Economic Growth and the Returns to Investment

Dennis Anderson

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ABSTRACT

The paper derives a relationship between the rate of economic growth and variables representing the rate and allocative efficiency of investment. Allocative efficiency is measured by the social rate of return to investment. The paper departs from the methods followed in a number of growth accounting studies over the past 30 years, in which investment's
contribution to economic growth was estimated to be small. It attempts to show instead that when efficiently applied to the task of raising output, investment accounts for most of a country's growth - and, conversely, when inefficiently applied to the task, accounts for most of a country's economic decline or failure to grow. Much emphasis is placed on the product of the rate of investment and the social rate of return to investment. But these are not the only variables emphasized, since the rates and choices of investments have appreciable effects on the ways labor is deployed and redeployed in an economy, and thus on the growth of labor productivity and real wages, on the returns to labor so to speak; it is argued that most growth accounting studies significantly under-estimate these effects both in 'positive' instances (when labor is being redeployed productively) and in negative instances (when, alas, it is not). Lastly, the paper is concerned not only with the rate of and returns to investment in and of itself, but of the policies which bear on these variables - prices, taxes, exchange rates, interest rates, the level and composition of public revenue and expenditure policies, the regulatory framework for investment, and, more generally, the 'climate' for public and private investment. The efficiency or otherwise of such polices can be assessed in terms of their effects on the social returns to investment (including the returns to labor). If then we can in turn establish a link between the allocative efficiency of investment and growth, we also have a means for determining what a wide range of economic policies might add up to in terms of economic growth.
INTRODUCTION

The aims of this paper are, first, to derive a relationship between the rate of economic growth, and the rate, allocation and efficiency of investment, and second, to discuss the implications of the relationship for the analysis of economic policies. In particular, an attempt is made to trace the quantitative links between economic policy and growth, with the efficiency (or otherwise) of economic policies being measured in terms of their effects on the allocative efficiency of investment. Allocative efficiency is measured by the social net present value or social rate of return to investment.

The paper draws extensively on theories developed to explain growth in the industrialized countries, while much of the applied work to which it refers relates to the developing countries. From the viewpoint of existing theories the main differences between the two groups of countries are that four quantities which have (until recently perhaps) held fairly 'steady' over long periods in the industrialized countries, namely the long-run rate of growth, the rate of investment, the returns to investment and labor's share in output, have often changed appreciably and systematically over time in developing countries. In the high growth developing countries the rates of and returns to investment have risen remarkably, while in those experiencing near-stagnant or declining output they have often fallen equally remarkably, as a consequence of (among other things) widely reported failings in economic policy; labor's share in output has
also varied with the growth rate and with the capital intensities of the
economic policies followed. The four quantities also differ appreciably
between developing countries (as they do between the industrialized
countries), again in a manner not inconsistent with economists' perceptions
as to differences in the efficiency or otherwise of economic policies. The
aim then is to suggest how existing theories might be adapted to account
for growth in these rather different and changing circumstances. In doing
so, a method is also proposed for inputing the \textit{ex post} average social rate
of return to investment from growth statistics and national accounts data.

Before turning to the analysis proper, it is necessary to address
an old issue regarding the 'contribution' of investment to growth, which
resurfaces as commonly in discussions of development (see e.g. Sen, 1983)
as it does elsewhere. A large number of empirical studies dating back to
Solow's paper on technical progress in 1957, and the various growth
accounting studies of Kuznets (1966), Denison (1962, 1967) and others, have
concluded that the contribution of investment to growth is not large, as
was once assumed in Harrod-Domar models and their derivatives, but compara-
tively minor, accounting perhaps for one quarter or one fifth of growth 1/.
Although these studies dealt mainly with the industrialized countries, they
have raised much dispute over the contribution of investment to growth in
the developing countries. In a recent book, Lord Bauer (1981) forcefully
argued that "it is clear from much and varied evidence that investment
spending is not the primary, much less the decisive determinant of economic
performance", and went on to cite a litany of examples of wasteful invest-
ments and policies in developing countries and how they have led to slow or
even negative growth in a not small number of cases. As discussed in Part I of this paper, however, the point that inefficient investment spending would lead to deteriorating economic performance is not disputed; indeed, there are reasons and evidence to suggest that, once the efficiency (or inefficiency) with which it is applied is suitably allowed for, investment remains a good explanatory variable for growth - whether growth is fast or slow, positive or negative, depending on the signs and magnitudes of the social rates of return to investments taking place. In addition, such conclusions have consistently ignored the findings of 'vintage' theories of investment-embodied growth which place great importance to the contribution of investments (efficiently chosen) to growth 2/.

To formulate the relationship described the paper follows Maurice Scott's lead 3/ and inquires how the procedures by which growth is accounted for might be improved. There are, I think, three problems requiring attention. They concern (i) the definition and measurement of the rate of investment, (ii) the need to use the social rate of return (or social NPV) in growth analysis instead of the rate of profit, and (iii) investment's influence on the redeployment of labor and thus on labor's income (with the influence again being large or small, positive or negative, depending on the kinds of investment taking place). Along with Scott, I believe that present practices with respect to (i) significantly under-estimate the influence of investment on growth but would add that present procedures for the treatment of (iii) similarly err, to a comparable or perhaps greater extent, on the side of under-estimation.
A discussion of these problems in Part II leads to a derivation of a simple aggregate relationship between four variables, namely the rate of economic growth, the rate of investment, the social rate of return to investment, and the present value of labor's share in the output of investment. The analysis begins with an investment-embodied, vintage model of growth, but it is later shown that a relationship between the four variables still holds with respect to the influences on growth of activities seemingly separate to or 'disembodied' from investment (such as managerial efficiency); the reason is that such influences can be measured by the changes in the quasi-rents of - and thus the returns to - investments in place and to new investments. Part III derives a disaggregated form of the relationship, and also attempts to generalize it in other ways. Part IV uses the aggregate form to estimate the imputed returns to investment in various countries; the estimates serve to illustrate the strength of the link between the allocative efficiency of investment and growth. Part V reviews some points of departure between the approach to growth accounting followed in this paper, and current approaches to growth accounting. Part VI makes some concluding remarks.
I DISPUTES OVER THE INFLUENCE OF INVESTMENT ON GROWTH

For many years, economic planning in developing countries, and also the provision of foreign aid, proceeded on the assumption that the crucial determinant of per capita economic growth was investment — in agriculture, industry, infrastructure (roads, drainage, electricity, communications, water supply and sewerage systems, and so forth), and in 'human resources', such as in education, training and health. Indeed, in numerous countries investment planning was based on an assumed relationship between investment and the growth of output. 1/ This assumption has been disputed increasingly in recent years by reference both to the experiences of the developing countries themselves, and to the inquiries of Solow (1957), Kuznets (1966) and others on the contribution of capital accumulation to growth.

To begin, consider the experiences of the developing countries. It is widely observed that countries with high rates of growth, and the East Asian countries in particular, have not had proportionally higher rates of investment, while some African countries have had low or even negative rates of growth notwithstanding historically high rates of investment. The data on the African countries in Table 1 are sufficient to make the point; some Asian and Latin American countries are included as well for purposes of comparison. There is a crude association between the rate of investment and the rate of growth of GDP (see the scatter diagram in Figures 1a and 1b): all the high growth countries in the 1960s and 1970s (e.g. Ivory Coast, Kenya, Malawi, Malaysia, Singapore, South Korea, Thailand and Colombia, with growth rates
Table 1: Rates of Investment and Rates of Economic Growth in Selected Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Gross Domestic Investment as % GDP</th>
<th>Rate of Economic Growth % per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botswana</td>
<td>22.2</td>
<td>43.0</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>9.9</td>
<td>70.0</td>
</tr>
<tr>
<td>Ghana</td>
<td>15.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Ivory Coast</td>
<td>18.1</td>
<td>26.3</td>
</tr>
<tr>
<td>Kenya</td>
<td>18.1</td>
<td>24.8</td>
</tr>
<tr>
<td>Mali</td>
<td>15.3</td>
<td>25.5</td>
</tr>
<tr>
<td>Mali</td>
<td>17.3</td>
<td>15.5</td>
</tr>
<tr>
<td>Niger</td>
<td>16.1</td>
<td>27.7</td>
</tr>
<tr>
<td>Nigeria</td>
<td>15.4</td>
<td>26.2</td>
</tr>
<tr>
<td>Senegal</td>
<td>12.8</td>
<td>17.3</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>13.6</td>
<td>13.6</td>
</tr>
<tr>
<td>Algeria</td>
<td>30.1</td>
<td>42.9</td>
</tr>
<tr>
<td>Egypt</td>
<td>15.2</td>
<td>27.4</td>
</tr>
<tr>
<td>Turkey</td>
<td>17.1</td>
<td>24.7</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>11.0</td>
<td>12.3</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>20.6</td>
<td>26.7</td>
</tr>
<tr>
<td>India</td>
<td>17.6</td>
<td>21.6</td>
</tr>
<tr>
<td>Indonesia</td>
<td>11.1</td>
<td>20.2</td>
</tr>
<tr>
<td>Korea, Rep. of</td>
<td>23.2</td>
<td>79.4</td>
</tr>
<tr>
<td>Malaysia</td>
<td>18.1</td>
<td>26.1</td>
</tr>
<tr>
<td>Pakistan</td>
<td>17.2</td>
<td>16.1</td>
</tr>
<tr>
<td>Philippines</td>
<td>20.1</td>
<td>28.7</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>15.3</td>
<td>22.7</td>
</tr>
<tr>
<td>Singapore</td>
<td>23.4</td>
<td>40.7</td>
</tr>
<tr>
<td>Thailand</td>
<td>22.5</td>
<td>26.1</td>
</tr>
<tr>
<td>Argentina</td>
<td>19.4</td>
<td>25.2</td>
</tr>
<tr>
<td>Brazil</td>
<td>22.5</td>
<td>21.8</td>
</tr>
<tr>
<td>Chile</td>
<td>15.8</td>
<td>19.5</td>
</tr>
<tr>
<td>Colombia</td>
<td>20.0</td>
<td>23.9</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>19.0</td>
<td>25.2</td>
</tr>
<tr>
<td>Mexico</td>
<td>20.8</td>
<td>25.7</td>
</tr>
<tr>
<td>Peru</td>
<td>18.8</td>
<td>17.0</td>
</tr>
</tbody>
</table>


1/ At factor cost except for Argentina, Bangladesh, Botswana, Chile, Costa Rica, Ghana, Indonesia, Ivory Coast, Korea, Malaysia, Mali, Mexico, Niger, Peru, Philippines, Senegal, Singapore and Thailand where only GDP growth rates at market prices are tabulated in the above source.
Fig 1: Investment vs Economic Growth

1970-1981
Fig 1: Investment vs Economic Growth

1960 - 1970

Growth Rate %

Inv. Rate %
of over 5%) had high rates of investment, while the low growth countries had generally lower and sometimes declining rates of investment. After scanning similar evidence, Sen (1983) thus concluded, "both in terms of cases of success and those of failure, the traditional wisdom of development economics [regarding the importance of policies which raise savings and the rate of investment] is scarcely contradicted by ... international comparisons." He cites as a negative example the case of Ghana, which in the early 1960s had investment rates of around 25%, yet experienced low, declining and eventually negative rates of growth, with the rate of investment falling to 3% by 1981, and notes that Ghana's slipping back is not at all inconsistent with the earlier models of growth which emphasized the importance of capital wisely accumulated (op. cit. p.750). The inefficiencies in Ghana's investment programs and policies which led to this situation have been well documented 2/.

It is apparent that the contribution of investment to growth cannot be properly assessed unless the social efficiency of investment is brought into the analysis in a satisfactory way. This obvious point might not need elaboration were it not for the following: (1) 'Investment spending', as noted, has come under increasing criticism on the grounds that it is often wastefully applied and does more harm than good. Unfortunately there are many cases where this has been true. But it does not follow from this that if investment were applied efficiently its contribution to growth and development would be unimportant. Indeed, as the examples given below illustrate, the task of applying investment efficiently has always been a major theme of the development literature, and the dispute about investment
was not whether, but how it could be applied efficiently to the task of
growth and development. Nevertheless, (2), there is the awkward conclusion
from the growth accounting literature regarding the apparently minor
contribution of investment to growth even when investment is applied
efficiently. Consider each point in turn.

There is now a huge literature and much instruction taking place
on the methods of investment analysis in which the aim is to influence
policy-makers to choose investments, and the policies which bear on them,
more efficiently. 3/ Furthermore, the discourse over efficiency has not
been narrowly concerned with the maximization of national income, but also
with the raising of living standards of people most in poverty. The issues
are wide ranging, and of course perceptions of which policies and types of
investment are, or are not, efficient have often changed significantly as a
consequence of economic research and developing countries' experiences with
various policies. But three examples may serve to illustrate the main
point.

1. Public and Private investment. In numerous countries it was once
assumed that public investment in large scale 'modern' industry would lead
to faster growth than the promotion of private investment. The political
and economic origins of this assumption are complex; in some countries they
included a historical mistrust of capitalism and a pre-occupation with
market failures, while in others it provided a convenient rationalization
for a large public sector, political patronage, and political control. 4/
But whatever the explanation, the policies were exceedingly costly in two
senses, both being most apparent in African countries, in which (with few exceptions) the shares of the public sector in total investment have been extraordinarily high. First, large-scale state manufacturing industries frequently failed because the domestic markets were not sufficiently developed for their products, because management and labor skills were lacking, and because maintenance was far more demanding than had been anticipated and the industries soon fell into disrepair; consequently, the returns were often not sufficient to cover operating costs, let alone service debt, and the net result was to decrease rather than increase economic output. Second, the policies were expressly pursued to the neglect of the provision of infrastructure and of economic incentives for private investments in agriculture and industry, so it was to be expected that the returns to and rate of such investments would also be poor.

ii. Investment - A Leader or Follower? Related to (i) was the intellectual confusion over whether or not investment 'led' growth. In a series of articles in the 1950s, Cairncross commented that "current discussion fastens too unrelentingly on capital investment, particularly on industrial investment, as the prime means of promoting living standards". In some public expenditure categories, such as roads and irrigation schemes, investment may have a leading role for the development of an area. But in private business, in agriculture, industry and commerce, it is a favorable political, legal, institutional and economic environment to invest profitably that is the key element and it would more accurate to say, I believe, that investment follows rather
than leads economic opportunity. Hence (for instance) the emphasis in much of the development literature on "getting prices right" for public and private investments. Even in the public services, such as electricity, water supply and sewerage, telephones, roads and drainage, it is the growth of demand - and thus the economic conditions that influence it - which determine the scale and type of investment required. In sum, it is now commonly accepted that it is the policies that bear on investment, not just investment in and of itself, which are important for development.

iii. The Efficiency of Investments Aimed at Reducing Poverty Directly. Various policies explicitly intended to raise living standards of people in poverty have been shown to raise the social returns of investment; they are aspects of the theme, 'redistribution with growth'. Examples are the provision of price incentives and supporting services for smallholder agriculture (small farmers 'work' the land more efficiently and use less capital-intensive methods of production), and investment in basic needs programs (water supply, sanitation, health, primary education, and so forth), which aside from being important in and of themselves, are thought to raise the health and productivity of the labor force and have very high social rates of return.

Commenting on the growth models that were influential in the 1950, and 1960s, Krueger (1986) notes that "the optimism inherent in the
view that capital was the main thing lacking has been replaced by an
appreciation of the complexity of development ..... Current thinking would
place equal stress on resource accumulation in both a quantitative and
qualitative sense, and an increased efficiency of resource use in the
economic, managerial and engineering senses of the term." It is neither
right nor proper to suggest, however, that earlier thinking, though
emphasizing the importance of investment, did not place equal or greater
stress on the efficiency of resource allocation; it was constantly
pre-occupied with it:

"Economic growth is associated with an increase in capital per
head. It is, as we have seen, also associated with much else:
with institutions which give incentive to effort, with attitudes
which value economic efficiency, with growing technical know-
ledge, and so on. Capital is not the only requirement for
growth, and if capital is made available without at the same time
providing a fruitful framework for its use, it will be wasted.
In what follows we take for granted all that has already been
said about these other matters. We are thus able to concentrate
upon studying the fruitfulness of capital when conditions are
appropriate to its use."

W. Arthur Lewis, The Theory of Economic Growth (1955, Twelfth Impression,
1978, p. 201).

Turning to the second point raised above, regarding the contribu-
tion of investment to growth, it remains that, even in economies where
investment is applied efficiently, present methods of economic analysis
still lead to the conclusion that investment would raise the growth rate
only by a small amount. Bauer (1981) cites the findings of Abramovitz
showing "that the growth of the capital stock cannot explain most of the
secular increase in output in the West" and quotes the following well-known passage from Kuznets 11/ 

".. while the results clearly vary among individual countries, the inescapable conclusion is that the direct contribution of man-hours and capital accumulation would hardly account for more than a tenth of the rate of growth in per capita product - and probably less. The large part of the remainder must be assigned to an increase in efficiency in the productive resources - a rise in output per unit input, due either to the improved quality of the resources, or to the effects of changing arrangements, or to the impact of technical change or to all three."

Bauer (op.cit p. 248) later on adds that "the same applies to the contemporary Third World. Emergence from poverty there does not require large-scale capital formation ..." With good reasons, he then goes on to criticize numerous examples of wasteful investment in the Third World. As discussed above, however, no economist would seriously condone an investment if it were perceived to be wasteful, and the point that investments are often wasteful helps to explain poor growth performance; it does not follow from the analysis of waste that investment and capital formation are of minor importance. It is more relevant to ask, what would countries stand to gain if investment were applied more efficiently? and, second, which types of investments and the policies that influence them would be efficient? There is a paradox here, which is that, if we apply the methods of analysis used by the authors just cited, we would conclude that even investments with high rates of return would barely raise output sufficiently for a country to avoid stagnant or declining per capita income growth. For example, if a developing country's rate of investment were 20% (quite a good rate) and the average social rate of return to investment 15% (a very good rate), could it only aspire to a growth rate of 0.2 X 15 = 3%
overall, barely sufficient to raise its per capita income given a population growth rate in the range 2-3% \(^{12/}\).

The problem arises, as Maurice Scott has variously argued, with the methods economists use to account for growth. The widely accepted conclusion is that physical investments, efficiently chosen and utilized, account for no more than one quarter of observed growth rates, and investment in education perhaps for another quarter \(^{13/}\). Most of the rest is ascribed to technical progress - though without a prescription as to how, in the absence of investment, developing countries may actually incorporate the fruits of technical progress into their production systems. That this is an unsatisfactory state of affairs was discussed over 20 years ago by Balogh and Streeten (1963), and more recently by Currie (1986) and others. Scott, for example, recently summed up the situation as follows \(^{14/}\).

Models of growth, or methods of accounting for it, assume that technical progress affects economic growth like "manna from heaven" and that

"later vintages of capital goods are better than earlier ones just because they are later, so that their efficiency is purely a matter of time and nothing to do with investment or the yield of investment itself. In vintage theory [of growth] this is precisely what is assumed to happen, but it is wildly implausible. It implies, for example, that if no investment had taken place anywhere in the world between 1881 and 1981 we would have been able to build jet aeroplanes and electric computers despite this century of stagnation."

Actually, vintage theory, with 'capitally-embodied' technical progress, assumes that growth is possible only if new investments embodying higher output per worker are in fact taking place. There is no presumption that this will happen or is inevitable, and it is, I think, more accurate to
conclude that the importance of capital accumulation is emphasized by vintage theory. Parts II and III below draw on Solow's earlier papers on the subject in an attempt to establish the connections between the rate of growth and the rate and allocative efficiency of investment. Scott's criticism, remains apposite, however, when the presumption is made, and also for the case of exogenous technical progress, which is the case on which conclusions as to the apparently 'minor' role of capital accumulation in the growth process rest.

Scott was commenting on growth models with exogenous technical progress fitted to the economic data for the industrialized countries. If applied to developing countries they would also suggest that development is possible without investment - or even when countries invested inefficiently. 15/ It turns out, however, that the models are less applicable to the circumstances of developing countries. The reason is that they have been used to interpret what are generally called the "stylized facts" of economic growth in the industrialized countries, which include roughly constant rates of growth over long periods (abstracting from irregularities associated with economic cycles); constant rates of growth of capital per worker; constant capital-output ratios and, by implication, constant rates of savings and investment; constant rates of profit; and constant income shares as between wage-labor and owners of capital. In developing countries, none of these conditions obtain, and what is most noticeable is how these quantities have changed over time: e.g. the upward shifts in the growth rates of several East Asian and other countries in the 1960s;
declining growth rates in several African countries; and significant
upwards or downwards changes, in the majority of developing countries, in
the rates of savings and investment (and thus of the growth of capital per
worker) in response to upwards or downwards changes of GDP growth (see
table 1). Nor is it likely that the rates of profit were approximately
constant in these circumstances; rather, they more likely were a distinct
function of economic policy, as one might infer from the literature cited
above on the efficiency or otherwise of investments and economic policies
in developing countries. Lastly, income shares have varied with the
capital intensity of the investment policies chosen, with the type of
agricultural development policy chosen and with tenurial arrangements for
agriculture. 16/

Hence present day growth models and methods of accounting for
growth - or at least those models and methods which regard technical
progress as being exogenous, or unassociated with investment - do not fit
the circumstances of the developing countries. As Sen concluded 17/, the
importance of raising the rates of savings and investment in the slow
growth countries is not inconsistent with their experience, nor with that
of the high growth countries, where the rates of savings and investment are
appreciably higher. What is needed is a method for assessing what could be
achieved if investment - and all the that bears on the rate and allocative
efficiency with which it is used - were indeed to be applied efficiently.
II. INVESTMENT, EFFICIENCY AND GROWTH:
SOME AGGREGATE RELATIONSHIPS

To arrive at the relationships, it is necessary (i) to decide whether net or gross investment should be used in the analysis, (ii) to reflect on why it is important to work with the social rate of return to investment, and (iii) to reconsider the old question of how physical investment, as well as investment in education and training, changes labor's income, and whether such changes are properly accounted for in the procedures currently used in growth accounting. The first two topics can be discussed together by reference to papers by Johnson, Shultz and Scott.

The rate of and returns to investment

Over twenty years ago, Johnson suggested that the influence of efficient resource allocation on growth would best be studied through "a generalized capital accumulation approach towards economic development," observing that: 1/

The growth of income that defines economic development is necessarily the result of the accumulation of capital, or of "investment"; but "investment" in this context must be defined to include such diverse activities as adding to material capital, increasing the health, discipline, skill and education of the human population, moving labor into more productive occupations and locations, and applying existing knowledge or discovering and applying processes. All such activities involve incurring costs, in the form of use of current resources, and investment in them is worth while if the rate of return over the cost exceeds the general rate of interest, or the capital value of the additional income they yield exceeds the cost of obtaining it. From the different perspective of planning, efficient development involves
allocation of investment resources according to priorities set by the relative rates of return on alternative investments.

Similarly, Schultz (1970, pp. 301-2), who refers to Johnson and seemed to hope "that we have disposed of the residual", remarked that "growth problem, thinking in terms of economic decisions, requires an investment approach to determine the allocation of investment resources in accordance with the priorities set by the relative rates of return on alternative investment opportunities. It is applicable not only to private decisions but, also, to public decisions .... For example, the investment in research where the fruits of it do not accrue to the individual researcher or his financial sponsor but are captured by many producers and consumers.....For particular investments, and there are many areas in the domain of human capital, the value of the resources added (services rendered) is exceedingly hard to come by. It is all too convenient to leave the hard ones out, yet each and every omission falsifies the true picture of the full range of investment opportunities."

In these remarks Johnson and Schultz are explicit about the crucial importance of a proper classification and enumeration of investment and consumption activities, a task taken up by Scott in the references cited. A large number of previous studies and the accounts data they use are shown to be faulty in this respect. Many expenditures commonly classified as consumption, including (but not only) so-called capital consumption or depreciation expenditures, turn out, on a closer inspection, to be a sacrifice of consumption intended to raise economic output; that is, they
would be better classified as investments. As Scott remarks (op. cit., pp. 212-213):

"In a static economy all output would be consumed and investment would be zero. There would, of course, be expenditure on maintenance, but that should be regarded as part of the current costs of production. If output is to grow, the static economy must be changed. It seems to me that this will involve incurring expenditures which need not be incurred in a static economy, for the building of new buildings, roads, vehicles, machines, etc., and the improvement of existing ones, for moving labor from places where its marginal product is low to where it is high, for improving labor quality through better health, education and skills, for developing new products, processes, markets and sources of supply, and so on. All these changes are costly, and so involve a present sacrifice of consumption in the hope of subsequent gain."

While some of these expenditures, such as those on new buildings and machines are sometimes counted as investment, in practice they are often unwittingly netted out of the analysis by imprecise distinctions between consumption and investment, and between maintenance and depreciation. Further, the neglect of the role of maintenance in preventing the physical depreciation of an investment together with the practice of regarding depreciation as capital 'consumption' leads to underestimates of the proportions of gross investment that are, on closer inspection, devoted to introducing economic change and growth. It is true that some studies are more careful in these respects, but Scott's review shows that the issues remain important nevertheless. 2/

In the following analysis the relevant measure of an investment is taken to be its gross value, with its economic lifetime, for a physical investment 3/, being defined by the point at which its quasi-rents become
zero or negative on account of changes in relative factor costs, product prices or markets. Any provision to keep an investment in service up to the end of its economic lifetime is not regarded as 'depreciation' but as maintenance, which in turn is considered as part of the operating costs. 4/ The net present value of investment is the discounted value of its quasi-rents less the discounted value of actual investment expenditures (which may take place over several years for investments with long lead times). These procedures follow Scott (1981), Salter (1960) and are also standard in cost-benefit analysis.

**Investment and the Redeployment of Labor.**

Current methods of accounting for growth also under-state the gains in output arising from the effects of investment on the redeployment of labor and thus on labor's income. Most growth accounting studies attempt to allow for the output and income gains from redeployment, but only for broadly defined occupations--e.g., for the movement of workers from agriculture to industry, defined at the one-digit level. The practice is broadly as follows 5/. The labor force is grouped according to the occupations, educations and ages of its male and female members. The contribution of the redeployment of labor to the growth of income is then taken to be a weighted average of the rates of change of the proportions of the labor force in each group, the weights being the average incomes of labor in each group divided by national income per worker. Then (i) if there is a net movement of workers from, say, agriculture to industry, with wages being higher in industry, there is a rise in income attributable to
the redeployment of labor from agriculture to industry; (ii) if there is an increase in the proportion of workers in the higher paid, higher educated groups, there is a rise in income attributable to redeployment associated with investment in education; (iii) if there is an increase in their average age, such that a greater proportion of workers are in the higher paid age groups, there is a further rise attributable to the increased experience of the labor force; and (iv) if there is an increase in the proportion of women in the labor force, the average contribution of the quality of labor to the growth of income may be estimated to fall, since women, within any particular education-age-occupation group, are paid less than men. 6/

It is likely that a greater disaggregation of occupational or industrial groupings would show the rate of redeployment of labor force, and the increases in income derived from redeployment, to be significantly greater than the analyses following the above approach have so far concluded. Take manufacturing activities for example, which are treated as homogenous group in most studies. In the course of economic growth both the size distribution and the composition of activities change appreciably over time — e.g., from a concentration of employment in small-scale cottage industries and workshops in food processing, textiles, wearing apparel and light engineering, towards a greater concentration on heavy engineering. 7/ The earnings differentials between these activities for workers of a given age and education are often large, e.g., over a 2 or 3 to one range as between large and small firms in a given industry, 8/ and it follows that an application of the above method of analysis would
attribute some, if not a large share of the observed increases of incomes of labor in manufacturing to redeployment **within** manufacturing. Similar remarks can be made about changes in the scale and composition of activities within agriculture (arising, e.g., from the transition from manual tillage to the use of draft animals, or from mechanization, changes in crop varieties, changes land tenure systems, investment in irrigation and so forth) 9/, commerce (arising from changes in the types and scales of retailing, wholesaling and banking activities for example), transport and construction. Furthermore, each generation of the labor force is continually redeploying itself through the introduction of new, higher technology industries and products in the industrialized countries, or through diversification of the industrial base in the developing countries. Insofar as the new industries are associated with higher productivity and earnings levels for workers in a given age and education group, a redeployment of the labor force towards them will again account for some - if not a large share - of the observed increases of both labor's income and value added.

It is unlikely, however, that a greater disaggregation of industries or of occupations, say to the 4 or 5 digit level, would provide a satisfactory estimate of the rate of redeployment that takes place as a consequence of investment in a growing economy, even assuming the formidable difficulties of data gathering and compilation could be solved. The reason is that workers of a given age and education may be redeployed by material investment without changing their industry or occupation-- or even their firm or place of employment. In agriculture, for example, changes
from rainfed to irrigation crops, from traditional to high yield seed-fertilizer varieties, from the use of bullocks to the use of tractors, all bring about a redeployment of agricultural labor, often without changing the crop variety. In factories, labor may be redeployed and, often, retrained at regular intervals in order to introduce new machines and new managerial methods with higher outputs per worker to produce essentially the same product. It is not difficult to think of examples in other industries, each being associated with a change in the nature of work, economic output and ultimately labor's income.

Since greater disaggregation will not work, let us consider an alternative approach towards estimating the effects of investment on labor's income drawing on vintage theories of growth. To begin, a 'pure', aggregate vintage model will be taken, after which various attempts will be made to generalize it, first to incorporate the influence on growth factors not embodied in new investment directly, and then to make the analysis less aggregative.

An Accounting Relationship for the Case of Embodied Technical Progress

Following the constructs of vintage theory 10/, Figures 2a and 2b show plots of output per worker against the numbers of workers deployed on various vintages of investments. Figure 2a shows a steady growth case, in which new vintages of investment with high outputs per worker are continuously redeploying workers from old vintages. Figure 2b shows a more
'dualistic' case in which the new vintages only redeploy a small fraction of the labor force still in traditional activities; it is discussed later.

First consider the steady growth case. Output per worker on the latest vintage, \( v \), is denoted by \( b e^{bv} \), where \( b \) is the rate of growth of output per worker, while on the oldest vintage still in use, it is \( b_0 e^{b(v-n)} \), where \( n \) is the economic lifetime of the investments. When a new vintage is introduced it will have higher quasi-rents. If the labor force were fully employed, or alternatively if the labor requirements of the new vintages exceeded unemployment levels plus the number of new entrants to the labor force, then labor would have to be redeployed from existing investments. As Solow explains, in any competitive economy, or in any planned economy maximizing output per worker, they would become redeployed from the oldest investments, which would be duly retired. Further, in a competitive economy, wages would be bid up to the point where the quasi-rents of the oldest (marginal) investments remaining in operation were zero (or close to zero). That is, the output per worker on the oldest investments determines the wage rate, which rises whenever those investments are displaced by, and labor is redeployed on, new investments. In explaining this, Solow (1970) considers the case history of a single factory as follows: 11/

"When it is new it earns profits equal to the difference between its productive capacity and its wage bill. As it ages, its productive capacity is unimpaired and its output per man is unchanged. But if, as is normal, the real wage rises through time because of technological progress and the competition of newer and more efficient factories, its bill will rise and its profits will diminish. Eventually the wage rises as high as the output per man in this factory and it
has become the marginal no-rent factory. Let the wage go a touch higher, and this factory goes out of business; it has become obsolete, not because of any reduction in its efficiency, but because the rising real wage has rendered it incapable of covering its own variable costs of production."

The only point one might add to this is that "old" factories may continue to operate in these circumstances by introducing the new methods of production, i.e. new vintages, themselves-- that is, by redeploying their own workers.

Now consider the question, what is the rate of return to investment in a period of steady growth, in which workers are being continually redeployed as just described, and real wages and real output per worker are rising? It is defined as the discount rate which equates the (gross) expenditures on new investments with the present worth of the quasi-rents over the economic lifetime of the investments. Let the annual output (value added) of investments introduced in v be \( q_v \). If we take exponential instead of compound growth to simplify algebra, then \( q_v = E_v b_o e^{bv} \), where \( E_v \) denotes the number of workers deployed on the investments introduced in v. The annual outputs of the investments, the growth of wages, and the (declining) quasi-rents are shown as dotted lines on figure 2a, and correspond to a stylized form (shown in the lower half of figure 3) of the costs of and returns to investments frequently encountered in project analysis. The net present value (NPV) of the outputs of these investments is thus given by:
Figure 2: A
Vintage Model: Employment, Productivity, Wages and Quasi-Rents for Successive Vintages of Investments

- Value added (net of maintenance) per worker
- Output of investments introduced in v
- Growth of wages on investments introduced in v.

Figure 2: B
As above, but with low rates of redeployment of the labor force on new investments (large shares of labor force on "old" vintages)
Figure 3:
Variations Over Time of Costs, Gross Output, Intermediate Inputs, Value Added, Wage Bill and Quasi-Rents of an Investment

ACTUAL VARIATIONS:

STYLISED FORM OF ABOVE:
where $I_v$ is the present value of the expenditures on investments whose outputs first appear in $v$, referred to the period $v$, $r$ is the discount rate, and $n$ is the average economic lifetime of the investment; as discussed above, $n$ is defined by the time when their quasi-rents have declined to zero. Denoting total economic output in $v$ by $Q_v$, and the annual rate of investment in $v$ by $i$, we also have

$$I_v = iQ_v$$

(This expression is really an approximation because the effects of lead times on the value of $I_v$ are being ignored for the moment.)

Total economic output in $v$ is given by the sum of outputs from all investments being utilized in $v$, i.e. by

$$Q_v = \int_{v-n}^{v} q_t \, dt$$

while the rate of change of output is obtained by differentiating (3) to give
\[
\frac{dQ_v}{dv} = \int_{v-n}^v q_t \cdot dt + q_v - q_{v-n} = q_v - q_{v-n}
\]  \hspace{1cm} (4)

(Note that \( \frac{dq_t}{dv} = 0 \) in the present case because the outputs of investment are, for the present, being assumed to be constant after they are brought into service.) From (4), the net change in output equals the output from new investments less the outputs of investments about to be retired. Since \( q_v = E_v b e^{bv} \), \( q_v - q_{v-n} \) can be written as \( q_v (1 - (E_{v-n}/E_v) e^{-bn}) \). If the labor force, \( L_v \), is growing at a rate of \( c \) per year, and the rate of redeployment, \( E_v/L_v \) is constant, then the expression for \( q_v - q_{v-n} \) further simplifies to \( q_v (1 - e^{-gn}) \), where \( g = (b+c) \) is the rate of economic growth. This simplification is used below since it reduces notation without affecting the analysis in any basic way.

To complete the above relationships, there is also the condition that investments are retired once their quasi rents have become zero, i.e. when

\[
W_{v,v+n} = q_v
\]  \hspace{1cm} (5)

For this to hold, we are also including the opportunity cost of entrepreneurial labor in the wage bill.
The above five expressions are sufficient for a relationship between the allocative efficiency of investment and the rate of economic growth to be derived. Taking \( g \) to be the exponential rate of growth and \( w \) to be the growth rate of wages, noting that \( g = \frac{1}{Q_v} \left( dQ_v / dv \right) \), and using (2), (4) and (5) in (1), gives

\[
\text{NPV} = \frac{1-e^{-nr}}{r} - \frac{e^{-wn} - e^{-rn}}{(r-w)} - \frac{i(1-e^{-ng})}{g}
\]  

(6)

In the pure vintage model sketched in figure 2a the growth rate of wages, \( w \), equals the growth rate of output per worker, \( b \). However, the above expression is applicable to a slightly more general case where the two may be different (as they often are in practice). In the developing countries real wages frequently grow more slowly than output per worker over long periods, and it seems important to allow for such possibilities.

To facilitate the interpretation of (6), redefine \( r \) to be the social rate of return and (by definition of the latter) set the \( \text{NPV} = 0 \). Also, note that the ratio of the second term to the first on the right hand side of (6) is the present value of labor's share in output; like the more familiar quantity, labor's share in current output, it would seem to merit its own definition and notation in the analysis. Denoting it by \( S \), (6) becomes,

\[
g = \frac{\sigma i r}{(1-S)}
\]  

(7)
where \( \sigma = \frac{(1-e^{-ng})}{(1-e^{-nr})} \). Since \( \sigma \) depends on \( r \) and \( g \), and \( S \) on \( r \), any solution for \( g \) in terms of \( i, r \) and \( S \), or for \( r \) in terms \( g, i \) and \( S \), has to be obtained iteratively. It turns out (see Part IV) that (6) is easier to work with in this respect, e.g. by scanning a range of \( r \)'s to find the value which makes NPV zero, as is the practice in project analysis. However, since \( \sigma \) and \( S \) are fairly stable quantities, (7) is easier to interpret.

The main point that emerges from (7) is that investment's contribution to the growth of economic output is significantly higher than growth accounting studies usually find, on account of its influence on the growth of wages. This is the reason for the \((1-S)\) term in the denominator. New investments not only generate annual returns of the order of the product \( ir \) for the investors, but also, as the vintage model makes clear, raise real wages by redeploying labor from one kind of activity to another - more productive - kind. Recalling the calculations of Cairncross and Kuznets referred to above, the effects of investment on growth are thus not measured by \( ir \), but by \( 1/(1-S) \) times this product, and, since \( S \) is typically in the range 60-75\%, the 'total' effects of investment on growth may be, in an economy redeploying its labor in productive ways, of the order of 2.5 to 4.0 times the estimates of these early studies 12/.

It should be emphasized that both Cairncross and Kuznets were careful to qualify their conclusions about the apparently small contribution of investment to changes in output, drawing attention to relationships between the two variables that are difficult to quantify 13/. However, the
point remains that if investment's contribution to growth is measured only in terms of the returns to investors, an exceedingly low estimate of its contribution is bound to emerge. Nor is this problem overcome by attributing changes in the quality of labor, as defined and estimated according to procedures discussed above (and later in more detail in Part V), to that part of investment devoted to education. First, as Nelson has variously pointed out [14], it is difficult to see how a more educated labor force can be fruitfully employed unless the complementary physical investments are in place; in practice, it is the joint product of physical and human investment which is important for growth. Second, in several growth accounting studies, there is a significant contribution to growth arising from the redeployment of workers in a given education group from one sector to another [15], e.g. from agriculture to industry. But the question must be asked, how can such redeployment, and the real wage gains associated with it, occur without physical investment either in industry to employ previously agricultural workers, or in agriculture to maintain or increase agricultural output with a reduced agricultural labor force? The same question arises, thirdly, with respect to the real wage gains associated with redeployment within sectors. On the second and third points, vintage theory, it seems to me, gives clearer answers.

A Purely 'Dualistic' Case: An Aside

It may help to demonstrate the influence of investment on redeployment and wages further if we consider the case depicted in figure 2b, in which investment is being concentrated in the 'modern' sector of a
developing country, with high outputs per worker but with, also, low labor-capital ratios and thus low rates of redeployment of workers from the traditional sector. The figure depicts what are often termed 'dualistic' or 'bimodal' forms of development (see e.g. Stewart (1977) and Johnston and Kilby (1976)). It has turned out, in some countries, that outputs per worker in the modern sector have sometimes fallen below those of the traditional sector; this case will be considered too, and may serve to show, in reference to Scott's criticism of vintage theory quoted above, that the theory can be adapted to cases where output per worker not only does not rise with investment, but may even fall if the contradictions in economic policy become extreme. The technical progress term, 'b', in other words, need not be viewed as an exogenous parameter, but as quantity varying over time with (among other things) the rate of and returns to investment 16/.

Let the output per worker in the modern sector be denoted by $b_m$, and in the traditional sector by $b_T$. To simplify algebra, though without losing the main point, changes of $b_m$ and $b_T$ over time are ignored. The labor redeployed from the traditional to the modern sector in period $v$ is denoted by $R_v$. The present worth of the quasi-rents on investments made in $v$ is then given by

$$\sigma_1 R_v b_m (1 - b_T/b_m) / r$$

(8)

where $\sigma_1 = (1 - e^{-rn})$. Since wages are not rising in this model, $n$ is large and $\sigma_1$ is approximately unity. Investment in $v$ is given by $iQ_v$, where $Q_v$
is total output in $v$, or by $\frac{i\Delta Q_v}{g}$, since $\Delta Q_v/Q_v = g$. Ignoring, for the moment, the growth of the labor force, the growth in output due to redeployment is given by $\Delta Q_v = R_v \left( b_m - b_T \right)$, and, multiplying this expression by $\frac{i}{g}$ (to obtain total investment in $v$), equating the result to (8) (so that $r$ again becomes the equalizing discount rate) and solving for $g$ gives:

$$g = \frac{1}{1 + \sigma_i} ir \quad (9)$$

In this case, growth is a function of the returns to investment only, with the redeployment of labor having no additional effects on value added because real wages and the marginal product of labor are unchanged. It might be thought that $r$ would be higher in this situation, on account of real wages not rising. Paradoxically, however, in economies with dualistic development there is evidence that it has sometimes been lower: e.g. the economic returns to more labor demanding investments in small-holder agriculture, and in small scale industry and commerce, which together employ perhaps 75 to 95% of the labor force in the African and South Asian countries, and more than 50% of it in Latin America, have consistently been found to be comparable to or greater than those in large scale activities promoted by the industrial incentives structures and by direct public investment 17/. It is the more labor demanding policies towards agriculture and industry, involving higher rates of redeployment within and between these sectors, which have been found to have the better returns to investment.
Returning to an earlier point, there have been some countries, of which Ghana is an example, where there are reasons and evidence for thinking that \( b_m \) was less than \( b_T \), such that \( r \) was negative as, eventually, was \( g \). As noted earlier, that wasteful investment spending may lead to declining or negative growth is not inconsistent with the capital accumulation approach to growth and indeed could be predicted by it, as it is hoped that the above (if elementary and stylized) use of the constructs of vintage theory has shown.

**Disembodied and Embodied Technical Progress Together**

The analysis has so far concentrated on a standard case of embodied technical progress, in which growth originates from new investments with higher outputs per worker than investments already in place, or from investments intended to 'modernize' (raise outputs per worker) in the latter. Now consider the effects on the returns to investment and growth of factors not embodied in new investment directly. Familiar examples are growth in agriculture arising from improvements in husbandry, and growth in industry and commerce arising from improvements in organization and reductions in managerial or "X" inefficiencies. Negative examples might be the economic costs bureaucratic and political harassment of public and private enterprises, which affect not only the choice and rate of investment (and thus the rate of embodied technical progress) but how well investments in place are worked and managed (and thus the rate disembodied technical progress). There are also some cases in which increases in output per worker, though seemingly disembodied from direct investment, require it in
significant amounts indirectly, as for example with public investment in agricultural extension services to improve husbandry as well as to facilitate the dissemination of the results of scientific research \(^{19/}\). However, one of the two main effects of such indirect investments is to raise the returns to investments already in place (the other being to raise the returns to new investments) such that output per worker, \(b_0 \exp (bv)\) in the preceding notation, is no longer constant after \(v\), but may rise (or fall, if managerial problems or bureaucratic harassment become worse) and, in this sense, the output per worker is not fully defined by, i.e. embodied in, the investment at the time it takes place. Again, it seems important to consider such possibilities as well.

Such sources of growth can be thought of as increasing the quasi-rents and thus the returns to investments in place and investments about to be commissioned (brought into operation). Changes in quasi-rents might also affect the deployment of labor on various vintages of investments and thus real wages, as is apparent, for instance, if a general upwards shift of the curve of output per worker is considered in figures 2a and 2b. The effects might be quite complicated depending on the incidence of the efficiency improvements on the various vintages of investments. But suppose (to take a simple case) they increase outputs per worker at a rate of \('d' per year on each vintage of investment, with \(q_{vt}\) being the output in year \(t\) of investments in the amount of \(I_v\) commissioned in year \(v\) (\(t \geq v\)). As before, let \(S\) be the present value of labor's share in output. Then by definition of the rate of return,
Using the previous notation, the value of \( q_{vt} \) is now given by

\[
q_{vt} = \frac{E_v b e^{(b+d)v+d(t-v)}}{1-S}
\]

The first term inside the exponent recognizes that new investment may capture the managerial and other such efficiency improvements as well, while the second term represents the effects of such improvements on the investment's output after it has been commissioned. Since \( q_{vv} \) represents the output of investments commissioned in \( v \) in their first year of service (\( v \)), it simplifies notation to re-write the last expressions as

\[
q_{vt} = q_{vv} e^{d(t-v)} \tag{11}
\]

Total output in \( v \), \( Q_v \), is then given by

\[
Q_v = \int_{t'=v-n}^{v} q_{t',v} \, dt' \tag{12}
\]

The variable \( q_{t',v} \) has the same form as (11), with obvious changes in notation. Substituting (11) into (12), and differentiating (see (4) above) leads to the following expression for the rate of change of output:

\[
\frac{dQ_v}{dt} = d.Q_v + q_{vv} - q_{v-n,v} \tag{13}
\]
But \( q_{v^n} - q_{v-n,v} \) can be written as \( q_{v^n} (1-(E_{v-n}/E_v)e^{-(b+d)n}) \), which again suggests the approximation \( q_{v^n} - q_{v-n,v} \approx q_{v^n} (1-e^{-qn}) \), assuming that the rate of redeployment is constant over time.

Substituting (11) into (10) and integrating, substituting for \( q_{v^n} \) from (13) in the resulting expression, noting that \( g = (1/Q_v)(dQ_v/dt) \) and taking \( I_v = iQ_v \) (we are continuing to ignore lead times for the moment), leads to

\[
g = \sigma r/(1-S) + d[1-\sigma i((1-S)]
\]

To compare this result with that of the 'pure' vintage case discussed above, denote the values of \( g, r \) and \( S \) in the latter case by the subscript 1, and in the present case by the subscript 2. The difference in the rates of growth in the two cases is \( d \), i.e.

\[
g_2 = g_1 + d
\]

where \( g_1 = \sigma i r_1/(1-S_1) \), while \( g_2 \) is given by (14) with the subscripts 2 attached to \( r \) and \( S \). It follows that, comparing (14) and (15),

\[
d = r_2 - r_1 (1-S_2)/(1-S_1)
\]

assuming \( S_2 > S_1 \).
Hence the contribution to growth of factors not directly embodied in investment can be measured by their effects on the returns to investment—in the present case, by the change in the returns to investment. Substituting for $r_2$ from (16) into (14) leads to

$$g_2 = \sigma r_1/(1-S_1) + \sigma d_1/(1-S_2) + d[1-\sigma_1/(1-S_2)]$$

(17)

The first term on the right hand side of (17) represents the rate of economic growth due to factors embodied in investments at the time they are brought into service. The second term, $\sigma d_1/(1-S_2)$, represents the effects on growth managerial and other such sources of efficiency improvement being captured by new investments. Note that it can be written approximately as $\sigma_1(r_2-r_1)/(1-S_2)$, so that not only is there a gain in terms of the returns to investment, measured by $\sigma_1(r_2-r_1)$, but a gain arising from the influences of disembodied sources of economic growth on the growth of labor's income as well (as we would expect if we consider an upwards shift of curves representing outputs per worker in Figure 2a); hence the appearance of $(1-S_2)$ in the denomination of this term. The third term, which is $d_1$ (the full growth effect of disembodied factors) minus the second, thus represents the effects on output of efficiency improvements to investments in place.

In the case considered, the effects of efficiency improvements not directly embodied in investment may be quite large, since they were considered to apply to the entire capital stock. If such improvements were confined to a smaller share of the capital stock (as they often are in
practice) the effects would be smaller. But the underlying conclusion remains the same. This is that, improvements in managerial and other sources of efficiency seemingly not embodied in investment directly can nevertheless be viewed as influencing growth by influencing the returns existing and new investments, and cannot accomplish much without them. Their economic desirability or otherwise (since they often entail significant indirect costs) can also be assessed using the economist's standard measure of economic efficiency, the social rate of return to investment.
III SOME GENERALISATIONS AND A MORE DISAGGREGATED RELATIONSHIP

In the analysis in Part II, the cost and revenue streams associated with investment were taken to have a simple form, with the yearly value added by an investment being assumed constant over its economic lifetime in the 'pure' investment-embodied case, or changing at a steady rate of $d$ per year with changes in managerial efficiency and other influences not initially embodied in investment. Furthermore, the only changes in prices considered were those of labor relative to other inputs and outputs together while the changes in labor costs were also assumed to take a simple exponential form. The assumptions were depicted graphically in the lower half of Figure 3. They are obviously restrictive assumptions, and it is necessary to determine how they might be relaxed:

- the value added each year by an investment may change appreciably over economic cycles, or with weather, political shocks, and other other random factors;

- it may also change over time with "learning-by-doing" and with the experience of the labor force working on the new vintages of investments;

- maintenance costs may rise (and generally do) as the investments age, leading to a decline in quasi-rents even if labor costs were to remain unchanged; and, more generally,
relative prices of outputs and inputs may change with innovation, changes in terms of trade and scarcities in the supply of certain factor inputs.

In general, and after smoothing out random and cyclical factors, the outputs and costs of an investment may look more like the form shown in the upper half of Figure 3 than in the rather stylized form shown below it.

It is apparent that once one begins to allow for such realities, explicit algebraic relations between the growth of output, investment, and the returns to investment (including the returns to labor), become more difficult to derive. But two points can I think fairly be made. First, when we are considering how the rate and efficiency of investment influence growth the principle of comparing the present value of the change in output (value added) associated with investment with the present value of the investment and labor costs of producing it remains applicable. The computational difficulties of estimating the returns to investment and to labor from data on output, investment and wages are significantly increased; and, as will be seen, it is also not easy to arrive at a simple formula for identifying changes in aggregate output with the various vintages of investments producing them once simple trend relationships are not applicable. However, it seems to me that the basic accounting identity for the rate of return or NPV of investment remains a valid starting point for analysis. Second, it is still useful to know how the averages of the various quantities of interest (1, g, r, and S) relate to each other in more complicated situations and how they might be estimated. Below, the
accounting relationship is first re-stated in general terms, after which a relationship between the averages of the four variables is derived.

Let $q_{vt}$ denote the output in year $t \geq v$ of investments commissioned (brought into service) in year $v$, with $I_v$ being the costs of the investments; $q_{vt}$ may vary over the period $t = v$ to $v+n$ for any one or all of the reasons discussed above, and also on account of changes (positive or negative) in managerial efficiency. As before, we have the accounting identity:

$$\left(1-S_v\right) \int_{v}^{v+n} q_{vt} e^{-r(t-v)} dt - I_v = 0$$

where $r$ is the rate of return to investment. Alternatively, $r$ could be the social discount rate, in which case the right hand side would not be zero but the social NPV; however, working in terms of the rate of return makes no material difference to the analysis. $S_v$, which like output and investment may vary over time, is again the present value of the labor costs divided by the present value of the output of the investments commissioned in $v$.

Also as before, the total output in $v$, $Q_v$, is the sum of outputs of all investments still in service or being utilized in $v$, i.e.
\[ Q_v = \int_{v-n}^{v} q_{t',v} \, dt' \quad (19) \]

while the change in output is given by the derivative of \( Q_v \),

\[ \frac{dQ_v}{dv} = \int_{v-n}^{v} \frac{\partial q_{t',v}}{\partial v} \, dt' + q_{vv} - q_{v-n,v} \quad (20) \]

I.e., the change in output in \( v \) equals the sum of changes in the outputs of the existing capital stock (the first term on the right hand side) plus the output of the new investments \( (q_{vv}) \) minus the value of the outputs no longer provided by investments retired in \( v \) \( (q_{v-n,v}) \). Lastly, and still ignoring the lead times of investments for the moment,

\[ I_v = iQ_v \quad (21) \]

As noted above, these basic relationships would seem to hold even when \( q_{vt}, q_{t',v}, Q_v, S_v \) and \( I_v \) vary with \( v \) and \( t \) in a manner less simple than in the cases considered Part II. Given sufficient information on output, labor costs and investment over time (and in sufficient detail such that the allocations of outputs and costs among the various vintages of investment can be identified reliably) no recourse to approximation or simplification would be necessary, at least in theory. In practice, however, such information is not available, so it might be helpful to see what kind of approximations are involved on using more commonly reported quantities.
Some headway can be made by defining two output variables and by taking averages. Let $\bar{q}_v$ be the mean output of the investments commissioned in $v$ over their lifetimes, and $u_{vt}$ be the deviations of their annual outputs from the mean. The variable $u_{vt}$ may be negative in the early years as outputs gradually build up to full capacity levels; negative in later years, as maintenance problems increase and the investments are gradually worked shorter hours until they are taken out of service; positive or negative at other times on account of business cycles, random factors, and so forth; rising or falling if there are any systematic improvements or deteriorations in managerial efficiency; and rising or falling with relative changes in factor and product prices. By definition of $\bar{q}_v$ and $u_{vt}$, the integral of the latter over $t = v$ to $v+n$ is zero. Below, the approximation is also used that the integral of the discounted value of $u_{vt}$ over this period is zero (which helps to simplify (18)). This approximation is quite accurate with respect to the treatment of random and cyclical factors, though less so with respect to more systemative deviations from the mean (if the latter are large, more general expressions for $q_{vt}$ than $\bar{q}_v + u_{vt}$ might be warranted). With these definitions, (18) becomes

$$\left(1-S_v\right) \bar{q}_v (1-e^{-\tau_n})/r - I_v = 0$$

(22)

while the various terms in (20) become

$$q_{vv} - q_{v-n,v} = \bar{q}_v - \bar{q}_{v-n} + u_{vv} - u_{v-n,v}$$

(23a)
and

\[ \frac{\partial}{\partial \nu} t' \nu = \frac{\partial}{\partial \nu} u t' \nu \]  
\[ (23b) \]

Substituting for \( q_{v}, q_{v-n,v} \) and \( \tilde{q}_{t' v}/\nu \) from (23a) and (23b) in (20), dividing through by \( Q_{\nu} \) (to give the growth rate), integrating over an interval \( \nu = 0 \) to \( T \), where \( T \) denotes the period over which growth performance is being studied, and dividing by \( T \) (to give the average growth rate \( g \)), the \( u \)'s and their derivatives average out to zero, leading to

\[ \bar{g} \approx \frac{1}{T} \left( 1 - e^{-\bar{g}_T} \right) \int_{0}^{T} \left( \bar{q}_{v}/Q_{\nu} \right) d\nu \]  
\[ (24) \]

where we have taken, as before, \( \bar{q}_{v-n,v} \) to be \( (1 - e^{-\bar{g}_T}) \bar{q}_{v} \). Lastly, dividing (22) through by \( Q_{\nu} \), and taking the average values of the various terms over the interval \( 0 \) to \( T \) (which enables us to substitute for \( \bar{g} \) from (24)), then an expression similar to the one derived in Part II emerges, namely \( \bar{g} / \bar{s} \);

\[ \bar{g} = \bar{\sigma} \bar{I} \bar{r}/(1-\bar{s}) \]  
\[ (25) \]

where the variables \( \bar{\sigma}, \bar{I}, \bar{r}, \bar{s} \) are now averages over the period of interest.

On interpreting (25) and its differences between the expressions derived in Part II, there are four comments to be made regarding the averaging process itself, the lead times of investments, the calculation of \( \bar{s} \), and disaggregation.
First, the taking of averages does not mean that the numerous events which may influence an investment's output over its lifetime after it has been commissioned are neglected from the analysis. The value of $\bar{q}_v + u_{vt} = q_{vt}$ in general cannot exceed the capacity output of an investment, which means that the larger the $u$'s, the smaller the average output $\bar{q}_v$, the smaller the average quasi-rents, the smaller the rates of return to investment and thus the smaller contribution of investment to the growth of output. In other words, the transitory factors represented by the $u_{vt}$'s exert their influence on growth through their influences on quasi-rents and this effects on the average returns to investment; they may also affect the rate of investment and labors' share in output. It should be added that the division of a particular vintage of investment's contribution to output into transient and average terms is in any case only one of several ways of expressing $q_{vt}$. E.g. it could be formulated to include a constant, a trend term (as was done in Part II, for the case embodied and disembodied technical progress together), a learning curve and cyclical terms, wherever the evidence suggests such terms are warranted; $u_{vt}$ would then become a random variable and the preceding approximations very small; such changes would serve to generalize the results, but would however not alter the underlying principles of the analysis.

Second, a comment ought to be made on the lead times of investments, a subject the analysis has so far neglected. Lead times vary greatly with the kinds of investments taking place, from a few weeks or months for machinery and equipment, to one to five years or more for factories, power plants, physical infrastructure, irrigation works and so
forth, and sometimes to more than 10 years for investments in, say, agricultural extension and research to have significant effects. Thus investments taking place in \( v \) do not have their effect on output until \( v + \) years later (depending on when they were begun in the period \( v - t \) to \( v \)), where \( \bar{\gamma} \) is the lead time of the investments, while the output of activities started up in \( v \) rests on investments taking place over the period \( v - \) to \( v \). Lead times raise the discounted costs of investment (if the discounted values are referred to period \( v \)), or alternatively lower the discounted benefits (if the discounted values are referred to the time when investments activities begin, \( v - \)). Taking the former case, we can define the proportionate effects on costs by a term \( L_v \), where

\[
L_v = \int_{t=v-\bar{\gamma}}^{v} a_t e^{-r(v-t)} dt, \quad \text{and} \quad \int_{t=v-\bar{\gamma}}^{v} a_t dt = 1
\]

Here, \( a_t \) represents the profile of investment expenditures, such as that depicted in Figures 3a and 3b. In this case, and again taking an average value of \( L_v \), (25) becomes

\[
\bar{g} = \bar{\sigma} \bar{f} \bar{\bar{L}} \bar{r} / (1 - \bar{S})
\]

(26)

Third, turning to the calculation of \( \bar{S} \), the main difference between this variable and the more familiar quantity, labor's share in current output (denoted by \( \bar{S}^* \)), is that the effects of discounting are to give the present value of labor's share in the (present value of) output a lower weight towards the end of an investment's lifetime, when labor's
share in output is high (see e.g. Figures 3a and b). Thus \( \bar{S} \) is generally lower than \( \bar{S}^* \), though not appreciably (because output is being discounted as well as wages). The procedures for calculating \( \bar{S} \) from data on wages (or on \( \bar{S}^* \)) follow, I think, fairly straightforwardly from discounted cash flow formulae (see e.g. table 2, f.n.2 in Part IV). When wages are constant, \( \bar{S} \) equals \( \bar{S}^* \).

Lastly, turning to disaggregated forms of (26) the basic point to note is that the accounting identity, (18), is applicable to any investment, while (20) represents the aggregate change in output from all individual investments and (21) the aggregate of cost of the investments. Denoting each investment activity by \( j \), the disaggregated form of (26) is readily shown to be

\[
\bar{g} = \frac{1}{J} \sum_{j} \bar{L}_j \bar{h}_j \bar{F}_j / (1 - \bar{s}_j)
\]

(27)

where the \( \bar{h}_j \) represents the average share of investment in activity \( j \) over the period 0 to \( T \). This relationship doesn't rest on any particular assumptions as to the number of investment activities or sectors. The composition of such activities or sectors within the group defined by \( j=1 \) \( \ldots J \) can be thought of as changing over time, with old sectors becoming a zero sub-group of \( J \) once they are obsolete, and new sectors having been a zero sub-group before their appearance. The lead-times and lifetimes of investments also differ among the sectors.
IV. IMPUTED AVERAGE RATES
OF RETURN TO INVESTMENT FOR SOME COUNTRIES

The following exercise uses the aggregate relationships derived in Parts II and III to impute the rate of return to investment from data on g, i and S for some developing and industrialized countries. The aims are to determine whether the approach gives estimates of r consistent with project experience and, second, to show how the three variables, i, S and r relate to the rate of economic growth in practice. The estimates of r are based on the NPV form of (26), and include a term to represent the costs of the lead times of investments 1/,

\[
NPV = \frac{(1-e^{-nr})}{r} - \frac{(e^{-wn} - e^{-rn})}{(r-w) - i}(1-e^{-gn})/g(1+r)^{L/2}
\]

(28)

where L represents the average lead time of investment (see figure 3). The procedure is to scan a range of r and find the value which makes NPV zero.

Estimated average rates of return to investment using this equation are presented for nineteen countries in table 2 (see end of Chapter). The period considered is 1960-81. The countries were chosen to give a broad sample in terms of development, rates of growth and region; thus there are five African, three Middle Eastern, five Asian, three Latin American and three industrialized countries in the sample; three of the countries are also major oil exporters (Saudi Arabia, Mexico and Nigeria).
Two estimates of $r$ are presented in the table, a low estimate (in column 10), and a high estimate (in column 11). Also shown (in column 12) is the effect on $r$, for the developing countries, of including current expenditures on health and education in the rate of investment; this will be commented on shortly; but first consider the reasons behind the low and high estimates of $r$ shown in columns 10 and 11.

Data on $g$, $i$, $c$ (the labor force growth rate) and $b = (g-c)$, the labor productivity growth rate, are shown in the first four columns. An attempt was also made to construct an index for the growth rate of real wages (which it will be recalled include the inputed wages of entrepreneurial labor). However, published data relevant for the estimate of this variable, and also on labor's share in output are surprisingly scarce or, when available, generally unreliable for developing countries; the main difficulty is that large proportions of the labor force are self-employed and family workers for whom it is difficult to impute a wage rate given the diversity of activities in which they are engaged; only India among the countries listed makes an explicit adjustment for this factor. Typically 30-50% of the labor force are self-employed and family workers in Latin American and Asian countries, and 70-90% in Africa, as compared to around 10% for the industrialized countries.

Given these uncertainties, the approach taken was to estimate a lower and an upper limit for $r$. The lower limit was obtained by setting $w = b$, the rate of growth of average output per worker, shown in column (4). It is considered a lower limit because real wages have probably grown more
slowly than average output per worker in most of the developing countries shown on account of a concentration of investment away from the traditional sector; i.e. their situations tend to vary between those depicted in figures 2a and 2b, and are unlikely to fit figure 2a, in which b=w. Taking a high value for w (and thus for labor's share in output) naturally lowers the value of r for given values of g and i, and conversely if a low value is taken.

The upper limit for r requires more comment, but briefly corresponds to the case where S=S^*, labor’s share in current output, and a value of S^* based on output per worker in agriculture less an allowance for operating surplus per worker (in agriculture). Thus it is based on the relation:

\[ NPV=0 = (1-S^*)(1-e^{-nR})/r-I(1-e^{-gn})/g(1+r)^{L/2} \]  

Let us comment further on the estimates of S^*. For six of the countries listed, the operating surplus of unincorporated enterprises (OSUE) is itemized in the national accounts, as are the wage labor bills of government and non-government activities. Hence, using the following definitions:

\[ W_g = \text{government wage bill as a proportion of (national) value added}; \]
\[ W_n = \text{non-government wage bill also as a proportion of value added}; \]
\[ V_n = \text{value added by non-government activities as a proportion of (national) value added}; \]
\[ V_n = 1-W_g; \]
\[ S_n^* = \text{share of labor in } V_n; \] and \[ OSUE = \text{Operating surplus of unincorporated enterprises as a proportion} \]
of (national) value added. Then:

\[ S^* = W_n + S^* V_n; \]

\[ S^* V_n = W_n + S^* OSUE_n, \]

assuming labor's share in output is the same in the unincorporated as in the incorporated sector. Hence, on this assumption,

\[ S^* = W_n + \frac{W_n}{1 - OSUE/V_n}. \]

The calculations of \( S^* \) using this procedure are shown in column (5) of Table 2, the background data and worksheets being provided in Table 3.

For thirteen of the countries listed (and indeed for many countries not listed) no information is published in the sources cited on OSUE, though data are available on \( W_n \) and \( W_n^g \). Hence an attempt was made to proceed by re-writing the accounting identity for the non-government sector as follows:

\[ S^*_n V_n^* = W_n + S^*_n (V_n - W_n/S^*_n) \quad (30) \]

Since \( W_n \) in (30) is the share of wage labor in value added, it follows that \((V_n - W_n/S^*_n)\) represents value added by non-wage labor (as a proportion of national value added), and the problem in hand, given that \( W_n \) and \( V_n \) are known, is to determine what this quantity might be. \( S^*_n \) would then follow as before from the identity \( S^*_n V_n^* = W_n + S^*_n V_n^* \). Several ways of estimating the value added by non-wage labor were tried of which the following gives
(it seems to me) a fairly conservative estimate: \( Va(NSE/Na) \), where \( Va \) is the value added in agriculture as a proportion of national value added, \( NSE \) is the number of self employed and family workers in the economy, and \( Na \) is the number of agricultural workers. This gives a conservative estimate because \( NSE \) includes a significant fraction of non-agricultural workers whose value added per worker, though higher than in agriculture, is costed at \( (Va/Na) \) in the analysis. That the proportion of family workers is greater in agriculture (one half to two thirds of \( NSE \) in agriculture) than in non-agricultural activities (around a quarter, the rest being proprietors) also leads to a downward bias in the resulting estimate of \( S^* \).

The calculations of \( S^* \) using this procedure are shown in column (6) of table 2, the background data being provided in table 3. Comparing the results in this column with those shown in column 5 for countries in which data on OSUE were available, it can be seen that the correspondence is generally quite good. Also shown in Column (7) is an estimate of \( S^* \) from the vintage model discussed in Part II, assuming \( w=b \). This estimate was made solely to begin the iterations to find \( r \) when using (28); it serves to show, however, when comparing the results with those in column (8), that the approximation \( S=S^* \) is not a bad one in an economy where wages are growing in step with output per worker, but will generally over-estimate the influence of investment on labor's income where \( w<b \).

The values of \( g, c, b \) and \( c \) used are those summarized in the 

World Tables published by the World Bank. Assumptions were needed about
the average economic lead-times and lifetimes of investment. The values used were 5 years for the Sub-Saharan African countries listed, 4 years for the other developing countries, and 3 years for the industrialized countries. The values of n used range from 15 years for the countries with high growth rates per worker employed up to 30 years for countries with low growth rates per worker, the shorter lifetimes in the high growth cases being considered more likely on the grounds that the rates of retirement of investments and the rates of redeployment of labor would both be higher.

The values of g shown in the table relate to the growth of GDP at factor cost, and of i to gross investment. No adjustments to these figures were made to allow for depreciation. It will be recalled that, when deriving the relationships discussed in Parts II and III, the change in output was formulated as the derivative (with respect to v) of the integral of the outputs of all investments in service in v introduced over the period v-n to v; a negative component of the change in output thus appeared in the resulting expression arising from the shift in the lower limit of the integral from v-n to v+dv-n, and represented the effects on output of the retirement of investments with zero quasi-rents. In addition, the finite life of the investments leads to appearance of the capital recovery factor in expressions like (28). It would thus be to double count costs to deduct official estimates of depreciation from the GDP and investment series as well 2/.

Before turning to the results a comment might be added on investment in health and education. The national accounts data cover physical
investment only, including physical investment in health and education services and in the training of the labor force. But in the developing countries most of the recurrent expenditures on health, education, training and (a major item) agricultural extension are devoted to improving the quality (i.e. productivity) of the labor force, as opposed to maintaining the quality intact. It is therefore arguable that, at least for the developing countries, such expenditures ought to be included in the investment cost stream. This was done in the results shown in column 12 of table 2. The general effect is to lower the returns by a factor of 1.1 to 1.3, depending on the size of such expenditures in relation to investment.

Turning to the results shown in columns 10 and 11, it is apparent that the capital accumulation approach to growth followed in this paper does not lead to anomalously high rates of return to investment. For the three industrialized countries the estimated returns vary between 4.6% (UK) up to 7.6% (Japan), while for the developing countries, the estimates vary from being negative (Ghana) to 12-16% for the high growth countries. These figures seem consistent with the social discount rates often recommended for public projects, and if anything (bearing in mind that the table is concerned with average rather than marginal returns) are lower than one would expect if these criteria were being strictly applied.

The results also prove the rule that what is important for growth is not a high rate of investment in and of itself, nor simply high social yields from investment, but the product of the two, with \( g \) being approximately equal to \( 3(\text{ir}) \). Savings and investment are emphasized by the
approach, but so are savings wisely invested— with the rewards, in terms of growth, being appreciable indeed. Figure 4 illustrates this point graphically by plotting the product $i.r$ against $g$. The high and low estimates of $r$ discussed above are identified separately in the figure so as to show the effects of the uncertainties (regarding the treatment of labor's share) on the results; the uncertainties are not small, but also not such as to obscure the rule just stated. Regrettably, the data on labor's share are not good enough for a third element to be investigated, which is that high growth rates might also be achieved with higher returns to labor than many developing countries have achieved in the past. This subject has been examined extensively elsewhere however 4/, and, broadly speaking, we might amend the opening statement of this paragraph and conclude that what matters for growth is the product of three variables: the rate of investment, the returns to investment, and the investment-induced returns to labor.
Investment vs Economic Growth

Figure 4

Rate of investment vs return

-100 100 300 500

rate of investment X return
<table>
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<tr>
<th>Country</th>
<th>Growth Rate</th>
<th>Investment Rate</th>
<th>Labor Force Growth Rate</th>
<th>Labor Productivity Growth Rate</th>
<th>Labor Share in Output %</th>
<th>PV of Labor's Share in Output %</th>
<th>Rate of Profit Return Using Equation (28)</th>
<th>Rate of Return, r %</th>
<th>Effect on r (col.11) of Including Health Expenditures %</th>
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TABLE 2. INFORTED AVERAGE RATES OF RETURN TO INVESTMENT IN SELECTED COUNTRIES, FOR THE PERIOD 1960-81.
Table 2: Sources and Footnotes

Sources

Values of g, i and c are taken from the IBRD's World Tables, Third Edition, 1983. Estimates of S* are derived from the data presented in table 3.

The values of n and L were assumed to be as follows: L = 5 years for the African countries, 4 years for other developing countries, and 3 years for the industrialized countries; n = 30 years for the slow growth countries (where the rate of 'turnover' of investment is low) with per-worker growth rates, b, of less than 2% per year, 25 years for countries with b in the range 2 to 3%, 20 years for countries with b in the range 3 to 5%, and 15 years when b 5% per year (since the rates of decline of quasi-rents would generally be greater in these situations).

1/ Using the relation $S^* = \frac{W_n}{1-OSUE/V} + W_g$, where $W_n$ is the share of non-government wages, $W_g$ of government wages and $OSUE$ of the operating surplus of unincorporated enterprises in value added.

2/ For the pure vintage model (leading to equations (1) and (7) in Part II), the value of $S^*$ is given by:

$$S^* = \frac{(g/c) (e^{-bn} - e^{-gn})}{(1-e^{-gn})}.$$

3/ The ratio of the second term to the first in equation 28, evaluated at the equalising discount rate (r, shown in column 10), assuming $w=b$.

4/ $r^* = (1-S^*)g/i$.

5/ Values of $S^*$ and $S>100\%$ are feasible for a period if capital stock and inventories are being consumed (as happened in Ghana in the 1970s).

6/ No feasible value exists because the benefit and cost streams are both negative. The analysis thus works with the rate of profit instead, as a proxy, shown in column 9.

6/ I.e. current expenditures on health and education, since investment expenditures on these items are already included in the figures for investment. Health and education expenditures are also tabulated in the above source and vary between 1 to 5% of GDP. To obtain the estimates in column (12), I have simply multiplied column (11) by $1/(1 + current\:\text{health}\:\&\:\text{education}\:\text{expenditures}\:\text{as}\:\%\:\text{GDP})$. The exercise was not done for the industrialized countries, since most of these expenditure are now to maintain the quality of labor force intact.
### TABLE 3. WORKSHEETS FOR ESTIMATES OF LABOR'S SHARE IN CURRENT OUTPUT IN THE 1960s AND 1970s

<table>
<thead>
<tr>
<th>Wages as % of GDP</th>
<th>Split of W between Government and Non-Government</th>
<th>Value Added in Agriculture as % GDP, Va %</th>
<th>% Labor Force in Agriculture Wa %</th>
<th>Labor Force Self Employed NSE %</th>
<th>S* from Equation (30)</th>
<th>Estimate of S* from Accounts Data OSHE as %</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
</tr>
<tr>
<td>Ghana</td>
<td>84</td>
<td>8</td>
<td>76</td>
<td>53</td>
<td>58</td>
<td>73</td>
<td>100</td>
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<tr>
<td>Ivory Coast</td>
<td>43</td>
<td>11</td>
<td>32</td>
<td>35</td>
<td>81</td>
<td>89</td>
<td>67</td>
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<td>Kenya</td>
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<td>30</td>
<td>40</td>
<td>80</td>
<td>85</td>
<td>67</td>
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<tr>
<td>Nigeria</td>
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<td>5</td>
<td>22</td>
<td>40</td>
<td>60</td>
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<tr>
<td>Sierra Leone</td>
<td>29</td>
<td>8</td>
<td>21</td>
<td>38</td>
<td>70</td>
<td>89</td>
<td>52</td>
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<td>32</td>
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<td>Philippines</td>
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<td>Thailand</td>
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<td>(53)</td>
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<td>2</td>
<td>3</td>
<td>14</td>
<td>74</td>
</tr>
<tr>
<td>USA</td>
<td>69</td>
<td>13</td>
<td>53</td>
<td>3</td>
<td>4</td>
<td>10</td>
<td>70</td>
</tr>
</tbody>
</table>

D. Anderson  
January 30, 1987
Table 3: Sources and Footnotes

Sources

W, W, and W obtained from the UN Yearbooks of National Accounts Statistics and are rough averages. The Operating Surplus of Unincorporated Enterprises (OSUE) shown in column (8) was taken from the same source. Note that the values of W, W, W and OSUE are expressed as percentages of GDP at factor cost. Va and Ra are tabulated in the IBRD's World Tables (Third Edition, 1983). Data on NSE are published by the ILO, Yearbooks of National Accounts Statistics, but for some countries were only available for one or two years in the period; the above estimates of NSE are thus approximate, based on "spotty" data.

1/ I.e. \( S^* = W_g + \frac{W_n}{(1-x)} \), where \( x = \frac{(V_a NSE)}{(V_a N_a)} \). See Text.

2/ As estimated from \( S^* = W_g + \frac{W_n}{(1-OSUE)} \). See text.

3/ For the non-oil economy, \( S^* \) is about 70%.

4/ Assuming \( S^* \) is 60% for the non-oil sector of economy, which accounted for about 45% of value added, on average, over the period.

5/ A nominal figure, taken for this exercise (Egypt does not publish estimates of \( W_g \)).

6/ Indian statistics estimate labor's share in current output directly, "including part of net operating surplus of unincorporated enterprises which cannot be separated from income on own account."

7/ Again, a nominal figure taken for this exercise, since \( W \) is not published in the sources cited.

8/ For Kenya, OSUE is taken to be the sum of the output of the 'Semi-Monetary' sector plus the marketed production of small farms and businesses. See Hazlewood (1979), Chapters 3 (p15), 4 (p39) and 5 (p57) for data.
V. RELATION TO CURRENT APPROACHES TO GROWTH ACCOUNTING

Growth accounting studies generally work with the rate of profit, \( p \), rather than the rate of return. To simplify algebra and the making of comparisons, the following analysis similarly works with the rate of profit analogues of the relationships derived earlier 1/.

Assessments of the contribution of investment to growth have been based on one or the other of two essentially equivalent approaches. The first, following Solow (1957), is to estimate a production function of the form

\[ Q = A \exp (g_a t) F(K,L), \]

where \( A \exp (g_a t) \) represents the technical progress shift term (\( g_a = \) rate of economic growth due to technical progress, or the "residual"), \( A \) being a constant. From this,

\[ g = g_k + (1-\lambda) g_L + g_a \] \hspace{1cm} (31)

where \( g \), \( g_k \) and \( g_L \) are the rates of growth of output, capital and labor (in man hours), \( \lambda = pK/Q \) is capital's share in output and \( (1-\lambda) = wL/Q \) is labor's share in output 2/. The other approach is to work with the "fundamental accounting identity," as Griliches and Jorgenson (1969) called it, in which the total value of outputs equals the total value of inputs, or, at an aggregate level, \( Q = pK + wL \). If \( Q \), \( K \), \( w \) (wage rates) and \( L \) are changing over time, then, from this identity,

\[ g = g_k + (1-\lambda) g_L + (1-\alpha) g_w \] \hspace{1cm} (32)

where \( g_w \) is the rate of growth of real wages.
Comparing (31) and (32), \( g_a = (1-\alpha)g_w \), and hence most of the attempts to explain or whittle down the residual since Solow's article have, broadly speaking, amounted to accounting for the growth of real wages - associated for instance with changes in the educational, age (experience), and skill compositions of the labor force, and with the redeployment of labor from low to higher wage sectors (e.g. agriculture to manufacturing). Thus it is now usual to decompose the rate of growth of labor's income into four parts: changes in the number of employed people, in their hours of work, in their educational levels, and in their occupations or sectors of work. Letting \( N \) denote the number of workers, \( H \) their hours of work, and for simplicity taking \( H \) to be the same for all categories of worker,

\[
W_L = NH \sum_i e_i \sum_j s_{ij} w_{ij}
\]

where \( e_i \) is the proportion of the total labor force (in worker hours) in education group \( i \), with \( \sum_i e_i = 1 \); \( w_{ij} \) denotes the wages of workers of education \( i \) in occupation or sector \( j \); and \( s_{ij} \) is the share of workers with education \( i \) in sector \( j \), with \( \sum s_{ij} = 1 \). Differentiating, omitting second order terms, and dividing by \( w_L \),
\[
\frac{1}{wL} \cdot \frac{d(wL)}{dt} = \frac{1}{N} \cdot \frac{dN}{dt} + \frac{1}{H} \cdot \frac{dH}{dt} \quad \text{(quantity inputs)}
\]

\[+ \frac{NH}{wL} \sum_{i} \frac{de_{i}}{dt} \sum_{j} s_{ij} w_{ij} \quad \text{(quality adjustment)} \]

\[+ \frac{NH}{wL} \sum_{i} e_{i} \sum_{j} w_{ij} \frac{ds_{ij}}{dt} \quad \text{(gains from redeployment)} \]

\[+ \frac{NH}{wL} \sum_{i} e_{i} \sum_{j} s_{ij} \frac{dw_{ij}}{dt} \quad \text{(wage growth ostensibly without quality change or redeployment)} \] (34)

where \(wL/NH\) is the average wage per worker-hour.

The first three terms on the right hand side of (34) follow Griliches and Jorgenson (1967) and Griliches (1970) except that I have also disaggregated by sector to identify redeployment effects on labor's income. The first four terms on the right hand side are similar to those in the disaggregated study of Nishimizu and Hulten (1978). Considering each term in turn, the first two represent changes in quantity inputs, and the third the familiar quality adjustments for changes in the educational composition of the labor force. The fourth represents the effects on labor's income of shifts in the sectoral or occupational composition of (each education group of) the labor force. The fifth represents wage growth over time of labor within given educational and sectoral or occupational categories. As indicated, this term represents wage growth ostensibly without changes in the quality of labor, and also without redeployment, because these two effects are intended to be measured by the third and fourth terms; in practice, however, both quality changes and redeployment may be appreciable.
within any i, j group even if, as discussed in Part II, one is working at quite high levels of disaggregation, so that significant quality changes and redeployment effects may be unintentionally included in the fifth term.

Growth accounting studies generally estimate the first four terms on the right hand side of (34), to obtain an estimate of the rate of growth of the quality and deployment adjusted labor force. Denote this by $g_{L^*}$.

Then $g = g_k + (1-\omega)g_{L^*} + g_{a^*}$, where $g_{a^*}$ is a new residual, variously termed 'total factor productivity' (TFP), output growth due to 'advances in knowledge', or, more simply, 'technical progress' (TP). It is apparent that, from this definition of $g_{L^*}$, TFP or TP is the fifth term on the right hand side of (34) multiplied by $(1-\omega)$; i.e., and substituting for NH/wL from (33),

$$\text{TFP or TP} = (1-\omega) \sum_{i} \sum_{j} e_{ij} s_{ij} w_{ij} (\hat{w}_{ij}/w_{ij}) / \sum_{i} \sum_{j} e_{ij} w_{ij}$$

(35)

That is, TFP or TP is the sum of the wage growth rates of labor within the various educational and occupational groups, weighted by the shares of each group in value added.

The preceding expressions ((34) and (35)) serve to reveal three points of departure between the capital accumulation approach to growth, as I have attempted to develop it in this paper, and current approaches to growth accounting. They concern the treatment of technical progress, the analysis of economic efficiency and growth, and the complementarities
between physical investment, human investment and the deployment of labor. Consider each in turn.

As regards the treatment of technical progress, terms like (35) have been left in labor's account in the present analysis (as the expression suggests they should be) when inputing the returns to investment from growth rates of output and wages, or when suggesting how growth rates of output might be estimated from assumptions about the rates of and returns to investment, the deployment of labor and the rates of growth of wages. In other words, following Scott (1981), no "residual account" is kept open to represent the effects on growth of TP. The residual is zero, by definition of the accounting convention used (the social rate of return convention), and the effects of TP on output are reflected in the returns to labor and the returns to investment. In adopting this convention, the intention is not to suggest that TP is unimportant or that its role in economic growth would be "catastrophically reduced" if the residual (as it is usually estimated) is small or zero, as Kennedy and Thiriwall (1973) suggested it would be in reference to the paper of Jorgenson and Griliches (1967). Rather, it is the opposite, and it turns out that technical progress, in the generic sense of the term, is given a greater role by the capital accumulation approach, not less: its contribution can be seen as being closer to the early estimates of Abramovitz, Solow, Kuznets and others, in which it was estimated to account for around 90% of output growth as opposed to the 30-50% figures later suggested by the growth accounting procedures just discussed.
Consider again, for instance, the relation \( g = \frac{\sigma \alpha r}{1 - S} \), and suppose that new techniques with higher outputs per worker were not being introduced - neither through new investment nor through improvements to investments in place. Let the value of \( g \) in these circumstances be \( g_1 \). Since this would be a static economy with constant real wages and output levels, the present value of labor's share in output would equal labor's share in current output, since the PV of a constant equals the constant, so that \( S = (1 - \alpha) \). Also, the lifetimes of the investments would be large, assuming maintenance is undertaken as required and so \( \sigma = 1 \). Hence \( g_1 = \frac{\sigma \alpha r}{1 - S} = \alpha r + (1 - \alpha) g_1 \). But \( \alpha r = \alpha g_K \), so that \( g_1 \), which under the preceding conditions also equals \( g_L \), can be written as \( g_1 = \alpha g_K + (1 - \alpha) g_L \), meaning that without new techniques and the redeployment of labor to utilize them, the growth rate of output collapses to a rate corresponding to the quantity inputs of labor and capital only. Hence the difference between such an economy and an economy in which technical progress is taking place, is given by (recalling (31) above),

\[
g_a = g - \alpha g_K - (1 - \alpha) g_L = \frac{\sigma \alpha r}{1 - S} - g_1
\]

Hence what the capital accumulation approach to growth does, as I have attempted to develop it in this paper, is to measure the 'fruits' of technical progress in terms of the returns to labor and the returns to capital 3/.

This result raises the issue, long-noted by Denison, that a small or zero contribution of TFP to growth can be correct "only, if.."
procedures have the effect of reclassifying .. a contribution of output per unit input to an input contribution" 4/. In a much cited critique of the paper by Griliches and Jorgenson, cited above, he concluded that 5/

"there is an advantage in matching growth sources with the reasons that income changes, and I have tried to adhere to this principle in my own work. In particular, confusion and misinterpretation are avoided if the contribution of capital is identified with changes in income that result from investment, and that can be altered by changing the amount of investment, and the contribution of advances in knowledge is identified with changes in income that result from advances in technical and managerial knowledge, and that can be altered by changing the state of knowledge. Confusion is hard to avoid if the consequences of advances in knowledge are classified as contributions of capital."

These remarks indicate the second point of departure between the capital accumulation approach to growth and current approaches, which relates to the measurement and analysis of economic efficiency. It seems reasonable that, if the economist is seeking to determine how perceived efficiencies or inefficiencies in economic policies affect the rate of economic growth, it is necessary, in the social as in the physical sciences, to compare outputs with inputs directly. This is the basic case for comparing the value of output changes with the costs of achieving them using the economist's measure of economic efficiency, the social rate of return or NPV of investment. Its use does not preclude the analysis of the various causal factors to which Denison refers, such as the relative contributions of physical and human capital to the growth of output - though such contributions need to be assessed in terms of their 'total' rather than their 'partial' effects on output, as discussed shortly below. Instead, it raises additional questions such as are expenditures on
physical and human investment, and the policies which bear on the rate and composition of such expenditures, being applied efficiently to the task of raising output? Is there too little investment in raising the quality of labor given the technologies available and the amount of physical investment taking place, or conversely too little physical investment to fruitfully employ an increasingly educated and skilled labor force capable, if they had the tools at their disposal, of raising the output of investment? In addressing these and other such questions, it is necessary to compare outputs with inputs, specifically, the present value of output changes with the present value of the investment and rising real labor costs of achieving them. The labor costs would be estimated at prevailing real wage rates over the periods in question, and would include allowances for real wage growth within well defined educational and occupational groups (the fifth term in (34) as well as for real wage growth arising from redeployment or changes in the quality of labor (the third and fourth terms). Thus all five terms on the right hand side of expressions like (34) are relevant. Together they represent the rising opportunity costs of labor; and it seems important for an economy, if it is to raise real wages as well as real output, for its policies to be assessed in terms of their capacity to generate positive quasi-rents in the presence of rising real wages.

The question arises, if it is the full costs of labor which need to be allowed for in the analysis of how economic policies affect growth, and not just the quality- and occupation-adjusted costs of labor (the first four terms on the right hand side of (34)), which are the ones growth accounting studies usually concentrate on, is there any purpose in
separating out the effects of education and redeployment on real wages from those within narrowly defined educational and occupational groups? The answer is that analysis of changes in the quality of labor, on which Denison and others have placed much emphasis, remains a natural starting point for the assessment of the marginal returns to investment in education. It seems likely, as Mary Jane Bowman (1980) suggested, that the approach significantly underestimates education's contribution to growth in many ways, while Blaug (1976) has noted several ambiguities in the assumptions and evidence underlying human capital theory. In addition (anticipating the third point below), the returns to human investment so estimated are unavoidably based on the derived demands for various qualities of labor and assume that the complementary physical investments are in place; they are higher than the joint returns to human and physical investment except in the special case where they equal the marginal cost of capital. Nevertheless, studies of quality changes in the labor force remain important in the analysis of growth, and the intention here is not to suggest otherwise - only that the analysis of the desirability of changes in the composition of human investment, even if we are only narrowly concerned with its contribution to output, does not end with the estimation of terms like the third and fourth on the right hand side of (34).

Turning to the third point raised above, regarding the complementarities between physical and human investment, and also between physical investment and the redeployment of labor, it seems important to recognize that it is the total rather than the partial changes that are relevant
when it comes to identifying "changes in income that result from investment." The redeployment of labor from rural to urban areas, for example, requires appreciable human and physical investment in urban areas - and also in rural areas in order to raise output per worker in agriculture to meet the rising food demands of urban areas when the size of the agriculture labor force is in relative or absolute decline. Parallel remarks apply, as discussed earlier, to the redeployment of labor from small-scale to large-scale industries or from lower to higher-technology industries as industrialization proceeds. Similarly, as Nelson remarked, in the absence of investment in new technologies "educated workers would be doing nothing different than uneducated worked and would not be more productive" and it can be misleading to suggest what education did or might contribute to growth without reference to the physical investments (and the policies which bear on them) required to employ the educated workers fruitfully; in several papers, he has commented the way "growth accounting tables .. repress inter-dependence" between physical and human investment. In Parts II and III above, an attempt was made to allow for interdependence as follows: (a) by considering the joint returns to physical and human investment, and (b) by considering the effects of these (joint) investments on the returns to labor as well as on the returns to investment itself.
VI. CONCLUSIONS

The above analysis has sought to show how a country's rate of economic growth (g) can be expressed in terms of variables representing the size and quality of its investment portfolio, where the size of the portfolio is determined by the rate and its quality by the allocative efficiency of investment. The principal relationships derived were based on an accounting identity for the social rate of return to investment, in which the present values of the output increases arising from the investments taking place in an economy were compared with the present values of the costs of achieving them.

The reason for seeking a relationship between g and the social rate of return is that the latter provides a robust measure of the efficiency or otherwise of economic policies. It is widely used for the analysis of public investments in industry and infrastructure, and for the analysis of the efficiency of prices, taxes, subsidies, interest rates, public versus private ownership, and so forth. It can also be applied to the analysis of laws and regulations designed to steer investments in a desirable direction where market failures are apparent and where the price mechanism would be impractical or too costly to apply (as in some natural resource and environmental problems). But it is rarely if ever used in growth accounting studies, nor are the prospective rates of return to investment of alternative policies used as a basis for assessing what these policies might achieve in terms of economic growth; on the other hand, the rather crude quantity, the incremental capital-output ratio, is often used
for both purposes, despite its long-known and much-discussed limitations. Three reasons were given for this, each of which pointed to the contribution of to growth investment being far greater than growth accounting studies usually conclude.

First, as several economists have argued, the amount of investment taking place in a growing economy is widely under-estimated due to faulty classifications of what comprises investment. Several adjustments are needed in the accounts data to arrive at a better classification, including a reclassification from consumption to investment of expenditures -- such as many of those in education, training and agricultural extension--devoted to raising the productivity of the labor force. In addition, concepts like capital 'consumption' or depreciation can be very misleading and, as Scott has argued, it is gross rather than net investment that is relevant for the analysis of growth. Second, there is the under-estimation, also, of investment’s effects on the growth of labor productivity and real wages. The reasons for this were examined at length above, and need not be repeated here. Suffice it to say that current growth accounting procedures estimate only the partial returns (ir) to investment when in practice the growth of real wages, also, depends greatly on the rate and composition of investment; that is, it is the total returns to investment which are important - the returns to labor as well as to investment itself - and these outweigh the partial returns, typically, by a factor of three or more in economies deploying and redeploying their labor well. Third, there is the common practice of placing the fruits of technical progress in a "residual" account, separate to those accounts
representing the returns to labor and the returns to investment, when in practice, and once the total effects of investment are considered, they must appear in one or the other of the latter two accounts. Following Scott's lead on the third point, it was argued that a residual account is not needed and that its closure, so to speak, might greatly facilitate the analysis of the influence of economic policy on growth.

The approach developed in the paper comes under the heading of what Johnson termed the "capital accumulation approach to growth and development," some of his remarks on which were quoted earlier. One great advantage of the approach is that it does not rest on any particular assumptions as to the "stylized facts" of growth, and indeed it can be used to analyze significant departures from them—such as rises and falls in the rates of and returns to investment, in labor's share in output, and in the rate of growth of output itself. Furthermore, it need not be concerned only with long-run development policies, important as such policies are, since short-run changes due (for instance) to business cycles, changes in the terms of trade, political shocks and, even, droughts, can all be accommodated in it by studying their effects on the variables discussed—on the rate and composition of investment, on the social returns to new investments and investments in place, on the deployment of labor, and on real wage rates. The approach, as Johnson's description of it made clear, is thus especially relevant to the analysis of development policies, since the developing countries do not fit the stylized facts of growth theory (and the accounting models derived from it) while short-run shocks loom far
larger than they do in the industrialized countries, severe as they have often been in the latter.

At various points, the paper has attempted to relate the approach to ongoing debates on developing policy. A proper discussion of this subject was beyond the scope of the paper. But one general conclusion is likely to emerge from further analysis, which I have tried to anticipate above. It is that wise policies towards investment in a country's physical and human resources are likely to be thrice blest: they would raise the rate of investment, the social returns to investment, and the returns to labor. It is the three together which represent the total effects of investment, and of the policies which bear on it.
Footnotes for the Introduction

1/ The literature on the subject is huge, and one necessarily must start with the papers and books of those who have reviewed it: e.g., Nelson (1981), Binswanger and Ruttan (1978), Kennedy and Thirlwall (1972), Hahn and Matthews (1967), and the readings in Sen (1970) and Stiglitz and Uzawa (1969). For historical and cross-country comparisons see Kuznets (1966); for a review of material and a study on Japan see Nishimizu and Jorgenson (1978) and Denison and Chung (1978); on US estimates, Denison (1962 and 1974); on US and Europe, Denison (1967). A review is also provided in Maurice Scott's forthcoming book on growth. The preceding list is unavoidably selective, since the present paper is not a review; but the references cited in the papers of these authors together provide a comprehensive bibliography.

2/ Solow (1959, 1963 and 1970). See also Abramovitz's review of Denison's earlier work (Abramovitz, 1962). Denison (1964) dismissed the "embodied question" as being unimportant, but, as Kennedy and Thirlwall (op. cit p.138) observed, he considered the effects of new vintages of investments on output to work only through the average age of capital stock and ignored point that the average vintage of investment progresses by about one year each year and, if the newer vintages indeed reflect 'good' investments with higher outputs per worker, significant growth may arise whether the average age of the capital stock rises or falls.

Footnotes to Part I

1/ E.g. relationships using incremental capital-output ratios. The literature is very large, much of it associated with extensions of early Harrod-Domar models of growth. Planning with input-output models took the same tack. See e.g. S. Chakravarty (1959) The Logic of Investment Planning, North-Holland; H. Chenery, Ed. (1970) Studies in Development Planning, Harvard University Press; and C. Blitzer et. al. (1975) Economy Wide Models and Development Planning, Oxford University Press. On the pitfalls and limitations of the INCORs, see Meiers (1976, pp. 258-261) and Streeten (1972, Chapter 6).


6/ Ibid.


8/ Again, another subject in which the literature is vast, especially if one gets into private investment and trade, or into financial intermediation and private investment, but see e.g. the influential work of Little, Scitovsky and Scott (1970); Balassa (1971); Corden (1974); Myint (1971); Mckinnon (1973); Shaw (1973; and Meier (1983). On pricing policies for public services, the World Bank has sponsored many studies, e.g. Turvey and Anderson (1977) on electricity, Churchill (1972) and Walters (1968) on roads; Bennathan and Walters (1979) on ports; Warford and Julius (1979) and
Footnotes to Part I, Continued


9/ See studies on investment in public services referred to in the preceding footnote.

10/ Paul Streeten (1979) provides an overview of much of his and others' work on the subject.

11/ Kuznets (1966, pp.80-81).

12/ e.f. the calculations of Cairncross (1961, Chapter 5, p.90).

13/ See the literature referred to in footnote 1 in the Introduction.

14/ op. cit., 1981.

15/ If the assumption of exogenous technical progress is retained.

16/ Direct evidence on income shares is poor in developing countries because of shortcomings in labor force and income surveys. But indirect evidence is appreciable. See e.g. the trade and industry study of Little, Scitovsky and Scott, cited above; on agricultural development policies see Johnston and Kilby (1976).

17/ op.cit., 1983.
Footnotes to Part II

1/ Johnson (1964, p.221).

2/ In developing countries there is also much under-enumeration of investment activities, since private investments in small-holder agriculture, small enterprises and the urban 'informal' sector are rarely estimated, though such activities employ the large majority of the labor force. E.g. Chuta and Liedholm (1985) found that employment in manufacturing activities was under-estimated by a factor of 2 in Sierra Leone, a not untypical order of error for surveys in the region.

3/ The special problem of investment in education is discussed further (Part V) below.

4/ Methods of estimating depreciation in national as in private accounts generally bear no relation to actual maintenance requirements, and may lead to a double counting of costs (see Part IV). The costs of maintenance include (a) the costs of establishing maintenance workshops and providing machines (routinely included in an industry's investment expenditure streams), (b) the costs of labor (included in its labor costs), (c) spare parts and materials (included in material inputs), and (d) the 'down times' of the machines and factories being maintained (reflected in the observed values of output).

5/ A fuller discussion appears in Part V below. The following paragraphs draw on Griliches (1970).

6/ Schultz questioned this last view of women's contribution to the growth of economic output drawing attention to the "troublesome omission" of investment in females and by them in the upbringing of children (op. cit. pp. 297-306).

7/ See Hoselitz (1959, 1968), Staley and Morse (1965), Banerji (1978) and Anderson (1982). On small-scale industries, see also Chuta and Liedholm, op. cit.

8/ See e.g. Shinohara (1968) on wage differentials between large and small firms in Japan.


10/ The following draws on Solow (1970).


12/ The underlying reason for the disparity seems to be that the calculations referred to are implicitly considering the only the partial change of output with respect to a change in capital stock, not the total change. Thus if we consider the accounting identity
Footnotes to Part II, continued

\[ Q = pK + \omega L, \text{ where } p \text{ is the rate of profit, then the estimates are} \]

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\[ \frac{dQ}{Q} = p \left( \frac{dK}{Q} \right) = p. \text{ However, if investment is} \]

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\[ \text{the presence of rising real wages, } \left( \frac{dQ}{Q} \right) = p \left( \frac{\omega L}{Q} \right) \left( \frac{\omega L}{K} \right) dK, \text{ where the latter term represents the effects of investment on real} \]

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13/ E.g. Kuznets (op. cit., p. 85) notes that "The low proportions of growth in per capita product allocated to increased output of man-hours and capital do not mean that the absence of such an input would have resulted in only a small proportionate loss .... The lines of the relationship between absolute increases in population, labor force and capital on the one hand, and growth in per capita partial on the other, are numerous and far reaching .... in ways that make it difficult, if not impossible, to establish the correct partial effects of increases in inputs of man hours and capital on growth of per capita product."

14/ See Nelson (1973 and 1981). The issues raised in this paragraph are taken up again in Part V.

15/ See Robinson (1972) for an ingenious effort to estimate the contribution effects of the redeployment of labor from agriculture to industry on the growth of output in developing countries.

16/ See Part V for a further discussion.


18/ See the reports on Ghana cited in fn. 2 of Part I.

19/ These expenditures are routinely treated as investment in the analysis of agricultural projects. See Gittenger (1982) and Baum and Tolbert (1985).
Footnotes to Part III

1/ In general, there is no restriction on the functional form that may be taken for $Q_{vt}$.

2/ Strictly, $S_v$ is a weighted average given by

$$
\int_0^T (c_{ijv}/Q_v) dv / \int_0^T (c_{ijv}/Q_v) dv
$$

which is probably close to $(1/T) \int_0^T S_v dv$.

3/ As was done in Part II for the case of disembodied technical progress, in which the form, $Q_v = Q_{v0} e^{it}$ was used.

4/ The disaggregated form of (22) becomes,

$$(1-S_{jv}) q_{jv} (1-e^{-r_j n}) - I_{jv} = 0 \quad (i)$$

while (24) becomes

$$
\bar{g} = (1/T)(1-e^{-\bar{g}n}) \sum_j \int_0^T (\bar{q}_{jv}/Q_v) dv \quad (ii)
$$

where $n$ is a mean lifetime of investments. To obtain (27), divide (i) by $Q_v$, let $h_{jv} = I_{jv}/I_v$, integrate (i) over 0 to $T$, use

$$
\bar{s}_j = \left( S_{jv}(\bar{q}_{jv}/Q_v) dv / \int_0^T (\bar{q}_{jv}/Q_v) dv \right) \sim (1/T) \int_0^T S_{jv} dv
$$

and take the average of the resulting expression.
Footnotes to Part IV

1/ The averaging symbols used in Part III have been omitted to simplify notation.

2/ Another way of making the same point is to note that the investment cost term in expressions like (6) and (28), can be written as:

\[ \int_{v-n}^{v} \frac{Q_0 e^{gt}}{Q_0 e^{gv}} dt \]

(neglecting the costs of lead-times), where \( Q_0 \) is value added at \( t = 0 \). The numerator of this expression equals capital stock in service, so that capital stock no longer in service is excluded.

3/ See f.n. 17 in Part II.
Footnotes to Part V

1/ See f.n. 12 of Part II.

2/ Scale economies are not discussed below.

3/ c.f. the growth model suggested by Eltis (1976, ch.6) in which he proposed putting \( g = a + b_i \), where \( a \) and \( b \) are parameters. If \( b \) is rewritten as \( orq(1-S) \) to allow for the efficiency of investment, and also for the effects of TP on labor's income, and \( a = -g_L \), a similar model follows from the above analysis.


5/ Ibid. p. 27

6/ Letting subscripts \( f \) and \( h \) denote physical and human investment respectively, the incremental output less incremental labor cost be \( (Q-wL) \) and incremental investments be \( I \), then the joint rate of profit \( p = (Q-wL)/(I_f+I_h) \) whereas the derived rates of profit are 
\[
\begin{align*}
\text{pf} & = [ (Q-wL) - h_p ]/I_f \\
\text{ph} & = [ (Q-wL) - f_p ]/I_h
\end{align*}
\]
where \( p \) represents the cost of capital expressed as marginal rate of profit. In general \( p_h \) and \( p_f \) are both greater than \( p \) unless \( p_h \) and \( p_f \) = \( p \), from which \( p = p \) also. Thus rates of return or profit estimated from derived demand schedules can give misleadingly high impressions as to the rates of return to particular factors; for estimating the optimum 'balance' of investments the returns so estimated give consistent results, but for estimating their contributions to growth it is their joint returns that are important.

7/ Nelson (1973)

8/ See e.g. his review article (Nelson, 1981) and his discussion of a paper by Kuznets: Nelson (1984).
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