	4.3	3,065,956,830
21	11,872,357	11,831,585	27.09	194,448,231	33,639,632	2,372,332	4.7	396,382,603
22	2,540,089	11,093,570	32.87	132,485,235	23,622,859	535,852	4.6	232,380,304
23	119,643	569,069	0.46	12,960,672	−51,688		7.6	6,499,833
24	174,235	2,289,333	50.64	35,503,642	6,357,393			6,829,235
25	89,682	218,368	0.65	24,907,281	−15,515,808			9,002,621
26	3,110	67,078	11.21	5,507,739	478,313			3,075,413
27	341,300	1,843,843	1.89	24,588,410	9,673,951		4.6	24,781,010
28	34,799,854	33,842,167	52.79	462,202,732	115,886,889	12,607,872	4.5	624,977,503
29	22,072	267,593	34.72	10,716,624	554,629			7,752,129
30	279,271	867,896	0.34	4,481,543	810,569			4,048,631
31	299,992	597,241	1.68	61,138,879	−11,382,373			88,785,755
32	9,896,009	26,749,633	49.46	545,322,973	175,242,480	10,896,604	4.5	529,567,708
33	619,741	2,629,348	10.25	62,524,200	−27,433,726			36,311,819
34	18,777,280	21,396,470	19.71	795,566,678	213,390,324	27,327,936	4.2	1,234,823,167

35	75,551	381,998	9.01	4,144,155	1,717,185			476,534
36	16,650,499	37,161,612	37.97	638,430,425	176,490,162	8,922,272	4.3	1,116,845,424
37	1,381,628	3,717,597	47.42	130,258,789	−26,912,122	210,297	5.0	166,505,745
38	4,010,294	7,286,097	26.49	201,204,519	6,391,733	187,049		151,918,673
39	398,711	795,545	9.07	15,755,080	127,490			13,231,913
40	13,454	411,967		1,961,965	1,158,049			2,500,517
41	381,086	763,363	7.17	68,729,037	2,664,725			17,936,215
42	10,226,116	27,072,956	21.34	325,604,018	29,600,891	2,301,405	4.6	816,404,662
43				Class II Road in 1927				
44	6,178,683	12,182,538	48.23	288,163,820	43,807,526	1,937,291	4.7	485,989,287
45	417,784	633,911	27.10	5,027,981	1,660,840			9,720,465
46	16,685,331	51,963,520	53.39	472,362,081	66,285,920	7,762,228	4.5	1,307,716,238
47	2,558,983	4,096,139	2.26	9,906,325	24,257,592		4.7	60,591,332
48	16,576	300,761	18.52	8,961,554	1,080,381		5.2	6,264,724
49	13,313,244	47,488,961	47.52	390,937,296	98,055,075	2,181,287	4.5	1,006,459,448
50	881,518	2,867,552	33.26	81,440,707	1,223,549	461,371	5.8	161,051,488
51	283,355	—428,666	24.32	5,660,625	−1,124,125			6,089,534
52	784,363	3,303,136	60.56	47,969,701	7,548,327		4.5	91,326,216
53	631,060	1,012,082	67.28	30,692,277	1,824,362			33,866,209
54	469,605	4,982,504	9.62	25,938,023	11,472,508		4.5	73,020,805
55				Class II Road in 1927				
56	65,021,158	133,998,502	10.46	989,712,626	154,484,422	42,314,029	4.4	3,168,674,719
57	13,574,163	36,110,303	28.81	398,742,748	26,688,317	5,814,023	4.3	574,293,455
58	5,019,503	6,689,215	55.66	141,538,217	11,292,966	189,572	5.1	114,460,501
59	1,049,640	4,103,736	37.58	84,379,220	15,011,261		4.5	62,304,095
60	12,984,665	38,583,338	60.40	380,026,610	101,652,615	2,149,239	4.2	647,670,492
61	949,405	2,223,354	10.95	28,635,999	6,886,062			57,142,009
62	2,629,421	10,036,042	20.27	129,812,330	24,931,942		4.5	98,491,088
63	19,433,658	57,772,962	37.73	689,811,830	206,095,665	11,188,271	4.3	1,600,533,984
64	238,978	93,987	100.00	280,639	414,745			5,843,536
65	668,506	1,647,975	39.42	114,016,649	19,297,801		5.5	81,152,989
66	1,471,082	267,898	100.00	19,059,988	32,022			8,914,649
67	988,506	1,387,716	69.01	27,918,655	4,613,736		4.7	37,931,847
68	8,365,227	43,124,657	64.67	487,327,301	87,286,901	6,628,342	4.4	1,359,763,051
69	80,268	418,941	35.37	8,476,304	474,268			5,490,441
70	110,358	769,874	75.08	16,683,521	1,218,367		5.4	11,448,158
71	320,339	1,862,126	18.87	32,775,999	6,227,099		5.2	41,100,316
72	3,730,215	12,216,348	89.78	227,911,570	7,679,764	2,172,870	6.9	336,211,393
73	26,996,850	49,270,258	57.99	613,909,991	164,222,599	8,732,236	4.5	1,214,245,816
74	188,395	381,581	100.00	4,814,789	655,086			12,205,663

Road No. (1)	Capital Expenditures 1928 (2)	Net Railway Operating Income before Depreciation 1927 (3)	Percentage Ratio of Cars Installed 1921-27 to Cars Owned 12/31/27 (4)	Investment in Road & Equipment Less Accrued Depreciation 12/31/27 (5)	Unappropriated Surplus 12/31/27 (6)	Net Non-operating Income 1927 (7)	Bond Yield 1928 % (8)	Car-Miles 1927 (9)
75	22,649,221	27,561,315	24.98	566,819,562	71,001,567	2,895,408	4.3	952,919,090
76	614,120	2,215,009	54.36	125,305,868	9,586,393	212,396	6.2	176,769,803
77	15,568,282	19,747,312	59.38	669,642,819	−1,257,418	1,168,401	4.8	1,016,728,381
78	1,319,356	6,640,871	1.71	34,286,040	32,514,525		4.6	53,083,355
79	34,198,160*	66,286,271*	37.02*	784,925,547*	260,044,512*	14,474,879	4.2	1,517,793,120*
80	22,433,515	61,041,284	62.74	323,519,200	237,652,793	28,788,601	4.4	1,413,307,052
81	679,811	84,030	55.64	10,080,476	−3,515,264			7,137,769
82	59,040	583,793		7,833,338	1,075,912			6,208,500
83	2,822,923	2,843,204	26.82	115,309,205	−359,511	342,736	5.0	107,940,523
84	51,376	71,353	8.88	6,988,217	−51,828			7,380,515
85	24,732,349	25,441,445	35.90	304,487,236	14,832,128	1,658,126	4.7	446,874,140
86	1,218,733	5,133,232	33.22	99,232,520	16,048,340	646,274	4.7	131,338,777
87	879,682	346,918	100.00	15,770,527	1,241,156			15,747,205
88	289,806	504,653	8.40	13,517,377	4,553,855			15,447,535
89	472,513	−11,020	3.25	24,321,072	−3,363,293			15,420,316
90	11,063	−83,641	31.97	1,108,664	−367,579			5,395,071
91	287,458	1,019,577	33.95	18,321,777	1,951,968		5.0	17,116,113
92	198,413	−14,136	17.30	3,951,727	−1,070,226			6,605,541
93	3,173,918	13,827,729	52.89	265,662,179	7,398,963	895,378	4.6	329,082,768
94	39,082,866	32,129,688	39.92	703,353,173	64,992,699	6,812,498	4.9	1,203,808,189
96	2,611,257	4,794,857	51.55	106,219,247	8,541,851	709,778	4.5	126,231,877
97	154,645	194,102	2.08	11,558,329	−7,355,642			15,291,292
98	Class II Road in 1927							

*Excludes Kansas City, Mexico and Orient Railway Company and Kansas City, Mexico and Orient Railway Company of Texas which were independent roads in 1927.

COLUMN
2 Annual Reports of Railroads to the ICC, 1928.
3 *Statistics of Railways*, 1927.
4 *Statistics of Railways*, 1921-27.
5 Same as 3.

COLUMN
6 Same as 3.
7 Same as 3.
8 National Bureau of Economic Research files.
9 Same as 3.

Appendix Table 3: Data for Class I Steam Railways, 1936 and 1937

Road No. (1)	Capital Expenditures 1936 (2)	Net Railway Operating Income before Depreciation 1935 (3)	Net Non-operating Income 1935 (4)	Train-Hours 1936 (5)	Capital Expenditures 1937 (6)	Net Railway Operating Income before Depreciation 1936 (7)	% of Cars Less than 20 Years Old 1/1/37 (8)	Cost of Reproduction 1/1/37 (9)	Unappropriated Surplus 12/31/36 (10)	Net Non-operating Income 1936 (11)	Bond Yield 1936 (%) (12)
1	$346,017	$1,840,035	$28,985	63,500	$1,004,990	$1,700,326	45.87	$28,388,354	$5,560,052	$36,613	3.2
2	2,921,028	8,252,756	1,078,771	479,094	5,161,635	6,483,851	48.80	253,016,074	3,174,202	1,045,430	6.1
5	417,454	2,346,858	488,771	144,032	2,287,753	1,998,908	45.53	58,220,655	3,199,802	462,650	7.5
6	6,577,871	13,197,645		701,555	7,187,197	12,808,085	11.92	369,418,106			14.3
8	21,004	−3,008		73,665	44,352	236,215	30.23	22,757,787			
9	663,605	1,030,244		4,187	1,812,776	1,025,093	58.43	4,680,116			
10	1,352,752	2,426,958	122,664	234,710	1,902,289	4,257,218	19.81	88,672,623	−15,519,787	137,996	6.2
11	1,361,958	6,284,309	1,078,060	362,234	1,479,340	9,018,032	53.48	240,059,473	54,502,559	1,215,916	4.4
12	53,008	100,841		14,474	48,572	165,278	0.15	6,430,729			
13	54,937	1,106,250		16,418	277,544	1,198,085	100.00	5,198,455			
14	5,793,882	17,000,790	982,033	759,619	4,736,874	20,300,152	62.76	344,835,575	−8,605,366	630,999	5.4
15	21,898	241,562		16,954	11,294	232,421	0.46	4,719,076			
16	591,828	1,047,064	4,857	52,018	381,275	1,024,746	38.82	14,626,837	2,645,540	−11,991	3.7
17	2,703,375	7,319,369	553,415	355,514	1,162,756	10,990,286	37.62	198,013,869	33,770,324	−45,075	7.8
18	78,088	1,185,584		45,584	59,998	1,538,255		16,818,825			3.6
19	44,076	977,062		45,355	1,226,264	1,085,421	98.11	6,574,259			
20	18,463,048	58,988,489	21,517,926	3,341,161	58,135,463	68,189,761	58.40	1,603,308,916	227,075,938	20,635,280	4.4
21	4,430,259	8,379,339	1,822,246	371,344	4,836,199	10,693,020	90.50	113,161,000	29,935,872	5,745,482	5.6
22	21,058,104	55,425,722	1,140,302	1,234,271	15,177,707	69,364,478	96.66	547,751,689	6,214,235	1,837,705	3.7
23	19,630	108,785	29,741	10,894	31,313	80,271	38.62	9,214,545	237,726	26,712	13.4
24	1,304,933	4,828,508	20,680	104,611	4,066,756	4,578,134	65.34	61,717,080	7,294,387	48,372	5.7
25	185,085	19,235		17,795	50,591	100,021		6,954,421			
26	1,817,563	8,104,652		483,569	3,058,100	8,945,051	95.93	146,361,844			5.1
27	25,700	440,292		24,104	119,911	535,930	0.43	6,568,653			
28	5,181,426	30,893,206	6,190,333	1,963,435	17,868,473	38,409,031	62.82	823,894,581	39,784,437	8,222,220	5.5
29	9,847,131	12,069,217	536,080	248,666	19,966,712	22,147,533	23.68	168,489,285	46,137,699	−273,586	3.2
30	802,102	1,228,344		173,833	2,545,496	2,245,180	80.46	46,343,519			

Road No. (1)	Capital Expenditures 1936 (2)	Net Railway Operating Income before Depreciation 1935 (3)	Net Non-operating Income 1935 (4)	Train-Hours 1936 (5)	Capital Expenditures 1937 (6)	Net Railway Operating Income before Depreciation 1936 (7)	than 20 % of Cars Less Years Old 1/1/37 (8)	Cost of Reproduction 1/1/37 (9)	Unappropriated Surplus 12/31/36 (10)	Net Non-operating Income 1936 (11)	Bond Yield 1936 (%) (12)
31	61,391	984,921		55,090	977,437	1,331,415	68.87	8,085,079			
32	120,006	718,773		133,932	279,600	979,768	56.56	29,047,536			
33	1,062,847	1,452,933		184,325	961,264	1,759,970	15.01	29,282,247			
34	42,293,132	93,965,805	34,904,532	4,019,819	52,653,666	108,081,620	29.95	2,046,425,109	185,358,231	34,266,815	3.7
35	152,593	−1,556,921		88,052	138,254	−1,145,153		31,343,928			
36	1,133,474	19,504,926	2,267,469	847,692	4,249,182	20,197,748	41.72	411,813,312	11,372,463	1,617,359	4.2
37	663,007	5,253,128	−260,107	163,624	3,528,584	5,915,190	30.62	84,028,320	21,528,253	−261,690	5.2
38	2,892,413	3,893,874	134,956	156,581	1,829,101	4,723,881	73.86	49,931,895	16,444,739	631,456	3.5
39	16,463,466	31,807,275	1,255,239	659,336	16,556,715	39,042,452	81.87	335,617,088	140,018,576	834,509	3.2
40	136,644	699,029	184,054	61,775	955,724	1,167,195	68.60	24,782,938	9,310,969	171,523	2.9
41	245,079	8,353,915	958,326	134,682	1,741,140	10,192,774	69.22	85,236,114	22,713,112	516,235	4.3
42	35,748	98,648		31,038	80,834	143,369	86.20	4,724,103			
43	296,669	525,735		80,967	475,538	1,492,954	95.11	53,515,229			8.3
44	37,925	82,210		31,911	92,234	49,089	96.06	12,267,227			
45	5,227,232	28,019,125	2,767,395	2,196,329	16,042,779	36,714,869	65.49	764,271,029	167,902,852	5,095,255	4.0
46	138,675	1,316,547	107,132	87,562	1,383,441	1,646,080	56.40	27,767,486	285,718	125,861	6.0
47	3,440,324	15,692,226	2,094,603	1,802,747	13,765,189	25,950,162	82.00	566,448,842	35,867,096	3,272,452	5.6
48	29,318	52,793		17,022	30,817	135,412		4,858,705			
49	410,295	435,243		82,912	578,696	435,297	96.52	18,116,270			
50	3,338,232	3,379,814		538,437	6,444,273	4,805,558	90.43	189,839,022			
51	1,951,808	23,406,514	1,544,618	1,748,362	17,455,891	31,978,565	90.45	549,560,195	101,280,135	3,108,468	6.7
52	108,095	478,516	6,133	42,537	1,580,752	543,434	42.17	12,387,151	1,171,368	6,679	7.4
53	4,313,236	9,385,974		1,495,543	11,349,662	11,248,190	65.68	550,852,003			
54	1,150,636	1,819,531		247,094	1,430,407	2,705,862	90.09	64,163,811			
55	8,433,719	10,145,452		1,385,981	15,111,463	14,821,322	79.60	573,946,849			6.3
56	2,540,797	27,136,467	2,984,233	914,666	10,138,255	27,218,944	43.36	460,641,511	106,586,171	4,111,951	4.2
57	187,587	183,446		29,383	381,518	226,167	11.31	5,531,025			
58	158,504	991,931		11,904	809,879	1,354,872		8,799,649			
59	468,238	490,861		166,305	925,579	1,062,804	60.69	37,397,654			

60	7,178,314	10,913,995	6,996,374	750,348	11,228,251	13,935,122	53.20	446,094,547	180,047,540	5,348,676	4.4
61	409,617	1,655,937		109,448	1,682,815	1,673,422	50.53	52,624,364			
62	15,637,372	27,193,657	6,778,987	1,710,289	35,105,727	29,839,222	61.87	805,614,235	296,584,686	4,504,062	3.5
63	10,863,379	17,008,144	4,025,082	1,537,459	17,899,302	20,446,945	59.76	616,174,598	161,500,076	2,690,151	3.7
64	2,101,151	3,585,886		326,533	4,285,005	2,722,640	21.27	125,976,211			
65	833,998	1,327,277		43,489	568,038	1,186,532	0.30	23,593,718			
66	2,313,074	3,510,459		1,108,954	9,044,947	5,298,819	49.25	372,696,427			
67	12,817,468	31,410,159	25,984,366	2,413,837	37,480,031	46,183,615	63.59	959,572,573	385,423,879	20,955,922	4.4
68	260,873	344,222		32,883	812,251	433,917		5,999,583			
69	12,213,465	14,754,350	17,976,115	1,486,252	25,517,552	31,694,751	34.12	652,823,402	270,778,031	16,541,038	3.3
70	46,561	316,802		11,767	98,025	309,439		6,348,036			
71	2,755,810	1,581,416		154,669	2,639,624	730,457	58.75	87,971,401			
72	38,265	−295,388		16,014	23,400	−251,773		8,005,730			
73	16,842	−28,551		14,996	*no data*	60,230		4,660,032			
74	2,733,082	4,527,877		668,766	4,700,812	8,365,845	73.89	221,248,147			
75	627,250	1,836,884	412,401	126,187	4,593,209	3,481,535	34.36	53,937,870	9,692,207	333,845	5.9
76	543,817	1,081,532	171,410	63,096	572,072	1,453,508	4.00	24,875,948	6,250,224	184,082	7.3
77	708,644	1,317,796	77,216	64,074	1,119,923	1,263,641	37.80	23,517,702	4,192,698	78,998	5.7
78	113,555	53,884		27,595	159,733	−62,457		3,482,965			
79	18,360	34,248		31,297	53,113	44,378	45.54	8,525,744			
80		3,211,751	536,573	375,331	4,850,263	5,505,334	80.15	99,111,566	−161,269	61,076	6.5
81	12,896,700	17,634,864		1,753,749	15,943,057	23,808,892	81.45	558,094,986			4.7
82	50,524	207,691		17,778	77,310	179,543		3,719,075			
83	5,706	119,004		10,584	*no data*	97,191		2,998,947			
84	3,771	158,755		6,585	27,326	240,868		3,000,239			

COLUMN

2 Annual Reports of Railroads to the ICC, 1936.
3 *Statistics of Railways, 1935.*
4 *Ibid.*
5 *Statistics of Railways, 1936.*
6 Annual Reports of Railroads to the ICC, 1937.
7 Same as 5.

COLUMN

8 *Car Building and Car Repairing,* American Railway Car Institute, 1936.
9 *Element of Value of Property Used in Common-Carrier Service to Jan. 1, 1937, Ex Parte No. 123,* ICC, Bureau of Valuation (1937).
10 Same as 5.
11 Same as 5.
12 National Bureau of Economic Research files.

Appendix Table 4: DATA FOR CLASS I STEAM RAILWAYS, 1940

Road No. (1)	Capital Expenditures 1940 (2)	Net Railway Operating Income before Depreciation 1939 (3)	% of Freight Cars Less than 20 Years Old 1/1/40 (4)	Cost of Reproduction 1/1/40 (5)	Unappropriated Surplus 12/31/39 (6)	Net Non-operating Income 1939 (7)	Train-Hours 1939 (8)
1	$144,197	$1,269,281	62.58	$28,155,320	$5,179,342	$42,326	48,806
2	3,139,969	8,475,008	58.57	185,380,637	−3,015,217	1,157,030	449,075
5	1,010,432	2,694,867	64.64	53,638,289	1,035,844	455,974	131,203
6	3,850,390	11,557,901					
8	19,701	267,952					
9	493,553	1,156,194	63.39	5,113,425	2,778,735	−4,638	4,211
10	6,205,816	6,527,149	17.98	88,438,927	−17,819,519	111,839	225,099
11	4,837,958	8,458,111	49.11	218,802,941	47,124,328	1,273,977	390,308
12	37,273	163,564	14.90	5,615,705	−1,176,737	−495	13,613
13	113,311	695,010		5,041,927	2,577,785	11,864	13,951
15	77,097	223,897		4,398,033	1,713,258	24,498	15,821
16	371,576	1,481,654	56.05	13,502,757	2,992,260	−2,673	43,073
17	1,151,016	9,268,413	36.52	174,750,061	13,019,027	45,339	273,738
18	143,293	1,319,593					
19	19,791	1,009,161	85.37	7,040,636	2,417,344	−1,402	30,453
20	31,660,647	59,279,130	55.62	1,395,168,511	208,949,973	15,132,415	3,023,403
23	43,316	110,552		8,863,968	440,225	16	11,443
24	1,199,216	3,694,325	68.84	61,471,767	14,638,248	333,882	85,976
25	75,747	137,497					
26	7,217,413	6,298,018					
27	98,697	374,340					
28	16,210,846	33,722,890	63.13	704,147,187	4,435,342	5,488,146	1,837,755
29	17,616,976	18,740,606	30.16	162,848,616	55,760,462	628,140	223,257
30	886,072	1,626,118					
31	583,411	1,135,025	83.79	8,683,831	1,530,131	5,894	50,937
32	1,005,909	861,523					
33	438,460	1,494,736	71.71	26,007,281	27,691	11,015	169,710
34	35,301,368	105,203,053	26.51	1,922,849,685	170,775,994	34,534,468	3,457,238
35	108,238	−1,631,707					
36	1,599,981[a]	15,044,811[a]	37.27[a]	219,596,670[a]	1,640,542[a]	1,131,288[a]	510,445[a]
37	3,340,439	5,949,646	35.73	79,587,480	20,873,369	41,086	149,913
38	1,556,800	5,024,954	64.45	46,003,310	16,932,402	120,959	134,388
39	19,494,099	36,730,617	76.90	321,888,550	159,616,922	1,072,561	579,642
40	406,745	1,567,307	10.43	23,887,619	9,975,161	206,496	61,144
41	3,556,680	10,759,485	39.32	80,655,256	27,339,979	76,568	141,819
42	78,344	129,131	75.37	4,362,836	1,497,203	18,948	26,602
43	577,198	1,213,219					

45	22,248,536	30,227,668	65.65	646,722,599	166,934,090	4,656,132	1,995,272
47	19,001,577[b]	24,580,363[b]	89.31[b]	451,685,772[b]	35,867,599[b]	3,107,124[b]	1,307,727[b]
48	132,711	16,741		4,712,582	−1,953,553	2,102	14,218
49	1,046,624	473,541					
50	6,772,432	5,753,196					
51	5,586,389	33,168,669	100.00	482,788,461	103,877,769	3,863,413	1,668,631
52	523,175	385,340	83.42	11,841,240	1,029,117	28,104	39,723
53	7,779,276	11,579,441					
55	15,869,194	13,917,168					
56	16,256,082	23,271,271	47.36	421,159,052	106,281,950	3,317,600	863,191
57	412,473	250,092	71.10	5,451,932	635,724	50,075	22,671
58	104,850	1,349,289	12.99	9,186,491	938,444	541	9,517
59	1,614,122	1,349,760					
60	9,848,609	13,853,644	45.62	419,476,594	173,505,526	4,089,828	685,134
61	1,582,716	1,028,683	15.68	66,326,460	−67,707,848	185,475	100,294
62	28,313,940	31,004,148	60.86	777,371,470	294,998,191	2,442,406	1,620,491
63	12,232,321	19,352,404	54.82	570,151,438	149,815,692	2,333,305	1,330,885
64	3,376,433	2,879,885					
65	180,700	900,236		23,375,636	−654,888	−1,043	31,020
66	13,438,610	9,180,334					
67	7,125,779[c]	36,036,057[c]	65.70[c]	832,761,724[c]	247,523,614[c]	18,692,774[c]	1,977,296[c]
68	314,431	554,260		6,731,749	2,167,122	8,103	21,170
69	12,453,472	27,702,753	36.11	602,586,326	251,198,972	13,128,820	1,435,799
70	20,676	161,509		5,539,535	449,512	2,308	7,951
71	503,601	2,357,579					
72	23,401	47,186	8.82	5,864,963	−9,174,631	2,010	18,328
74	2,958,527	6,851,126					
76	254,609	1,371,501	9.93	23,937,307	6,179,084	155,629	55,933
79	33,940	59,268	29.41	8,123,918	116,536	1,806	31,710
80	233,384	2,529,143	89.38	120,481,304	−9,708,533	286,050	343,224
81	11,547,008	20,918,521					
84	29,765	280,566					
85	16,121,198[d]	60,309,056[d]	87.06[d]	559,553,986[d]	204,039,639[d]	2,818,013[d]	1,419,821[d]
86	3,099,057	5,406,906	52.61	81,088,588	16,575,174	374,129	180,172

[a] Excludes Central Railroad Company of New Jersey which was in trusteeship.
[b] Excludes Central of Georgia Railway Company which was in trusteeship.
[c] Excludes St. Louis Southwestern Railway Company and affiliated companies which were in trusteeship.
[d] Excludes Erie Railroad Company (including Chicago and Erie Railroad Co.) and New York, Susquehanna and Western which were in trusteeship.

COLUMN
2 Annual Reports of Railroads to the ICC, 1940.
3 *Statistics of Railways, 1939.*
4 *Car Building and Car Repairing,* American Railway Car Institute, 1939
5 *Elements of Value of Property in Common-Carrier Service to Jan. 1, 1940,* Ex Parte No. 148, *Exhibit No. A 11,* ICC, Bureau of Valuation (December 1942).
6 Same as 3. 7 Same as 3. 8 Same as 3.

Appendix Table 5

Data for Electric Light and Power Companies, 1920-1941

	Gross Capital Expenditure	Net Operating Income	Depreciation	Construction Cost Index 1911:1.00	Yield % New Bonds	Yield % Shares	Generating Capacity (mil.kw.)
	(millions of dollars)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1920	437	219	54	2.14		8.06	12.0
1921	276	240	57	1.98	7.34	8.29	12.8
1922	395	328	62	1.71	6.02	7.62	13.4
1923	723	408	74	1.90	6.14	7.59	14.8
1924	827	461	88	1.94	5.90	7.35	16.7
1925	766	540	102	1.93	5.55	6.13	20.0
1926	704	627	121	1.89	5.40	5.57	21.8
1927	722	716	130	1.85	5.11	4.96	23.4
1928	679	790	145	1.88	5.01	4.09	26.0
1929	774	865	153	1.98	5.37	2.29	28.0
1930	835	911	156	1.90	5.11	3.19	30.3
1931	538	911	160	1.86	4.65	4.43	31.5
1932	257	818	161	1.74	5.66	7.36	32.0
1933	113	742	166	1.78	4.95	6.27	32.2
1934	126	729	177	1.94	4.81	6.56	31.5
1935	166	756	184	1.98	3.92	5.97	31.8
1936	251	787	197	2.03	3.56	4.31	31.8
1937	423	777	216	2.20	3.56	5.12	32.0
1938	445	757	226	2.20	3.49	6.88	33.2
1939	433	807	249	2.22	3.45	5.46	33.9
1940	466	812	260	2.26	3.09	5.67	34.4
1941	490	776	279	2.36	3.15	6.57	36.0

COLUMN

1 George Terborgh, 'Estimated Expenditures for New Durable Goods, 1919-1938', *Federal Reserve Bulletin,* September 1939, p. 732, for 1920-36. J. B. Epstein, 'Electric Power Output and Investment', *Survey of Current Business,* May 1949, p. 23, for 1937-41.

2 *Statistical Bulletin, 1948,* Edison Electric Institute, p. 38. These data are for 1926-41 and are extrapolated to 1920-25 by constructing a series with the same year to year percentage changes as Simon Kuznets' series on net income less wages and salaries originating in electric light and power companies (*National Income and Its Composition, 1919-1938*), pp. 661 and 664.

3 Same as 2 for 1926-41. In the *Census of Electrical Industries* the values of plant and equipment of commercial central electric light and power establishments for census dates are 1917, $2,933,016,941; 1922, $4,229,356,023; 1927, $8,880,-291,499. Depreciation in 1917 and 1922 is estimated as the same proportion of the valuation figures for those years as 1927 depreciation is of the 1927 valuation. The estimates for 1918-21 are interpolated linearly between 1917 and 1922. Similarly, the estimates for 1923-25 are interpolated linearly between 1922 and 1927.

4 *Engineering News-Record,* April 23, 1942, p. 132. These data are given for five regions. The separate indexes are combined into a United States index by forming a weighted sum of the regional estimates with the weights proportional to regional

population estimates from the nearest census. The index is published for January and July of each year. An annual index is computed from a weighted sum of beginning of year, middle of year, and end of year figures. The weights are 0.25, 0.50, and 0.25 respectively. A quotation is missing for 1922; therefore this figure is interpolated by making it have the same ratio to the 1923 estimate as the 1922 figure of the Richey index has to its 1923 value. The Richey index is published in the *Survey of Current Business*, 1932 Supplement.

5 *Moody's Public Utilities, 1947*, p. a5.

6 Alfred Cowles and Associates, *Common Stock Indexes* (Principia Press, 1939), p. 373, for 1920-38; *Moody's Public Utilities, 1948*, p. a6, for 1939-41.

7 *Statistical Bulletin, 1948*, Edison Electric Institute, p. 16.

$$I = \frac{(1)}{(4)};\ \pi = \frac{(2) + (3)}{(4)};\ i = (5);\ s = (6);\ C = (7)$$

$$K_t = K_{1918} + \sum_{i=1919}^{t} \left[\frac{(1) - (3)}{(4)}\right]_i, \qquad t > 1918$$

COMMENT

JAMES W. ANGELL, *Columbia University*

Most of Mr. Klein's paper is devoted to the American railroads in the interwar period, and it is with this part of his work that I shall be chiefly concerned.

Mr. Klein has made an important contribution to the study of business cycles. It is important not so much because of the principal hypotheses he sets up for examination — for in the main these are not novel — but rather because he offers an analysis of a single major, yet relatively compact and homogeneous, sector of the economy. It is true that the conclusions drawn from an analysis of this type must in themselves lack generality. But they may have greater precision and meaning than those reached for the economy as a whole, because the main categories of data handled presumably have much greater internal consistency and homogeneity than do analogous categories when taken for the economy as a whole. For the economy as a whole, for example, the category 'gross investment' is made up of many diverse elements, which at any one time are changing at different speeds and often in different directions. The meaning of a change in the national total, therefore, is inevitably somewhat ambiguous. Although marked interfirm differences also exist even within a single industry, the difficulties just referred to are usually much less severe within any one industry than on the national scale. Mr. Klein's study hence makes a substantial addition to our knowledge of those specific relations in specific economic areas, on which any general theory of economic fluctuations must be built in some degree, and with which any such theory must be consistent. It has the further convenience that the estimating equations established are linear.

The American railroad industry, in the interwar period here examined, presented certain characteristics that mark it off sharply from the majority of the other large sectors of the economy. Most important of all, perhaps, as Mr. Klein points out, it was approaching economic maturity. Net new investment was still going on, but at far lower rates in the second decade of the period than in the first. Much the highest level reached was in 1923. Gross investment likewise fell sharply. From 1921 to 1930 it averaged over 750 million dollars a year, but from 1931 to 1941 under 300 million. Second, the great bulk of railroad investment is in roadbed, structures, and rolling stock, which are relatively long lived, and which take a good deal of time to produce. The puzzling problems of large and rapid inventory fluctuations hence are not present; the objects of railroad investment are, from one point of view, relatively homogeneous.

Third, what were treated as maintenance expenditures were relatively high, averaging roughly three times estimated gross investment. Fourth, a large proportion of gross investment decisions were routine in the sense that a large proportion consisted simply in the replacement of worn-out capital goods, when and if funds were available. Fifth, a substantial though shifting number of railroads were bankrupt through most of the period examined. Finally, government supervision and regulation was intensive and continuous. Among other things, the ICC made it difficult for the roads to abandon lines or even reduce service, i.e., reduce output.

All these differences from the usual situation in the larger sectors of manufacturing industry must be kept in mind. They imposed on the economic variables in the railroad investment situation both patterns of behavior and apparent interrelations that were presumably not characteristic of much of the rest of the economy.

The problem Mr. Klein sets himself is the analysis of the factors influencing gross investment in the railroads. He uses two sets of data. One is a time series for the railroad industry as a whole, over a twenty-year period; the other what he calls a cross-section study of individual roads in each of four years. As he says, his three principal conclusions are these. First, and most conspicuous, investment was clearly and heavily influenced by gross operating profits of the preceding year. The elasticity of this relation for the industry as a whole, as estimated from the time series for the twenty years, was 1.4; but as estimated from the slopes of the log-log regressions in the cross-section studies, it was only 0.8 to 1.0. The study does not provide a complete explanation of this difference. Second, gross investment was clearly but much less strongly influenced by the rate of interest. The time series study, using yields on new railroad bonds, shows a relatively low negative elasticity, of about —0.73. This is bad news, for what it is worth, for those who wish to make interest-rate changes an important element in analysis and policy. Finally, one or more powerful trend variables that worked to depress railroad investment were clearly in play. The most plausible candidate is, Mr. Klein believes, the stock of capital, which continued to grow through nearly all of the period but at a slow rate. Other trend factors may also have been involved, however; these data do not permit an unequivocal answer. These three principal relations he is able to express in linear estimating equations.

These are important findings; and it is striking that the principal estimating equation for the interwar period gives such good results when used to 'forecast' the value of gross investment in 1948. But certain questions necessarily suggest themselves.

The first and perhaps the most important concerns the relation between gross investment and gross operating income, which Mr. Klein calls 'profits', of the preceding year. This relation, as measured in terms of deflated or 'real' volumes, was usually quite close. The chief exception is that from 1922 through 1929 the general movement of profits as thus defined was upward, but in 1924 and 1925 gross investment declined sharply,[1] and from 1926 to 1930 was at most roughly constant. This exception, however, does not seriously affect the broad parallelism of the major movements of gross investment and profits over time.

But what is the general economic significance of the parallelism itself? If gross investment had shown a persistent tendency to increase relatively more rapidly than profits, or to fall less rapidly, we would have to look for large sources of outside funds to provide an explanation. Various other complex problems would then have presented themselves, including an analysis of the motives and decisions of the suppliers of the outside funds. If gross investment, on the other hand, had persistently increased relatively less rapidly and fallen more rapidly than profits, it would have looked as though the owners of the railroads were at most trying to keep their capital investment constant, and more probably were trying to withdraw their capital. Neither of these things happened. In the broad, the railroads expanded their gross investment operations when their profits permitted, and contracted when they did not. Although there was a certain amount of net expansion, the replacement of worn-out facilities seems to have been the dominating component of gross investment. Given the facts that this was a relatively mature industry, that access to additional outside funds was relatively difficult and restricted for most roads, and that the owners and managers desired to stay in business, it would have been most surprising if gross investment had *failed* to move broadly parallel to profits. The economic significance of the relation established is therefore limited, although it is useful to have an estimate of the coefficient.

A second and related question concerns the light the study casts on the formulation of investment decisions and the considerations involved in them. One has the feeling that this light is substantial; yet it is hard to evaluate.

In the first place, as already noted, the investment data used are gross, not net. One would expect to find that the considerations governing decisions to replace worn-out or obsolescent capital goods would be in part different from those relating to net expansions of investment, but this study gives little explicit information on these possible differences. It is true that the series presented for recorded and for unrecorded depreciation are quite stable, and show relatively little year to year fluctuation. It presumably does not follow, however, that the difference between them and the

[1] The 1923 peak in investment, which Mr. Klein does not discuss, was presumably due to catching up on deferred replacements after the ending of government operation.

figures for gross capital expenditures represents new net investment. This question should be clarified. The behavior of net new investment taken separately should itself be tested and compared with the other series.

In the second place, Mr. Klein himself emphasizes that a large part of the gross capital expenditures represented routine replacements of capital. Replacements were made when and as funds — derived largely from operating income — became available, and advantage was then taken of technological advances that seemed likely to be profitable. But he does not make it appear that the desire to take such advantage of technological advances was a major factor in most decisions to spend money on new capital goods.

Third, Mr. Klein finds that lower interest charges stimulate investment: bond yields show a definite effect in the time series study. But this influence, even though statistically identifiable, must have been of relatively minor quantitative importance. The interest component of the estimating equation is numerically small; in 1923-31 the general drift of interest rates was downward, but so was the general drift of gross investment; and in 1935-41, when interest rates were far below the level of the '20's, gross investment was also far below — though it is true that the general drifts of the two series in this period were in opposite directions. It is hard to see in this picture any clear effect of interest rate changes on gross investment decisions.

Moreover, Mr. Klein measures interest charges only by bond yields; and whereas in the time series study he uses new issues alone, in the cross-section study he uses outstanding issues. Since the real objective is presumably to measure the cost of obtaining additional capital funds, it is not easy to see why the effects of including stock issues, and likewise other forms of longer-term borrowing, were not also tested. The effect of capital costs on investment decisions might then stand out more sharply.

Fourth, no systematic data are provided to show the extent to which gross investment was financed with funds drawn from outside sources. Without such information, however, it is difficult to make any complete appraisal of the nature and characteristics of the investment decisions that were in play. It is presumably one thing to decide to reinvest from operating income, but something rather different to decide to bring in new money from outside. The absence of data on the sources of funds, and the absence of any analysis of them, seem to me a major gap in the study as presented. It would also be helpful, incidentally, to have some sort of partial balance sheet showing all that was done with operating income. For example, no data on cash positions are given, and therefore it is not possible to appraise the effect of changes in cash holdings on investment decisions.

Fifth, Mr. Klein is disposed to explain the generally downward trend of gross investment primarily in terms of the stock of capital, which was itself slowly increasing. But surely his argument here is debatable. Many other industries, in which the stock of capital was also large, showed rising rather than falling trends in their gross investment. Moreover, as the stock of capital grows, the replacement component of gross investment, other things equal, should likewise increase, not fall. Rather, the most plausible superficial 'explanation' of the declining trend is simply that net new investment in the railroads was declining, that the industry was approaching maturity! Why this should have been so is in no sense explained by the data presented here.

Sixth, Mr. Klein cites the great traffic increases during World War II, in the face of a nearly constant stock of capital, as evidence that "the relations imposed by the acceleration principle are not generally valid". This inference seems to me unwarranted. The principle surely implies full utilization of existing facilities before the 'acceleration' process begins. But the wartime traffic increases were obtained largely by using existing facilities more efficiently, especially by decreasing freight-car turn-around time. That is, the facilities had in effect been seriously under-utilized before the war.

Finally, what is perhaps a minor point, I am not entirely comfortable with discussions of investment decisions that are couched in terms of the relation between deflated variables, when one of these variables is lagged. At times, the railroad construction index used as a deflator fluctuated from one year to the next by as much as 9 to 11 per cent. This means that the data on operating income for the preceding year, which were actually available to the decision makers, differed by these amounts from the data used in the present study, and could well have led to conclusions different in degree and even in direction from those here implied.[2]

On balance, I come out with two conclusions which are rather unsatisfactory from the viewpoint of general business cycle analysis, though I hasten to add that they are only preliminary.

First, Mr. Klein himself indicates that in the period here studied, gross investment in the railroads was in the main an essentially passive function of previous operating income and of the desire of the railroad managers to stay in business. But this means that its size was determined largely by the levels of income, the volume of business activity, and the movements of costs and prices, in the rest of the economy. It seems quite possible that gross railroad investment would show as close a relation with any one of several aggregative national economy variables, or perhaps a combination of them, as with gross railroad profits. If this proved to be so, one might

[2] I am indebted to Michael Gort of Columbia University for helpful discussions of some of the preceding questions.

then interpret changes in gross railroad profits as merely a vehicle or channel — and perhaps only one of several — through which national economy aggregates affected the railroads. In other words, Mr. Klein has shown that his hypothetical explanation of gross investment in terms of previous gross profits is plausible both on *a priori* and on statistical grounds, but he has not tested comprehensively, nor attempted to test, what we may call the exclusiveness of this hypothesis. He has tested the explanatory value of several variables other than profits that lie within the immediate universe of the railroad industry itself, but not of major variables that in the main lie outside the railroad universe as such, yet that likewise might plausibly be thought to have explanatory value with respect to railroad investment. Such further tests of exclusiveness should not be difficult on an exploratory scale, and I believe should be made.[3]

Second, on Mr. Klein's own showing, in this period the railroad industry does not seem to provide a very rich field for the study of investment decisions. This is true precisely because gross investment was apparently so largely determined by the levels of activity in the rest of the economy. It was not determined primarily by independent initial decisions of the railroad managements to expand, for example, in the expectation of large future traffic increases (as had been true in earlier decades); or to expand in order to profit by technological advances, of which they hoped to obtain the sole or at least the earliest command; or to expand in order to take advantage of favorable interest rates.

If these inferences are justified, however, the fluctuations in gross railroad investment were still an important factor in our general economic scene; but from the viewpoint of business cycle analysis, the chief proximate 'explanation' of these fluctuations proposed, which runs in terms of gross railroad profits, seems to be of somewhat limited interest, except for the usefulness of getting a preliminary determination of the form and coefficient of this relation. Perhaps an analysis of net investment taken alone, a more detailed examination of the major sources and uses of funds, and a separation of the solvent roads from those which went bankrupt, would yield more sharply focused results.[4]

[3] In a sense this is perhaps a criticism of Mr. Klein for not succeeding in what he did not even attempt to do. Obviously the national aggregates, such as national income, are not part of the internal 'structure' of the railroad-industry universe. The preceding comments relate more properly, perhaps, to a subsequent stage of the analysis, when the railroad industry will be related to the national economy as a whole. Yet these comments also bear directly, I think, on the general meaning of the results obtained even at this early stage of the analysis.

[4] Thus an inspection of the charts in the cross-section study suggests that the slope of the investment-profits relation for the bankrupt roads was not the same as for the solvent roads, and in at least one of the four years, 1940, was probably not linear.

WASSILY LEONTIEF, *Harvard University*

I

Being obviously unable to do full justice to Klein's interesting and highly provocative paper in thirty minutes, I shall concentrate attention on two points that appear to me to be of fundamental importance. The first is the general question of the effectiveness of the well known techniques of indirect statistical inference (based in most cases on time series) as applied to the explanation of as complex a phenomenon as the investment behavior in general and investment in a single branch of the national economy in particular; the second is the much more special problem of the importance or unimportance of the changes in the level of output of an industry as a factor to be considered in connection with explaining the investment behavior of that industry, in short, the role of the 'acceleration principle'.

Before arriving at his final equations, one explaining the annual rates of the aggregate gross investment in the American railroads of the twenty years 1920-41 in terms of four independent variables (gross operating profits, interest rates on new capital, the total stock of capital, and the price of capital goods), the other explaining the difference between investments of individual railroads in terms of the same types of independent variables but on the basis of several cross-cut studies, and the last explaining annual aggregative investment changes in the electric utilities between 1920 and 1941, again in terms of similar variables, Klein presents a very interesting discussion of factors affecting investment in general and a not less illuminating discussion of various institutional and technological circumstances affecting the railroads' investment in particular. I submit that, in turning to the indirect statistical estimation of parameters of his final explanatory equations, Klein neglects almost completely, and he could not do otherwise, all the various important considerations enumerated in the introductory sections of his paper. Technical changes, and the replacement requirements, for example, to mention two of the most significant of these explanatory factors, are left entirely out of the final analysis. To be explicitly used in actual explanation, these factors would have to be not only mentioned but systematically described in concrete quantitative terms, admittedly a task of no mean proportions but which, I suppose, will have to be accomplished before one proceeds toward a real interpretation of the investment behavior of the American railroads or of any other industry. I surmise that, once this indispensable factual information has been collected and put to work, it will also carry the main weight of the actual explanation, while the indirect statistical inference used by the author as the principal operational basis of his analysis will be relegated to a secondary, albeit still important, role.

In this connection it is consoling to observe that, relieved from the unbearable burden so frequently assigned to them in econometric analysis, these methods of statistical estimation will also be much less exposed to the very annoying difficulties connected with the so-called 'identification problem', that is the problem of deciding, after one has computed all the various regression coefficients, what real relationship they actually represent.

In discussing, for example, the coefficient that reflects the statistical relationship between investment on the one hand and the relative prices of capital and labor on the other, Klein expects it to be negative on the ground that a reduction in the relative price of capital should increase the demand for that factor and *pari passu* reduce the demand for labor. He does not take into account the fact so well presented in one of his own earlier publications that this coefficient might represent not the negative slope of the demand curve for capital but rather the positive slope of the corresponding supply curve. Here we are obviously skirting the margin of the all too often neglected distinction between studies designed to discover previously unknown empirical relationships and studies that are only intended to test the efficiency of the analytical tools employed by comparing the relationship obtained with the help of these tools with the previously known true relationships.

II

Turning to the second more substantive point of these comments, I would like to question Klein's radical decision to disregard entirely the change in the output of an industry as a possibly important factor in the analysis of the rate of investment in that industry. Through the concept of a production function the relation between the level of output and the quantities of various factors (including stocks of capital) plays a central role in the modern theory of the firm. Through the acceleration principle in combination with the notion of technical change, it has been used as an important element in the formulation of dynamic models. Why doesn't Klein like the capital-output relationship?

His paper, excepting a few casual critical observations on the acceleration principle, does not answer that question. In experimenting with various alternative explanatory equations, he tries out and rejects a great number of possibly relevant variables but in no instance does he consider the change in the rate of output of an industry in its relation to the change in its rate of investment — not even in the case of the electric utilities which nearly quadrupled the scale of their operation in twenty years.

To see whether this studied neglect might have a formal statistical reason, I have derived as a comparable alternative to Klein's 'explanation' of the twenty-year railroad investment series a different equation in which profits — the central explanatory variable of his statistical relationships — are entirely omitted and output figures (car-miles and kilowatt hours respectively) are used in conjunction with his two other independent variables, the bond yield and the total stock of capital.

$$I = 1{,}205{,}474 + \underset{(0.0038)}{0.027P} + \underset{(22300)}{20051i} + \underset{(0.025)}{0.061K_{-1}} + u$$

$$\bar{R} = 0.91$$

I, K, i, and u represent investment, total capital, interest, and 'random errors' as in Klein's original equation, while P is the annual output measured in car-miles. The figures in parentheses are the standard deviations of the corresponding regression coefficients.

Klein's 'explanation' gives a coefficient of multiple correlation of 0.95 while the new equation, using the level of output as a principal explanatory variable, gives a corresponding coefficient of 0.91.

Even in the case of railroads where the applicability of the acceleration principle would be less obvious, the rather crude introduction of output as an explanatory variable and the omission of the profit factor gives good statistical results. The close relation between the fluctuation in gross annual investment and the ups and downs of output is in this case, I think, due to the fact that postponable maintenance and replacement expenditures constitute a large part of gross railroad investment. Such expenditures are likely to be reduced in times of low traffic and increased in years of rising traffic, for obvious technical reasons.[1]

Although abstaining from making any explicit use of 'output' as one of the explanatory factors in his analysis, Klein in his cross-cut studies 'deflates' the capital, income, and other variables that describe the position of each individual railroad by dividing each by the output of that railroad as represented by the number of annual 'train hours' run by it. Does this operation represent anything except an implicit acknowledgment of the importance of the 'level of output' as a strategic factor to be used in explaining the 'level of investment'?

In the course of the same cross-section study, Klein rightly observes that the bankrupt railroads systematically invest a much larger amount of capital than that which would correspond, according to his explanatory equation, to their obviously low level of profits. He considers this behavior to be the sign of increased demand for cheapened capital because of defaulted interest payments. The necessity to maintain a given rate of

[1] During the general discussion of Klein's paper Franco Modigliani stated that a replacement of the profit variable in Klein's electric utilities equation by an appropriate output variable increased the correlation coefficient. A similar result was obtained by Hollis Chenery in his as yet unpublished thesis (Harvard, 1949).

output (level of traffic) irrespective of the current rate of profit might, I think, give a better explanation of this exceptional (from the viewpoint of Klein's equations) behavior.

This leads me to the final query. Are total profits a good explanatory variable in the analysis of the investment behavior of an industry? In so far as they are usually correlated with the level of output and the latter variable, for one reason or another, is excluded from consideration, it is obviously better to have it represented indirectly than not at all. In so far as undistributed profits constitute an important component of the total capital supply, they might have independent significance but in this connection the 'identification problem', i.e., the distinction between supply and demand, is likely to become particularly bothersome.

In affecting the relative attractiveness of any particular kind of investment, profits certainly might play a significant role in directing the flow of capital, but considered from this point of view, profits in their turn depend to a large extent on the volume of sales, i.e., the level of output. This consideration is particularly important if statistical equations are to be used for predictive purposes. Demand can, I think, at present be predicted much more easily than the profit per unit of output.

In this connection it should be observed that profits are used in all Klein's equations with a one-year lag while the output variable in my alternative computations is entered without any lag. Examination of the corresponding time series indicates, however, that the introduction of such a lag into the investment-output relation might somewhat improve the statistical results. In so far as at least one variable, the interest rate, in Klein's equations is used without a lag, these also could not be utilized directly for predictive purposes.

Within the wider framework of more general dynamic analysis (of which the investment equations of individual industries naturally constitute only a small part) the outputs of individual commodities and services will, I think, be 'explained' more easily than the corresponding profit figures which typically represent a much more volatile element of the economic system. Thus from this wider point of view even for purely pragmatic, predictive purposes preference would have to be given to the output as against the profit variable.

REPLY BY MR. KLEIN

An author of a research paper is indeed fortunate to have the benefit of criticism from two such scholars as Professors Angell and Leontief who have obviously read the manuscript assigned to them with care. In their discussion, however, points are raised on which I feel compelled to render further comment.

Leontief and I are agreed that empirical, quantitative research should build wherever possible on *a priori* information of an institutional, legal, technological, theoretical, and other sort. We are, however, at opposite poles on the problem of mixing this information with methods of statistical inference. I interpret Leontief as arguing that information obtained from engineers, legal sources, and the like should be dominant in the empirical determination of investment behavior equations. I offer the countersuggestion that this sort of information is invaluable as far as it goes, but that it leaves us hopelessly distant from any useful objective. Investment processes are permeated with economics as distinct from engineering, for example, and the economics of the situation can in many cases be inferred from empirical observations. Even in the case of the estimation of production functions, where technical engineering information carries its greatest weight, there are very few processes that could be estimated from such information alone without the aid of statistical inference.

There are various ways in which I used *a priori* information in deriving my estimates of investment equations for United States railroads, and I would like to stress these facts for the reader's benefit since Leontief claims that I have 'neglected almost completely' to incorporate outside considerations in my empirical equations. In the first place, the fact that gross investment outlays of railroads contain a large sum representing routine replacement led me to use gross rather than net operating income as a strategic variable of analysis. In debating in my own mind whether to use 'profits' rather than output (contrary to Leontief's inference that I decided to overlook output), I was impressed by the fact that the ICC asked railroads to estimate their postwar investment outlays on the basis of an assumed operating income realized in 1941. I would guess that the ICC has an excellent insight into railroad decision making processes and consequently attaches some significance to the form of its questionnaire. I am also encouraged in this respect by the fact that answers to this question were obtained throughout the industry.

The decision to separate out the bankrupt carriers from some of the cross-section analyses was based on legal and institutional considerations. The form of the resulting equation is substantially affected by this step.

I frankly do not believe that it would be possible to go even a major part of the distance toward my final goal without using statistical inference. The shape of functions and the size of parameters cannot be determined from information supplied by engineers and lawyers; at best these sources will be able to *suggest* important variables to be taken into consideration.

Certainly, it should be possible to go much further in the direction of Leontief's approach. Carefully designed interview surveys of executives who make investment decisions have great potential value, but this is an extremely difficult project that is yet to be carried out, and for the moment research on investment behavior will have to rely more heavily on statistical inference than Leontief would like to admit.

The fact that the use of statistical inference from nonexperimental observations brings in the problem of identification is no reason to turn away from these methods. Inherent in the nature of social scientific analysis is the identification problem, one important reason being that truly controlled experiments cannot be used except in some rare cases. Leontief in his approach must unfortunately face the identification problem also. If he obtains from engineers some superficial capital-output ratios, is he justified in interpreting these ratios as parameters in an investment function, *à la* naive acceleration principle? I would argue that capital-output ratios cannot be generally identified with any structural equations in economic systems, but that in some cases they come closer to approximations of production functions than anything else. One point that I would make emphatically is that such ratios do not lead us directly to an equation of investment behavior. A related point is whether I claim that I can in my paper identify the estimated parameters with structural properties of railroad investment behavior. Leontief's allusions to the traditional identification problems in supply-demand analysis or in the determination of the aggregate investment function play upon false analogies. The conventional situation is the following: supply and demand variables are indistinguishable as statistical observations under nonexperimental conditions since inventories are not adequately handled. If they are equal and both depend upon the same price variables there is often no method of making a statistical distinction between the supply equation and the demand equation. A parallel situation prevails when saving and its equal, investment, are each written as functions of the same income (or output) variable. Again inventories are usually not given adequate treatment. But do I face the same situation with regard to railroad investment? The industries supplying capital goods to railroads or the institutions supplying financial resources to railroads do not behave according to exactly the same set of variables that determine railroad investment (demand) behavior. I have tried to select my motivating variables in a very limited way so that they would not overlap with the variables on the supply side. If Leontief wants to push his point deeper, he must turn to a specific analysis of the supply side of the market rather than rely on casual references to other problems that do not even have the same formal mathematical structure as the one at hand. To me it is quite clear that I have the identification I need for a study of railroad investment behavior. At the most aggregative level of analysis, I believe that the identification problem is overcome in the estimation of savings and investment functions if some of the variables are sharpened. Income in the personal savings function should be personal disposable income, and if profits are used in the investment function, full identification is likely to be achieved, depending, of course, on the structure of other equations in a complete system. I mention this point because I consider it as a further argument for using profits rather than output in the investment equation.

It is true that the acceleration principle has been utilized in some dynamic models developed as theoretical curiosities. I can find no place for a pure *technological* acceleration principle as an explanation of an *economic* phenomenon such as investment behavior on either theoretical or empirical grounds. At the theoretical level, it is only in very special circumstances that any accepted theory of the firm implies the acceleration principle for investment demand. Leontief thinks that the acceleration principle comes into being once the theory of the firm is developed from a production function including the stock of capital as a variable. I raise an objection at this stage and argue that the stock of capital has no place in the production function. The appropriate variable in this case is the flow of capital services. Idle capital does not produce output, and the intensity of utilization of employed capital has an effect on output. To draw an analogy, I would say that the labor force or the number of persons employed is not an appropriate variable for the production function. Man-hours are a much more satisfactory measure. The passage from the stock of capital to the flow of capital services (train-hours perhaps in the railroad industry, at least, for equipment capital) is much the same as the passage from the labor force to man-hours. This discussion has the additional relevance to Leontief's comments that it shows he has misinterpreted a measure of the flow of capital services (train-hours or train-miles) as a measure of output (ton-miles or passenger-miles) at two places in his paper.

Among his general arguments supporting the acceleration principle for railroad investment, Leontief remarks that postponable maintenance constitutes a part of gross railroad investment. I fail to understand the meaning of such a statement. I wrote plainly in my paper that I was investigating outlays on capital account (investment), not outlays on current account (maintenance). Railroad accounting procedures distinguish clearly between the two types of expenditure.

Angell observes that the acceleration principle implies full employment of existing capital and uses this to argue against my contention that the acceleration principle is not generally valid. His admission of the implication of full use is, in itself, enough to show that this theory is not generally valid and is precisely one of the things I had in mind when rejecting the principle.

Leontief's empirical argument of a high correlation between car-miles (not a measure of output) and investment as evidence supporting the acceleration principle is indicative of the most dangerous type of promiscuity in econometrics. High correlation is not an objective or a criterion for correctness. The objective is to estimate structural behavior patterns, and although the statistical probability properties of the estimates are important considerations, high correlation is not one of them. The residual variation (random disturbances) is assumed to behave like a random variable, but it is not necessarily expected to be small, especially for a discussion of investment behavior. Unless there is some mistake in the calculation of some of Leontief's coefficients, I would argue that the strange values he gets for the effects of i and K on investment are enough to lead me to believe that his formulation is incorrect.

Leontief's rationalization of the relatively high investment by bankrupt railroads in terms of his own theory of investment behavior neglects much information that is known in the industry about the effect of court reorganization. If the only objective were to meet traffic, the bankrupt companies could have done so with their old equipment and other capital facilities. Reorganization enabled bankrupt roads to issue attractive first mortgage bonds and thus get capital at a reasonable charge in order to modernize with a view towards realizing expected profits. I fail to see how the acceleration principle can be worked into such behavior.

As a final remark in reply to Leontief, I must again labor the point that the goal of the present investigation is to estimate patterns of investment behavior. The pragmatic use of a single equation for the pure prediction of investment is as useless a criterion of correctness as high correlation. There is some point in extrapolating estimated equations beyond the sample observation to see how they are related to independent observations, but one must await a final process of fitting the equations of investment behavior into a more complete system of relationships before the usefulness in prediction is judged. At present, Leontief's so-called pragmatic arguments are not helpful in choosing between output or profit as a variable in the investment equation.

Angell raises a question about the choice of net as opposed to gross investment. In other empirical studies, I have used the net concept, and under the pressure of criticism switched to gross investment in the present study. The reasons for preferring the gross concept are that gross capital outlays are more intimately related to aggregate activity and that basic investment decisions are more likely to be formulated in gross than in net terms. Railroad investment decisions are made in terms of so many freight cars, locomotives, square feet of floor space, signals, etc. It seems unrealistic to subtract depreciation from gross investment, regardless of the correctness of the depreciation estimates, then consider the transformed variable as an objective of entrepreneurial decisions.

Simple two-variable relationships that Angell cites between investment and interest or investment and capital may be quite misleading. Most economic processes are multivariate, and many things must be considered simultaneously. A positive relation between investment and interest rates alone would not be the least disturbing if the relation turned out to be negative after the effects of profits, capital stock, and other variables were taken into account.

Two remarks about the effect of capital accumulation on investment are in order. Angell must bear in mind that the concept of maturity is not entirely independent of the size of the capital stock; thus he has not produced an alternative explanation of trend factors in railroad investment by referring to maturity instead of the stock of capital. Secondly, the replacement effect does not necessarily impose a positive component on the coefficient of K in the investment equations since the replacement effect is taken care of by using gross rather than net operating income as a measure of profits.

Share issues did not play much of a role in railroad finance during the period studied. A sources and uses analysis is hardly necessary to establish this point. While the conditions of the share market should not be expected to have much influence on railroad investment, they may be of much more importance in the electric utility industry. On the basis of criticism by Angell and others, I did make some later investigations about the importance of share yields for electric utility investment and, as stated in the revised version of my paper, find it to be of some plausible significance.

The effect of the cash position was not neglected, as Angell states. Some calculations involving working capital are mentioned in the original version of the paper, and the findings are largely negative for the railroad industry. More direct measures of cash holdings were used in the cross-section studies, with similar results.