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CAPITAL-OUTPUT RATIOS AND DEVELOPMENT PLANNING

by

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I. INTRODUCTION

NPA's Center for Development Planning is undertaking a series of studies for projecting total output and associated quantities such as aggregate investment, consumption, savings, exports, imports, population, and labor force. The focus of these studies is on the role of aggregate projection techniques in development planning in the less developed countries. The studies are part of a project dealing with development planning techniques which the Center has undertaken for the Agency for International Development.

The present paper focuses on the use of capital-output ratios for projecting aggregate investment requirements. This, of course, is the role typically played by capital-output ratios in development planning. There is a voluminous literature, both theoretical and empirical, dealing with various aspects of this role of capital-output ratios.[1/] Yet no single study looks at this role from the standpoint of the development planner, evaluating whether or not capital-output ratios yield investment projections of sufficient reliability to justify their use in the formulation of development policy. The present study seeks to do this.

The paper is in three parts. The first deals with the problem of deciding which among the many possible forms of the capital-output ratio is most appropriate for projecting investment requirements. There are several alternative measures of the numerator of the ratio: gross or net capital stock, including or excluding land, inventories, and net foreign assets, or gross or net investment, also including or excluding these several components.

1/ A selected bibliography of this literature is given in Appendix B of this paper.

The denominator, output, also may be measured in a variety of ways; for example, gross or net national product, gross or net domestic product, or national income. In the face of this diversity a certain flexibility of attitude toward the choice of a proper ratio is justified. Nonetheless, we believe it can be shown that there are clearly definable grounds for choosing among the various alternative forms of the ratio.

The second part of the paper is an analysis of the observed behavior of the aggregate ratios for many different countries. The general objective of the analysis is to determine whether there are regularities in the behavior of the ratios which would provide guidance to projections. More specifically, the analysis is addressed to three questions: (1) Are there significant time trends in the ratios for given countries? (2) Are there significant differences between the ratios for different countries, grouped in various ways? (3) How stable are the ratios? Stability is used here in two senses. One refers to the amount of variation around the ratio's time trend, if any, for given countries. The other refers to the amount of variation around the average ratios for groups of countries when the group averages have been found to differ significantly. The three questions are related, but the third is the key to assessing the usefulness of capital-output ratios for projecting investment requirements.

The analysis in the second part is concerned only with economy-wide ratios. However, a substantial amount of data on sectoral ratios has been compiled and will be analyzed subsequently. Visual inspection of these sectoral ratios strongly indicates that the principal conclusions of this study will not be substantially altered by the analysis of the sectoral ratios.

The third part of the study summarizes the principal findings of the first two parts and draws the implications for the role of capital-output ratios in making investment projections for use in the formulation of development policy.

II. CHOOSING AMONG ALTERNATIVE FORMS OF THE RATIO

It is useful to distinguish two issues which must be confronted in choosing the proper form of the capital-output ratio. One has to do with the definitions of capital, or investment, and of output. The other concerns the valuation of these components of the ratio; i.e., whether values should be expressed in fixed or current prices.

A. The Problem of Definitions

There is a problem of defining the capital-output ratio because there are numerous alternative forms of the ratio, depending on what measure of capital is included in the numerator and what measure of output in the denominator. This problem can be resolved most readily, we believe, by asking the two-part question: What does the planner need to know about investment and which form of the capital-output ratio is most likely to give him the information he needs?

Typically, the planner confronts the problem of determining the volume of resources which must be mobilized for gross investment in order to achieve a target growth rate.[1/] This investment requirement may be

1/ Alternatively, the planners' assignment may be to project the maximum achievable growth rate given the volume of resources which can be reasonably mobilized for investment. Whether investment or output is the variable to be projected has no bearing on the problem of defining the capital-output ratio.

projected as an absolute amount over a specified period of time or, perhaps more commonly, as a proportion of the target levels of aggregate output. In either case, the key to the investment projection is the presumed relationship between investment and output.

This presumed relationship - expressed as the capital-output ratio - accounts for the widespread use of Harrod-Domar type projection models in development planning. There are two characteristics of the capital-output ratio as it typically appears in Harrod-Domar models which are relevant to the present discussion: (1) It is a ratio between two flows per unit of time, investment in the numerator, and the change in output resulting from that investment in the denominator. This is the incremental capital-output ratio, or ICOR for short. (2) The ratio presumes the existence of a stable causal relation between investment and capacity expansion.

1. ICOR or Average Ratio

If the ICOR is the proper form of the capital-output ratio in Harrod-Domar models, then the ratio of capital stock to output - the average capital-output ratio - in principle has no role to play in these models. This principle is clear enough. It follows from the structure of Harrod-Domar models and is virtually self-evident. Nonetheless, a substantial effort has gone into the measurement of capital stock for many countries, and these stock estimates almost invariably are used in the computation of average

capital-output ratios.[1/] While these average ratios are clearly inappropriate in principle for use in Harrod-Domar models, they may be satisfactory in practice if the ICOR has been constant over a substantial period of time. In this case, of course, the average ratio will equal the ICOR.

In this context, therefore, the long-run behavior of the average capital-output ratio becomes of critical importance. It frequently is asserted that aside from periods when capital is under- or over-utilized, the average ratio is a constant, or very near to it.[2/] Others, observing the

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1/ The National Bureau of Economic Research's program of Studies in Capital Formation and Financing has produced estimates of capital stock for the United States as a whole and also for various producing sectors. In each case, the capital stock estimates have been used to compute average capital-output ratios. The National Bureau studies, all published by the Princeton University Press, are as follows: Leo Grebler, David Blank and Louis Winnick, Capital Formation in Residential Real Estate: Trends and Prospects, 1956; Alvin S. Tostlebe, Capital in Agriculture: Its Formation and Financing Since 1870, 1957; Melville J. Ulmer, Capital in Transportation, Communications and Public Utilities: Its Formation and Financing, 1960; Daniel Creamer, Sergei P. Dobrovolsky and Israel Borenstein, Capital in Manufacturing and Mining: Its Formation and Financing, 1960; Simon Kuznets, Capital in the American Economy: Its Formation and Financing, 1961.

John W. Kendricks' Productivity Trends in the United States, National Bureau of Economic Research, Princeton University Press, 1961, also contains estimates of aggregate and sectoral capital stock and corresponding indexes of average capital-output ratios for the U. S. Kendrick draws heavily on the National Bureau studies listed above and also, for his capital-stock estimates, on Raymond W. Goldsmith, A Study of Savings in the United States, Princeton University Press, Vols. I and II, 1955, and Vol. III, 1956.

Estimates of capital stock and average capital-output ratios for Belgium, West Germany, Norway, Australia, South Africa, Canada, India, Argentina, Brazil, Chile, Colombia, Mexico, and all of Latin America have been published in R. Goldsmith and C. Saunders (eds.), The Measurement of National Wealth, Income and Wealth Series VIII, Bowes and Bowes, London, 1959.

More detailed estimates for Canada are in W. C. Hood and Anthony Scott, Output, Labour, and Capital in the Canadian Economy, Royal Commission on Canada's Economic Prospects, February, 1957. Estimates for Israel are in A. L. Gaathon, Capital Stock Output and Employment in Israel, Bank of Israel, Jerusalem, 1961.

average ratio is a constant, or very near to it.[1/] Others, observing the identical historical experience, deny this assertion.[2/] Clearly the resolution of this difference requires prior agreement on some standard by which to evaluate long-term movements in the average ratio.[3/] For present purposes the criterion should be the differences between the ICOR and the average ratio which are implied by movements in the average ratio, because the ICOR, not the average ratio, is the relevant variable for investment projections.

The following charts present average ratios and ICORs covering long periods of time for the United States, South Africa, Norway, and all of Latin America. The ICORs are derived from annual changes in the capital stock and output data which make up the average ratios. To reduce the variation in the ICORs, they have been calculated as ratios of three-year moving sums of capital stock changes to three-year moving sums of output changes.

There are, of course, many questions that might be asked about the behavior of these ratios, but the central issue here is the behavior of the ICORs relative to the behavior of the corresponding average ratios. It is quite evident that despite the use of three-year moving sums, and aside from

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1/ For example, Paul Streeten, "A Critique of the Capital-Output Ratio and of Its Application to Development Planning," mimeo, no date, p. 5; Nicholas Kaldor, "Capital Accumulation and Economic Growth in F. A. Lutz and D. C. Hague (eds.), The Theory of Capital, Macmillan, London, 1961, p. 178; Walther G. Hoffman, "Long-Term Growth and Capital Formation in Germany," Ibid., p. 127.

2/ For example, comments by F. A. Lutz and R. W. Goldsmith in Ibid., pp. 343 and 346, respectively.

3/ This was recognized by the participants in the discussions of the various papers published in Ibid.

periods of obvious cyclical instability in output, the ICORs are far more unstable than the corresponding average ratios. Moreover, and perhaps more pertinent in the present context, barely discernible time trends in average ratios can imply substantial and systematic differences between ICORs and corresponding average ratios. For example, in the United States the average ratio edged gently but steadily downward between 1900 and 1931. This, of course, implies that the ICOR was less than the average ratio through most of this period, and the chart bears this out. In only three of the years in this period was the ICOR greater than the average ratio.[1/]

Moreover, the mean ICOR in this period was 3.21, while the mean average ratio was 3.82. For the use of investment projections in development planning, this is a substantial difference. Suppose a country with a GDP of $10 billion sets a five year GDP growth target of 5 per cent per annum and uses an average ratio of 3.82 to project its net investment requirements, believing that the average ratio is an adequate substitute for the ICOR. The "required" proportion of net investment to GDP over the plan period in this case is .191. If in fact the ICOR is only 3.21, the "required" proportion is only .161. Suppose now that the country expects net savings to equal 15 per cent of GDP over the plan period. In this case the actual requirement for foreign assistance over the plan period will be $600 million compared with a projected foreign assistance requirement of $2.4 billion. If the country behaves

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1/ This comparison is affected by the fact that the ICORs are three-year moving averages while the average ratios are ratios for single years. The point of the comparison - the systematic difference between the average ratios and the ICORs - is not affected, however.

rationally in shaping its development policies, the erroneous investment projection will lead it to attach an excessively heavy weight to foreign exchange, thus distorting resource allocation throughout the economy.

The preceding discussion can be summarized as follows:

(1) Very substantial variations in ICORs are consistent with seemingly small variations in average capital-output ratios.

(2) Barely discernible time trends in average coefficients can imply systematic differences between average coefficients and ICORs which, for purposes of development planning, are substantial.

For these two reasons we conclude that substitution of average coefficients for ICORs in making investment projections in Harrod-Domar models not only is wrong in principle but usually will be wrong in practice also.[1/]

2. The Investment-Capacity Change Relation

The key idea underlying the ICOR is that there is a stable relationship between investment and the expansion of output. In fact, the ICOR can be viewed as a one factor production function linking increments in capital stock to increments in capacity output. The assumptions about the relation of increments of non-capital inputs to increments of capacity usually are not

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1/ Of course, Harrod-Domar models are not the sole vehicles for investment projections. If one has a sound basis for projecting the average capital-output ratio - such as a well established stable time trend - this can be used for investment projections without recourse to Harrod-Domar models. The product of the average ratio and expected output in the target year provides a projection of the capital stock in the target year. The difference between this stock figure and the stock in the most recent year is the amount of net investment required to support the amount of output produced between the most recent year and the target year. This use of average capital-output ratios is not available to most underdeveloped countries, however, since few of them have capital stock estimates from which reliable time series for the average ratio could be derived.

made explicit in discussions of the ICOR. The presumption that the ICOR is stable over time, however, necessarily implies that the relation of increments of non-capital inputs to capacity increments also is stable over time. This implication follows because capacity increments in fact are functions not only of changes in the capital stock but also of changes in the supply of non-capital inputs.

The presumed relationship between investment and capacity change provides a guide to choosing among alternative measures of investment and output in calculating the ICOR. The four measures of aggregate output typically considered in computing aggregate capital-output ratios are Gross and Net Domestic Product and Gross and Net National Product.[1/] However, it seems clear that domestic product, in principle, is a better output measure for this purpose than national product. National product will move with changes in the proportion of domestic capital which is owned by foreigners, even though the total amount of domestic capital is unchanged. Since the capital-output ratio is a measure of the investment required per unit change in capacity output, national product conceptually is a less appropriate measure of output than domestic output. As a practical matter, the distinction usually will not be critical since the percentage difference between national product and domestic product in most countries is both quite small and quite stable (aside from cyclical distrubances). However, since most

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1/ For example, these are the four aggregate output measures used by Kuznets in calculating capital-output ratios for a large number of countries. Simon Kuznets, "Quantitative Aspects of the Economic Growth of Nations V. Capital Formation Proportions: International Comparisons for Recent Years," Economic Development and Cultural Change, Vol. 8, Number 4, Part 2, July, 1960.

countries produce estimates of domestic product as well as of national product, the conceptually more appropriate measure ordinarily can be used.

In our view gross domestic product is a better measure of output than net domestic product for two reasons. In the first place, planners in most countries set their output targets in terms of gross product rather than net product, and for good reason. While movements in net product may provide a better index of welfare than gross product, any economy must make provision in its annual output for replacement of part of its capital stock. From the planner's standpoint, therefore, it is important to deal with a measure of output which includes this charge against current output.

In the second place, in all countries, including the U. S., which probably has the best data, estimates of capital consumption are based on almost wholly arbitrary assumptions about average asset lifetimes and the patterns of decline in asset values over time.[1/] Consequently, it is doubtful that available estimates of capital consumption in any country measure declines in asset values in any useful sense at all. Accordingly, differences between gross and net domestic product must be viewed with great skepticism, suggesting that gross domestic product is the more meaningful measure of output.

1/ This statement is developed at some length and supported below.

Measures of Investment

In principle all expenditures which contribute to an increase in the flow of measured output ought to be counted as part of investment. The usual candidates for inclusion as part of investment are fixed investment; i.e., publicly and privately owned plant and other structures, including housing and roads, producer and consumer durables; changes in inventories; and changes in net foreign assets. Less commonly, changes in the value of land, in the stock of monetary metals, and outlays for military assets are included as part of investment.

Among these various categories it seems clear that consumer durables, changes in the stock of monetary metals and in the value of land, and outlays for military assets ought to be excluded from investment since they contribute little if anything to capacity to produce measured output. By this criterion, publicly and privately owned plant and other structures and equipment should be included, as should housing. Inventory change perhaps is more doubtful. Yet there is no question that the carrying of some amount of inventories is vital to the maintenance of efficient production processes and that, other things remaining the same, increases in national capacity output ordinarily will require larger inventories.

Since changes in net foreign assets represent the difference between domestic investment and domestic saving, they clearly should not be counted as part of investment for purposes of measuring capital-output ratios. To do so converts a measure of domestic investment to a measure of domestic savings. For calculation of capital-output ratios, domestic investment, not savings, is

the relevant variable.[1/]

It frequently is argued that expenditures for health, education, research, and development ought to be counted as part of investment on the ground that they contribute importantly to future increases in productive capacity.[2/] This argument is sound in principle. Certainly secular declines in capital-output ratios, which now frequently are attributed to increases in the "productivity" of capital, would be reduced or perhaps eliminated if expenditures of this nature were counted as part of investment. To the present time, however, such expenditures have not been so treated in the national accounts of any country, making it impossible as a practical matter to do so in this study.

So far we have not raised the issue of whether the investment term in capital-output ratios should be measured on a gross or on a net basis. This issue now must be faced. The concept of the capital-output ratio as a measure of the investment required to generate a unit increase in capacity clearly suggests that in principle the investment term in the ratio ought to be on a net basis. That is, the ratio should include only that investment which expands capacity as distinct from investment required to replace

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1/ The United Nations' concept of capital formation also excludes net foreign investment: "Net changes in foreign investment are excluded since the concept of capital formation is designed to measure changes in the physical capacity of a country's economy." U.N., Concepts and Definitions of Capital Formation, Statistical Papers, Series F, No. 3, July, 1953, p. 8. We shall argue below, however, that capital formation measured in accordance with the UN concept does not in fact measure changes in capacity, despite the exclusion of net foreign investment.

2/ In recent years a considerable literature has been devoted to discussion of "investment in human beings," the label frequently given to expenditures on health and education. For a recent view of the status of this discussion see especially the October, 1962, Supplement to The Journal of Political Economy, Vol. No. 5, Part 2, titled "Investment in Human Beings," containing articles by T. W. Schultz, Gary S. Becker, George J. Stigler, and others.

capacity. There is a basic difficulty here, however: no country in the world estimates net and replacement investment in accordance with these concepts. Moreover, it is doubtful that the information necessary to do so is available for any country in the world. Consequently, there is no reason to believe that existing estimates of replacement and net investment even remotely approximate the measures needed for proper calculation of net capital-output ratios. This point obviously is of considerable significance for the proper definition and measurement of the capital-output ratio. It is, therefore, necessary to develop the point at some length.

Existing estimates of net and replacement investment

It is safe to say that all existing estimates of annual aggregate net investment in all countries, whether prepared by official or private bodies or individuals, are found by taking the difference between estimates of gross investment and estimates of replacement investment (defined either as capital consumption or as retirements).[1/] Net investment, in other words, is a residual. This would present no problems in the measurement of capital-output ratios, provided the estimates of replacement investment adequately measured the investment required to replace capacity. For in this case, net

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1/ This statement is true for all cases in which national accounts investment data are used. Some investigation of capital formation in particular sectors of the economy have used census type data (e.g., the study by Creamer and Bernstein of capital formation in American manufacturing referred to above), or, in at least one case, sample survey data, i.e., the work of Tibor Barna on manufacturing in the U.K., described by Barna in Chapter 5 of F. A. Lutz and D. C. Hague (eds.), The Theory of Capital, Macmillan, London, 1961. These studies, of course, attempt to measure the capital stock directly, not as the cumulated sum of net investment over a number of previous years.

investment necessarily would consist only of that investment required to expand capacity, and this is the measure of investment called for by the concept of the capital-output ratio.

In fact, no country in the world measures replacement as the investment required to replace capacity. According to the U. N., which apparently recommends that replacement investment should be measured in this fashion, enterprises generally provide for replacement by charging depreciation in accordance with "the concept of maintaining the money value of their capital intact by allocating the original cost of the asset over its expected lifetime."[1/]

The concepts of maintaining capital intact and maintaining capacity intact are quite different. The core of the difference is that the first concept requires that no account be taken of changes in the average productivity of investment in calculating replacement while the second concept insists that allowance be made for such changes. For example, the maintenance of capital intact implies that replacement of a $100 machine requires an outlay of $100 over the life of that machine, even if newer models of the machine are more productive than the original model. Capacity

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1/ United Nations, A System of National Accounts and Supporting Tables, Studies in Methods, Series F, No. 2, Rev. 2, N. Y., 1964, p. 32. The UN statements on the proper definition of replacement investment are not entirely clear. In Concepts and Definition of Capital Formation, cited earlier, the concept of "maintaining capital intact" is specifically endorsed, but as stated there it means something quite different from the concept by the same name just stated in the text.

On page 6 of A System of National Accounts and Supporting Tables, however, there is a discussion which suggests by implication that replacement ought to be defined as the maintenance of capacity, not capital. This implication emerges from the statement that in a dynamic economy in which the stock of capital is increasing and the quality of capital goods is improving, straightline depreciation of assets may not equal the investment required for replacement of assets.

maintenance requires an outlay less than $100 in this example, the amount of the reduction depending on the difference between the productivity of the old machine and the new one which replaces it.[1/]

There is a general presumption that because of technological change capital productivity rises over time. This implies that replacement investment calculated in accordance with the concept of maintaining capital intact systematically overstates replacement requirements and understates net investment by an exactly equal amount (since net investment is the residual difference between gross and replacement investment). Accordingly, existing estimates of the net capital-output ratio - defining the ratio as investment required per unit increase in capacity - would tend to understate the "true" ratio.

But the failure to allow for capital productivity change is not the only indictment that can be brought against existing estimates of replacement and net investment. Proper estimation of replacement investment requires detailed information on average lifetimes of different classes of assets and on the time patterns of decline in asset capacities. Both types of information

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1/ In a League of Nations report, Richard Stone clearly stated the crucial distinction between the two concepts of maintaining capacity intact and maintaining capital intact:

"The basis of valuation of these (depreciation) allowances depends on the meaning attached to maintaining capital intact. If one is concerned with money capital, it is sufficient to set aside each year sums which are expected to add up to the original value of the equipment by the time the equipment is worn out or obsolete, since in this way the enterprise is always able to repay its original debt. On the other hand, it is sometimes thought that the maintenance of so-called real capital is the more important concept. If this is so, the allowances must be calculated in such a way that they will provide a sum in due course which will reinstate a certain amount of capacity; i.e., will take account of changes in the price of equipment and also perhaps of changes in the design of equipment."

League of Nations Committee of Experts, Measurement of National Income and the Construction of Social Accounts, Studies and Reports on Statistical Methods, No. 7, Geneva, 1947, Appendix by Richard Stone, pp. 59-60.

are virtually non-existent for all countries. With respect to asset lifetimes, for example, the U. N. has stated that "a knowledge of the average economic life of different physical assets is generally lacking."[1/] Even in the United States, which generally is conceded to have the best investment data in the world, very little is known about asset lifetimes.[2/]

Even less is known about the time pattern of decline in asset capacities over their lifetimes. Since, for purposes of capital-output ratio measurement, replacement means replacement of capacity, the manner in which an asset's capacity declines over its lifetime will determine the pattern of replacement outlays on that asset over its lifetime. Typically replacement outlays are allocated on the basis of some alternative depreciation pattern - straightline, or declining balance for example - or on the "one hoss shay" assumption; namely, that assets retain their original capacity throughout their lifetime. We have been completely unsuccessful in turning up any solid information on actual patterns of decline in asset capacity, however.[3/]

We have indicated that existing estimates of replacement investment for all countries are highly questionable because they make no allowance for changes in the average productivity of investment and because of virtually complete ignorance on the vitally important matters of asset lifetimes and

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1/ Concepts and Definitions of Capital Formation, p. 17.

2/ George Jaszi, Robert C. Wasson and Lawrence Grose, "Expansion of Fixed Business Capital in the United States," Survey of Current Business, U. S. Department of Commerce, November, 1962, pp. 11-12.

3/ For a review of the current state of knowledge in this field so far as the U. S. is concerned, see the author's unpublished Ph.D. dissertation, Harrod-Domar Growth Models of the U. S. Economy: Concepts vs. Empirical Materials, Columbia University, 1964, pp. 96-101.

patterns of decline in asset capacity. The consequence is that existing estimates of replacement investment may differ widely from true replacement investment; i.e., replacement required to replace capacity.

This can be easily demonstrated. Replacement investment for any asset in any year t calculated on the basis of the "one hoss shay" replacement pattern, and ignoring changes in the productivity of assets of this type, is equal to gross investment in the asset in year t-m, where m is the life of the asset in years. That is

$$R_t = I'_{t-m} \tag{1}$$

where R_t = replacement investment in year t.

I'_{t-m} = gross investment in year t-m.

If gross investment in the asset has been increasing at a constant annual proportionate rate r, then (1) can be rewritten as:

$$R_t = \frac{I'_t}{(1 + r)^m} \tag{1.a}$$

If $I'_t = 100$, $r = .04$ and $m = 30$ years, then $R_t = 30.9$.

Now suppose, however, that in fact m = 20 years, not 30, and that the true pattern of decline in asset capacity is described by the straightline depreciation pattern rather than by the "one hoss shay" pattern. Moreover, suppose the average productivity of investment is increasing by 1 per cent per annum. What then is the value of "true" replacement investment?

To find the answer, another equation is needed, one which accommodates the effect of changing productivity on replacement investment and which is based on the straightline depreciation replacement pattern. The following

equation meets these requirements:

$$R_t = \left[\frac{I'_t}{m(1+r)^m\,(1+p)^m}\right]\left[\frac{(1+r)^m(1+p)^m - 1}{(1+r)\,(1+p) - 1}\right] \qquad (2)^{1/}$$

where p = the annual proportionate rate of change in the average productivity of investment, a constant, and all other terms are defined as before. Substituting r = .04, m = 20 years, p = .01, and I'_t = 100 in (2) gives R_t = 62.1. "True" replacement investment in this case is more than twice as much as "observed" replacement investment.

These illustrative cases demonstrate clearly that replacement investment is highly sensitive to the time pattern of decline in asset capacity, to the length of asset life, and to whether allowance is made for changes in the average productivity of investment.[2/] Given our virtually complete ignorance concerning patterns of decline in asset capacity and length of asset service lives, and since rising investment productivity may well be a pervasive phenomenon, there are strong grounds for questioning whether existing estimates of replacement investment for any country bear any meaningful relation to actual replacement requirements. It follows that existing estimates of net investment are equally suspect as measures of the investment required per unit increase in capacity.

1/ The derivation of this equation is given in Appendix A.

2/ R_t is inversely related to m and to p, and when r is positive, R_t with straightline depreciation will always be greater than R_t with the one-hoss shay pattern. In the present illustrations, equation (2) gives a higher value of R_t than equation (1.a) because the shift to the straight-line depreciation pattern and the lower value of m more than offset the tendency of a positive p to lower the value of R_t.

Since the net capital-output ratio for any country almost surely is spurious, use of this ratio ought to be avoided. This suggests that perhaps the ratio ought to be calculated with gross investment rather than net investment in the numerator. This alternative is immediately subject to the criticism that it defies the underlying logic of the capital-output ratio since replacement investment in principle bears neither a behavioral nor a technical relation to changes in capacity. Moreover, the proportion of replacement investment in total gross investment is certain to be substantial on any reasonable assumptions about the factors influencing replacement. For example, if "true" replacement follows the "one hoss shay" pattern, gross investment has been growing at 4 per cent per annum, the average productivity of investment has been increasing at 1 per cent per annum, and the life of capital assets is 20 years, then replacement investment will be .37 per cent of gross investment. If "true" replacement investment follows the straight-line depreciation pattern, and the other variables have the same values as above, then replacement investment will be fully 63 per cent of total gross investment.[1/]

Thus the use of gross investment in calculating the capital-output ratio not only defies the underlying logic of the ratio; in addition, the investment component not related to capacity change (replacement investment) may be very large relative to the investment component which is so related (net investment).

1/ The equations from which these numerical results have been derived, and some additional illustrative values of the ratio of replacement investment to gross investment are given in Appendix A.

Despite these serious objections against the use of gross investment in calculating the capital-output ratio, we believe that this is preferable to the use of net investment. The relation between existing measures of net investment and capacity change is spurious in part because some of what passes for replacement investment contributes to capacity expansion (because of technological improvements). On the other hand, some of measured net investment may in fact represent replacement if capacity generated by that investment results in reduced capacity elsewhere in the economy (because of reduced availability of resources elsewhere). Consequently, measured gross investment may in fact be more closely related to capacity change than measured net investment although the logic of the capital-output ratio indicates this should not be so.[1/]

This argument for using gross investment in calculating capital-output ratios is not strong. The best that can be said in its favor is that the case for using net investment is even weaker, given the impossibility of drawing a meaningful distinction between net and replacement investment. On these grounds we have elected to use the gross capital-output ratio in this study.

B. Current or Constant Prices

Accepted practice holds that capital-output ratios ought to be measured in constant prices, and there is sense in this. The concept of the capital-output ratio as a kind of one-factor production function implies a

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1/ V. V. Bhatt in "Aggregate Capital-Output Ratio: Some Conceptual Issues," Indian Economic Journal, April, 1963, has endorsed use of the gross rather than the net ratio for essentially the same reasons as those given here.

relation between physical quantities of capital and output, the measurement and analysis of which ought not to be influenced by price changes.

Nonetheless, at least for the purposes of this study, there are cogent reasons for departing from accepted practice and measuring capital-output ratios in current prices. This finds some support in the objectives of this study and some, more securely, on grounds of data reliability. The focus of this study is on the use of capital-output ratios for making investment projections. For planning purposes, these investment projections (as well as output projections) ought to be in current prices. The resources required for investment will have to be paid for in prices current at the time even if the strictly quantitative relations between capital and output remain unchanged. The financing of their needed investment is the vital concern of tax policy and, especially in the less developed countries, of foreign exchange policy. Obviously, tax and foreign exchange policies cannot be intelligently formulated unless investment requirements are stated in the prices expected to prevail in the projection period.[1/]

Inadequate information about deflation procedures followed in various countries around the world, as well as some serious doubts about these procedures based on what little information is available, provide additional

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1/ V. V. Bhatt, Ibid., also argues for measurement of capital-output ratios in current prices on the grounds that the rate of capital formation and the choice of technique are both affected by relative price changes. Moreover, he argues that for projection purposes it is always the relative prices expected to prevail which are relevant.

Domar also has contended that while measurement in constant prices generally is quite proper, an incremental capital-output ratio in current prices may be more significant if "one is interested in immediate policy questions." Evsey Domar, "The Capital-Output Ratio in the United States: Its Variation and Stability," in The Theory of Capital, previously cited, pp. 99 and 339.

grounds for working in current rather than constant prices. If relative prices of investment and non-investment goods diverge, current price capital-output ratios will move differently from the ratios computed in constant prices. It makes no sense in this case to argue that one pattern of movement is "right" and the other "wrong." If one chooses to deal with the deflated data, however, firm knowledge concerning the nature of the deflators is essential to avoid erroneous interpretations of the causes underlying observed patterns of movement. In the sources with which we have worked - principally the United Nations Yearbook of National Accounts Statistics and the studies referred to in a footnote on page 5 - information on the deflators used generally is inadequate or completely lacking.

Such information as is available provides evidence of one possibly serious bias in the investment deflators used by several important countries. It is well known that the indexes used in the U. S. to deflate construction expenditures are biased upward, thereby imparting a downward bias to real construction expenditures. Kuznets has indicated that this bias exists also in the construction deflators of other countries. Since there is reason to believe the bias may be substantial and since construction expenditures are a large part of total investment, the downward bias in deflated gross investment may not be trivial.[1/]

1/ For discussion of this problem with respect to the United States, see Paul S. Anderson, "The Apparent Decline in Capital-Output Ratios," Quarterly Journal of Economics, November, 1961; also Jaszi, Wasson and Grose, op. cit., Crosson, op. cit., pp. 79-88, contains an extended discussion and an effort to indicate possible orders of magnitude of the effects of the bias on deflated gross investment.

Kuznets' discussion of the problem with respect to other countries in "Quantitative Aspects of the Economic Growth of Nations: VI. Long Term Trends in Capital Formation Proportions," Economic Development & Cultural Change, Vol. IX, Number 4, Part II, July, 1961, pp. 13-15.

In the case of the less developed countries the question of deflation is further complicated because a substantial proportion of capital goods are imported. Should these expenditures be deflated by an index of prices paid by importers? In this case, should one adjust for differences between free and actual rates of exchange? And in any case, is an index of the price of imported capital goods the proper deflator? It can be argued that deflation by an index of export prices provides a better measure of changes in the real cost of investment goods to the using country. We do not argue that by using current price ratios all problems of valuation are avoided. In countries where the domestic currency is overvalued and imports are priced at official rates of exchange, the ratio of investment to output will tend to be biased downward. The reason is that a substantial portion of investment goods, being imported, will be undervalued relative to domestic output. The effects of this bias may not be trivial. It is a major contribution to the low ratio of investment to output in Indonesia, for example.[1/]

Hence, the use of investment and GDP in current prices by no means solves all the problems of valuation. We believe, however, that it avoids more of these problems than the alternative of working in constant prices. In any case, the crucial question concerns the effect of the valuation procedure on the observed behavior of the capital-output ratios. Do constant price capital-output ratios behave differently from current price ratios? We already have noted that if prices of investment goods change relative to

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1/ See the chapter by Douglas Paauw in Ruth McVey (ed.), Indonesia, Human Relations Area Files, New Haven, 1963, pp. 197-198. Also, Conference of Asian Economic Planners, Review of Long-Term Macro-Economic Projections for Selected Countries in the ECAFE Region, Economic Commission for Asia and the Far East, Bangkok, 18 September 1964, pp. 150-152.

prices of non-investment goods, the two kinds of ratios will move differently. In addition, the level of current price ratios ordinarily will be lower than the ratios in constant prices. This is because in most countries around the world the drift of prices, at least in the post-war period, has been upward. This general inflationary drift ordinarily will have a proportionately greater effect on the rate of growth in output in current prices than on the ratio of investment to output in current prices. Since the capital-output ratio is the quotient of the ratio of investment to output divided by the rate of growth of output, inflation generally will cause the capital-output ratio in current prices to be less than the ratio in constant prices. This fact is of major importance in interpreting differences in the size of ratios for different groups of countries experiencing different rates of inflation. We take careful note of this in the statistical work below. But the principal concern of this study is the stability of capital-output ratios rather than their level. It is of particular interest to note, therefore, that current price ratios, as they can be calculated from the available data for many countries, show less dispersion than the ratios in constant prices.[1/]

For all of these reasons we decided to work with current price capital-output ratios in the empirical portion of this paper. It is now time to turn to the analysis of this empirical material.

1/ The data on which this statement is based are described below. We will note here only that we had 268 observations for constant price ratios with a mean of 5.41 and a standard deviation of 7.44. For current price ratios we had 506 observations with a mean of 2.97 and a standard deviation of 1.63.

III. THE BEHAVIOR OF AGGREGATE CAPITAL-OUTPUT RATIOS

Before presenting the results of the statistical analysis, it will be well to say a word about data sources. For the period roughly covering 1950 to 1962 the principal source is national accounts data shown in various issues of the United Nations Yearbook of National Accounts Statistics (hereafter YNAS). For a few countries, other information indicated that the data appearing in the 1963 issue of YNAS had subsequently been revised. This was the case, for example, with Guatemala and Argentina. In these instances, if the revised data were available, they were used in place of the YNAS data.

The ratios were computed as ratios of three-year moving sums of gross domestic investment in fixed assets plus inventory change to three-year moving sums of changes in Gross Domestic Product. As noted above, both investment and output were measured in current prices. The investment sum for any three years is related to the change in GDP between the last of the three years and the year just preceding the first of the three years. In other words, it is assumed that all of the capacity increases resulting from investment in any three-year period occur within that same three-year period. This almost surely is wrong. However, experiments with ratios based on a one-year lag in output change behind investment produced no discernible change in the pattern or stability of movement in the ratios. In view of this, and because satisfactory information on actual investment lead times is not available for any country, the assumption of no lag was made.

Three-year moving sums were used in computing the ratios to reduce some of the extreme variability existing in single year ratios. Some of this variability results from variation in the rate of capacity utilization and

ought, in principle, to be removed. Of course, to do this correctly for each country would require detailed examination of each country's experience, an impossibility in this study. Consequently, the use of three-year moving sums only roughly corrects for variations in capacity utilization for many, perhaps most, countries.

Three years, rather than two or more than three, were taken for reasons of expediency. We wanted more smoothing than two years would have provided, but we wanted to retain the largest possible number of observations consistent with minimum smoothing. It could be argued that ratios based on five-year moving sums of investment and output change would be more appropriate since five years probably is the most common length of planning period, and for investment projections the ratio covering total investment and output change over the entire planning period is most relevant. However, use of five-year moving sums would have greatly reduced the total number of observations and made the computation of time trends highly questionable for many countries.

It has not been possible to investigate the quality of the data used. YNAS provides no evaluation of the data appearing therein. Yet there is every reason to believe that the quality varies widely from very good (in some of the developed countries) to practically worthless (in some of the less developed countries). If we were to hazard a guess, it would be that among the less developed countries the investment data probably are better than the output data because much of the investment data is derived from foreign trade statistics, typically among the most reliable data sources in any country. However, it is quite possible that in the less developed countries

a significant amount of investment in the form of non-wage labor on small construction projects (e.g., irrigation ditches, fences, crude animal shelters) escapes the statisticians' net. Of course, the difficulties of estimating other types of output, particularly but by no means exclusively in agriculture, are notorious.[1/]

A. The Statistical Analysis - Time-Series Data

1. Analysis of YNAS data.

Table 5 summarizes the results of fitting least squares trend equations to capital-output ratios, calculated as described above, for 63 countries. The table indicates that in the great majority of countries - 48 out of 63 - capital-output ratios were trending upward over the period covered by the data. Only slightly more than one-third of the trends, however, were sufficiently pronounced to be statistically significant (23 at the 5 per cent level and 12 at the 1 per cent level). Only 2 of the 15 negative trends were statistically significant, those for Puerto Rico and Sudan, both at the 5 per cent level but not at the 1 per cent level.

No attempt has been made to account for the upward drift in the ratios for most countries. To do so in any satisfactory way would be a considerable undertaking and, in any case, our principal interest here is in the stability

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1/ Argentina provides a dramatic example of the errors that may lurk in official output data. The series on GDP in use until very recently indicated that real output in Argentina rose by only 24 per cent between 1950 and 1961. Recent revisions, however, (one by the Central Bank and one by the National Development Council) indicate that in fact real output rose by 41 to 45 per cent in this period. The old series, based in part on an obsolete census of manufacturing, greatly understated the rise of industrial output.

For a very useful account of investment estimating procedures in less developed countries, see William I. Abraham, "Investment Estimates of Underdeveloped Countries: An Appraisal," American Statistical Association Journal, September, 1958.

TABLE 1: LEAST SQUARES TIME TRENDS IN CAPITAL-OUTPUT RATIOS FOR 63 COUNTRIES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Trend Significant at the			
	a 1/	b 1/	S_y 2/	1% Level	5% Level	No. of Observations	No. of Observations Within ± 10 Per Cent of Estimated Value
Australia	4.63	.23	.486	Yes	-	10	4
Austria	2.79	.23	2.752	-	No	10	2
Belgium	4.38	.20	1.070	-	No	10	2
Belgian Congo	4.84	.60	1.220	-	No	5	3
Brazil	.84	- .05	.027	-	No	8	6
Burma	4.50	.42	1.442	-	No	9	2
Canada	4.76	.18	1.034	-	No	10	2
Chile	.37	.03	.106	No	Yes	9	2
China (Taiwan)	1.28	.10	.080	Yes	-	9	8
Colombia	1.28	.06	.164	No	Yes	9	7
Costa Rica	3.30	.15	.506	No	Yes	10	5
Cyprus	31.95	- 3.01	62.100	-	No	6	0
Denmark	4.46	.12	4.250	-	No	10	0
Dominican Rep.	3.10	.31	1.910	-	No	9	3
Ecuador	2.30	- .006	.652	-	No	10	3
Egypt	2.39	- .57	.321	-	No	3	0
Finland	3.50	- .07	1.120	-	No	9	4
Germany (Fed Rep)	2.65	.05	.340	-	No	10	5
Ghana	2.24	.18	.487	Yes	-	10	3
Greece	2.48	.39	.720	Yes	-	10	3
Guatemala	3.27	.35	.808	Yes	-	10	1
Honduras	3.52	.22	.920	-	No	10	2
Hungary	2.33	.035	.412	-	No	5	1
Iceland	2.05	.10	.240	No	Yes	8	3
Iraq	1.86	.75	.470	No	Yes	4	0
Ireland	3.15	.10	2.550	-	No	10	2
Israel	1.61	.14	.611	-	No	10	5
Italy	2.83	.06	.260	-	No	10	5
Jamaica	2.07	.32	.298	Yes	-	9	4
Japan	2.93	.08	.506	-	No	10	4
Kenya	5.02	.30	1.876	-	No	6	0

TABLE 1: LEAST SQUARES TIME TRENDS IN CAPITAL-OUTPUT RATIOS FOR 63 COUNTRIES (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Trend Significant at the		No. of Observations	No. of Observations Within ± 10 Per Cent of Estimated Value
	a 1/	b 1/	S_y 2/	1% Level	5% Level		
Korea - South	1.16	.12	.201	-	No	5	2
Luxemburg	11.14	3.18	5.410	-	No	8	0
Malta	4.53	.33	.857	-	No	6	1
Mauritius	4.37	.29	1.360	-	No	10	1
Mexico	1.77	.23	.193	Yes	-	7	4
Morocco	3.79	1.08	.651	-	No	3	1
Netherlands	3.66	.16	.529	No	Yes	10	4
New Zealand	3.96	.12	.520	-	No	10	6
Nicaragua	11.25	- 1.53	14.040	-	No	5	0
Nigeria	1.37	.35	.838	-	No	4	0
Norway	5.22	.05	1.487	-	No	9	2
Panama	2.47	.03	1.058	-	No	10	1
Paraguay	.77	.14	.138	No	Yes	5	3
Peru	5.68	1.82	1.685	Yes	-	7	2
Philippines	1.49	- .05	.250	-	No	10	8
Portugal	3.50	- .25	.884	-	No	8	4
Puerto Rico	2.70	- .15	.440	No	Yes	10	1
Rhodesia + Nysaland	5.16	.89	4.650	-	No	10	2
Spain	2.77	1.28	.046	-	No	3	3
Sudan	2.04	- .30	.087	No	Yes	4	4
Sweden	3.32	.02	.510	-	No	10	5
Switzerland	4.58	.65	.115	-	No	3	3
Tanganyika	3.53	- .25	.460	-	No	6	2
Thailand	3.55	- .32	1.863	-	No	5	0
Trinidad	2.57	.21	.527	No	Yes	9	2
Turkey	.98	- .002	.259	-	No	9	1
Uganda	4.63	.69	2.672	-	No	6	1
United Kingdom	2.89	.19	.174	Yes	-	10	9
Union of S. Africa	2.90	.33	1.131	No	Yes	10	2
United States	3.88	- .001	.841	-	No	10	6
Venezuela	4.04	.74	1.913	Yes	-	10	1
Yugoslavia	2.51	- .001	.505	-	No	8	3

TABLE 1: LEAST SQUARES TIME TRENDS IN CAPITAL-OUTPUT RATIOS FOR 63 COUNTRIES (Continued)

1/ In the least squares equation, $Y = a + bX$ where Y is the aggregate capital-output ratio and X is time in years. The capital-output ratios are ratios of three-year moving sums of aggregate gross investment to GDP change, both in current prices. The period covered generally is from the early 1950s to the early 1960s, although for some countries it is shorter than this.

2/ Standard error of the estimating equation.

Source: United Nations, Yearbook of National Accounts Statistics, various issues.

of the ratios around their time trends rather than in the time trends themselves. To say anything very useful about the stability of the ratios over time, it is necessary to set some standard by which stability can be judged. The focus of this study is on the role of capital-output ratios for making projections of the ratio of gross investment to GDP for use in development planning. What is the widest acceptable range of a projection of the gross investment-to-GDP ratio consistent with its playing a useful role in development planning? There is, of course, no conclusive answer to this question, but complete agnosticism is not the only response to it. A range of plus or minus 10 per cent in a projection of the ratio of gross investment to GDP probably should be considered rather large. For example, suppose this ratio is projected at 15 per cent with a "reasonably high" expectation that the actual ratio will fall within 13.5 and 16.5 per cent. Such a projection already is of questionable usefulness for development policy formulation because the policy implications of a 13.5 per cent investment requirement are likely to be quite different from those of a 16.5 per cent investment requirement. In the typical less developed country the lower investment requirement implies far less foreign assistance in financing the development plan than the higher investment requirement.

Any standard by which to judge the stability of capital-output ratios over time must be partly arbitrary. We believe that a range around the projected ratio of plus or minus 10 per cent is a fair standard of stability if the projected ratio is to play a useful role in the formulation of development policy. We have adopted this standard in judging the stability of the ratios around the time trends depicted in Table 1. If the reader

believes the standard is too restrictive, he will feel that we have judged the stability of the ratios too harshly. We believe it unlikely, however, that even the most generous reasonable standard of stability would produce a judgment markedly different from ours.

We have applied the standard of stability by counting the number of observations for each country which lie within plus or minus 10 per cent of the time trend for each country. The results are shown in Column 7 of Table 1. Statistically this is an unsophisticated approach, but we believe it more honest than attempting probability statements about the number of observations which would be expected to fall within plus or minus 10 per cent of the time trend. Such statements are always on questionable theoretical grounds when applied to projections of time series, especially so when the time trend is based on a relatively small number of observations as in the present cases.

Comparison of Column (7) with Column (6) in Table 1 indicates that for most countries the number of observations within plus or minus 10 per cent of the time trend is half or substantially less than half of the total number of observations. Taking the results for all countries together, 34.4 per cent of the actual observations lie within plus or minus 10 per cent of the trend values for the various countries.

Is the performance of the capital-output ratios over time to be judged as stable or unstable by this standard? There is no finally conclusive answer to this question, but consider it from the standpoint of the development planner. Suppose that planners in each country wanted to make a projection of the capital-output ratio covering the coming three-year period and that they proposed to use the time trends depicted in Table 1 for this purpose.

Since the data are three-year moving sums of gross investment to output change, the correct procedure would be to project the ratio for the second of the up-coming three years. Given the amount of variation in the historical data about the time trend and imposing the condition that the error in the projected ratio must not exceed plus or minus 10 per cent, would planners have much or little confidence in their projections? In a few countries the confidence level might be quite high, but in most countries it probably would be low. If in the past fewer than half of the observed ratios have fallen within the prescribed limits, the planners' subjective evaluation of their ability to project with the required accuracy likely will be unfavorable. On this basis we conclude that for most of the countries listed in Table 1 aggregate capital-output ratios have been unstable over time.

2. Analysis of U. S. Data

The conclusion just stated cannot transcend the data on which it is based. We have noted already some reasons for mistrusting much of the data, but we are not able in this study to do anything on this score. Moreover, the time period covered by the YNAS data is short for effective time series analysis.

We have attempted to cope partially with these two problems of quality of the data and length of time covered by conducting some experiments on data for the United States. There appears to be a widely held concensus among development economists that the investment and output data for the United States probably are the best in the world. Moreover, as the result of work by Raymond W. Goldsmith, Simon Kuznets, and others, these data now cover long spans of time. It would appear useful, therefore, to construct

a capital-output ratio time series for the United States and to examine its behavior. The results will not prove or disprove the conclusion drawn from the YNAS data, but they may either strengthen or weaken this conclusion.

The investment data used were compiled by Kuznets.[1/] They are gross domestic investment, including inventory change, valued in current prices. With the exception of the inclusion of public investment they conform to U. S. Commerce Department concepts.

The output data are Gross National Product[2/] valued in current prices and adjusted for departures from full employment (taken as 97 per cent of the labor force). The details of the adjustment are tedious and need not be described here.[3/] The reason for the adjustment, of course, is to reduce the impact on the capital-output ratio of cyclical fluctuations in output. The adjustment must be considered only approximate, however. In principle, the capital-output ratio states a relationship between changes in capital stock and changes in capacity of the capital stock. In using full employment output to compute capital-output ratios, we assume implicitly that labor force capacity and capital capacity are the same. Unfortunately this may not be the case. That is, the level of output produced with a fully employed labor force is not necessarily the same as the output produced with a fully utilized capital stock. In much of the period since 1929 this lack of identity between

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1/ These data were most readily available in John W. Kendrick's Productivity Trends in the United States, Table A-IIb, pp. 296-297.

2/ The difference between Gross National Product and Gross Domestic Product has no effect on the conclusions reached in this exercise.

3/ They are given in Crosson, op. cit., Appendix.

labor force capacity and capital capacity appears to have characterized the American economy. For example, between 1929 and 1945 the number of manhours worked per year under conditions of full employment increased substantially in the United States while the increase in the country's capital stock was almost negligible.[1/] The increase in full employment manhours reflected continued population growth not offset by declines in annual hours worked per man. The much smaller increase in capital stock resulted from greatly depressed levels of investment during the Depression and war years. After 1945, capacity manhours continued to grow but capital stock, freed of wartime restrictions and spurred by bouyant post-war demand, shot ahead much faster.

While capital stock and capacity manhours need not grow in fixed proportions, sharp and long sustained changes in their relative rates of growth almost surely reflect divergences between labor force capacity and capital capacity. Consequently, it is probable that labor force capacity cannot be legitimately substituted for capital capacity in the computation of capital-output ratios for the U. S. in much of the period since 1929. Accordingly, we have confined our analysis of these ratios to the period between 1900 and 1929. While the quality of the investment and output data for this period undoubtedly is poorer than that for the post-1929 period, our inability to satisfactorily approximate capital capacity in the Depression, War, and post-war years more than compensates, in our judgment.

Two experiments have been conducted on the capital-output ratios for the U. S. between 1900 and 1929. In the first, time trends for capital-output

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1/ The computation of full employment annual manhours is described in Crosson, op. cit. Capital stock figures are in R. W. Goldsmith, A Study of Saving in the United States, Vol. III, 1956, Table W-3.

ratios have been computed and used to project the ratio of gross investment to GNP for successive five-year periods. For example, the trend in the capital-output ratio for the period 1900-1909 is used to project the ratio covering the years 1910-1914. This projected capital-output ratio is used with the actual growth rate in capacity GNP in 1910-1914 to project the ratio of gross investment to capacity GNP in this period. The time trend for the capital-output ratio is then computed for the period 1900-1914 and used to project the ratio for 1915-1919 and so on through 1925-1929. There thus are four five-year projections of the capital-output ratio based on 10, 15, 20, and 25 year periods, and each of these projections is combined with actual capacity GNP growth rates to derive four projections of the ratio of gross investment to capacity GNP.

In the second experiment, the capital-output ratio for each five-year period is used to project the ratio of gross investment to GNP for the succeeding five-year period.

In each experiment, the projected values of the ratio of gross investment to GNP are compared with actual values of this ratio. The results are given in Table 2.

TABLE 2

Projected and Actual Ratios of Gross Investment to GNP in the United States, Successive Five-Year Periods, 1910-1929, Current Prices

	Experiment One 1/		Experiment Two 2/	
	Actual	Projected	Actual	Projected
1910-1914	.183	.073	.183	.109
1915-1919	.171	.453	.171	.465
1920-1924	.183	.067	.183	.023
1925-1929	.201	.106	.201	.370

1/ Capital-output ratio projections based on least squares time trends covering 10, 15, 20, and 25 year periods.

2/ Capital-output ratio projections based on actual ratios for preceding five-year periods.

A hypothetical planner in the United States drawing up five-year investment plans in 1909, 1914, 1919, and 1924 might have employed one or the other, or perhaps both of the procedures underlying Table 2. If he had, and even if he had been able to predict output growth precisely, he would have made very poor projections of the investment ratios "required" to achieve the successive output growth rates. The poor quality of these projections, of course, reflects the instability of the capital-output ratio in the United States in the period 1900-1929. The hypothetical planner would have been much closer to the mark if he had ignored the capital-output ratio entirely and had assumed simply that the ratio of gross investment to capacity GNP in each successive five-year period would be identical to the ratio in the preceding five-year period.

It may be argued that much of the instability in the capital-output ratios reflected in the results shown in Table 2 arises from the sharp price changes which occurred in the period between 1914 and 1921 and that ratios in constant prices would exhibit greater stability. To test this hypothesis we performed experiment two on capital-output ratios calculated in constant (1929) prices,[1/] with the results shown in Table 3.

TABLE 3

Projected and Actual Ratios of Gross Investment to GNP in the United States, Successive Five-Year Periods, 1910-1929, Constant Prices

	Experiment Two[a/]	
	Actual	Projected
1910-1914	.195	.122
1915-1919	.171	.190
1920-1924	.160	.179
1925-1929	.203	.167

a/ Capital-output ratio projections based on actual ratios for preceding five-year period.

The projected ratios in Table 3 are much closer to the actual ratios than in Table 2. However, in every case, the actual ratios differ from the projected ratios by more than plus or minus 10 per cent. Perhaps more

1/ The data in 1929 prices are from the same sources as the data in current prices.

important, the relevance of constant price projections of the gross investment ratio to the formulation of development policy is questionable, as was pointed out above.

The analysis of the experience of the United States in the period 1900-1929 suggests that even under the best of data circumstances the aggregate capital-output is too unstable over time to yield investment projections of sufficient reliability to justify their use in development planning. This finding, therefore, tends to support the conclusion reached on the basis of the YNAS data covering many countries.

B. The Statistical Analysis - Cross-Sectional Data

Charts 5-9 present frequency distributions of capital-output ratios in the form of histograms. The data used are exclusively those available in YNAS and are identical with those used in the time series analysis of the YNAS data. In this case, however, the ratios are treated in various country groupings and the time element is ignored. The countries included in each group are listed in Table 4.

TABLE 4

List of Countries Included in Each Country Group

Country Group	Countries Included
Developed Countries	Australia, Austria, Belgium, Canada, Denmark, Finland, Germany (Fed. Rep.), Hungary, Iceland, Ireland, Italy, Japan, Luxemburg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, Union of South Africa, United States
Less Developed Countries	
Latin America	Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Trinidad, Venezuela
Asia-Africa	Belgian Congo, Burma, China (Taiwan), Cyprus, Egypt, Ghana, Greece, Iraq, Israel, Kenya, Korea (South), Malta, Mauritius, Morocco, Nigeria, Philippines, Rhodesia and Nysaland, Sudan, Tanganyika, Thailand, Turkey, Uganda, Yugoslavia

The particular groupings used here, of course, are not the only ones that might be employed. In a completely exhaustive analysis of capital-output ratios, additional groupings would be essential. For example, aggregate capital-output ratios may be systematically related to country economic structure. Accordingly, the analysis of ratios for countries grouped according to various criteria of economic structure possibly would be interesting.[1/]

1/ We performed one experiment along these lines. Using country data available in YNAS, we examined the relationship between aggregate capital-output ratios and the proportion of output originating in agriculture. In the regression of aggregate ratios on the agricultural proportion, the regression coefficient was negative but not significant. That is, higher values of the proportion of agriculture in GDP were associated with lower aggregate capital-output ratios, but the association was not statistically significant.

There is one important point worth noting in this connection, however. The analysis of time series data on capital-output ratios demonstrated that the aggregate ratios for most countries are quite unstable over time even after the smoothing imparted by using ratios of three-year moving sums of investment to output change. Given this instability over time in the ratios for most countries, it is unlikely that any country grouping of ratios would yield a highly stable cross-sectional pattern of ratios. Thus, while country groupings other than those used in this section certainly are possible and probably interesting, it is unlikely that any alternative set of groupings would markedly reduce the variation in group ratios from that observed in the groupings used here.

Since this paper is concerned with development planning in the less developed countries, the country groupings used here suggest themselves rather obviously. It is of interest to examine capital-output ratios for the less developed countries separately from those for the developed countries, since the profound differences between these groups with respect to per capita income and the structure of economic activity strongly suggest that group capital-output ratios also might differ.[1/] The rationale for treating the less developed countries of Latin America separately from those in Asia and

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1/ Per capita income is a proxy for a number of variables bearing on the aggregate capital-output ratio; for example, the relative endowment of capital, labor, and natural resources, and the efficiency with which these resources are employed. The possibility that economic structure might be systematically related to capital-output ratios already has been discussed in the text.

Africa is less obvious but still urgent. By and large, inflation has been more severe in Latin America in the post-war period than in Asia and Africa. The capital-output ratios used here are calculated in current prices and, as pointed out above, capital-output ratios in current prices will tend to be inversely related to the rate of inflation.

The point of the cross-sectional analysis is three-fold:

(1) to determine whether there are discernible central tendencies in the ratios available for developed and less developed countries;

(2) to measure the variation in the ratios about these central, or mean, values;

(3) to determine whether there are statistically significant differences between the means for developed and less developed countries, treating the latter both as a single group and as two groups classified as Latin America and Asia-Africa.

The charts leave no doubt that for all five country groupings there is a definite tendency for the ratios to cluster. The answer to the first question posed, therefore, is a clear affirmative.

In the preceding time series analysis of capital-output ratios it was argued that if the error in capital-output ratio projections exceeds plus or minus 10 per cent, the projections are of questionable usefulness in the formulation of development policy. This same standard can be used to evaluate the amount of variation in the ratios depicted in Charts 5-9. We will contend that only those ratios within plus or minus 10 per cent of the group means will give acceptably narrow ranges of the investment-to-output ratio for any reasonable projected growth rate. For example, the mean

capital-output ratio for all countries taken together is 2.97 (Chart 5). The ratios within plus or minus 10 per cent of this mean lie between 2.67 and 3.27. For a 5 per cent output growth rate the corresponding proportions of investment to output are 13.35 per cent and 16.35 per cent. For an 8 per cent growth rate the corresponding proportions of investment to output are 21.36 and 26.16.

This suggests that the amount of variability in the various groupings of capital-output ratios can be judged by answering the question for each grouping, what percentage of the ratios lie within plus or minus 10 per cent of the mean? The answers to this question for each of the five groupings is given in Table 5.

TABLE 5

Percentage of Capital-Output Ratios Within Plus or Minus 10 Per Cent of Group Means, Various Country Groupings

Country Groupings	Percentage of Observations
All countries	24.7
Developed countries	30.7
All less developed countries	27.9
Asian and African countries	18.3
Latin American countries	
Including Chile	34.0
Excluding Chile	36.3

In calculating these percentages all of the observations within the class intervals containing the limiting ratios have been counted. For example, the mean ratio for all countries is 2.97 and the range within plus or minus 10 per cent of this mean is from 2.67 to 3.27. In calculating the

percentage of observations within plus or minus 10 per cent of the mean, however, all observations between 2.50 and 3.50 have been included.

The effect of this procedure, of course, is to overstate the percentage of observations within plus or minus 10 per cent of the respective group means. Even so, for none of the various groupings do as many as 40 per cent of the observations lie within the indicated range. In fact, allowing for the overstatement implicit in our procedure, it probably is safe to say that in no case do more than one-third of the observations lie within plus or minus 10 per cent of the mean, and for most of the groupings the percentage is substantially less than this. For this reason we conclude that the amount of variability in each of the group distributions of capital-output ra ios is large.

The third objective of this section is to consider the differences between the means of the various country distributions. The relevant information is presented in Table 6.

TABLE 6

Significance of Differences Between Means of Various Distributions of Capital-Output Ratios

	Differences Between Means (D)	Standard Error of Differences (σ_D)	$\frac{D}{\sigma_D}$	Differences Significant at 5% Level	Differences Significant at 1% Level
Developed-Underdeveloped	.780	.137	5.70		Yes
Developed-Latin America					
Including Chile*	1.050	.157	6.69		Yes
Excluding Chile	.910	.157	5.80		Yes
Developed-Africa Asia	.550	.175	3.14		Yes
Africa Asia-Latin America					
Including Chile	.500	.142	2.60		Yes
Excluding Chile	.360	.142	1.88	No	

* There are 9 observations for Chile. Eight of them lie between 0 and .5, the other between .5 and 1.0.

The table makes it quite clear that the mean capital-output ratio for the developed countries differs significantly from the mean ratios for the three groupings of less developed countries. The difference between the means for Asian-African countries and for Latin American countries, including Chile, is just barely significant at the 1 per cent level. Excluding the very low observations for Chile, the difference between African-Asian countries and Latin American countries no longer is significant even if the 5 per cent standard of significance is employed.

We have had occasion to point out several times already that the size of capital-output ratios is inversely related to the rate of inflation. If

the rate of inflation in less developed countries has exceeded that in the developed countries, this may account for part of the difference between the mean ratios for the two classes of countries.

To get at this problem, we have re-calculated the mean ratios for developed and less developed countries, excluding from both groups those countries in which the rate of inflation exceeded 5 per cent per annum in the period covered by the capital-output ratio data (generally the early 1950s through the early 1960s). In most cases inflation was measured by the average annual rate of change in GNP deflators over the period covered. (Beginning and terminal values were averages respectively of the deflators for the first two years and the last two years.) GNP deflators were not available for a few countries, in which cases wholesale price or cost of living indices were used.

The countries excluded under this criterion were all in the less developed class, as follows: Brazil, Chile, Colombia, Greece, Israel, Mexico, Paraguay, Peru, South Korea, Taiwan, Turkey, and Yugoslavia. The mean ratio for the remaining group of less developed countries is 3.15. The mean ratio for the developed countries is 3.45. The difference between these two means is significant at the 5 per cent significance level, but it is not significant at the 1 per cent level.[1/]

1/ No tests were run on the difference between the mean ratios for African-Asian countries and Latin American countries. Visual inspection indicated quite clearly that exclusion of countries with more than 5 per cent inflation would raise the mean ratio for Latin American countries much more than the mean ratio for African-Asian countries. Since the difference between the means of these two groups was not significant before allowing for inflation (except for Chile - see Table 6), the small difference after allowing for inflation clearly would not be significant.

The difference between the mean ratios for developed and less developed countries remaining after allowance for inflation may represent genuine economic factors or it may represent inadequacies in the data. It was suggested above that the available data may systematically understate investment in the less developed countries. On the other hand, the relative scarcity of capital in the less developed countries compared to the developed countries provides theoretical grounds for expecting lower capital-output ratios in the less developed countries.

The careful exploration of the possible reasons for the observed differences between the mean ratios for developed and less developed countries would carry us far afield and is not feasible in this study. Consequently, the question of the real significance of this difference must remain moot at this time.

The time series analysis of the data for each country indicated that for most countries there was a tendency for the capital-output ratio to rise over time, although in most cases this tendency was not statistically significant. Nevertheless, because of this tendency, we would expect the mean ratio for all countries, and possibly for the other country groups also, to rise over time. In addition, the dispersion of the ratios also might be affected.

To check on these possibilities, we have analyzed a frequency distribution consisting of the last two (in time) ratios available for each country. This distribution is presented in Chart 10. As would be expected, the mean of this distribution, 3.32, is higher than the mean of the ratios shown in Chart 5 (2.97). This, of course, reflects the upward drift in the ratios

found in the time series analysis. However, the standard deviation of the distribution shown in Chart 10, 1.77, is larger than that of the distribution shown in Chart 5 (1.63). The existence of time trends in the ratios for most countries, in other words, does not increase the dispersion in the ratios for all countries taken together. Moreover, the number of observations in Chart 10 within plus or minus 10 per cent of the mean is 25.4 per cent of the total number of observations, much like the percentages found in the distributions shown in Charts 5-9.

It appears, therefore, that the existence of positive time trends in the ratios for most countries does not alter the earlier conclusion of this section that the dispersion in the ratios for all countries taken together is substantial.

C. Summary of the Statistical Analysis

1. The YNAS data, covering the period roughly from the early 1950s to the early 1960s, indicate a tendency for the capital-output ratio to rise in virtually all countries. In only a handful of countries, however, was this rising tendency statistically significant.

2. For most countries covered by the YNAS data, the capital-output ratios were quite unstable over time. For all countries taken together, only 34 per cent of the actual ratios were within plus or minus 10 per cent of the time trend values.

3. The capital-output ratio for the United States in the period from the first decade of the century through the 1920s also was judged to be unstable. Tests simulating projections of the investment-to-output ratio

which might have been made by planners using historical data for the U. S. indicated a wide margin of error in the projections. This was true even on the assumption that the planners were able to project output growth with no error.

4. The cross-sectional analysis of the YNAS data indicated that for all countries taken together and for various groupings of countries, there was a clearly discernible tendency for ratios to cluster in the range of 1.5 to 4.5.

5. For each of the various groupings it was judged that the variation about group means was large, using as a standard of judgment for each group the percentage of all ratios in the group lying outside plus or minus 10 per cent of the group mean.

6. The mean ratio for developed countries was significantly different (higher) from that for less developed countries taken together and from the means for Latin American countries and for Asian-African countries taken as separate groups. The mean ratio for Asian-African countries was higher than the ratio for Latin American countries, but the difference was on the borderline of statistical significance.

7. When all observations for countries with 5 per cent or more inflation in the period covered by the data were excluded, the mean ratio for all less developed countries taken together rose sharply and that for developed countries was unchanged. The remaining difference between the two means was on the borderline of statistical significance.

8. The existence of positive time trends in the ratios for most countries causes the group means to rise over time but does not increase the dispersion about these means.

IV. CONCLUSIONS

This paper has been addressed to the question of whether capital-output ratios will yield aggregate investment projections of sufficient reliability to justify their use in the formulation of development policy. The findings of the paper suggest strongly that the answer is negative. Even with the best available data it is impossible to obtain measurements which correspond to the concept of the capital-output ratio. The concept calls for measures of aggregate capacity change and aggregate net investment linked by technical and economic relations to that capacity change. Such measures of capacity and net investment do not exist. In a few countries, such as the United States, the deficiencies in the capacity data can be partially compensated by substituting estimates of labor force capacity. However, in most of the period since 1929 the conditions necessary for the validity of this substitution have not existed.

No reasonable approximations to net investment as called for by the concept of the capital-output ratio are possible. The only course here, unless the concept is to be abandoned entirely, is to use gross investment rather than net investment. Since replacement investment almost surely is a substantial proportion of gross investment in all countries, and since replacement investment is unlikely to be closely linked to capacity expansions, the expedient of substituting gross for net investment does not inspire confidence.

Despite these measurement problems, the capital-output ratio perhaps still would be useful if the ratios which can be measured showed sufficient

stability. Even if there were little apparent theoretical reason to expect stability in the ratio of observed gross investment to observed output change, if the ratio nevertheless were stable, it could play a valuable role in investment projections.

Our findings show, however, that insofar as the aggregate capital-output ratio can be measured with available data it has been quite unstable. This is true for most countries over time and it is true of the ratios for all countries taken for given periods of time. It is true also of the United States where the sheer data problems probably are smaller than in any other country. Finally, the statement is true even though the ratios have been smoothed by calculating them as three-year moving sums of gross investment to output change.

The preceding paragraph stressed that the conclusion stated is based on analysis of data presently available. This is an important qualification, and it means that the conclusion must be taken as tentative. Conceivably, more data, or better data for many countries would show substantially more stable capital-output ratios, although the data for the United States lend little encouragement to this view. Of greater importance, intensive analysis of the ratios calculated from presently available data might alter the conclusion stated above. It already has been pointed out that a major source of instability in capital-output ratios over time is cyclical swings in output. In countries where agriculture is a major producing sector the weather may be an important additional source of instability. In those cases where foreign trade is large relative to total GDP, and capital-output ratios are calculated in current prices, changes in the terms of trade can have a

major impact on the behavior of the ratios. In smaller countries with relatively undiversified economies, the start-up or completion of major investment projects can produce wide fluctuations in the aggregate capital-output ratio. In all countries, changes in the relative shares of various producing sectors in increments of aggregate output can be a major source of aggregate capital-output ratio instability if the different sectors themselves have different capital-output ratios. Data we have collected from YNAS and other sources leave little doubt that in fact sectoral capital-output ratios within any given country are likely to differ sharply.

Our use of three-year moving sums of gross investment and output change in calculating aggregate capital-output ratios helps to reduce the instability arising from these various sources, but the adjustment at best must be considered very rough. To do much better than this would require careful, intensive analysis of the data and economic structure and performance of each country, a job which is quite beyond our resources.

Thus, the conclusion that aggregate capital-output ratios for most countries have been quite unstable is not final. Conceivably, intensive analysis of each country's situation would explain much of the observed instability in the ratios and thus provide the basis for reasonably reliable investment projections. But such an analysis would be a large job for any one country, and for all countries it would be enormous. Until such studies are undertaken, aggregative projection models have no alternative but to use presently available data. Our findings, therefore, imply that the results obtained from such projection models are likely to be quite unreliable, so unreliable, in fact, as to make them of little use in the formulation of development policy.

Where does this leave development planning? Is the capital-output ratio so essential to planning that, to paraphrase Voltaire's alleged quip about the existence of God, if it does not exist we must invent it? It may be argued that the required rate of investment typically is the keystone to the entire plan and that intelligent planning, therefore, "must" include projections of aggregate investment. Must it? What does it mean to say that we "must" do something which we cannot do? The only possible meaning of this statement in the present context is that effective development planning is impossible without reliable projections of aggregate investment. But is this true? Surely not. For any country the principal objective of development planning is to raise the productivity of the country's human and non-human resources. Enough already is known about the productivity effects of education, health, market incentives, and the organization of production in various sectors to provide considerable guidance to planners and policy-makers, guidance which in no way depends on aggregate investment projections. To be sure, such planning is piecemeal and may well involve implicit inconsistencies in the total demand for resources. Yet few will deny that, given the will to act, any less developed country can with the intelligent application of existing knowledge and technique increase productivity significantly above the existing level in that country.

The notion that aggregate investment projections are essential to effective development planning no doubt reflects the time-hallowed view among economists that increased capital per head is the sine qua non of rising productivity. The persistence of this view in the face of a rising body of contrary evidence gives melancholy testimony that economics, like other

disciplines, suffers more than we would like from intellectual lag.[1/] This lag is the more peculiar because everyone now recognizes that many factors contribute to higher productivity in addition to increased capital per head.

Analysis of the available data on output growth and gross investment provides strong support to this view. This analysis indicates there is little if any relationship between the rate of output growth and the ratio of gross investment to output. We examined this relationship using cross-sectional data for 48 countries.[2/] For each country the proportionate growth rate in deflated GDP was calculated as a least squares time trend. These growth rates were regressed on the ratios of gross investment to GDP over the period covered by the data (generally from 1950 - 1962). The data used are plotted in Chart 10. The coefficient of determination in this regression is .34 and the standard error of the regression coefficient is just significant at the 1 per cent level.

1/ The literature on the sources of economic growth in the United States leaves no doubt that increases in the total capital stock, or in the stock per employed worker, accounts for only a relatively small proportion of the increase in the nation's measured output since the turn of the century. Some of the more important items in this literature are Moses Abramovitz, Resource and Output Trends in the United States Since 1870, Occasional Paper 52, National Bureau of Economic Research, 1956; John W. Kendrick, Productivity Trends in the United States, National Bureau of Economic Research, 1961; Edward Denison, The Sources of Economic Growth in the United States and the Alternatives Before Us, Committee for Economic Development, 1962; Robert Solow, "Technical Change and the Aggregate Production Function," The Review of Economics and Statistics, August, 1957.

2/ The countries included were Australia, Austria, Belgian Congo, Belgium, Bolivia, Brazil, Burma, Canada, Ceylon, Chile, China (Taiwan), Colombia, Cyprus, Denmark, Ecuador, Finland, W. Germany, Greece, Honduras, Iceland, Ireland, Israel, Italy, Jamaica, Japan, S. Korea, Luxemburg, Mexico, Morocco, Netherlands, Nicaragua, Nigeria, Norway, Paraguay, Peru, Philippines, Portugal, Puerto Rico, Rhodesia and Nyasaland, Sweden, Switzerland, Thailand, Trinidad, Turkey, United Kingdom, United States, Venezuela, and Yugoslavia.

The regression is strongly influenced by the observations for ten countries with growth rates in excess of 7 per cent per annum. If these countries are excluded, the coefficient of determination falls to .038, and the regression coefficient is not significant, even at the 5 per cent level.

There no longer can be any doubt that achieving steady increases in per capita output is a far more complex business than simply raising the stock of capital per head. The analysis just described, the literature on the sources of economic growth in the United States, previously cited, and the findings of this study on the instability of capital-output ratios all bear consistent witness on this point. Aggregate planning models of the Harrod-Domar type which implicitly defy this now well established fact of economic life must be reckoned crude devices, yielding little if any guidance to the formulation of development policies. Probably few development economists would dispute this. Isn't it time we shaped our practice accordingly?

APPENDIX A

Derivation of equation (2)

Let R_t = annual replacement expenditures for a given asset, equal to the original cost of the asset divided by the number of years it is expected to last, and adjusted for changes in the average productivity of new assets of this type which occur over the life of the asset. For simplicity salvage value is set at zero. This statement defines annual replacement investment as the amount of investment required to replace the annual decline in asset capacity, assuming that this decline is spread in equal annual increments over the life of the asset.

I'_t = annual gross investment in the given asset.

r = the annual proportionate increase in I'.

m = the life of the asset in years.

p = the annual proportionate change in the average productivity of new investment in assets of this type, where productivity is defined as asset capacity per dollar expenditure for the asset.

Assume that r, m, and p are constant and the same for all classes of assets. Also assume that r always is positive and that m always is 2 or more. Then aggregate replacement expenditure in any year is the sum of replacement expenditures on all assets installed in the previous m years.

Algebraically,

$$R_t = \frac{I'_{t-m}}{m(1+p)^m} + \frac{I'_{t-m(1+r)}}{m(1+p)^{m-1}} + \frac{I'_{t-m(1+r)^2}}{m(1+p)^{m-2}} + \ldots + \frac{I'_{t-m(1+r)^{m-1}}}{m(1+p)} .$$

This expression can be reduced to a geometric progression of the form

$$R_t = \frac{I'_{t-m}}{m(1+p)^m} [1 + (1+r)(1+p) + (1+r)^2(1+p)^2 + \ldots + (1+r)^{m-1}(1+p)^{m-1}].$$

Applying the rule for summing a geometric progression and noting that

$$I'_{t-m} = \frac{I'_t}{(1+r)^m} \quad \text{we get}$$

$$R_t = [\frac{I'_t}{m(1+p)^m(1+r)^m}] \; [\frac{(1+r)^m(1+p)^m - 1}{(1+r)(1+p) - 1}] \tag{2}$$

<u>The ratio of replacement investment to gross investment</u>

If equation (2) is divided by I'_t, we get

$$\frac{R_t}{I'_t} = [\frac{1}{m(1+r)^m(1+p)^m}] \; [\frac{(1+r)^m(1+p)^m - 1}{(1+r)\;(1+p) - 1}] , \tag{3}$$

the ratio of replacement to gross investment on the assumption that replacement follows the straight-line depreciation pattern.

When replacement follows the "one-hoss shay" pattern, the relations giving the ratio of replacement to gross investment are less complex. We know that in the "one-hoss shay" case replacement investment, after adjustment for changes in the average productivity of investment as defined above, can be written

$$R_t = \frac{I'_{t-m}}{(1+p)^m} \tag{4}$$

where the terms are as defined above. Since

$$I'_{t-m} = \frac{I'_t}{(1+r)^m} ,$$

equation (4) can be rewritten as

$$R_t = \frac{I'_t}{(1+r)^m (1+p)^m} . \qquad (4.a)$$

Dividing (4.a) by I'_t yields

$$\frac{R_t}{I'_t} = \frac{1}{(1+r)^m (1+p)^m} . \qquad (5)$$

Some illustrative values of the ratio of replacement investment to gross investment are given in Tables A.1 and A.2. Table A.1 is derived from equation (3); hence, the ratios are based on the assumption that replacement follows the straight-line depreciation pattern. Table A.2 is derived from equation (5); hence, the ratios are based on the assumption that replacement follows the "one-hoss shay" pattern.

TABLE A.1*

Illustrative Ratios of Replacement Investment to Gross Investment, Different Values of r, m, and p

r \ m	p = 0			p = -.01			p = .01		
	10	20	30	10	20	30	10	20	30
.02	.90	.83	.75	.92	.89	.85	.86	.76	.65
.04	.81	.68	.58	.89	.74	.65	.77	.63	.51
.06	.74	.58	.46	.77	.62	.51	.71	.50	.41

*Assumes replacement follows straight-line depreciation pattern.

TABLE A.2*

Illustrative Ratios of Replacement Investment to Gross Investment, Different Values of r, m, and p

r \ m	p = 0			p = -.01			p = .01		
	10	20	30	10	20	30	10	20	30
.02	.82	.67	.55	.91	.82	.75	.74	.55	.41
.04	.68	.46	.31	.75	.56	.42	.61	.37	.23
.06	.56	.33	.17	.62	.38	.24	.51	.26	.13

*Assumes replacement follows "one-hoss shay" pattern.

APPENDIX B - BIBLIOGRAPHY

This bibliography does not pretend to provide exhaustive coverage of the literature on capital-output ratios and related topics. To do this is not feasible in a paper of this sort since this literature is virtually conterminous with the entire literature on development planning. The items in this bibliography include all references cited in the paper plus certain additional ones reviewed in preparation of the paper but not cited because they do not bear directly on specific points discussed in the paper.

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