CHAPTER 4

Trends in Capital Coefficients

ONE of the findings drawn from our analysis of secular trends in the regulated industries thus far is the disparity in behavior of output and capital formation. We have seen, however, that the differences in growth rates between the two evidenced a certain regularity. Their relative behavior suggested a systematic, progressive divergence rather than capricious differences following no apparent pattern. We may be thus encouraged in our expectation of finding a regularity of behavior in the ratio of capital to product studied directly.

Before proceeding to an examination of the record, we may take cognizance of the needs of the following chapters, in which the factors underlying capital formation are explored. In particular, we may distinguish the forms—of possible interest here—in which the ratio may be defined.

Principal Concepts and Their Relationships

The first of these concepts of the capital-product ratio is highly abstract. It cannot be measured directly, and yet it represents a relationship of interest. Consider an industry operating in long-run equilibrium, in the sense that its output has been attuned to demand and its stock of reproducible capital has been adjusted to output, in the most profitable way possible, given the factor prices prevailing and other relevant conditions. Now suppose there is an enduring change in the volume of demand (a shift in the demand curve) to a new and higher level which is maintained without revision. To this change the industry will adjust by expanding its stock of capital and its output as well, until a new equilibrium (in the sense defined above) is attained. The ratio between the increment in the stock of reproducible capital (net capital formation) and the increment in output, between these two equilibria, we may term the capital coefficient.

Thus defined, the capital coefficient is in considerable part a technological concept. For prevailing technology will establish the limits of its dimensions, in many cases—and in the regulated industries especially—rather narrowly. But technology will not fix its magnitude uniquely, unless we assume that the relative prices of the factors of production are unchanged between the two equilibrium positions—and unchanged, strictly, in terms of efficiency units. For many analytical purposes the latter assumption is too restrictive,

and may accordingly be omitted. This means that the capital coefficient, so defined, may vary over time because of: (1) technological changes; or (2) changes in relative factor costs; or (3) discontinuities (i.e. indivisibilities) in the units of the physical capital stock, which irresistibly limit the adjustment to equilibrium required between two particular levels of demand. The model should be further elaborated to permit short-run fluctuations about the enduring levels of demand at each equilibrium. Then, in equilibrium, allowance may be made for the maintenance of a certain "normal" reserve capacity. Insofar as such concepts may be applied at all to observable growth phenomena, this is the framework which appears most pertinent for the present study. It is the ratio of concomitant changes in capital and output between such equilibria, which we term the capital coefficient. It is, of course, not directly observable.

The observable concepts are the actual average and marginal capital-product ratios. The first of these may be defined as $\frac{C}{O}$, where C is the stock of reproducible capital and O is the volume of output, both measured in constant prices. The marginal capital-product ratio may be defined as the ratio between the change in the stock of reproducible capital and the change in output—i.e. as $\frac{\Delta C}{\Delta O}$. The familiar relationship between average and marginal quantities would suggest that when the average ratio is stable, then—during this period of stability—it is equal to the marginal ratio. Otherwise, they would differ in the following way: (1) So long as the average ratio is moving downward, it must remain higher than the marginal ratio. (2) So long as the average ratio is moving upward, it must remain lower than the marginal ratio. (3) The slower the movement in any direction, the smaller is the difference between the two. (4) Whenever the two ratios change direction, it is the marginal ratio which turns first. In the present case, however, such relationships would hold only approximately. For the *efficiency* of the capital stock may be improved merely through replacement. Hence, the *average* capital-product ratio could decline over time even in the absence of *net* changes in that capital stock—i.e. while the *marginal* capital-product ratio was zero.

The relationship between the observable ratios and the capital coefficient, defined above, cannot of course be framed with exactitude. But attention may be called to one possibility. The long-run average behavior of the marginal capital-product ratio may approximate that of the capital coefficient, at least broadly. In the long run there is an opportunity for the errors born of uncertainty, lack

of knowledge, etc., to cancel out. And insofar as investment is made on the basis of estimates of the most profitable level of output in the future, we should expect that this estimated production would tend to converge with *actual* production in the long run. For though expectations may at times diverge sharply from current realizations, business—including utilities—will not *indefinitely* act upon hopes or fears which run counter to experience. Such reasoning implies that the marginal capital-product ratio, on the average in the long run, would resemble the capital coefficient, though we must be alert to allow for possible exceptions. Thus, such enduring catastrophes as the Great Depression of the 1930's and the war years of the 1940's represent obvious occasions for substantial differences between the two.

The Data

In Chart 16 the average capital-product ratio is depicted for all regulated industries in the aggregate from 1880–1950. Similar data are shown for the several components in Charts 17–22. The ratios were computed by dividing the value of plant and equipment in 1929 dollars existing at the beginning of each year by output in 1929 dollars in that same year. It should be borne in mind, however, that the measures of output employed in this study are gross, in the sense that no deduction is made for the quantity of goods and services consumed by these industries which were produced elsewhere in the economy. Thus, railroad output is measured in terms of freight ton-miles and passenger miles, appropriately weighted and valued at 1929 prices. No deduction from this figure is made for the coal, oil, and other materials used by the railroads but produced outside this industry.

Had we employed the concept of net rather than gross output, the capital-product ratios we show would have been in general about 50 per cent higher. There would have been, however, no substantial differences in their trends. This is shown in Table 20, which presents the ratio of net output (national income originating) to gross output (operating revenues) in selected years for the major divisions of the regulated industries of interest here. It will be observed that the ratios remain remarkably constant over the long run in every case, despite moderate short-term fluctuations reflecting—among other things—relative price changes as well as statistical errors. We may conclude, therefore, that the secular behavior of gross and net physical output is, in the case of our industries, much the same. This means, of course, that the trends in capital-product ratios would be about the same, whether the denominator was measured in net or in gross terms.

TABLE 20

Ratios of National Income Originating in Regulated Industries to Operating Revenues, Current Dollars, Selected Years, 1890–1946

Year	*Railroads, Pullman and Express*	*Street and Electric Railways and Affiliated Bus Lines*	*Telephones*	*Telegraph*	*Electric Light and Power*	*Manufactured Gas*	*Weighted Totals, All Included Industries*
1890	0.52						
1902	0.66		0.75		0.46		0.66
1907	0.61		0.65		0.47		0.60
1912	0.62		0.68		0.48		0.61
1917	0.61		0.63		0.47		0.60
1922	0.63	0.61	0.71	0.72	0.54	0.33	0.62
1927	0.67	0.59	0.68	0.79	0.61	0.50	0.65
1929	0.69	0.60	0.69	0.74	0.75	0.41	0.68
1932	0.62	0.51	0.61	0.62	0.66	0.39	0.61
1937	0.65	0.50	0.63	0.68	0.54	0.51	0.60
1939	0.64	0.52	0.63		0.51		0.59
1946	0.68	0.54	0.68		0.54		0.63

Ratios are based on comparisons between net income originating and operating revenues in current dollars. The industries listed accounted, in 1929, for 91 per cent of income originating in transportation and public utilities as defined by Kuznets in *National Income and Its Composition, 1919–1938* (National Bureau of Economic Research, 1941); water transportation and pipelines are omitted here. The data for income originating for 1922–37 were taken from Kuznets (*ibid.*). The Kuznets figures, which are available for 1919–38, were extrapolated to 1890 by use of data shown by Robert F. Martin, *National Income in the United States, 1799–1938* (National Industrial Conference Board, 1939) and extrapolated to 1946 by use of Department of Commerce national income data. The figures for operating revenues (or sales) were obtained from the Bureau of the Census, the Interstate Commerce Commission, the Federal Power Commission, the Federal Communications Commission, and trade sources.

The Aggregative Trend

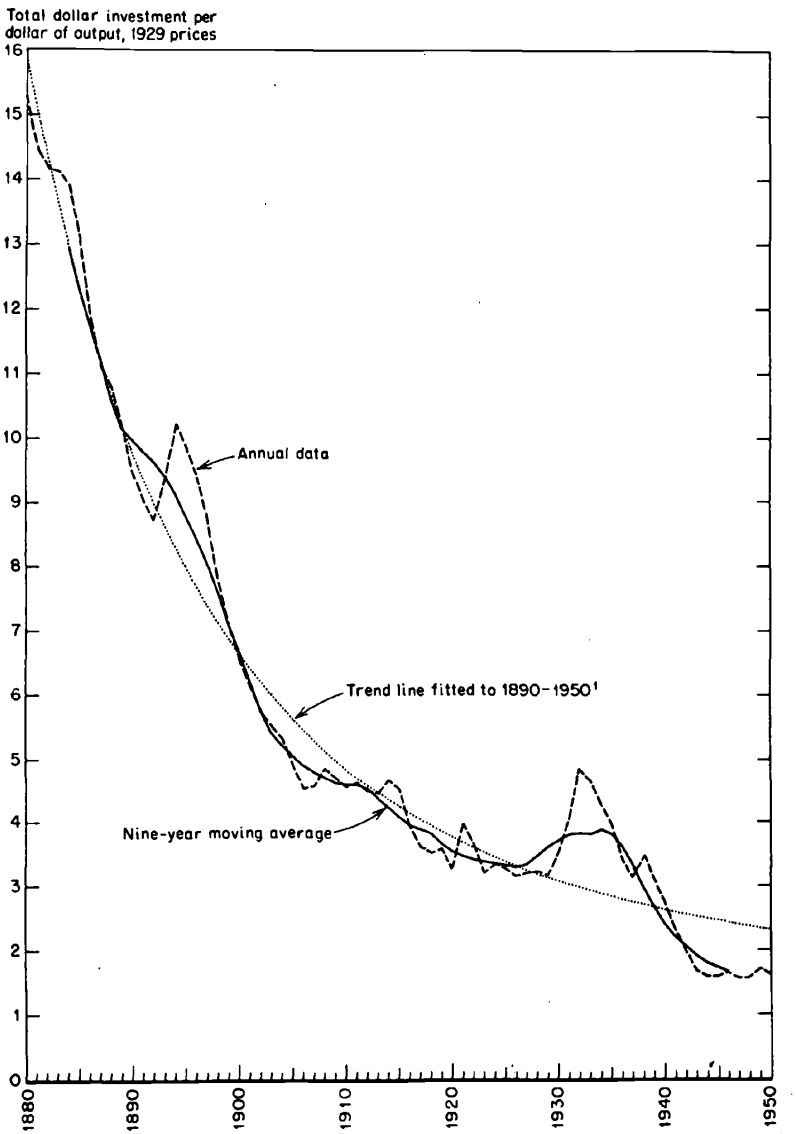
The general trend in the average capital-product ratio of all regulated industries, shown in Chart 16, is so pronounced that, despite the volatility of the series, it is quite evident in the annual data. But it is even more clearly represented in the nine-year moving averages, and more unequivocally still in the trend lines fitted to the data. The movement is progressively downward over the 1880–1950 span, and at an extraordinarily brisk rate.

Most striking, perhaps, is the very high level from which this decline begins. For in the 1880's the ratio of capital to product exceeded 12, meaning that on the average the regulated industries possessed 12 dollars in plant and equipment for every one dollar of

CHART 16

Capital-Product Ratios, All Regulated Industries, 1880–1950

(ratios of value of plant and equipment in 1929 dollars to output in 1929 dollars)



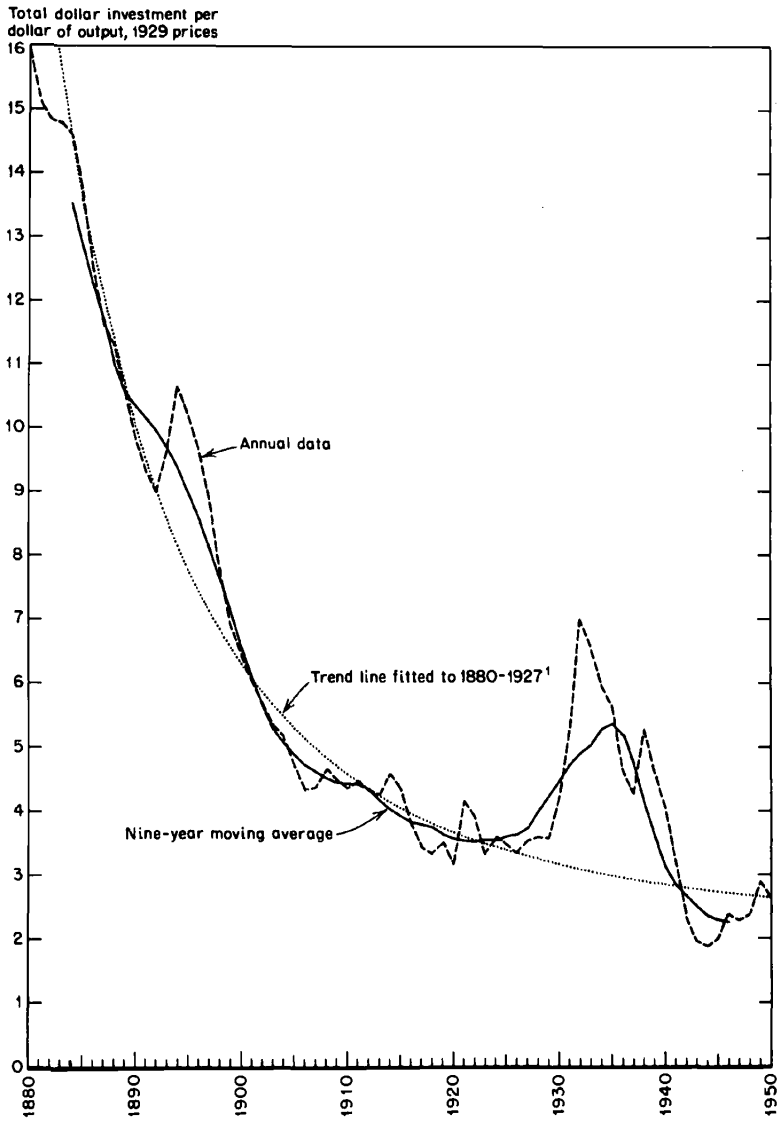
[1] Capital-product ratio (1929 dollars) = $(1.36)(7.2197)^{0.97836^t}$ where t is measured in years with 1890 as origin.

Source: Appendix Tables I-1, K-10.

CHART 17

Capital-Product Ratios, Steam Railroads, 1880–1950

(ratios of value of plant and equipment in 1929 dollars to output in 1929 dollars)



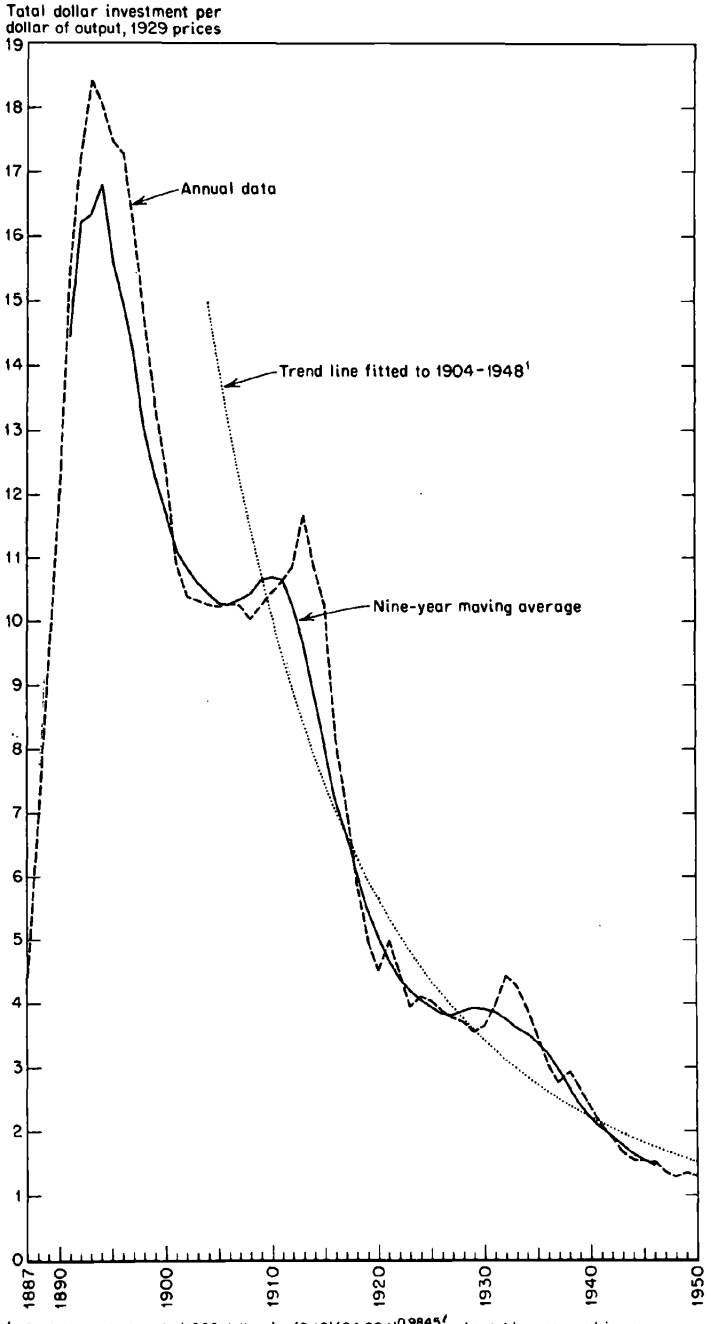
[1] Capital-product ratio (1929 dollars) = $(2.26)(8.7263)^{0.9633^t}$ where t is measured in years with 1880 as origin.

Source: Appendix Tables I-13, K-10.

CHART 18

Capital-Product Ratios, Electric Light and Power, 1887–1950

(ratios of value of plant and equipment in 1929 dollars to output in 1929 dollars)



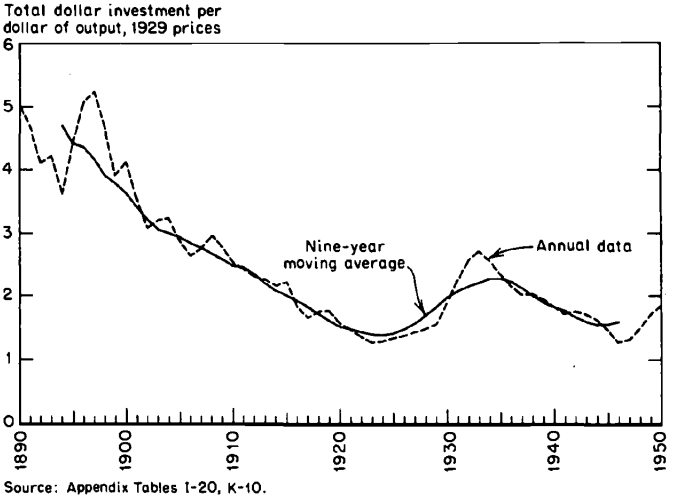
[1] Capital-product ratio (1929 dollars) = $(0.18)(84.894)^{0.9845^t}$ where t is measured in years with 1904 as origin.

Source: Appendix Tables I-16, K-10.

CHART 19

Capital-Product Ratios, Telephones, 1890–1950

(ratios of value of plant and equipment in 1929 dollars to output in 1929 dollars)



Source: Appendix Tables I-20, K-10.

annual output. This compares with average capital-product ratios of less than one for manufacturing, and of less than two for agriculture and mining in the same period.[1] Since the ratios for the other industries were computed in terms of net output, the comparison here actually understates the difference. It is also slightly understated by the fact that in the numerator of our ratio we include only *fixed* capital, while for the other segments *total* reproducible capital is included; but the variation arising from this factor is for most purposes—including this comparison—negligible.[2]

The subsequent decline in the average capital-product ratio for all regulated industries is sharp, though it gradually loses momentum. By the turn of the century it was down to about 6.5; by the 1920's, to about 3.5; and by 1950, to 1.7. Of course the latter figure may be abnormally low, still reflecting some of the remaining backlog of capital requirements accumulated during the years of privation in World War II. This is suggested, albeit very roughly, by the position

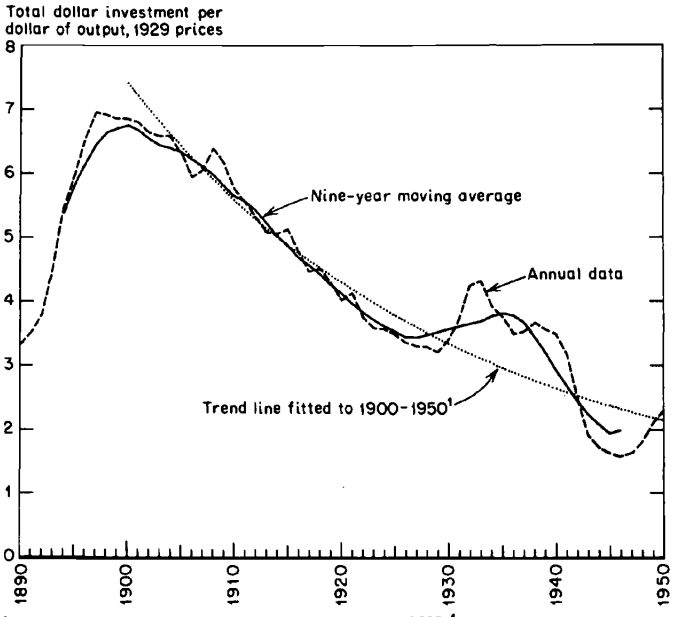
[1] Simon Kuznets, "Capital Product Ratio and Technological Change," *Conference on Quantitative Description of Technological Change*, Social Science Research Council, 1950, Table 4.

[2] In the regulated industries, inventories typically account for less than 2 per cent of total reproducible capital. See Chapter 8.

CHART 20

Capital-Product Ratios, Street and Electric Railways, 1890–1950

(ratios of value of plant and equipment in 1929 dollars to output in 1929 dollars)



[1] Capital-product ratio (1929 dollars) = $(0.10)(70.902)^{0.9931^t}$ where t is measured in years with 1900 as origin.

Source: Appendix Tables I-22, K-10.

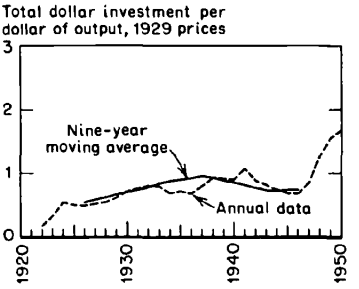
of the trend line, which ranges somewhat above the actual capital-product ratio throughout the 1940's. But even if—illustratively—we take the *trend line* capital-product ratio in 1950 as more representative of its "true" long-run value than the actual figure in that year, we note that it is still little more than 2, or about a sixth of its size of seventy years before.

The tendency of the absolute rate of decline in the ratio to diminish gradually is reflected in the form of the curve fitted to the data. Its equation is given in the footnote to the chart. It is the declining branch of a Gompertz curve, and falls gradually toward a fixed lower limit—the value of which in our fit is 1.4. Taken literally, this would imply that the long-run value of the average capital-product ratio will continue to decline very gradually in the future, approaching by ever smaller amounts the floor of 1.4. But there is no intention here to employ the curve for a mechanical

CHART 21

Capital-Product Ratios, Local Bus Lines, 1922–1950

(ratios of value of plant and equipment in 1929 dollars to output in 1929 dollars)



Source: Appendix Tables I-27, K-10.

extrapolation of this kind. It serves as a descriptive, smoothing device, and aids in the detection and—to some extent—the appraisal of periods such as the 1930's and the 1940's when the ratio departed from its general long-run drift.[3]

Despite the substantial decline in the capital-product ratio over the 1880–1950 span, and despite the repression of this ratio by the special conditions of the 1940's, it remained considerably above similar ratios computed for other segments of the economy. Thus, in manufacturing, the average capital-product ratio in 1948, computed on the same basis as ours, was 0.65,[4] compared with 1.7 in the regulated industries. In mining the ratio was 1.3.[5] Accordingly, the regulated industries remained a segment in which reproducible capital played an extraordinarily large role in the productive process, though the differences in this regard are very much smaller than they were seventy years before. It should be noted, however, that disparities in the capital-product ratios among industries provide only a rough guide to divergences in the amount of capital *consumed* for each dollar of output. In the regulated industries, capital is on the average considerably more durable than in the economy as a whole. In the 1930's the average depreciation rate in this segment was 1.9 per cent compared with from 5.4 to 9.2 per cent in manufacturing industries, 4.9 in mining, and to 3.5 per cent in the

[3] These remarks apply as well to the curves fitted in Charts 17, 18, and 20. Nothing in the mechanics of the curves themselves justifies extrapolation.

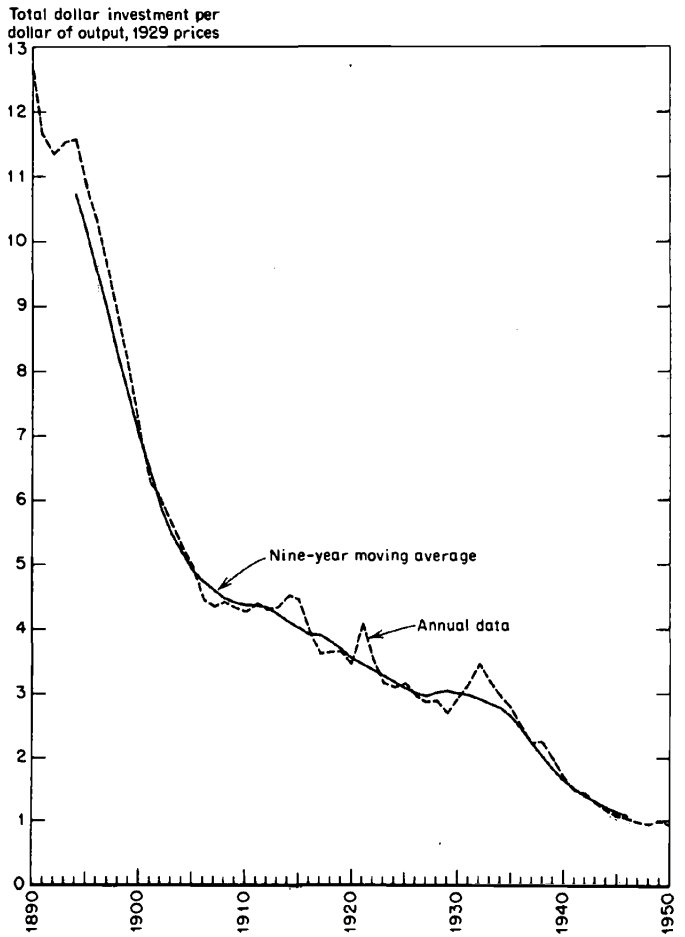
[4] Daniel Creamer, *Capital and Output Trends in Manufacturing Industries, 1880–1948* (National Bureau of Economic Research, Occasional Paper 41, 1954), Table 8, p. 43.

[5] Israel Borenstein, *Capital and Output Trends in Mining Industries, 1870–1948* (National Bureau of Economic Research, Occasional Paper No. 45, 1954), Table 13, p. 54.

CHART 22

Capital-Product Ratios, All Other Utilities and Transportation, 1890–1950

(ratios of value of plant and equipment in 1929 dollars to output in 1929 dollars)



Source: Appendix Tables I-29, K-10.

economy in the aggregate.[6] Such discrepancies alone, other things being equal, would result in observed differences in capital-product ratios at least as large as those in the 1940's, though not nearly so large as those observed in the later decades of the nineteenth century.

Perhaps the most important aspect of the capital-product ratio is the light it casts upon the impact of an alteration in demand upon

[6] Solomon Fabricant, *Capital Consumption and Adjustment* (National Bureau of Economic Research, 1938), p. 34.

investment—i.e. upon the capital coefficient. Of course no simple, empirical ratio can measure this exactly, for the causal relationships will typically remain, to a large extent, obscure. In practice, investment is always undertaken with *future* needs in mind, and may have little relationship with current changes in output. But as noted earlier, in the long run, business expectations are brought closer in line with actualities, errors in one direction find compensatory counterparts in the other, and sufficient time elapses for adjusting the stock of capital to realized requirements as they appear. We may countenance, therefore, the possibility of at least approximating the general drift of the capital coefficient and—over sufficiently long periods—its general magnitude. For this purpose the *marginal* capital-product ratio is most pertinent.

Measuring the trend of the marginal capital-product ratio, however, presents some difficulties. Because of its highly erratic nature, values in particular years have little or no meaning for the purposes in view here. Values computed over a considerable span remain peculiarly sensitive to the choice of end years—a difficulty which is modified, but not often eliminated, by the use of broad averages. In Table 21 we have tried to refine the measurements

TABLE 21

Marginal Capital-Product Ratio,
All Regulated Industries and Components, Selected Periods

Period	*All Regulated Industries*	*Railroads*	*Electric Light and Power*	*Telephones*	*Street and Electric Railways*	*Local Bus Lines*	*All Other*
To 1891[a]	9.2	10.2	16.9	4.6	5.9	...	11.4
1891–1910	2.9	1.8	11.5	2.4	5.9	...	2.4
1910–1927	1.9	2.0	3.0	1.0	−4.5	0.8	2.2
1927–1950[b]	0.4	−0.2	0.6	2.2	4.0	0.9	0.4

These are the ratios of the change in the stock of reproducible capital between the ends of the indicated years to the change in the nine-year averages of output, centered in the indicated years. Both numerator and denominator are measured in 1929 dollars.

[a] From the starting date of the industry.

[b] Data used for 1950 are for the single year only.

further by selecting end periods which are centered about the peak years of long cycles. The numerators of the ratios therein presented are the changes between the ends of the indicated years in the stock of reproducible capital, measured in 1929 dollars—i.e. net capital formation. The denominators are the changes in the nine-year averages of output, centered on the years indicated. An exception was made for the terminal year, since here it was desired to extend

the period as far as possible in order to reflect the activity of the post-war period; rather than stop with the nine-year average centered in 1946, we terminate the change with 1950, for which output in that year alone was employed.

The data show a sharp and progressive downward trend in the marginal capital-product ratio. In the period prior to the 1890's, an increase of one dollar in the output of the regulated industries was accompanied on the average by an increase of 9 dollars in capital formation. In the 1891–1910 span, an increase of one dollar in output was accompanied by one of only 3 dollars in capital formation, in 1910–27 by one of only 2 dollars, and in the 1927–50 span, by only a 40-cent advance in capital formation. Thus the impact of an expansion in demand upon investment grew steadily weaker over time. This conclusion is reinforced when we examine the record of individual components.

Individual Industries

The trend of the average capital-product ratios in the components is depicted in Charts 17–22. In every case but one—local bus lines—the general long-run drift is downward, in keeping with that of the aggregate. But there are some important distinctions to be noted in the pace and the regularity of this movement.

Most similar to the aggregative average capital-product ratio in the regularity and general form of its decline is that of steam railroads. Here, the ratio dropped from about 16 in 1880 to somewhat over 6 at the turn of the century, to less than 4 in the 1920's, and finally to about 3 in 1950. The pace of decline was progressive, proceeding by diminishing amounts, and broken mainly by cyclical fluctuations—especially the severe depressions of the mid-1890's and the early 1930's, when output was contracted sharply and the ratio correspondingly boosted. Like the aggregative ratio, its trend is well described throughout its range by a Gompertz curve. No one of the other components adheres to this pattern so closely.

In electric light and power the trend is also sharply downward, but is broken by a temporary "bottoming out" and modest rise in the first twelve years of the twentieth century. Nor can this interruption be explained by cyclical changes in the level of business activity. Only in the last forty years of the time span covered is the movement of the average capital-product ratio in electric light and power adequately described by the Gompertz curve. Nevertheless, the over-all drop in the ratio was substantial, extending from about 15 in the early 1890's to about 10 in the 1900's, to about 4 in the 1920's, and to less than 2 in 1950.

In street and electric railways there is also a divergence from the over-all pattern. From 1890 to 1910 the average capital-product ratio in this segment rose very sharply, from slightly more than 3 to nearly 7. Thereafter, the Gompertz curve pattern is evident, and the decline proceeds from somewhat less than 7 in 1900 to between 3 and 4 in the 1920's and to a bit more than 2 in 1950.

Although both declined over the long run, in neither telephones nor the all other group does the average capital-product ratio follow the Gompertz pattern. In the former, the ratio declines sharply from about 5 in 1890 to less than 2 in the 1920's. But in the mid-1920's the ratio began a significant rise. The advance was powerfully accelerated in the early 1930's by the effects of the Great Depression. However, when the influence of the depression had subsided, and—still later—when in 1950 the influence of the wartime squeeze on investment had been largely erased, the ratio stood at a level slightly above its previous low point of the 1920's. In short, over the last thirty years, taken as a whole, stability in the neighborhood of 1.5 to 2, rather than continued decline, was characteristic of the ratio in this component.

In the all other group the decline in the average capital-product ratio is progressive, but not at the same evenly diminishing rate which characterized behavior in the aggregate and in steam railroads. From 1890 to 1906 the ratio dipped sharply, from somewhat less than 13 to a little more than 4. During the next twenty years the decline proceeded, but very slowly, with the ratio ranging in the neighborhood of 3 in the late 1920's. In the following years there was a moderate acceleration in the pace of decline, and by 1950 the average capital-product ratio in the all other group was slightly less than 1.

As indicated earlier, the ratio for local bus lines departs materially from the general trend, though it must be borne in mind that the history of this industry is very brief. The general trend of its average capital-product ratio was upward, rising from about 0.5 in the mid-1920's to about 1.7 in 1950. A substantial part of the increase in the post-World War II period, however, was of short-run nature, reflecting both the cutback in traffic from the wartime high as private passenger cars came into wider use, and the extension of lines into new suburban areas where the intensity of traffic was at least initially light. Save for this brisk post-war advance in the average capital-product ratio for local bus lines, the over-all secular upward trend was of narrowly limited dimensions.

With the exception of this small component, however, the broad generalization reached in connection with our study of the aggregate, holds as well for its several parts. The over-all trend of the average

capital-product ratio was distinctly downward over the 1880–1950 span. In the case of telephones, this decline was substantially arrested in the last thirty years, though it was by no means reversed. In all other components the reduction in the average capital-product ratio has proceeded progressively for at least the past forty years and, in two of them, for the entirety of the seventy-year period of record.

In the same way, the generalization concerning the *marginal* capital-product ratio holds for the components as well as for all regulated industries in the aggregate. This is shown in Table 21, where data are presented for each of the components computed by the same method as that employed for the aggregate. But for local bus lines, the marginal capital-product ratio moves downward in every case. The declines are most pronounced in railroads, electric light and power, and the all other group. In the first, the reduction proceeds briskly from somewhat more than 10 dollars of capital formation for every one dollar advance in output, to a long period of stability at a level of about 2 for 1 during 1891 through 1927. Then in the final twenty-three years the ratio actually turned negative, for in this period output was substantially increased even though the stock of reproducible capital was reduced. In both electric light and power and in the all other group, however, the decline in the marginal capital-product ratio was sharp and progressive throughout the period, proceeding from nearly 17 to 0.6 in the former and from more than 11 to 0.4 in the latter.

For telephones the reduction was much smaller. Indeed, after the initial drop from the pre-1891 period, there was on balance but a moderate downtrend. In street railways the reduction in the marginal ratio was also relatively modest, though it should be remembered that in this component the stock of reproducible capital had been contracting since early in the twentieth century. During the 1910–27 period, this contraction was accompanied by a rise in output. During 1927–50, output also declined. The data for local bus lines suggest virtual stability in the marginal capital-product ratio, but here the historical base for defining the secular trend is very small.

Thus, with a minor exception, advances in output were accompanied by progressively smaller amounts of capital formation over the 1880–1950 span—in each of the regulated industries as well as in the aggregate. Moreover, the dimension of this change in the long-run relationship between demand for final product and investment was very substantial. Both the reasons for the trend, as well as its implications, present an intriguing and challenging problem for analysis. Some tentative explorations in this area are included in the subject matter of Chapter 6.