ON THE SECULAR MACRO-ECONOMIC CONSEQUENCES OF TECHNICAL PROGRESS[1]

I

THERE is an old riddle that crops up from time to time in discussions of technical progress: in an economy where consumption and capital goods are produced by means of capital goods and labour, how can one measure the extent of technical progress when it is affecting the capital goods sector? For not only is there the direct effect on output, but there is also the much more complicated indirect effect via the reduced resource cost of the capital goods required as inputs. Another aspect of the same problem: how does one classify technical progress in these circumstances?

The answer, of course, like that of many riddles, is inherent in the question itself. It all depends upon whether one confines one's attention to the immediate consequences of the change in the characteristics of the production process, taking prices as given, or whether one is willing to consider all the repercussions on the whole economy after it has fully adjusted. In other words, it is simply a matter of whether one is undertaking partial or general equilibrium analysis.

This distinction provides the background for the present paper, whose object is to investigate whether one may trace, in any reasonably simple and yet acceptably general way, the effects of technical progress on such complex macro-economic variables as the capital–output ratio and the share of profits in total income.

Such statistics have, of course, been the subject of extensive analysis at the aggregate level, but, for the present purpose, the traditional framework is undesirably restrictive both in its assumptions and in its applications. A cursory survey of the literature reveals a tendency to neglect two important features of technical progress—its influence on the allocation of resources between different sectors, and its influence on relative prices.[2] Instead there appears to have been a preoccupation with its effects on the relative use of different factors within a given production process. The existence of a continuously differentiable production function is usually taken for granted, and it is assumed that technical progress takes the form of wholesale shifts in such functions. The subsequent discussion seldom strays far beyond definitions of neutrality and their implications for aggregate growth.

To take into account the effect of technical progress on the allocation of resources and relative prices, the aggregative approach must be discarded in favour of a two-sector or multi-sectoral model. Further, one must specify a

[1] I am indebted to George Psacharopoulos, Thomas Rymes, Adrian Wood and a referee for helpful comments.

[2] For an outstanding exception, see McCain (1972).

notion of general equilibrium which is capable of rendering the production of commodities, their sectoral allocation, and their prices, determinate. Clearly, given any classification of technical progress based on the characteristics of the production process, the reliability of a prediction concerning the ultimate effects of a particular type of technical progress will depend upon the notion of general equilibrium chosen. In the following analysis equilibrium will be defined as steady state growth with a constant rate of profit, the cases in which the equilibrium level of the rate of profit falls, remains unchanged, and rises as a result of technical progress being treated separately. The reasons for this choice are set out in Section V.

The present analysis departs from the traditional framework in two further respects. Continuously differentiable production functions are replaced by sets of production techniques with fixed coefficients[1] (but the usual assumption of constant returns to scale is retained) and, correspondingly, the representation of technical progress as a shift in a production function is replaced by the older, classical conception that it consists of the discovery of a single new technique. The present approach thus has much in common with that explored by Kennedy (1961; 1962) and by Asimakopulos and Weldon (1963).[2]

The main feature of the first part of the paper is the two-sector model discussed in Section III, which presents a systematic analysis of the effects of technical progress in the two sectors on the equilibrium values of the major macro-economic statistics. It is hoped that the discussion yields insights into the way that technical progress affects not only the utilisation of resources in the sector in which it occurs, but also the utilisation of resources in the other sector and the relative price of the capital good in terms of the consumption good, factors which contribute to the overall change in, say, the (current-prices) capital–output ratio for the economy as a whole.

The paper begins, however, with an analysis of technical progress within the context of a one-sector model. This will provide a reference base for the analysis of the two-sector model and will be helpful for evaluating the differences caused by the introduction of the second sector. It will also provide a convenient opportunity for defining the classification of technical progress that will be employed.

The analysis of the two-sector model follows. Even a two-sector model is too limited in scope to permit a discussion of some important issues that should be raised. Not the least of these are the questions of what is meant by "capital" and how it should be measured when one admits the existence of

[1] This is, of course, a weaker assumption when constant returns to scale obtain, since a continuously differentiable production function may be regarded as a special case of a set of fixed coefficient processes.

[2] The functional shift characterisation of technical progress seems to have had the upper hand in recent years; indeed, whole books on technical progress have been devoted to it (Meade (1960), Salter (1960), Brown (1966)). But the other view has not been wholly eclipsed. To mention a few instances, it has been employed by Harrod (1937; 1948) (for the purpose of defining neutral technical progress), Joan Robinson (1956), and Kennedy (1961; 1962), and it has been treated formally in the cited paper by Asimakopulos and Weldon and in Atkinson and Stiglitz (1969).

more than one capital good. And so the next stage in the analysis is its extension to a multi-sectoral model and a survey of the accompanying difficulties.

In conclusion, Part B of the paper uses the results of the two-sector model to provide a schematic interpretation of some long-term data on changes in factor productivity in the United States.

Part A: Analysis of Technical Progress

II

The one-sector model is simplicity itself. A single commodity is produced by means of labour and stocks of the commodity according to a variety of techniques subject to constant returns to scale. Output is Y per worker and part of it, C per worker, is consumed; the remainder, M per worker, is added to the stock,[1] S per worker. The stock depreciates at a constant proportional rate δ. The supply of labour is growing at a rate λ. The wage rate, measured in terms of the commodity, is w, the rate of profit is ρ, and profits per worker are Π.

In equilibrium, which, as has been mentioned above, is defined as steady state growth (with full employment) at a constant rate of profit, the following relationships must hold:

$$b(C+M) = S \qquad (1)$$

$$h(C+M) = 1 \qquad (2)$$

$$M = (\lambda+\delta)S \qquad (3)$$

$$b(\rho+\delta)+hw = 1 \qquad (4)$$

where b and h are the stock and labour coefficients, respectively, of the particular technique in use. Equations (1) and (2) represent the stock and labour constraints on production; (3) states that the amount of capital added to the stock must be equal to the increase in stock required to maintain the stock–labour ratio together with an allowance for depreciation; (4) states that the cost of production of a unit of the commodity must be equal to its price, which is unity by virtue of its being the numeraire.

From these relationships one may easily determine the endogenous variables C, M, S and w in terms of the parameters and the rate of profit, and hence derive such secondary statistics as the share of profits[2] in gross output.

Fig. 1 shows a production set for the economy. The solid line shows those techniques which, if they existed, would have the same unit cost as the technique in use. It will be referred to as the constant-cost line through that

[1] The term "stock" is used to emphasise that it is being defined in physical terms. Later in the analysis the term "capital" will be introduced to denote the aggregate value of stocks of capital goods, in terms of consumption goods. In a one-sector model, stock and capital are, of course, equivalent.

[2] Throughout this paper profits will be defined gross of depreciation. Net profits are simply $\rho/(\rho+\delta)$ of gross profits.

point. An alternative technique with stock and labour coefficients b^*, h^*, respectively, would lie on it if

$$b^*(\rho+\delta)+h^*w = 1 \quad . \quad . \quad . \quad . \quad (5)$$

Technical progress, in its broadest sense, might be defined to be the discovery of any new technique. However, here it will be defined to be the discovery of a technique which is cheaper than the technique in use, and which is therefore represented by a point lying under the constant-cost line.

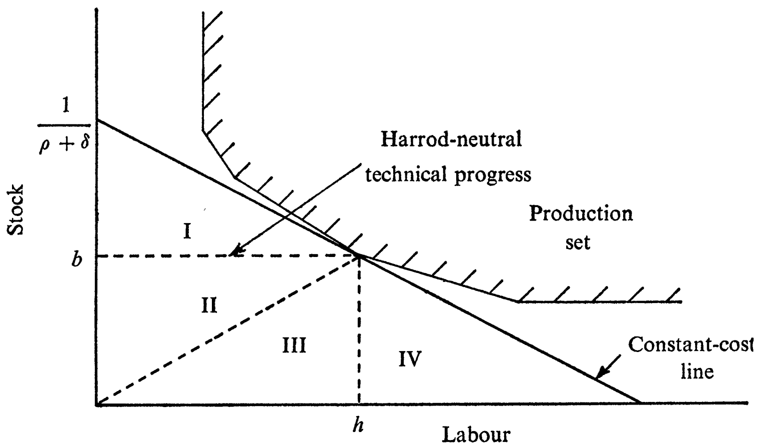

FIG. 1

In the following discussion of its effects, technical progress will be classified by the change in the coefficients of the inputs to the production process, these being defined in physical terms. It will be described as labour-saving or labour-absorbing, and stock-saving or stock-absorbing, depending on whether the respective coefficients fall or rise. One may further describe it as relatively labour-saving or relatively stock-saving according as to whether the ratio of the labour coefficient to the stock coefficient falls or rises. This classification, or equivalent variants of it, has generally been employed in those studies which have treated technical progress in the manner of the present paper.[1] Its significance is limited by the adoption of the technique in use as a point of reference, but, given this point, it does have the virtue of being independent of prices,[2] an important consideration when the model is extended to two sectors in order to analyse the effects of technical progress on the price system.

Fig. 1 illustrates the four basic types of technical progress which result from the classification: I, labour-saving, stock-absorbing; II, both labour-saving and stock-saving, but relatively labour-saving; III, both labour-saving and stock-saving, but relatively stock-saving; IV, labour-absorbing, stock-saving. The figure also shows Harrod-neutral technical progress. In

[1] See, in particular, Asimakopulos and Weldon (1963).

[2] Apart from the economic boundary of categories I and IV imposed by the constant-cost line.

this fully aggregated framework, this may be regarded as purely labour-saving and hence is represented by the boundary between types I and II.

Table I summarises the effects of the different types of technical progress on the behaviour of the more important macro-economic statistics, after the economy has had time to readjust to steady state growth, in the case when the equilibrium rate of profit is unchanged. The proofs of the results are simple and will be left to the reader, but it may nevertheless be helpful to offer intuitive explanations for some of them.

TABLE I

The Macro-economic Effects of Technical Progress in a One-sector Model (Rate of Profit Unchanged)

Statistic	Type of technical progress I	II	III	IV
w	+	+	+	+
C	±	+	+	±
S, M	+	+	−	−
Π	+	+	−	−
Y	+	+	+	−
Π/Y	+	−	−	−
C/S	−	+	+	+

+, rises; − falls; ±, may rise or fall.

Any reduction in the labour coefficient will cause the economy to expand with the same structure as before. w, C, S, Π and Y will therefore rise, and the ratios Π/Y and C/S will remain unchanged. If the labour coefficient were to increase, as would be the case with technical progress of type IV, the first set of statistics would fall.

A reduction in the stock coefficient will decrease the size of S, both directly, and indirectly through its effect on M, and the release of labour will allow a subsequent expansion of the economy with its new structure. As a result, w, C and C/S will rise, and M, S, Π and Π/Y will fall. Again, the effects are the reverse if technical progress is of type I and the stock coefficient increases.

The overall impact of technical progress in each case, before taking into account the influence of the rate of profit, depends on the balance of the effects of the changes in the labour and stock coefficients.[1]

Since the production of machines is determined by the amounts required to offset depreciation and to provide for steady growth, it and the stock of machines are independent of the rate of profit, given any specific set of techniques. Consumption and, in this one-commodity model, output are therefore also independent of the rate of profit. Hence one may confine one's

[1] Note, in particular, that if the share of profits is to remain unchanged, given a constant rate of profit—and this was Harrod's original (1937) definition of neutral technical progress—then technical progress must be solely labour-saving. Thus one has the famous result derived by Joan Robinson (1938).

attention to the behaviour of w, Π and Π/Y when one considers what happens if the equilibrium rate of profit is altered as a result of technical progress.

If the rate of profit rises, Π and Π/Y will rise and w will fall, *ceteris paribus.*[1] The upward movements in Π and Π/Y due to technical progress of type I, and in Π due to type II, will thus be reinforced. But the downward movements in Π and Π/Y due to types III and IV, in Π/Y due to type II, and the upward movement in w due to any type of technical progress, will now all be partially or completely offset.

If the rate of profit falls, the upward movement in the wage rate will be increased. Likewise Π and Π/Y will fall more than before with technical progress of types III and IV, and Π/Y with type II. The movements of Π and Π/Y in the case of technical progress of type I, and Π in the case of type II, become subject to conflicting pressures, with the result that the net movement may be in either direction.

Some of the results derived from the model are not observed in practice. For example, output per worker (unaffected by changes in the equilibrium rate of profit) would fall if technical progress were stock-saving but labour-absorbing.[2] The fact that full-employment output per worker seems to rise monotonically through time suggests that technical progress is not of this kind. Likewise, a rising share of profits is contrary to experience. Anticipating for a moment the empirical evidence cited in Section V, it appears that the results for technical progress of types II and III are likely to be of more interest than those for types I and IV, since in most industries in the United States both inputs have been saved in the long run.

III

The next step in the development of the model is the replacement of the single, all-purpose commodity by two commodities which will be referred to as the consumption good and machines. These commodities are produced by means of labour and stocks of machines in distinct sectors, and in each sector there exists a set of such production techniques, all subject to constant returns

[1] These and the following results are stated on the assumption that the change in the rate of profit is not such as to cause an old, previously-dominated technique to appear superior to the new technique and be adopted instead of it. This could occur in principle because a change in the rate of profit will cause the constant-cost line in Fig. 1 to rotate, clockwise if ρ falls, anti-clockwise if ρ increases, and hence the new line may intersect the old one. Denoting the original technique in use by P and the innovation by P', it is possible that a third technique P'' may lie above the constant-cost line through P and yet below that through P'. In the case of a one-sector model it may be argued that this situation is unlikely to occur: *ceteris paribus*, if P'' were indeed superior to P, taking into account the change in the associated rate of profit, then it seems reasonable to suppose that it would have been adopted without the mediation of the introduction of P'. (Obviously, it is impossible to present a rigorous argument either way without extending the model to full general equilibrium analysis with an endogenously-determined rate of profit.) However, in the case of a two-sector model this issue is less easily dismissed and it will be raised again in the next section.

[2] A possibility not envisaged, for example, by Hicks (1932), who wrote (p. 121): "Under the assumption of competition, it inevitably follows that an invention can only be profitably adopted if its ultimate effect is to increase the National Dividend."

to scale. The price of a machine, in terms of the numeraire consumption good, is q. The symbol K denotes aggregate capital in value terms, equal to Sq. The remaining data characterising the economy are the same as before.

It will be supposed that the consumption technique in use has machine coefficient a and labour coefficient g, and that the machine technique has coefficients b and h respectively. The steady state growth relationships now become

$$aC+bM = S \quad . \quad . \quad . \quad . \quad (6)$$

$$gC+hM = 1 \quad . \quad . \quad . \quad . \quad (7)$$

$$M = (\lambda+\delta)S \quad . \quad . \quad . \quad (8)$$

$$aq(\rho+\delta)+gw = 1 \quad . \quad . \quad . \quad . \quad (9)$$

$$bq(\rho+\delta)+hw = q \quad . \quad . \quad . \quad . \quad (10)$$

Equations (6) and (7) are the stock and labour constraints on production. (8) equates the production of machines to the quantity required for the growth of the stock and the quantity lost through depreciation. (9) and (10) state that the cost of production, in terms of profits and wages, of a unit of the consumption good or a machine, respectively, should be equal to its price. Again, these relationships are sufficient to determine the endogenous variables (C, M, S, q and w) in terms of the parameters and the rate of profit, and hence the other macro-economic statistics may be derived.

Technical progress is defined as before, but it may affect either sector independently. The repercussions on the economy as a whole of an advance in either sector will be examined separately.

Figs. 2 and 3 show production sets for the consumption and the machine sectors, respectively. The solid lines are the constant-cost lines through P and Q, the techniques in use. In the consumption sector an alternative technique with machine and labour coefficients a^*, g^*, respectively, will lie on the line if

$$a^*q(\rho+\delta)+g^*w = 1 \quad . \quad . \quad . \quad . \quad (11)$$

In the machine sector an alternative technique with coefficients b^*, h^* will lie on the line if

$$b^*q(\rho+\delta)+h^*w = q \quad . \quad . \quad . \quad . \quad (12)$$

It may be observed that the lines have the same slope $-q(\rho+\delta)/w$. This may be expressed in terms of the parameters by rearranging equation (10):

$$-\frac{q(\rho+\delta)}{w} = \frac{h(\rho+\delta)}{1-b(\rho+\delta)} \quad . \quad . \quad (13)$$

The prices used for deriving the constant-cost lines are those associated with the technique in use, but it may easily be verified that they are the same as the prices that would be associated with any other pair of consumption and machine techniques represented by points on the lines, given the rate of profit.

From equation (13) it is apparent that the slope of the constant-cost lines depends only on the coefficients of the machine technique. This is an immediate consequence of the decomposition of the economy into consumption and machine sectors, with the latter providing inputs for the former, but not *vice versa*. All intermediate commodities have implicitly been solved from the system, so that the input coefficients take account of both the direct and the indirect requirements of the input in question. Since the price of a machine depends only on the cost of the machine input and the labour input, that is, on itself and the wage rate, it follows that it is proportional to the latter, for a given rate of profit.

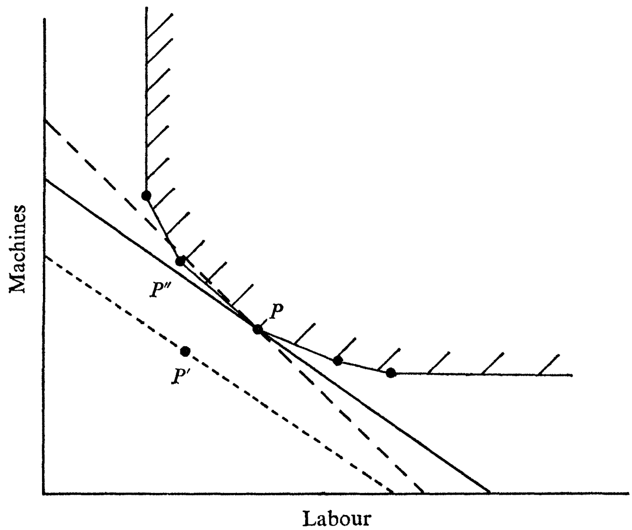

FIG. 2. Consumption sector. Constant-cost lines: ——, original; - - -, after t.p. in consumption sector; – –, after t.p. in machine sector (in the case where the rate of profit is unchanged).

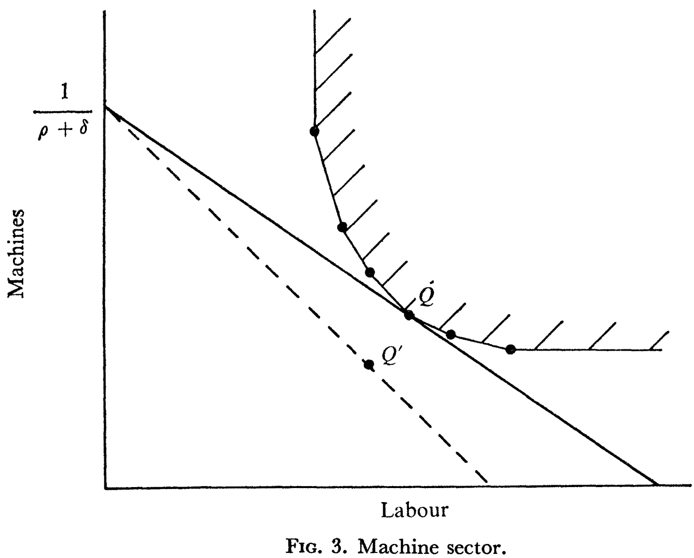

FIG. 3. Machine sector.

Table II summarises the effect of technical progress on the behaviour of the more important macro-economic variables, according to its type and the sector in which it occurs. The first two sets of columns show the results of changes in the production coefficients in the consumption and machine sectors, respectively, for the case in which the equilibrium rate of profit is unaltered. The last two columns show the separate effects of a fall and a rise in the rate of profit, respectively. If technical progress in either sector causes both a change in the production coefficients and a change in the equilibrium rate of profit, its overall effect can be found by combining the corresponding symbols. Where these indicate movements in the same direction, they are mutually reinforcing; where they are opposed, the net effect is ambiguous and will depend on the relative strengths of the two components.

TABLE II

The Macro-economic Effects of Technical Progress in a Two-sector Model

	Technical progress in the consumption sector				Technical progress in the machine sector				Additional effect if rate of profit	
Type ...	I	II	III	IV	I	II	III	IV	Falls	Rises
Statistic										
w	+	+	+	+	+	+	+	+	+	−
q	+	+	+	+	−	−	−	−	−, +	+, −
q/w	=	=	=	=	−	−	−	−	−	+
C	±	+	+	±	±	+	+	±	=	=
Π	+	+	±	±	±	±	±	−	−	+
K	+	+	±	±	±	±	±	−	−, +	+, −
Y	+	+	±	±	±	±	±	±	−, +	+, −
Π/Y	+	+	−	−	±	−	−	−	−	+
K/Y	+	+	−	−	±	−	−	−	−, +	+, −
C/Y	−	−	+	+	±	+	+	+	+, −	−, +
S, M	+	+	−	−	+	±, +	−, ±	−	=	=
$C/M, C/S$	−	+	+	+	−	+	+	+	=	=

+, rises; −, falls; ±, may rise or fall; =, unaffected.

In some cells of the table there appear two symbols, separated by a comma. Here some of the indeterminacy can be removed by distinguishing between the case in which the machine sector is more machine-intensive than the consumption sector ($b/h > a/g$), and the case in which it is less machine-intensive; the first entry refers to the former case, the second to the latter.

Only the direct effect on the sector in question is shown. In general, technical progress in one sector may have an indirect effect on the other sector: if it alters the equilibrium rate of profit, the constant-cost line will rotate and a previously-dominated technique may become cheaper than the technique in use. Even if the rate of profit is unchanged, technical progress in the machine sector will cause the constant-cost line in the consumption sector to rotate and, again, a technique like P'' in Fig. 2 may become cheaper than the technique in use, P. To evaluate the total effect of technical progress in either sector, and *a fortiori* the joint effect of technical progress in both sectors, additional assumptions would have to be introduced into the analysis. Rather than court the unprofitable controversy that this would entail, the analysis will be left in its present form in this and the next section. In the final empirical section it will be argued that the long-term data on factor productivity in the United States are consistent with a simplifying assumption which would resolve the indeterminacy.

It may perhaps be argued that rotation of the constant-cost lines is likely to have a further important indirect effect via changes in the general direction of technical progress in both sectors. Even if the equilibrium rate of profit is unchanged, the reduction in the ratio q/w caused by technical progress in the machine sector will make the cost of labour rise relatively to that of machines, and this may curve the path of technical progress in both sectors in a relatively labour-saving direction. Pursuit of this point would, however, require a discussion of the theory of induced innovation, which lies outside the scope of the present analysis.[1]

The proofs of the results in the table are quite straightforward and will be left to the reader, but, as before, a few notes may nevertheless be helpful. First, it should be noted that, as in the one-sector model, the production of machines is determined by the rates of depreciation and steady state growth, and so, for a given set of techniques, it, and hence the stock of machines and aggregate consumption, are unaffected by changes in the rate of profit. But aggregate income is now affected since it depends on the relative value of a machine in terms of consumption.

If the equilibrium rate of profit is unaltered, technical progress in the consumption sector cannot affect the ratio q/w, and so the increase in productivity causes q and w to rise at the same rate. In the machine sector, technical progress causes q to fall relatively to w; since the cost of the numeraire consumption good is a weighted average of q and w, q must fall absolutely and w must rise absolutely in this case.

The effects on the remaining quantities are less simple. A reduction in the coefficient of the labour input in either sector would release labour, permitting the expansion of the economy as a whole. A fall in the coefficient of the machine input would decrease the size of the total stock of machines required, and hence permit a reduction of output in the machine sector, again freeing labour and allowing a subsequent expansion of the whole economy. Technical progress of types II or III in either sector is thus bound to cause both C and C/S to rise, but S may either rise or fall. As may be expected, technical progress of type I (labour-saving, machine-absorbing) in either sector causes S to rise and C/S to fall, and technical progress of type IV has the opposite effects.

It is possible for the value of the stock of machines to fall, both because the price of a machine may fall and because the physical stock may be reduced. In any event, in the majority of cases capital does not grow as fast as the out-

[1] See, for example, Kennedy (1964).

put of the consumption good, and so both the capital–output ratio and the share of profits in gross output fall, and the share of consumption in gross output rises.

The last two columns of Table II show the additional effects of a change in the equilibrium rate of profit. *Ceteris paribus*, a fall in the rate of profit causes the wage rate to rise and profits per worker to fall. The effect on the price of a machine depends on the relative machine-intensity of the two sectors: if the machine sector is the more machine-intensive, it will fall; if not, it will rise. The effects on K, Y, C/Y and K/Y may easily be traced by expressing them as simple functions of q and the unchanged C, M and S ($K = Sq$, $Y = C+Mq$, etc.). K, Y and K/Y move in the same direction as q, and C/Y in the opposite direction. Π/Y and q/w can, however, be shown to fall with a fall in the rate of profit, regardless of relative machine-intensity. A rise in the rate of profit causes a movement in the opposite direction in each case.

The total effect of a technical change is thus given by the interaction of the first eight columns of the table with the last two, unless the equilibrium rate of profit remains the same as before. For example, the price of a machine in wage-units, which is not affected directly by a change in the coefficients of the consumption sector, will fall or rise with the equilibrium rate of profit if there is a secondary effect on the latter; a change in the coefficients in the machine sector will by itself cause q/w to fall, and the fall will be increased if the rate of profit is induced to fall, and reduced or perhaps more than offset if the rate of profit rises.

Parenthetically, one may add some observations on the more familiar classifications of technical progress in the light of the foregoing results. Harrod (1937) originally defined technical progress to be neutral if it left the shares of profits and wages in total income undisturbed at a constant rate of profit; subsequently (Harrod, 1948) he adopted Joan Robinson's (1938) reformulation of the definition, that neutral technical progress causes a reduction in the amount of labour required when the capital–output ratio and the rate of profit are kept constant (equivalent to the earlier definition if constant returns to scale obtain). The problem with this definition, in a two-sector model, is that neutral technical progress may arise as a result of an infinite number of combinations of changes of technique in the two sectors.[1] For example, it might be caused by a combination of types I or II in the consumption sector and any type in the machine sector; or it might be caused by

[1] This point is brought out by Kennedy (1961) in the course of an analysis of the extent to which overall Harrod-neutral technical progress required net physical investment (that is, an increase in S; one might hypothesise that there might exist some combination of technical progress in the two sectors which would be Harrod-neutral in aggregate and cause a reduction in S, but it may quite simply be shown that this is not possible). Conceding the point, Harrod (1961) suggested that it would be more satisfactory to use Joan Robinson's concept of "real" capital (capital measured in value terms with the wage rate as numeraire) in this context, for the amount of "real" capital, so defined, would not be affected by Harrod-neutral technical progress (this observation was originally made in Harrod (1948); $K/Y = K/(\Pi+w)$, so if K/Y and K/Π are constant, K/w must be constant). This is true regardless of the number of sectors in the economy and regardless of what combination of sectoral technical progress is responsible for overall Harrod-neutrality.

a combination of types III or IV in the consumption sector and type I in the machine sector. If the definition is applied at the sectoral level, with the sectoral capital–output ratios defined in physical terms, then the economy as a whole will not, in general, be exhibiting neutral technical progress even if both sectors are.[1]

Hicks-neutral technical progress (Hicks, 1932) cannot be defined in this model as it stands, given the absence of a continuously differentiable production function with which to evaluate the marginal products of machines and labour. But one may observe that if the technique in use in the consumption sector were part of such a function, and if the whole function were subject to Hicks-neutral technical progress (defined physically, so that the function shifts in such a way as to leave the relative marginal products unchanged for any given machine-labour ratio, at a constant rate of profit), then the new technique chosen will be that point on the function with the same machine–labour ratio as the old technique (note that the ratio q/w is unaffected by technical progress in the consumption sector, providing that the rate of profit is constant). Hence Hicks-neutrality in that sector leads to the selection of a technique which represents technical progress on the boundary between types II and III, and so is equivalent to Harrod-neutrality for the economy as a whole.[2] Hicks-neutrality in the machine sector is more difficult to analyse because it is bound to cause the ratio q/w to fall.

IV

Suppose next that the economy produces many capital goods, say n, where n is large.[3] An immediate consequence is the unwieldy proliferation of categories of technical progress. Even if one does not make use of the relative concepts defined above, but simply classifies an advance according to whether it saves or absorbs each factor of production, one is faced with $2^{n+1}-1$ categories in all, and an unmanageable task of analysis.

Two simplifications might seem worth considering. One is prompted by the observation that output per unit of "real" capital (where "real" capital is measured by a constant-prices index of individual capital goods) appears to have been rising secularly in the United States.[4] One might be tempted to hypothesise that, in the long run, output per unit of any individual capital good would also rise, and hence one could concentrate on the single category of technical progress in which all factors are saved. The weakness of such a hypothesis lies in the implicit assumption that a given production process

[1] A sufficient condition is that the proportional rate at which labour is being saved should be the same in all sectors. Harrod (1948), discussing the implications of his definition of neutrality, gives the impression that he thought this to be a necessary condition.

[2] This result is, of course, well known. See Kennedy (1962), Asimakopulos (1963), Jones (1965).

[3] In the interest of generality one might also replace the consumption commodity by a set of such commodities, and the labour constraint by a set of primary factor constraints. But such refinements would complicate the present discussion without contributing to it, and therefore they will not be adopted.

[4] See Section V below.

will always utilise the same set of capital goods, and that technical progress in it takes the form of all-round improvements in efficiency. A more realistic description would make allowance for the introduction of new techniques utilising new capital goods. Thus while it might be true that the coefficients of most capital goods would gradually be falling (if they are not eliminated from the production process altogether), at the same time the coefficients of other capital goods would be jumping from zero to positive levels,[1] and the analysis would appear to remain as intractable as before.

An alternative approach which might appear promising involves aggregating the capital inputs in each production process in value terms using current prices, and then classifying technical progress according to whether it increases or decreases value capital per unit output (and, as before, according to whether it increases or decreases the input of labour per unit output). Such a procedure constitutes a departure from the previous analysis, since the classification of technical progress is no longer independent of prices. In order to discuss its implications the model will be extended formally:

$$\mathbf{a}C+\mathbf{Bm} = \mathbf{s} \qquad (14)$$

$$gC+\mathbf{h}'\mathbf{m} = 1 \qquad (15)$$

$$\mathbf{m} = (\lambda\mathbf{I}+\mathbf{\Delta})\mathbf{s} \qquad (16)$$

$$\mathbf{a}'(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q}+gw = 1 \qquad (17)$$

$$\mathbf{B}'(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q}+\mathbf{h}w = \mathbf{q} \qquad (18)$$

here

$\mathbf{m}$ = vector of outputs of machines
$\mathbf{s}$ = vector of stocks of machines
$\mathbf{q}$ = vector of prices of machines
$\mathbf{a}$ = vector of machine inputs into the consumption sector
$\mathbf{B}$ = matrix of machine inputs into the machine sectors
$\mathbf{\Delta}$ = diagonal matrix of depreciation rates

and the remaining parameters are defined as before. A prime denotes a transpose.

A new technique in the consumption sector would then be described as capital-saving if

$$\mathbf{a}^{*\prime}(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q} < \mathbf{a}'(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q} \qquad (19)$$

where $\mathbf{a}^*$ is the new vector of machine inputs. Similarly, a new technique in the sector producing machines of type i would be described as capital-saving if

$$\mathbf{b}_i^{*\prime}(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q} < \mathbf{b}_i'(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q} \qquad (20)$$

where $\mathbf{b}_i$ is the ith column of the matrix $\mathbf{B}$ and $\mathbf{b}_i^*$ is the equivalent vector belonging to the new technique.

Now it may easily be demonstrated that $\mathbf{q}$ depends upon the coefficients of $\mathbf{a}$, $\mathbf{B}$, g and $\mathbf{h}$. Hence although $\mathbf{a}^{*\prime}(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q}$ may be smaller than

[1] Note that in this model quality changes are handled by considering a machine of improved design to be a completely distinct type of machine.

$\mathbf{a}'(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q}$ given one set of techniques in the machine sector, it is possible that the reverse might be the case given another set of machine techniques. The same is true for comparisons of $\mathbf{b}_i^{*\prime}(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q}$ and $\mathbf{b}_i'(\rho\mathbf{I}+\mathbf{\Delta})\mathbf{q}$. Thus the classification of technical progress in any given sector depends on the state of the arts in the other sectors.

Finally, one might consider a variation on the above approach which consists of the construction of an aggregate measure of "real" capital input in each sector and a return to the two-factor model of Section III. Such a measure is, of course, one of the more notorious will o' the wisps in the whole of economic theory, and this is not the place to attempt a review of the problems associated with it (for a guide to the literature, see Harcourt, 1969). Nevertheless, since statistics on "real" capital inputs will be discussed in Section V, the following points may be worth considering.

First, one should of course note that when the rate of profit changes, the value of capital will also, in general, change, even when the techniques of production, defined in physical terms, remain unaltered. The analysis becomes subject to the difficulties associated with the reswitching phenomenon,[1] and it is impossible to summarise it with diagrams like Figs. 2 and 3.

However, even when the equilibrium rate of profit is unchanged, the "real" measure is as vulnerable as the current-prices money measure. It is open to the same criticism that whether or not a new technique in a given sector appears to require a smaller or larger "real" capital input than the old one depends upon the choice of weights for aggregating the individual capital goods. And if these weights are endogenously-determined prices, then, as with the money measure, the classification of technical progress in any sector is affected by the coefficients in other sectors.

Another disturbing aspect of the use of "real" capital for classification purposes is that there is no "correct" (non-arbitrary) way of measuring changes in its input in a given sector, even if the coefficients of the other sectors (and the rate of profit) remain constant.[2] For as the coefficients of the capital inputs change, so also will their prices, since they depend on all the technical coefficients in the system, including those of the sector in question. This implies that any index of "real" capital which uses endogenously-determined prices as weights[3] will effectively be a line integral. Hence, given any cumulative change from an initial technique to a final technique by way of a set of intermediate techniques, the measure of the difference in "real" capital employed by the initial and final techniques will not be independent of the intermediate techniques. Given one set of intermediate techniques, one

[1] See, for example, the symposium on reswitching in the *Quarterly Journal of Economics* 80 (4) (November 1966).

[2] This problem seems to have been first treated by Wold (1953), p. 147, exercise 51. It is discussed in detail by Richter (1966).

[3] The use of any index other than the Divisia will in general lead to even worse problems. For example, the use of a fixed-weights index could give rise to a situation in which one technique, which requires the same amount of labour as another, might also require more "real" capital, and yet be cheaper at current prices. Richter shows that the Divisia index makes the best of a bad job.

will get one figure; given a different set, another. And the same goes for any measure of technical progress that one might construct. So even in principle one cannot draw a line between increases in output due to capital accumulation and increases due to technical progress.[1]

None of the three proposed simplifications is without its defects, and thus it would appear to be a hopeless task to undertake a rigorous, price-free analysis of the effects of technical progress. However, so striking have been the changes in factor productivity in the United States during the past century that one might nevertheless be willing to venture some predictions for that and similar economies.

Part B: An Interpretation of Some Empirical Evidence

V

Before proceeding to discuss the statistical data one should first pause to consider the question of the extent to which the foregoing analysis is empirically relevant. The analysis has shown how the equilibrium structure of an economy is affected by the introduction of a new technique, equilibrium being defined as steady-state growth at a constant rate of profit, in the three cases in which the equilibrium rate of profit falls, remains unchanged, and rises. If technical progress occurred in isolated bursts, separated by sufficient time for the economy to adjust to the new equilibrium, it might be possible to accept this as a plausible representation of the facts. But technical progress is continuous, and so for this reason, if for no other, a steady-state growth equilibrium is never achieved. However, if the effect of technical progress is to make the equilibrium values of the macro-economic statistics move predominantly in given directions, and if their actual values tend to move in the direction of their equilibrium values, the results obtained will apply to the actual values as well, at least in the long run.

Tables III and IV give data on labour and capital inputs per unit of output, obtained from what appears to be the most comprehensive such study of any economy at any time—Kendrick's (1961) *Productivity Trends in the United States*. In every case the 1953 level of each input coefficient is given as a ratio of its level in 1929, both those years being peak years on the business cycle. Table III gives the ratios for the economy as a whole, according to four different definitions, and for those major sectors for which they were computed by Kendrick. Table IV gives the ratios for twenty industries within manufacturing.

Output is defined net of depreciation, except in two of the four cases of the economy as a whole. The first two definitions of the latter utilise the real net product of the national economy according to the Kuznets and the Department of Commerce concepts respectively.[2] The third and fourth

[1] It would be interesting to know the conditions under which one could place bounds on the ambiguity.

[2] Kuznets (1941), U.S. Department of Commerce (1954).

Table III

Labour and Capital Inputs per Unit of Output in 1953, as Proportions of their Levels in 1929, for the Aggregate Economy and the Major Sectors of the U.S.

	Labour input	Capital input	Ratio
National economy (Kuznets concept, real net product)	0·71	0·78	0·91
National economy (Department of Commerce concept, real net product)	0·62	0·67	0·93
Private domestic economy (real gross product)	0·58	0·68	0·85
Private domestic non-farm economy (real gross product)	0·59	0·67	0·88
Agriculture (farming sector)	0·46*	0·97	0·47
Mining	0·52	0·60	0·87
Manufacturing	0·64	0·63	1·01
Trade	0·64*	0·75	0·85
Transportation	0·36	0·45	0·80
Communications and Public Utilities	0·35	0·57	0·61

* Manhours.

Sources: Kendrick (1961), Tables A-XX, A-XXI, A-XXII, A-XXIII, B-I, C-I, D-I, F-I, G-I and H-I.

Table IV

Labour and Capital Inputs per Unit of Output in 1953, as Proportions of Their Levels in 1929, for the Industries within the Manufacturing Sector of the U.S.

	Labour input*	Capital input	Ratio
Food and kindred products	0·70	0·61	1·15
Beverages	0·26	0·25	1·04
Tobacco products	0·29	0·72	0·40
Textile mill products	0·45	0·52	0·87
Clothing	0·82	0·96	0·85
Lumber prods., exc. furn.	0·63	0·59	1·07
Furniture and fixtures	0·67	0·41	1·63
Paper and allied products	0·58	0·63	0·92
Printing and publishing	0·71	0·67	1·06
Chemicals	0·39	0·51	0·76
Petroleum and coal prods.	0·50	0·71	0·70
Rubber products	0·62	0·54	1·15
Leather products	0·73	0·64	1·14
Stone, clay and glass	0·64	0·47	1·36
Primary metal industries	0·74	0·83	0·89
Fabricated metal prods.	0·63	0·53	1·19
Machinery, exc. electric	0·64	0·67	0·96
Electric machinery	0·48	0·50	0·96
Transport equipment	0·82	0·64	1·28
Misc. and instruments	0·58	0·47	1·23

* Manhours.

Source: Kendrick (1961), Table D-IV.

definitions utilise the real gross output of the private domestic economy, and the private domestic non-farm economy, respectively, according to the Department of Commerce concept. For a more detailed account of the measures of output and inputs, see Kendrick, Chapter 2.

The change in labour input takes into account the change in employment per unit of output, the changes in the hours worked per year, and, for the economy as a whole and for most of the major sectors, the change in the quality of labour caused by shifts in the occupational distribution.

In the context of the present analysis, the definitions of output and labour input may be acceptable in spite of their obvious deficiencies. But the definition of "real" capital input must inevitably be subject to criticism, in view of the remarks in Section IV. Kendrick's calculation of the capital input uses a quantity index weighted by 1929 prices. However, so great have been the declines, in the various sectors of the economy, of the "real" capital input, according to this measure, that it seems reasonable to suppose that any other conventional measure of "real" input would have given results similar in qualitative, if not quantitative, terms. And so one arrives at a paradoxical state of affairs in which one would dispute the existence of "real" capital, and yet at the same time one can assert that it has certainly fallen, relatively to output, in every sector. The apparent robustness, in this respect, of the measure might encourage one to suppose that a two-factor model is not a wholly misleading representation of reality. Further evidence on this score will be provided below where it is shown that the two-sector model of Section III can explain the long-term behaviour of such macro-economic variables as the share of profits as a result of changes in factor productivity. If one is willing to believe that the failure of the two-sector model to take into account changes in the relative outputs and the relative prices of capital goods (relative to each other) is of less consequence than its success in analysing changes in the output and price of "capital" relative to consumption, then its predictions may be of some interest. Without further apology, the interpretation of the statistical data will proceed on this basis.

The data in Tables III and IV do not permit one to divide the economy into a consumption sector and a capital goods sector, both because intermediate commodities have not been netted out of the system, and because in any case some of the categories include both consumption and capital (and intermediate) goods, but the industry breakdown within manufacturing does give some indication of what one might expect to find if one could.

Briefly, it appears that there is not much difference in the way that those industries concentrating on consumption goods, and those on capital goods, have been affected by technical progress. In both cases technical progress has been simultaneously labour-saving and machine-saving, approximately at the same rate, there being some instances in which it has been relatively labour-saving and others in which it has been relatively machine-saving. The extent of technical progress, taking the inputs together, appears to have been the same in both cases.

If one can assume that technical progress affects the production of consumption goods and that of capital goods in the same way and to the same extent,[1] and that it is both labour-saving and machine-saving, one can simplify the analysis summarised in Table II considerably. The results are shown in Table V.[2]

TABLE V

The Macro-economic Effects of Technical Progress in a Two-sector Model, under the Assumption that it Affects both Sectors Similarly

	Type		Additional effect if rate of profit	
Statistic	II	III	Falls	Rises
w	+	+	+	−
q	−, +	−, +	−, +	+, −
q/w	−	−	−	+
C	+	+	=	=
Π	±, +	−, ±	−	+
K	±, +	−, ±	−, +	+, −
Π/Y	−	−	−	+
K/Y	−	−	−, +	+, −
C/Y	+	+	+, −	−, +
S, M	±, +	−, ±	=	=
$C/M, C/S$	+	+	=	=

+, rises; −, falls; ±, may rise or fall; =, unaffected.

Looking first at the case in which the equilibrium rate of profit is unaltered, perhaps the most significant result is the resolution of the ambiguity in the direction of movement of the share of profits. In Table II it may be seen that technical progress of type III causes the share of profits to fall, regardless of whether it occurs in the consumption sector or the machine sector, but if it is of type II its overall effect is uncertain, since it causes the share of profits to rise if it occurs in the consumption sector and to fall if it occurs in the machine sector. Under the assumption that technical progress affects both sectors similarly (as described above), it can be shown that the net result is for the share to fall in the type II case as well. This follows from the fact that the share is inversely related to C/Mq; C/M must rise, and although q may also rise, it cannot do so fast enough to prevent C/Mq from increasing.

Most of the other results are obvious enough. Those for the wage rate, the

[1] So that the labour coefficients in the two sectors fall at the same rate, and likewise the capital coefficients fall at the same rate (but these two rates not necessarily being equal to each other). Actually, one can relax the assumption concerning the capital coefficients and still obtain the same results. The equal proportionate fall in the labour coefficients would, by itself, be equivalent to Harrod-neutral technical progress and would, for example, leave Π/Y and K/Y unchanged. Looking at Table II any fall in either machine coefficient would, by itself, cause Π/Y and K/Y to fall. Adding the two effects together, one obtains the results in Table V.

[2] As in Table II, where there appear two entries separated by a comma, the first entry refers to the case where the capital sector is the more capital-intensive, the second to the case where the consumption sector is the more capital-intensive.

wage-rental ratio,[1] the output of the consumption good, and the ratio of the latter to the output of machines, follow directly from Table I. The rise in the share of consumption in national income is a consequence of the fall in the capital-output ratio.

The variations in the results caused by a rise or fall in the equilibrium rate of profit follow the same lines as in Table II. A fall reinforces the effects on w and q, and hence on q/w and K, while a rise offsets them partially or wholly. The effects on Π, Y, K/Y, C/Y and, in the case of ρ rising, Π/Y, become more ambiguous. C, S, M, C/S and C/M are of course unchanged.[2]

Which of the different possible sets of results is likely to be most relevant in practice? If the past is any guide to the future, Table III would suggest that, as far as the type of technical progress is concerned, more attention should be paid to type II than to type III, in the United States at least: although technical progress appears unbiased in the manufacturing sector, in the other sectors relatively labour-saving technical progress appears to be the rule.

Evaluating any long-term trend in the rate of profit is bound to be a

[1] In the case of the prediction that the wage-rental ratio should rise, it may be worthwhile to quote some observations of Kuznets: "But the share of labor in national income in current prices rose to 77·3 per cent in 1954–58. To attain this level... the price per man-hour of labor *relative* to the price per service unit of capital... had to increase 2·41 times between 1909–13 and 1954–58. That this change in relative prices did in fact take place in the United States economy is suggested by other data. The most comprehensive measure of wages per man-hour available—that for all production workers in manufacturing—rose 9·5 times from the average of 1909 and 1914 to 1955–57; while the most comprehensive measure of prices of reproducible capital (and some land)—prices implicit in domestic gross capital formation—achieved a less than fourfold rise from 1909–13 to 1955–57. If we 'deflate' the wage per man-hour by prices of capital services (implying a constant rate of return), wage per man-hour so deflated would have multiplied 2·44 times—an increase quite close to that in the price differential in favor of labor services of 2·41 times suggested above" (Kuznets, 1966, pp. 182–3). Kuznets suggests that much of the increase in the ratio, perhaps three-quarters, might be ascribed to improvement in the quality of labour due to education, but nevertheless a substantial part would remain after this had been taken into account.

[2] One should perhaps mention here some empirical findings that might seem to indicate an upward trend in q. Gordon (1961) has drawn attention to the fact that the ratio of the price deflator for capital goods to that for consumption goods has increased substantially during the present century in the United States, the United Kingdom, Canada and Denmark (but not in Sweden); Anderson (1961) similarly observes that the constant-prices capital–output ratio for the United States has declined relatively to the current-prices ratio. But as both Gordon and Anderson, and Kennedy (1962) and Jorgenson and Griliches (1967), point out, failure to take adequate account of improvements in quality is likely to impart a strong upward bias to a capital goods price deflator. Unless there is some simple way of relating it to an existing capital good, the constant-prices value of a new capital good is typically determined by its cost of production, and thus the element of technical progress is suppressed.

Consider, as an illustration, the following two cases. In the first, a given technique for constructing a specific type of machine is superseded by another which can produce two machines of the same type with the same resources; in the second, the technique is superseded by one which produces, again with the same resources, a new type of machine that can do the work of two of the old machines. If it is valued at its cost of production, the new type of machine will be taken to represent the same amount of constant-prices capital as one machine of the old type. Hence the market price per unit of constant-prices capital will be twice as high in the second case as in the first. This bias is probably capable of accounting for the whole of the relative upward trend in the capital goods price deflator.

(Note that in the first case in the illustration, the rise in aggregate output will be attributed to technical progress in the sector producing the machine; in the second case it will appear that no technical progress has occurred in that sector, and that the rise in aggregate output is due to technical progress in those sectors employing the machine as an input.)

hazardous task. On the one hand, any estimate of profits must face the problem of resolving the income of the self-employed into profits and wages. On the other, the measurement of capital, even at current prices, inevitably involves guesswork with untrustworthy data.

Hardly surprisingly, it does not seem possible to come to any firm conclusion for the United States. Klein and Kosobud (1961) found a slight downward trend in the (reproducible) capital–output ratio, and no significant trend in the share of profits, in the period 1900–53. The implicit rate of profit, the ratio of the latter to the former, would therefore appear to have had a slight upward trend. But they include all the income of the self-employed in the share of labour, which may account for part of the discrepancy between this result and their estimate of a small downward trend in the yield of corporate bonds over a marginally longer period (1900–59).

TABLE VI

Share of Profits, Capital–output Ratio, and Implicit Rate of Profit in the United States

Period	Share of profits (%) Assumption* 1	Share of profits (%) Assumption 2	Capital–output ratio	Rate of profit (%) Assumption 1	Rate of profit (%) Assumption 2
1899–1908	24	31	5·6	4·3	5·5
1919–28	26	31	5·2	5·0	6·0
1929	27	32	5·1	5·3	6·3
1939–48	24	24	4·1	5·9	5·9

* See text for assumptions.

Sources: Share of profits (gross profits/national income): lines 1–3, Kuznets (1966), Table 4.2; line 4, Kuznets (1959), Appendix Tables 17 and 18. Capital–output ratio (total wealth/national income): Goldsmith, Saunders and van der Weide (1959), Table VI (from Goldsmith (1956), Table W-1, column 1, and Table N-1, column 7), average over periods in question.

Table VI shows some estimates based on data drawn from the most recent studies by Kuznets and Goldsmith: estimates of the (current-prices) share of profits from *Modern Economic Growth* and estimates of the (current-prices) capital–output ratio from *A Study of Saving in the United States*. Little weight should be attached to the absolute figures for the implicit rate of profit in the table, in view of their sensitivity to the assumptions employed in the preparation of the two underlying series; but given that the assumptions are unchanged, the estimates of the movements in the rate of profit may be more reliable, at least qualitatively.[1]

Kuznets proposes alternative methods for dividing the income of the

[1] Since Kuznets' figures for the share of profits are calculated as the ratio of gross profits, including rents, to national income, it seems most appropriate to use Goldsmith's figures for the ratio of total wealth to national income for the capital–output ratio. However, if one replaces total wealth by reproducible capital, one obtains similar results. Column 1 of the table below gives the ratio of reproducible capital to national income derived from Goldsmith's data (column 2 of Goldsmith (1959), Table W–1 has been substituted for column 1), and columns 2 and 3 give the corresponding implicit rates of profit under Assumptions 1 and 2 (see below), respectively, for the periods in

self-employed between profits and wages. What will be called Assumption 1 supposes that "the labor component of income per entrepreneur and self-employed equals per worker income of all employees", and Assumption 2 supposes that "the rate of return on the equity of entrepreneurs and self-employed equals that on all other equity and that their equity is in the same proportion to all income-yielding wealth as their number is to the labor force" (Kuznets, 1966, p. 170). Correspondingly, one derives alternative time series for the rate of profit. Under Assumption 1 it rises gradually from 4·3 % in the first period, 1899–1908, to 5·9 % in the last period, 1939–48, and under Assumption 2 it rises from 5·5 % initially to 6·0 % in 1919–28, 6·3 % in 1929, and falls again to 5·9 % in 1939–48.

The interval most relevant to the statistics of Tables III and IV is that between 1929 and 1939–48, and the two assumptions indicate movements in opposite directions. The figures are thus inconclusive, but as far as they go they suggest that the movement has been moderate. For example, one can see from Table VI itself that the movement has not been large enough to override the predicted effects of the change in production coefficients on the share of profits. If one follows Assumption 1, there has been a slight rise in the rate of profit which, taken by itself, would cause an increase in the share of profits. Since the share of profits, as estimated under the same assumption, has in fact fallen slightly, this would imply that the effect of the changes in the production coefficients has been relatively strong. If, instead, one follows Assumption 2, the rate of profit has fallen slightly, but under the same assumption the share of profits has fallen substantially, and again the figures are consistent with the predicted effects of technical progress of types II or III.

If one looks at other countries, the scattered data that are available indicate that, on the whole, both the share of profits and the capital–output ratio have fallen over time. But, given the general lack of the necessary additional data,[1] it is impossible to say to what extent these falls should be ascribed to changes in the production coefficients or to changes in the rate of profit, or to both.

question. Alternatively, using the estimates of the ratios of reproducible capital to national income supplied by Klein and Kosobud (averaged for the relevant periods) in column 4, one obtains the estimates of the implicit rate of profit shown in columns 5 and 6, under the two assumptions.

Period	Goldsmith c–o ratio	Rate of profit: Ass. 1	Rate of profit: Ass. 2	Klein–Kosobud c–o ratio	Rate of profit: Ass. 1	Rate of profit: Ass. 2
1899–1908	3·7	6·5	8·3	3·9	6·2	8·0
1919–28	3·6	7·1	8·5	3·6	7·3	8·7
1929	3·7	7·4	8·7	3·3	8·1	9·3
1939–48	3·2	7·6	7·6	3·1	7·9	7·9

[1] A partial exception is the United Kingdom, for which Feinstein (1968) has calculated a time series for the rate of profit. It takes the form of a declining step function, with the steps occurring in the intervals covering the two World Wars. Unfortunately, the accompanying time series for the share of profits has the same (qualitative) form and so one cannot deduce whether changes in the production coefficients have had any appreciable effect.

Concluding Remarks

One should emphasise the limitations of the present analysis. Quite apart from the difficulties involved in distinguishing between the effects of changes in production coefficients and changes in the rate of profit, there are the distortions that have been introduced by the use of a two-sector model that side-steps important capital–theoretic problems and by the restriction of the discussion to the comparison of steady state growth paths. In the short run (and in the present context, anything less than 50 years is a short time), any trends are likely to be obscured by the dynamic disequilibrium process that more accurately describes the behaviour of the economy.

The analysis is therefore only intended to be suggestive, and of course it depends on the validity of the assumptions made both about the present and about the future. Needless to say, some of the suggestions are empirically trivial, but others, in particular the prediction that, even if the rate of profit were to become constant, the share of profits and the capital–output ratio should fall indefinitely, are perhaps not so obvious and have important implications. For example, it raises the possibility that the activities of IBM may be as effective as any political movement in reducing the inequality in the distribution of income in the long run.

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