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CHAPTER 6

Factors Underlying Long-Term Trends: Capital-Product Ratios and Capital Formation

IN the previous chapter we proposed a general framework linking the secular behavior of net capital formation in the regulated industries to the long-run trends in two series: the marginal capital-product ratio and the *increments* in output. In addition, we explored the factors underlying the secular pattern of production in this segment of the economy. In the present chapter we turn to the determinants of the capital-product ratio, and then once again to our central problem—the long-run trend of investment.

Determinants of Trends in the Capital-Product Ratio

The average capital-product ratio is essentially an inverse measure of the efficiency with which capital is employed. It is one-dimensional, of course, since it takes no account of the length of life of capital, its cost, or the cost of the other principal factor of production —labor. Nevertheless, other things being equal, a decline in the capital-product ratio is a gain in efficiency. In a business economy, therefore, there are bound to be forces making for its reduction, though these might indeed be counterbalanced by others. Thus, in the static framework often employed in theoretical analysis, a rise in the capital-product ratio would occasion little speculation: it would represent rather obviously an adjustment to an increase in labor costs relative to that of capital. But in the actual long-run behavior of industry, pronounced alterations in other conditions greatly overshadow adjustments of this kind. For one thing, technological advance has been a continuing phenomenon, and may result in economies in the use of any or of *all* factors of production. Other conditions of dynamic change also enter into the determination of the capital-product ratio, as we shall see, so that the causal nexus binding the actual events of history is necessarily clouded with the complexities of a variety of interconnections. Through it all, however, remains the tendency for increasing the productivity of capital (i.e. reducing the capital-product ratio) as well as that of labor.

It is of some significance, therefore, that a *rising* capital-product ratio in the initial period of an industry's existence is evident in the records in every case in which our analysis covers the activity of an industry from its inception. Reference to the charts in Chapter 4 will call to mind that for electric light and power there was a very sharp

rise in the capital-product ratio from about 4 in 1887 to more than 18 in 1893. For telephones the advance was very much more modest, though quite perceptible, and lasted from 1890 to 1897. The application of electricity to street railways—and the subsequent swift growth of a virtually new industry—is reflected in the substantial rise in the capital-product ratio for this component from 3 in 1890 to nearly 7 in 1897. A similar development could have been observed for railroads in the earliest days, not covered in our charts.

This phenomenon springs at least in part from an outstanding characteristic of the regulated industries—the indivisibility of their most important capital units. In order to provide any service at all between two points a railroad must undertake some minimum amount of investment in the grading of roads, the purchase of equipment, and the construction of track, terminals, and auxiliary structures. Electric light and power and telephone companies, street and electric railways, and most other utilities must similarly make substantial investments in central facilities as well as in lines of communication or transportation before any output at all may be expected. In the earliest days of an industry's history, while many large units are being put in place and very few are actually in operation, it may be expected that the capital-product ratio will increase. It is possible that such "extensive expansion" in new or radically reorganized industries accounted in part for the upward trend in the capital-product ratio in manufacturing and mining for at least a portion of the latter decades of the nineteenth century. But since indivisibility is not so pronounced a general characteristic, the advance in these segments was much smaller,[1] though it was prolonged by the development and spread of a series of radical technological innovations. These innovations required large aggregations of capital, and were profitable because of the correspondingly large savings achieved in the use of labor—particularly since wage rates rose through most of this period in relation to the cost of capital. Once the *regulated* industries were established, however, innovations of this type in this segment of the economy were in the minority.

The initial rise in the capital-product ratio in the regulated industries, then, was in part a manifestation of early extensive expansion in a technological environment characterized by a high degree of indivisibility. By its nature, an upward trend so generated cannot last for very long.[2] It denotes, after all, a gestation period

[1] Daniel Creamer, *Capital and Output Trends in Manufacturing Industries, 1880–1948* (Occasional Paper 41, National Bureau of Economic Research, 1954), Table 8, p. 43, and Israel Borenstein, *Capital and Output Trends in Mining Industries, 1870–1948* (Occasional Paper 45, National Bureau of Economic Research, 1954), Table 7, p. 34.

[2] Cf. the remarks of Simon Kuznets in his Introduction to Creamer, *op. cit.*, pp. 8–10.

only. In the regulated industries for which we have early records, the gestation period was relatively short, lasting for barely a decade, in which many facilities were gradually brought to the point of completion at which their use could begin. As soon as this point is reached output may be started and expanded rapidly. Moreover, once a given installation is complete, its initial operating capacity may typically be further extended by substantial amounts with relatively small additional investment. Thus, after the huge outlays required for the building of roads and terminals, a railroad may double or triple the capacity on a given line with relatively small expenditures for additional rolling stock, double track, or passing track. The latter phenomenon would appear to have been evidenced in the steady increase in the relative importance of equipment, especially rolling stock, in the total volume of fixed operating capital of the railroads, from 9 per cent in 1880 to 26 per cent in 1917 and to 35 per cent in 1951.

These factors would alone explain a distinct tendency for the capital-product ratio to *decline*, after the first brief period of increase. But there were in fact other influences operating in the same direction and intensifying this decline, which in the regulated industries were both pronounced and prolonged. One was the distant horizon typically envisaged by the utility builders, perhaps most notable in the case of the railroads. In numerous instances the completion of lines was followed by strenuous efforts to encourage the establishment of towns and industries along an otherwise barren way. The capacity of roads as initially established—both because of techniques and ambitions—was geared to a volume of business which could be realized only with the passing of decades. The same influences, though not so spectacular, were in operation in other components, and reinforced the effect of capital indivisibility upon the capital-product ratio. Thus, central telephone facilities and electric generating plants were necessarily constructed with relatively distant needs in mind, for economical planning precluded frequent and small additions later as actual needs arose. Some weight must be given, too, to the role of speculation and promotion in the construction of the regulated industries—especially steam railroads and street railways. The financial rewards of promotion were typically great and tended to vary, moreover, with the size of the project; often in the calculations of the organizers the subsequent profitability was apparently a matter of consideration secondary to the gains obtained from initial construction and financing. Here was an additional factor making for initial capacity greatly in excess of immediate needs. But most important for our analysis is the fact that the very

existence of such capacity virtually compelled a *decline* in the capital-product ratio as output expanded in subsequent years. Reference once again to the data of Chapter 4 will remind us that this reduction proceeded at an extremely swift pace in the early years, shortly after an initial increase where our records cover the industry's beginnings. In the aggregate of all regulated industries, of course, the initial rise in industries which made their start in the 1870's or 1880's was overshadowed by the continuing decline of the capital-product ratio in the older and larger segments.

Were these the *only* influences depressing the capital-product ratio, one would expect that the decline might persist for as long as an industry expanded, but not after growth had ceased. For once growth is at an end, the factors discussed above lose their force. Yet, as we have seen, a gradual reduction in the capital-product ratio persisted, though at a progressively slower pace, even in the case of declining industries such as steam railroads and street and electric railways—and long after expansion of facilities had ended. Obviously, certain influences, other than those already mentioned, were at work.

Chief among these were changes in the *nature* of the capital stock and changes in the way this stock was used. In the first connection, a nearly constant stream of technological improvements occurred in the industries under review. A few of the improvements were capital-*using* inventions, in that they led directly to larger proportionate increases in capital formation than in output. Such was the introduction of the dial system which induced the sharp rise in the capital-product ratio of telephone communication which began in the mid-1920's. In the same class were the revolutionary changes in generating facilities of electric utilities in the first decade of the twentieth century. And in manufacturing and mining until 1910 technological advances of this type were the rule, making for a gradual rise in the capital-product ratio during the period of these industries' most rapid expansion. But the great bulk of all innovations which occurred in already established regulated industries were capital-*saving*, in the sense that they increased output per unit of capital.

Introduction of alternating current and the transformer and the resulting interconection of plants, and later the successful introduction of high-voltage lines and system interconnection, gradually made possible steadier electric light and power service, smaller reserve capacity requirements, and the ability of central installations to service far more extensive areas than had previously been possible. In the railroads, the work-capacity of freight cars, passenger cars,

tracks, ties, locomotives, etc., has been steadily enhanced. Similar capital-saving improvements mark the history of most of the other regulated industries. By their nature, such innovations lower the capital-product ratio.

Aside from changes in the physical characteristics of capital, there have been changes in its use which have operated in this direction. This factor was most pronounced in the railroads and was of particular importance in the years succeeding World War I. Thus, there was a substantial rise in the average length of haul in freight cars and in the average distance traveled by passengers. The former rose by more than 30 per cent and the latter by nearly 70 per cent between 1919 and 1950. These advances mirror in part the development of the western states and the concomitant rise in transcontinental traffic, and in part the greater diversion to the automobile and truck of short-distance business.[3] Their effect was to augment the capacity output (as measured in passenger miles and freight ton-miles) of existing road and equipment.

There is a third, and related, factor which served to depress the capital-product ratio. Since the work capacity of capital is almost constantly improved, replacement investments are nearly always something more than the name implies. A capital unit purchased today, even if it sells at the same price, is likely to have a substantially greater productive capacity than one obtained twenty years ago. Since price indexes do not reflect alterations in the volume of productive service that goods can perform, it is apparent that even if the growth of an industry ceased entirely, the decline of its capital-product ratio would be likely to proceed. Furthermore, as an industry matures its relative rate of growth is retarded, and the proportion of replacement to the total stock of capital expands.[4] Here, then, we have another factor operating to reduce the capital-product ratio long after the industry's gestation period and its aftermath have passed. Its role was undoubtedly significant through most of the history of the regulated industries.

A concluding factor, also related to the character of our measurements, may be noted. The numerator of the capital-product ratio is of course the *net* depreciated stock of capital. But as industries mature the volume of *accrued* depreciation rises. The physical reality behind such accruals are units of capital which have partly aged but remain in use. In some cases, partly depreciated units remain *fully and*

[3] For a description of these trends see Harold Barger, *The Transportation Industries, 1889–1946: A Study of Output, Employment, and Productivity* (National Bureau of Economic Research, 1951).

[4] Cf. the Introduction by Simon Kuznets to Creamer, *op. cit.*, p. 7.

efficiently in use. Nonetheless, accrued depreciation is deducted in full from the net stock of capital. Thus, a machine which costs a thousand dollars, and with an expected life span of ten years, may at the end of five years perform with its original efficiency completely intact. But—assuming straight line depreciation—one-half of its value (the five hundred dollars of accrued depreciation) would already have been deducted from the net stock of capital. Clearly, this too is a factor which served to depress the capital-product ratio as we have measured it.[5]

From these observations there emerges a general pattern of events shaping the capital-product ratio in the regulated industries. Initially, there is a period of gestation in which preparatory investment is made on a wide scale, and many large indivisible units are started and only gradually brought to completion. For a number of reasons cited above, this inaugural build-up in the regulated industries was unusually large. Of course, actual output in this period was necessarily small, and the capital-product ratio rose.

But this introductory stage is, by nature, short-lived. It can last only so long as *new* plants are established at a faster pace than output rises in facilities that are brought to completion. The duration was less than a decade in the regulated industries for which relevant data are available. Also, it should be recalled that in the *aggregate* of the regulated industries this initial increase in the ratio for electric light and power, for telephones, and for electric railways was overshadowed by the sharp decline simultaneously in progress for the older industries—especially steam railroads and some of the older components included in the all other group. Accordingly, the capital-product ratio in the regulated industries as a whole moved downward throughout the 1880–1950 span. In manufacturing, this initial period of extensive expansion, characterized by the rise of a multitude of new firms and new industries, was accompanied and followed by the sweep of pervasive capital-demanding innovations which were the earmark of the industrial revolution. As a result the capital-product ratio remained on the rise until World War I.

The second stage of the pattern in the regulated industries is a natural outgrowth of the first and followed swiftly. Once many large installations are completed, output is free to expand with relatively

[5] Our use of *net*, rather than gross depreciated capital in the numerator of the capital-product ratio is warranted only by our judgment that it *more closely* approximates the volume of capital actually in use. Even if we had used gross capital, the general nature of the trends in capital-product ratios, already described, would have been undisturbed. In short, the imperfection of our measurements accounted for only a small part of the downtrend in the ratio of net capital to product.

little additional investment necessary. The capital-product ratio is therefore profoundly depressed.

In the third stage the drop in the capital-product ratio is perpetuated. Capital-saving inventions enhance the efficiency of plant and equipment. In some cases, existing facilities are put to more economical use. In addition, the growing relative importance of capital consumption, in the company of general technological advance, ensures that the stock of capital will be replaced at a progressively faster rate with units capable of greater productive service. Finally, the expansion of accrued depreciation serves to depress the *net* stock of capital, as ordinarily measured, in relation to that actually in use. For all of the foregoing reasons the capital-product ratio continues downward even after the influences at work in the second stage have completely lost their force. It is certain that these factors were significant not only in the regulated industries, but—in whole or in part—in many other major segments of the economy; for, at least since the 1920's, the downward trend of the capital-product ratio was nationwide.

From the general pattern described there are, to be sure, deviations. Even after the first stage of the pattern had ended, capital-*using* innovations occurred in the regulated industries and resulted, for a time, in rising capital-product ratios. This was the case in the early 1900's in electric light and power, and in the mid-1920's in telephones. But such deviations in the seventy-year experience of our industries have proved temporary. The dominating, pervading factor in this segment of the economy in the long run, once the initial period of gestation had been surmounted, was the steady flow of capital-*saving* devices and the persevering drop in the capital-product ratio.

In one of our components—at least in the brief period of its recorded history—the general pattern is barely perceptible at all. This is local bus lines—a component in which several distinctive forces were in operation during the twenty-five years of its activity covered by our records. Here, the gestation period lasted roughly as long as in other cases: from the early 1920's to the early 1930's. But this initial stage was followed by an extended period of stability, rather than decline in the capital-product ratio. Furthermore, in the years following World War II this stability was replaced by an abrupt advance, which placed the capital-product ratio at a level materially higher than the one prevailing twenty-five years earlier. This contrary behavior appears to have been attributable to three characteristics peculiar to local bus lines, coupled with the nature of the impact of the immediate postwar situation upon its business.

In the first place, there was a virtual absence of significant capital-saving innovations in the industry, owing to the technological conditions under which it operated. Instead of a variety of machines, layouts, central and subsidiary installations, and communication and transportation systems, the principal investment of the industry consisted of a single, relatively homogeneous unit—the bus. The limits to which its efficiency might have been expanded by increasing its speed or carrying capacity were obviously set not by technology, but by the municipal regulations in force in its service areas. Indeed there has probably been some *reduction* in the efficiency with which buses have been used in recent years, because of greater traffic and the slower pace at which they must operate.

Second, as street railways were gradually displaced, local bus lines were to an increasing extent required to maintain full schedules of service over given routes, with a consequent reduction in the average load per bus. Thus, in a sense, the gestation period of local bus transportation was extended by its continued, though piecemeal, expansion into new areas—a movement accelerated with the growth of suburbs in the post-World War II period. This tended to push the capital-product ratio up rather than down.

Third, the typical unit of capital investment is considerably smaller—that is, more "divisible"—for local bus transportation than for the regulated industries in general. New business arising from the growth and spread of the population in the post-World War II period was for the most part met by railroads, electric light and power, telephones, and other utilities by more intensive use of already constructed "central facilities" (road and terminals, generating plants, and central stations) coupled, of course, with *relatively* small supplementary investments such as in rolling stock and transmission lines. The capital-product ratio in these cases continued downward. But for the local bus transportation it meant simply the purchase of new buses, with virtually no offset in the more economical use of central facilities. And new lines established in new areas typically operated with smaller than average bus loads, at least initially. These considerations explain why the industry's capital-product ratio did not decline and suggest also why it tended to increase.[6] A substantial rise in the postwar years, however, was a necessary outgrowth of the special conditions then prevailing. For on the one hand, bus lines were induced to extend their services to

[6] For completeness, mention should also be made of capital-using innovations in buses, though these do not appear to have been quantitatively important. Reference is to the introduction of devices to improve the safety and comfort of passengers. Besides, in the case of a few lines, there had been conductors who were ultimately displaced by the introduction of automatic coin receptacles.

new suburban areas, and this required new investment along with the large-scale replacement of over-age or obsolete buses as postwar supplies became available. On the other hand, the total volume of fares dropped precipitously as wartime restrictions were lifted on the manufacture of private automobiles and on gasoline purchases. This factor accounts in the main for the rise in the capital-product ratio of local bus lines to about 1.7 in 1950, compared with about 0.7 in the war years and 0.9 in the late 1930's.

If our analysis of the situation for this component is true, then a decline in its capital-product ratio may be expected sometime in the period after that covered by the study. For as suburban areas grow less extensively and more intensively, the average load per bus should increase. An offsetting factor, however, may be the declining income elasticity of demand for bus service discussed in the previous chapter. Another offset may be the declining speed at which buses operate as auto traffic continues to increase.

Some Aspects of the Variation among Industries

One further difference among our components may be noted: the rather substantial variation in the *extent* of the declines in the capital-product ratio over the 1880–1950 span. Measured from the peaks to 1950, they vary from a decline of 93 per cent for electric light and power to one of 65 per cent for telephones. Furthermore, in one case—local bus lines—the ratio rose. It will be noticed, too, that the extent of variation was closely correlated with the initial standing of the capital-product ratio itself. The higher the ratio, the steeper the relative decline.

This is shown in Table 25, in which we have included the major divisions of mining and manufacturing industries. Changes in the capital-product ratio were measured in each case from the peak to the last date available—1950 for the regulated industries and 1948 for the others. The industries are ranked according to the size of their capital-product ratios at the initial date. The correlation between this rank and the degree of the ratio's subsequent decline is obviously nearly perfect.

This correlation has suggested the hypothesis that differences in the extent of decline in the capital-product ratio reflect variations in the *motivations* involved in the respective industries.[7] The more important the role played by capital in the productive process, the

[7] Cf. William Fellner, "Long-Term Tendencies in Private Capital Formation: The Rate of Growth and Capital Coefficients," in *Long-Range Economic Projection, Studies in Income and Wealth*, Vol. 16 (Princeton University Press for National Bureau of Economic Research, 1954), pp. 312–313.

TABLE 25

Relationship between Level and Magnitude of Decline in Capital-Product Ratios, Selected Industries

Industry	CAPITAL-PRODUCT RATIOS[a] *Peak Value*	*1950*[b]	*Percentage Decline*[c]
Electric light and power	18.4	1.3	93
Steam railroads	15.9	2.7	84
All other regulated industries	12.6	0.9	92
Street and electric railways	6.9	2.3	67
Petroleum and natural gas	5.9	1.8	70
Telephones	5.2	1.9	65
Metal mining	2.7	1.0	63
Producers' supplies manufacture	1.7	0.9	48
Construction materials manufacture	1.4	0.8	43
Bituminous coal	1.3	0.9	31
"Other" mining	1.3	0.6	54
Capital equipment manufacture	1.3	0.7	46
Consumption goods manufacture	0.9	0.6	33
Anthracite	0.5	0.4	19

[a] All are based on values in 1929 dollars. However, the numerators in the ratios for regulated industries include fixed capital only. For other groups they include fixed, plus working capital.

[b] For groups other than regulated industries, 1948.

[c] Computed from unrounded data.

Source: Data for manufacturing industries, from Daniel Creamer, *Capital and Output Trends in Manufacturing Industries, 1880–1948* (National Bureau of Economic Research, Occasional Paper 41, 1954), Table 10, p. 58; data for mining industries, from Israel Borenstein, *Capital and Output Trends in Mining Industries, 1870–1948* (National Bureau, Occasional Paper 45, 1954), Table 13, p. 54.

greater the motivation for economizing its use. Plausible as it appears, this view is relieved of much of its force by the factors discussed below:

1. The innovations adopted by an industry are at times developed in its own laboratories. In such cases, research may be directed in one channel or another at the industry's will. But in many cases relevant research is conducted by supplying industries, or in laboratories with no initial industrial connection at all. The introduction of steel, the steam engine, and electricity, to cite perhaps the most important examples of the nineteenth and early twentieth centuries, were innovations whose effects extended into virtually every segment of the economy. Nor was the timing or the nature of their impact upon any given industry subject to its control. Electricity was fortuitously available from the industry's point of view; its use promised to increase profits. Whether it proved to be capital-saving or capital-using was incidental.

Thus, the steam engine was swiftly embraced by streetcar companies, generating a substantial flow of investment. The resulting smoke, smell, and soot, especially embarrassing in urban transportation, soon brought back the horsecar. Some decades later electric power was successfully introduced. But for the streetcar transportation industry, the timing and nature of these innovations were entirely adventitious. The relevant conclusion for our own problem should be obvious. Even supposing that high capital-product ratio industries have greater motivation for selecting capital-saving innovations, their ability to manifest this predilection in practice would be very narrowly limited.

2. Differences in the capital-product ratios often prove to be widely deceptive guides in judging differences in the relative importance of capital in operating costs. For variations in the former may reflect mainly discrepancies in the durability of the capital used. Thus two firms may each expend five thousand dollars per year for depreciation charges, five thousand for materials, and five thousand for labor costs. Assume that these are the total expenses and that profits are zero. Now in one firm the capital used may on the average last five years and in the other twenty years. Then in the first industry the ratio of fixed capital to product would be 1.7 and in the second 6.7. Yet the direct relative contribution of capital to the productive process—and its relative importance in operating costs—would be the same in each case. Data were presented earlier suggesting the wide variation in the average durability of capital in the several branches of the American economy.[8] There are also substantial differences in this regard among the regulated industries.[9] This does not deny, of course, that firms with high capital-product ratios will ordinarily have relatively high fixed charges for the use of money capital. Unless this were so, there would be no point to the motivation hypothesis at all.

It is even more relevant to point out, however, that differences in capital-product ratios offer virtually no guide to differences in the relative importance of labor costs among industries. Illustratively, we present the data of Table 26. This shows the relative importance of labor costs in selected periods for two segments of industry, one characterized by a very high capital-product ratio, the other by a relatively low capital-product ratio. For manufacturing, the proportion of labor is measured in relation to the value of net output—i.e. value added by manufacturing. For railroads, the importance of

[8] See pages 71–72.

[9] See tables relating to the derivation of capital consumption in Appendixes C through H.

TABLE 26

Capital-Product Ratios and Relative Importance of Labor Costs in Steam Railroads and Manufacturing, 1899, 1919, and 1939

Year	CAPITAL-PRODUCT RATIO[a]		RATIO OF SALARIES AND WAGES TO VALUE OF OUTPUT[b]	
	Railroads	*Manufacturing*	*Railroads*	*Manufacturing*
1899	6.94	0.80[c]	0.40	0.49
1919	3.52	1.02	0.55	0.52
1939	4.59	0.74[d]	0.47	0.47

[a] Ratio of values in 1929 dollars.

[b] Ratio of values in current dollars. For railroads, gross value of output; for manufacturing, value added.

[c] For 1900.

[d] For 1937.

Source: Capital-product ratios for manufacturing, from Daniel Creamer, *Capital and Output Trends in Manufacturing Industries, 1880–1948* (National Bureau of Economic Research, Occasional Paper 41, 1954), Table 8, p. 43; ratio of salaries and wages to value of output, from *Historical Statistics of the United States, 1789–1945* (Bureau of the Census, 1949), pp. 174 and 205–206.

labor costs is somewhat understated, since it is expressed in relation to the total (gross) value of output. Judged by the capital-product ratios, it might be supposed that the relative importance of labor in the railroads would be very much smaller. Yet, for the purposes at hand, the differences between the two industrial divisions in this regard are negligible. Surely, if labor-saving devices were welcomed in one, they would be welcomed with equal warmth in the other. It may also be noted that the proportion of labor costs to the value of output varied only moderately over time in the railroads, despite the sharp decline in the capital-product ratio for this segment during the same period. We must conclude that the motivation for reducing labor costs is likely to be as great in a high, as in a low capital-product ratio industry. If the reduction of labor costs could be accomplished *only* by adopting capital-using innovations, we may assume that they would both do so, with approximately equal vigor.

3. Industry is of course primarily concerned with the reduction of *total* costs. Whether the saving is made in the operating costs of labor or in the total cost of capital, provided they are of equal magnitude, the accounting conclusion in a statement of profit and loss will be much the same. It is a mistake, in any event, to assume that the gains accruing from capital-saving innovations are exclusively—or even primarily—in the capital account. This is demonstrated in Table 27.

In Table 27 we present data on labor productivity trends in two of the components—railroads and electric light and power—for

TABLE 27

Nine-Year Averages of Indexes of Capital-Product Ratios, Output per Man-Hour, and Capital-Labor Ratios for Steam Railroads and Electric Light and Power

(*1939 = 100*)

Central Year of Nine-Year Average	STEAM RAILROADS			ELECTRIC LIGHT AND POWER		
	Capital-Product Ratio	*Output per Man-Hour*	*Capital-Labor Ratio*	*Capital-Product Ratio*	*Output per Man-Hour*	*Capital-Labor Ratio*
1896	187.1	32.4	60.6	...	...	...
1900	145.2	35.2	51.1	...	...	...
1906	103.1	39.5	40.7	...	...	...
1910	96.1	43.2	41.5	...	...	...
1916	82.5	52.2	43.1	273.0[a]	43.1[a]	117.7[a]
1920	77.3	57.6	44.5	172.8[b]	46.0[b]	79.5[b]
1926	78.6	69.1	54.3	141.6	52.1	73.8
1930	97.1	75.9	73.7	149.5	57.9	86.6
1936	112.7	94.6	106.6	122.6	84.8	104.0
1940	67.7	115.8	78.4	84.4	124.5	105.1
1946	49.0	136.1	66.7	56.7	174.6	99.0

[a] For 1917 only.

[b] For 1922 only.

Source: Output per man-hour for 1916–50, from *Historical Statistics of the United States, 1789–1945* (Bureau of the Census, 1949), and Bureau of Labor Statistics; for years prior to 1916 for railroads, obtained by adjusting railroad employment data (from *Historical Statistics*) for changes in standard workweek, coupling with our own series on railroad output, and linking to index for later years.

Indexes of the capital-labor ratio are products of those for the capital-product ratio and output per man-hour.

which such figures were available. It will be noted that in both cases the indexes of output per man-hour rose sharply over the entire period of record. The declines in the capital-product ratios in these components during the same periods—reflecting in considerable measure capital-saving innovations—were steeper than in any other major divisions of the American economy.

The capital-labor ratios in Table 27 indicate that in railroads, taking the period as a whole, the gains in the productivity of labor were even greater than in that of capital. For the capital-labor ratio rose. In electric light and power there was a moderate decrease in this ratio, indicating a slightly greater relative advance in output per unit of capital (the reciprocal of the capital-product ratio) than in output per man-hour. It will be recalled that in both mining and manufacturing after World War I, capital-product ratios also declined under the impact of capital-saving innovations. In both of these divisions, in this period, the capital-labor ratio rose.[10]

[10] See Table 28.

From the above considerations, we may conclude that the simple tie between cause and effect supposed by the motivation hypothesis is much more tenuous than would at first appear. Its essence of truth lies in the fact that an industry characterized by high, fixed charges may be credited with a particularly intense desire to reduce them. But judged by their results, capital-saving as well as capital-using innovations have profoundly reduced the cost of labor—investing them both with a universal appeal for virtually all of industry, which was only enhanced by the advance in wages in progress over the entire period under review. Moreover, we have noted that the choice between one type of innovation and another is narrowly limited in an environment in which the fortuitous plays so significant a role.

Nevertheless, the observed correlation between the height of a capital-product ratio and the extent of its fall is an undeniable fact, which requires explanation. If the motivation hypothesis contributes but little to our understanding of this phenomenon, we must conclude that some other forces bear the principal responsibility. This role, we suggest, may be fulfilled by the three factors discussed below.

First, those components in which particularly high capital-product ratios were achieved are the very ones in which capital is characterized by a high degree of indivisibility. In such industries, as we have seen in the previous section, the way is smoothly paved for a subsequent and particularly sharp reduction in capital-product ratios as output expands in later years. This factor alone may account for a substantial portion of the observed correlation.

Second, the more diverse the physical stock of capital of an industry, the greater the chance that scientific advances will result in improving its efficiency. Large and expensive capital installations are likely to be characterized by a wider degree of variety in component units, materials, processes, and so forth, than smaller ones. Besides, complex facilities of this kind are probably more frequent in capital-extensive industries than in those in which man-power plays a relatively greater role. Hence it is in the former that there will be greater opportunity for improvements in capital efficiency. It should be emphasized that it is not a matter of motivation that is referred to here, but one of technological opportunity. We may reiterate that industry in general is interested in reducing *total* costs.

Third, there is no upper limit to the capital-product ratio, though there is a lower limit at least at zero, and as a practical matter somewhat above zero. Accordingly, at their peak, capital-product

ratios may be very widely scattered. But as they decline they must converge toward, at least roughly, the same general minimum. There is thus some arithmetical compulsion in the finding that at the peak the variation among capital-product ratios is much greater than at the trough. And this finding is simply another way of stating that the highest capital-product ratios tend to fall by the largest relative amounts.

The Role of Wages and Interest

It follows from the conclusions of the previous sections that no simple or straightforward relationship may be expected between the secular trend of the capital-product ratio and the behavior of interest and wages. For we have seen that this ratio is affected by a variety of other factors. But even if we were to hold other factors constant—such as the stage of an industry's technological development, the degree of indivisibility of its capital units, and its rate of growth—the resulting picture would not be clear. The difficulty lies in the fact that capital-saving and capital-demanding innovations are not clear-cut alternatives. This is true in the sense that the availability of one or another type of innovation may be largely fortuitous from the industry's point of view, as described above. It is also true in terms of the *effects* of such innovations on the proportions in which the factors of production are combined and upon the pattern of operating costs.

Since the trend of the capital-product ratio was generally monotonically downward in the regulated industries, after an initial rise, we must turn to the other segments of the economy for examples of movements in both directions. In Table 28 we have assembled data bearing on this problem drawn from the studies, cited earlier in this chapter, of Creamer and Borenstein on manufacturing and mining, respectively. In both segments the period from 1880 to 1919 was characterized by a substantial rise in the capital-product ratio reflecting the many capital-using innovations introduced in this period. The result was, of course, a substantial economy in the use of labor, reflected both in the advancing output per man-hour and the rise in the capital-labor ratios shown here. A trend of this kind would, of course, have been encouraged by a rising level of wages relative to interest rates—a development which was in fact characteristic of the period. The establishment and expansion in these years of some of the regulated industries—such as electric light and power, telephones, and electric railways—were probably likewise facilitated by this trend, for these were all high capital-product ratio areas in relation to the rest of the economy.

TABLE 28

Capital-Product Ratio, Labor Productivity, and Capital-Labor Ratio in Manufacturing and Mining; Wages in Manufacturing; and Interest Rates, 1880–1948

(*all values in ratios in 1929 dollars*)

	MANUFACTURING INDEXES, 1929 = 100			MINING INDEXES, 1929 = 100				
Year	*Capital-Product Ratio*	*Output per Man-Hour*	*Ratio of Capital to Man-Hours*	*Capital-Product Ratio*	*Output per Worker*	*Ratio of Capital to Workers*	*Hourly Earnings in Manufacturing*	*Long-Term Interest Rates*
1880	0.55	...	...	1.16[a]	26[a]	15[a]	...	4.46
1890	0.73	...	...	1.36[b]	29[b]	22[b]	$0.199	3.75
1900	0.79	53	48	...	...	...	0.216	3.30
1909	0.97	58	64	1.80	...	45	0.252	3.78
1919	1.02	66	76	2.30	62	69	0.529	4.78
1929	0.89	100	100	2.14	100	100	0.566	4.42
1948	0.65	135	99	1.33	180	111	1.350	2.79

[a] For 1879 only.

[b] For 1889 only.

Source: Basic data for manufacturing, from Daniel Creamer, *Capital and Output Trends in Manufacturing Industries, 1880–1948* (Occasional Paper 41, National Bureau of Economic Research, 1954). Basic data for mining, from Israel Borenstein, *Capital and Output Trends in Mining Industries, 1870–1948* (Occasional Paper 45, National Bureau, 1954). Hourly earnings in manufacturing for 1890–1919, from *Historical Statistics of the United States, 1789–1945* (Bureau of the Census, 1949), Series D124; for 1929 and 1948, from Bureau of Labor Statistics. Interest rates for 1900–1948 are average yields of twenty-year and fifty-year bonds extrapolated to 1880 by use of average of highs and lows for railroad bond yields; basic data, from *Historical Statistics* and *Statistical Abstract of the United States*, 1951, Bureau of the Census.

But now we turn to the subsequent years. Capital-saving innovations came to the fore in mining and manufacturing, and capital-product ratios declined. Would a rise in the level of wage rates relative to interest have *discouraged* this development, as it had encouraged the "opposite" trend in earlier years? It should be noted from the last two columns of Table 28 that in this second period taken as a whole wages rose, interest rates dropped, and the growing disparity between the two was even greater than that prevailing in the first. Yet the remaining data of the table suggest why capital-saving, no less than capital-using, innovations represented a favorable adjustment to this environment. For when capital-product ratios declined, output per man-hour continued to rise. In mining the rate of advance was even higher in the second period than in the first; in manufacturing the later increase in labor's productivity was somewhat smaller. In both segments the capital-labor ratio also rose in the second period, though at a slower pace than in the first. In

short, capital-saving innovations resulted in even greater economies in the use of labor than in the use of capital.

In Table 29 we give some of the relevant data bearing upon the railroad segment—capital-product ratios, an index of wages, and long-term interest rates. If we consider the period from 1880 to 1910 we observe that the trend of interest was moderately downward and that of wages moderately upward, while the capital-product ratio dropped sharply. In the following forty years taken as a whole, the

TABLE 29

Capital-Product Ratios for Steam Railroads, Wages of Railroad Employees, and Interest Rates

Year	*Capital-Product Ratio*[a] (1)	*Index of Wages 1939 = 100*[b] (2)	*Long-Term Interest Rates*[c] (3)
1880	15.95	...	4.46
1890	9.84	29	3.75
1900	6.43	28	3.30
1910	4.35	35	3.84
1920	3.17	93	5.14
1930	4.23	89	4.40
1940	4.10	100	2.62
1950	2.66	132	2.71

[a] Ratio of values in 1929 dollars.
[b] Based on average hourly earnings in steam railroads, from Bureau of Labor Statistics.
[c] See note to Table 28.

prevailing trends in wages and interest were accelerated, while the decline in the capital-product ratio continued, though at a somewhat slower pace.

From these observations the following conclusions are suggested. Rising wage rates will of course encourage economies in the use of labor—but these may in fact accompany either a rising or a falling capital-product ratio. A progressive reduction in the cost of money capital would encourage investment in general, and would facilitate a rise in the capital-product ratio in particular, *if such an advance were generated by other forces*. But on the other hand a declining interest rate would not in any way inhibit a *reduction* in the capital-product ratio if it were induced by technological or other conditions. Both propositions are drawn directly from the experience of the 1880–1950 period. They suggest that the cost of money capital and of labor do not *determine* the capital-product ratio, nor in the period under review do they appear to have been the most important contributing

influences. The determinants are the variety of factors described in the previous sections, taken together.

Secular Trends in Investment: Some Concluding Observations

The long-run trends in investment may be viewed as the proximate results of the secular patterns assumed by the marginal capital-product ratios and by changes in output. The present and the preceding chapters were designed to probe the forces which determined the long-run movements of these strategic components—output and the capital-product ratio—in the regulated industries. By this indirect route, we hoped to illumine the trend of investment itself.

Perhaps the most striking result of this branch of our analysis is the power of the factors which have dampened the capital-product ratios over the long run. Had these ratios remained unchanged, the secular pattern of net capital formation would have duplicated that of changes in output, and the trend in the physical stock of capital would have traced a path exactly like that of output. Though there is some resemblance in the trends, they are distinguished by large, significant, and systematic differences. Thus it is seen that the vigor of the advance in the stock of capital of the regulated industries is very much less than that of the rise in output; in some cases a pronounced retardation—or even a decline—occurred in the former, while the latter continued upward at a progressively expanding rate over the period of review. The difference lies in the trend of the capital-product ratio, which was definitely downward for all regulated industries in the aggregate, and for every component except local bus lines. It was this which dampened the flow of investment significantly in the total and in each of the components with the exception noted. In railroads, for example, the decline of the capital-product ratio accounts for the contraction in the stock of capital in the two decades following 1930, in the company of a continued *rise* in the secular trend of output. And differences in the pace of the decline in this ratio explain why the flow of net investment has remained more vigorous in telephones than in electric light and power. Of course, such "explanations" would remain in the category of tautologies if severed from the context in which they are made. Trends in the capital-product ratio explain nothing, except in terms of the underlying forces which they in turn reflect, as described earlier in this chapter.

It is in this sense, then, because of the downward trend in capital-product ratios, that the growth of the nation over the latter part of the 1870–1950 span required a progressively smaller flow of capital into the regulated industries. This was true despite the fact that

output for all regulated industries in the aggregate, and for some of the components, had grown more rapidly *throughout* this period than did the national income or the population. The relevant data are shown in Table 30. Here, for each of the industrial divisions, the

TABLE 30

Value of Plant and Equipment of the Regulated Industries as Percentage of Net National Product, 1870–1950

(*based on values in 1929 dollars*)

Central Year of Nine-Year Average NNP	*All Regulated Industries*	*Steam Railroads*	*Electric Light and Power*	*Telephones*	*Street and Electric Railways*	*Local Bus Lines*	*All Other*
1870	122	105	...	...	1.60	...	16.3
1876	96	81	...	...	1.50	...	13.2
1880	80	79	...	0.12	1.64	...	11.0
1886	77	65	0.07	0.34	1.64	...	9.9
1890	77	64	0.57	0.39	2.65	...	9.6
1896	75	59	1.16	0.68	4.67	...	9.3
1900	66	60	1.99	1.42	6.85	...	8.4
1906	59	39	3.06	2.07	7.72	...	7.5
1910	67	42	5.06	2.37	8.35	[a]	8.9
1916	65	40	5.98	2.07	7.27	0.001	9.8
1920	58	35	5.52	1.76	5.96	0.004	9.6
1926	51	30	6.92	1.92	3.98	0.077	8.8
1930	63	34	10.30	3.56	3.55	0.159	11.6
1936	57	31	9.48	3.14	2.67	0.219	10.8
1940	38	24	7.56	2.62	1.43	0.289	8.3
1946	35	19	5.94	2.27	0.86	0.261	6.6
1950[b]	35	16	6.78	3.67	0.55	0.256	7.5

The numerator of the ratios is the value of plant and equipment taken at the beginning of the year (Appendix Tables B–1, C–1, D–1, E–1, F–1, G–1, and H–1); the denominator is the annual average of the net national product for the nine years centered in the year.

Source: Net national product in 1929 dollars, from revised annual estimates of Simon Kuznets, National Bureau of Economic Research (Variant I).

[a] Less than 0.001 per cent.

[b] For 1950 only.

value of plant and equipment at the beginning of a given year is expressed as a percentage of the nine-year annual average of the net national product centered in that year, with all values in 1929 dollars.

For all regulated industries in the aggregate, as the table shows, the stock of capital in the 1870 period was 122 per cent of the net national product. From this lofty level it declined almost without interruption to reach about 35 per cent in the post-World War II

period. The drop means, of course, that *increases* in the net national product required progressively smaller additions to the physical capital stock of the regulated industries—i.e. smaller amounts of net capital formation. The same percentage also declined steadily for the railroads. For the other components, the trends were more complex. If the figures for 1930 and 1936 are ignored because of the sharp contraction in business activity, it will be observed that the value of plant and equipment as a percentage of the net national product was downward in the all other group after 1916, in local bus lines after 1940, and, of course, in street railways after 1910. In electric power, the ratio was steady between 1926 and 1950. Only in telephones did an increase persist throughout the period; in this component, it will be recalled, the decline in the capital-product ratio was relatively modest and had virtually ceased between the 1920's and 1950.

The same general picture develops when we compare investment directly, as in Table 31. Here, gross capital formation in the

TABLE 31

Gross Capital Formation of the Regulated Industries as Percentage of National Gross Capital Formation, 1876–1950

(*based on nine-year averages; values in 1929 dollars*)

Central Year of Nine-Year Average	*All Regulated Industries*	*Steam Railroads*	*Electric Light and Power*	*Telephones*	*Street and Electric Railways*	*Local Bus Lines*	*All Other*
1876	15.4	12.4	...	...	0.70	...	2.15
1880	16.3	13.5	...	...	0.60	...	1.88
1886	14.2	11.2	0.32	0.259	1.04	...	1.46
1890	15.9	11.2	0.62	0.31	1.93	...	1.84
1896	13.5	6.4	1.16	0.92	3.28	...	1.75
1900	12.6	4.3	1.79	1.36	3.46	...	1.62
1906	18.2	8.3	2.86	1.59	2.88	...	2.51
1910	19.9	9.8	3.36	1.46	2.01	...	3.31
1916	11.4	4.8	1.98	1.08	0.95	0.003	2.58
1920	11.3	4.1	2.50	1.28	0.77	0.040	2.53
1926	15.4	4.9	4.15	2.14	0.65	0.112	3.51
1930	15.8	4.5	4.10	2.54	0.63	0.166	3.92
1936	11.2	2.9	2.56	1.80	0.55	0.376	3.08
1940	7.1	2.1	1.51	1.16	0.21	0.226	1.92
1946	8.2	1.9	1.86	1.64	0.06	0.168	2.64
1950[a]	10.3	1.9	1.69	1.67	0.01	0.073	3.94

[a] For 1950 only.

Source: Gross capital formation for the United States from revised annual estimates of Simon Kuznets, National Bureau of Economic Research.

regulated industries is given as a percentage of gross capital formation in the nation as a whole. Here, too, the general trend in the last several decades was downward, reflecting primarily the sharper decline in the capital-product ratio in the regulated industries. In the aggregate the proportion dropped from a high of almost 20 per cent in the pre-World War I period to about half that in 1950. The trend was also materially downward, at least in the later years, in all of the components except those of the all other group.

The impact of the declining capital-product ratio is perhaps most distinctly revealed when it is recalled that aggregate output in the regulated industries rose more rapidly through most of the period of record than swiftly rising urban income, and even in later years moved forward at an approximately equal rate. In contrast, net capital formation barely kept abreast of the much slower advance of the total population. As Table 32 shows, the per-capita value of plant and equipment of the regulated industries reached a high of 368 dollars in 1930, and then drifted downward. To be sure, the

TABLE 32

Per-Capita Value of Plant and Equipment,
Regulated Industries and Components, 1929 Dollars, 1870–1950

(based on nine-year averages)

Central Year of Nine-Year Average	*All Regulated Industries*	*Steam Railroads*	*Electric Light and Power*	*Telephones*	*Street and Electric Railways*	*Local Bus Lines*	*All Other*
1870	221	189	...	...	2.80	...	29.50
1876	239	202	...	...	3.80	...	33.10
1880	242	239	...	0.36	4.96	...	33.25
1886	254	214	0.22	1.12	5.41	...	32.80
1890	267	221	1.96	1.34	9.16	...	33.10
1896	281	221	4.38	2.57	17.60	...	35.20
1900	281	253	8.40	6.02	28.90	...	35.60
1906	286	187	14.85	10.03	37.50	...	36.20
1910	332	209	25.20	11.75	41.50	0.01	44.20
1916	340	209	31.20	10.80	37.90	0.06	51.20
1920	332	201	31.60	10.07	34.20	0.24	55.30
1926	333	192	44.60	12.40	25.70	0.33	57.10
1930	368	197	60.50	21.00	20.85	0.94	68.40
1936	329	178	54.80	18.15	15.40	1.25	62.40
1940	316	170	54.40	18.85	10.30	2.08	59.70
1946	294	158	50.30	19.18	7.27	2.21	56.25
1950[a]	321	150	62.00	33.50	4.97	2.33	68.40

[a] For 1950 only.

Source: Total continental population, from the Bureau of the Census.

per-capita value of plant and equipment rose throughout the period in electric light and power, telephones, local bus lines, and the all other group; but the increases in later years were modest. They were more than balanced in the total by the sharp reductions which set in for the railroads after 1900 and for street railways after 1910.

In closing this section, some remarks may be in order concerning the influence of the social environment in which the regulated industries operate. What effect did this have on the trends in output and investment? Obviously, a full-dress approach to this question —involving the changing scope, forms, and standards of public regulation—would carry us far beyond the purview of this study. Some broad observations may nonetheless be ventured.

The intervention of the public in those segments of the economy which have achieved utility or near-utility status appear to have had two general consequences of relevance to the present study: (1) the granting and protection of complete or limited monopoly positions, and (2) the maintenance of rates lower than those which would otherwise have prevailed. Both have probably had the effect of expanding output and capital formation. For the limits placed upon competition have greatly reduced the risk involved in investment in the regulated industries; and the risk element in some cases, in the absence of such protection, may have been prohibitive. The prospect of several telephone companies, for example, several electric light and power companies, or several local bus lines operating without limitation in the same areas, would seem likely to have retarded the establishment and growth of these industries. At the same time, the regulation of rates have seldom been permitted to depress profits below the levels required for the attraction of capital on a competitive basis with other industries.[11] There is some evidence, on the other hand, that if they had been permitted to go higher (toward the monopolistic levels they otherwise might in some cases have attained), the growth of consumption would have been significantly retarded.[12]

[11] Eli Winston Clemens, *Economics and Public Utilities* (1950), pp. 234–239, and G. Lloyd Wilson, *Transportation and Communications* (1954), pp. 140–144. Both, Appleton-Century-Crofts.

[12] Clemens, *op. cit.*, pp. 357–360. See also Wilson, *op. cit.*, pp. 25–27.