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REVIEW ARTICLE/ARTICLE CRITIQUE

CAPITAL THEORY UP TO DATE

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The lectures which Professor Solow gave in Holland (published in 1963[1]) opened with the remark: Everybody except Joan Robinson agrees about capital theory. He did not say what it was that they agreed, and a few years later the "reswitching" controversy brought some important differences of opinion to light. Now, fortunately, we have a clear exposition of what Professor Solow must have meant. Professor Ferguson, in *The Neoclassical Theory of Production and Distribution*,[2] asserts that belief in neoclassical theory is a matter of faith. "I personally have the faith" he declares, so that we can learn from him what it is that the neo-classicals believe neoclassical theory to be. But first let us trace the history of the "reswitching" affair.

Reswitching

In the course of investigating the meaning of a production function for output as a whole, I set up what Profesor Solow later correctly described as a pseudo-production function, showing the possible positions of equilibrium, corresponding to various values of the rate of profit, in an imagined "given state of technical knowledge." The analysis showed that there is no meaning to be given to a "quantity of capital" apart from the rate of profit, so that the contention that the "marginal product of capital" determines the rate of profit is meaningless. (In the present argument "land" as a separate factor of production is not taken into account.) Incidentally, I found that over certain ranges of the pseudo-production function the technique that becomes eligible at a higher rate of profit (with a correspondingly lower real-wage rate) may be less labour-intensive (that is, may have a higher output per man employed) than that chosen at a higher wage rate, contrary to the rule of a "well-behaved production function" in which a lower wage rate is always associated with a more labour-intensive technique. (I attributed this discovery to Ruth Cohen – a private joke.)

I had picked up the clue from Piero Sraffa's Preface to Ricardo's *Principles* and my analysis (errors and omissions excepted) was a preview of his. When his own treatment of the subject was finally published in *Production of Commodities by Means of Commodities* (in 1960) the "Ruth Cohen case" (which I

[1]Robert M. Solow, *Capital Theory and the Rate of Return* (Amsterdam, 1963).
[2]C. E. Ferguson, *The Neoclassical Theory of Production and Distribution* (London and New York, 1969).

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had treated as a *curiosum*) was seen to have great prominence; the striking proposition was established that it is perfectly normal (within the accepted assumptions) for the same technique to be eligible at several discrete rates of profit. It was from this that the soubriquet "reswitching of techniques" was derived. (The difference between my treatment and Sraffa's was accidental. I put the main emphasis on differences in the amounts of "labour embodied" in the equipment appropriate to different techniques while Sraffa illustrates his point with a case in which two commodities require the same labour applied in different time-patterns. The backward switch, from a lower to a higher output per head with lower wages, is connected with the inter-relations of the time-patterns of the techniques; his examples gave more scope for it than mine.)

The neo-neoclassicals took no notice; they went on as usual drawing production functions in terms of "capital" and labour and disseminating the marginal productivity theory of distribution. In 1961 I encountered Professor Samuelson on his home ground; in the course of an argument I happened to ask him: When you define the marginal product of labour, what do you keep constant? He seemed disconcerted, as though none of his pupils had ever asked that question, but next day he gave a clear answer. Either the physical inputs other than labour are kept constant, or the rate of profit on capital is kept constant.

I found this satisfactory, for it destroys the doctrine that wages are regulated by marginal productivity. In a short-period case, where equipment is given, at full-capacity operation the marginal physical product of labour is indeterminate. When nine men with nine spades are digging a hole, to add a tenth man could increase output only to the extent that nine dig better if they have a rest from time to time.[3] On the other hand, to subtract the ninth man would reduce output by more or less the average amount. The wage must lie somewhere between the average value of output per head and zero, so that marginal product is much greater or much less than the wage according as equipment is being worked below or above its designed capacity.

In conditions of imperfect competition, under-capacity operation of plant is normal (except in an acute seller's market) and, in industry as a whole, it seems that, on average, wages are usually about half of value added. The marginal product of labour, in the short-period sense, is therefore generally about twice the wage.[4]

In long-period equilibrium, with a constant rate of profit, the stock of equipment and the amount of employment have been adjusted to each other. When competition prevails in the long-period sense of free entry to all markets, so that a uniform rate of profit tends to be established throughout the economy, the wage is equivalent to what Marshall called the marginal *net* product of labour – that is the value of average output per head *minus* a gross profit sufficient to pay for replacement and net profit at the going rate on the value of capital per man employed, when all inputs are reckoned at the prices appropriate to the given rate of profit. The wage is determined by technical conditions and the rate of profit, as at a particular point on a pseudo-production function. The question then comes up, what determines the rate of profit?

[3]See D. H. Robertson, "Wage Grumbles," 1930, republished in *Economic Fragments*.
[4]Cf. A. M. Okun, *Potential GNP. Its Measurement and Significance*, Cowles Foundation Paper 189.

But this was going too far. Professor Samuelson retreated behind what he called a surrogate production function.[5] It was a special case (as Piero Garegnani promptly pointed out[6]) of a pseudo-production function with labour-value prices. When, for any one technique, the capital-labour ratio and the time pattern of inputs are uniform throughout all the processes of production, prices are proportional to labour-time. The value of capital in terms of product, for that technique, is then independent of the rate of profit. When each technique in the "given state of knowledge" has this character and the time-patterns are all alike, the order of techniques in terms of output per head is the same as the order in terms of value of capital per man for each technique at the rate of profit that makes that technique eligible; a higher output per man is associated with a higher wage and lower rate of profit. When a pseudo-production function of this type is set out as a relationship between "capital" and output it looks just like a well-behaved production function.

Professor Samuelson believed that in this he had provided for the "neoclassical parables" of J. B. Clark "which pretend there is a single thing called "capital" that can be put into a single production function and along with labour will produce total output."[7]

At first the neo-neoclasicals were happy to accept his parable. (This was the period of Professor Solow's lectures and of the first draft of Professor Ferguson's book in which, he tells us, he relied upon the surrogate production function to protect him from what he calls Cambridge Criticism.) For some years they remained cooped up in this position, repelling all attacks with blank misunderstanding. Then, growing bold, they descended to the plains and tried to prove Sraffa wrong.

This rash enterprise was not successful; Professor Samuelson very handsomely admitted that he had been mistaken.[8] But he mistook his mistake. The trouble was not merely that he had ignored Garegnani's warning and treated labour-value prices as the general case. The real mistake was to suppose that a pseudo-production function, which relates the rate of profit to the value of capital at the prices corersponding to that rate of profit, provides the "neoclassical parable." Neoclassical "capital" is a physical quantity which is independent of prices.

Capital

The neo-neoclassicals' concept of capital is derived from Walras, but they have transformed it into something quite different. In a Walrasian market, when dealing begins, there are particular supplies of factors already in existence each measured in physical terms – man-hours, acres, tons, pints, and yards. In the neo-neoclassical concept of capital all the man-made factors are boiled into one,

[5]"Parable and Realism in Capital Theory: The Surrogate Production Function," *Review of Economic Studies*, 29 (June 1962), 193–206.
[6]*Ibid.*, 202 n.
[7]*Ibid.*, 194.
[8]"A Summing Up" in "Paradoxes of Capital Theory: A Symposium," *Quarterly Journal of Economics*, 80 (Nov. 1966), 568–83.

which we may call *leets* in honour of Professor Meade's *steel.*[9] But leets, though all made of one physical substance, is endowed with the capacity to embody various techniques of production – different ratios of leets to labour – and a change of technique can be made simply by squeezing up or spreading out leets, instantaneously and without cost. A higher output per man requires a larger amount of leets per man employed. In Walrasian competitive equilibrium there can never be increasing returns from one factor applied to a given quantity of another. This rule is observed by leets. There is a well-behaved production function in leets and labour for each kind of output, including leets. Moreover, leets can absorb technical progress, without losing its physical identity, again instantaneously and without cost. Then to simplify still further, output is also taken to be made of leets; the whole Walrasian system is reduced to a "one-commodity world."

This is the conception in which Professor Ferguson has re-affirmed his faith.

Many economists, nowadays, who are interested in practical questions are impatient of doctrinal disputes. What does it matter, they are inclined to say, let him have his leets, what harm does it do? But the harm that the neo-neoclassicals have done is, precisely, to block off economic theory from any discussion of practical questions.

When equipment is made of leets, there is no distinction between long and short-period problems. The answer to Dennis Robertson's question is simply fudged. Nine spades are a lump of leets; when the tenth man turns up it is squeezed out to provide him with a share of equipment nine-tenths of what each man had before.

There is no such thing as a degree of utilisation of given equipment rising or falling with the level of effective demand. (Professor Solow pretends that his production functions are drawn in terms of concrete capital goods, but the fact that the short-period utilisation function is identical with the long-period pseudo-production function gives him away.)

There is no room for imperfect competition. There is no possibility of disappointed expectations – indeed, there is no difference between the past and the future, for the past can always be undone and readjusted to a change in the present situation.

There is no problem of unemployment. The wage bargain is made in terms of product and there is perfect competition both between workers for jobs and between employers for hands. Unemployed workers would bid down wages and the pre-existing quantity of leets would be spread out to accommodate them. The neo-neoclassicals have reconstructed the vague doctrines of the neoclassicals from which was derived the dogma which Keynes had to attack in the great slump of the 'thirties, that unemployment can be caused only by wages being too high.

In long-period analysis, the neo-neoclassics are prone to confuse a comparison of positions of equilibrium (as in a pseudo-production function) with a "Wicksell process" of accumulation without technical progress. "A given state of technical knowledge" consists simply of a production function in terms of leets and labour. Accumulation consists of adding some leets to the pre-existing

[9] J. E. Meade, *A Neoclassical Theory of Economic Growth* (London 1961).

stock and squeezing it into a new quantity per man employed. This entails raising the wage rate and reducing the return per ton of leets. Thus a process of raising the capital-labour ratio means creeping along the production function, moving step by step from lower to higher ratios of leets to labour. (It is notable that when Professor Samuelson conceded defeat in the "reswitching" controversy, he did so in this form. He seemed to suppose that if the process of accumulation hit a backward switch, where a lower rate of profit is associated with a lower value of capital per man, the economy would suddenly find itself able to consume part of its capital without reducing its productive capacity.)

This brings into play the other aspect of pre-Keynesian theory. Saving consists in a decision not to consume a part of the current output and this causes investment to make a corresponding addition to the stock of "capital." The neo-neoclassicals have succeeded in tying themselves up again in habits of thought from which Keynes had had "a long struggle to escape." (However, when it comes to offering advice on questions of national policy many of them propounded quite simple-minded Keynesian views.[10])

Wages and profits

The main function of the concept of leets is to provide a theory of the distribu- of the product of industry between wages and profits.

At any moment, with a given quantity in existence of leets regarded as capital equipment, the wage in terms of leets regarded as product is at the level compatible with full employment of the available labour force. Then, with a few extra assumptions, such as that there is no charge for interest on the part of working capital which represents the wage fund, it is shown that the wage is equal to the marginal product of the available labour force, that is, the amount of product per week that would be lost if one less man were employed and the stock of leets squeezed up appropriately. If the wage were less than this, competition for hands would drive it up. If it was greater, less men would be employed and competition for jobs would drive it down. The wage being equal to the marginal product of labour, it is shown by Euler's theorem that the product minus the wage is the marginal product of a ton of leets multiplied by the quantity of leets in existence.

Now, capital in the world we live in has two aspects. It consists of the stocks of equipment and materials which (with education and training) permit workers to produce marketable goods and it consists of the command over finance which permits employers to organise the production of goods which they can sell at a profit. In the "one-commodity world" the price of a ton of leets-capital in terms of leets-output is unity. The two aspects of capital are fused. A ton of leets is both a piece of equipment and a sum of purchasing power. Then the return to a unit of leets, leets over leets, is the rate of profit on capital. Thus labour and capital each receive a "reward" equal to their marginal productivity.

[10]Cf. R. M. Solow, *The Nature and Sources of Unemployment in the United States* (Wicksell Lectures, 1964).

As J. B. Clark himself put it: "What a social class gets is, under natural law, what it contributes to the general output of industry."[11]

Here, indeed, we find the origin of the concept of leets. First came the dogma that the rate of profit that the owners of capital enjoy is equal to the productivity of capital equipment, and that saving continues to cause capital to accumulate so long as its marginal product exceeds the rate of interest which represents the "discount of the future" in the minds of its owners. Then the question is asked, what is this "capital" that has a marginal product? Leets had to be invented to give an answer to that question.

Of course, all this is not intended to be taken literally. Even Professor Ferguson admits that capital equipment actually consists of a variety of hard objects that cannot be squeezed up or pressed out, without cost, to accommodate less or more workers. Leets is only a parable, as Professor Samuelson claimed. But as soon as they give it up, their argument comes unstuck.

Professor Ferguson, for instance, incorporates a "vintage model" in his system. The vintage model is taken over from Harrod's conception of an economy realising the "natural" rate of growth given by technical progress.

Gross investment, in each period, is embodied in equipment for the latest, most superior technique. The conditions for equilibrium growth are that technical progress should be raising output per head at a steady rate and that it should be neutral in Harrod's sense, so that a constant rate of profit on capital is compatible with a constant capital-output ratio and constant relative shares of wages and profits in net output. A constant share of gross investment in total output then produces growth of output per head at a steady rate.

On any one equilibrium path, the rate of profit on capital is constant through time, but there may be different paths (with the same sequence of technical innovations) with different rates of profit. Thus there is a kind of pseudo-production function relating the rate of profit to the value of capital in terms of product and the share of gross investment in output.

The level of wages in terms of product rises in step with output per head (this follows from the condition that the rate of profit and the share of wages in output are constant) and the equipment for each technique is scrapped when the wage absorbs its whole output so that its quasi-rent is reduced to zero. A higher share of profit entails a wider gap between the wage rate and output per head with the latest, best, technique. Thus it entails a longer service life of equipment, therefore a higher proportion of older, more inferior, techniques in use at any moment, and lower average output per head. There is then a presumption that the pseudo-production function relating the rate of profit to the capital-output ratio will be well-behaved (a lower output per man being associated with a lower value of capital per man) though there still might be some "Cambridge" tricks in it. But what determines the rate of profit?

Professor Ferguson follows Professor Solow's argument that a very small *extra* investment over and above that required by the equilibrium path yields a return equal to the rate of profit. That is true, whatever the rate of profit may

[11] J. B. Clark, "Distribution as Determined by a Law of Rent," *Quarterly Journal of Economics*, 5 (April 1891), 313.

be. And he shows that the marginal product of labour in the short-period sense is equal to the wage; the "last man" is employed in the equipment that is just about to be scrapped. This is true because, for a given pseudo-production function, both the wage relative to output per head with the latest technique and the age of the least productive equipment are determined together by the rate of profit. Evidently they are so used to thinking in terms of leets (for whatever he may say, Professor Solow's capital is made of leets) that they forget that, when capital is embodied in specific equipment, the short-period marginal physical product of labour is not the same thing as the value of the net product allowing for profit at a particular rate. They describe the competitive equilibrium position corresponding to a given rate of profit without offering any explanation of what the rate of profit is.

There have been three types of theory of the distribution of the product of industry between wages and profits. In classical theory (of which von Neumann provides the most systematic account) the real wage per man is a technical datum; the rate of profit on capital emerges as a residual. In Marx, the rate of exploitation (the ratio of net profit to wages) is the result of the balance of forces in the class struggle. For Marshall, there is a normal rate of profit and the real wage emerges as a residual; an extension of Keynes' General Theory into the long period finds a clue to the level of profits in the rate of accumulation and the excess of consumption out of profits over saving out of wages.

When the neo-neoclassicals reconstituted orthodoxy after the Keynesian revolution they eschewed all these and went to Walras, who does not have a theory of profits at all.

Econometrics

The strangest part of the whole affair is that many neo-neoclassicals seek to identify leets-capital with the dollar value of capital as it appears in statistics. Professor Ferguson concludes his account of "reswitching" thus: "The question that confronts us is not whether the Cambridge Criticism is theoretically valid. It is. Rather the question is an empirical or econometric one: is there sufficient substitutability within the system to establish neoclassical results?"[12] And he states in the Preface: "Until the econometricians have the answer for us, placing reliance upon neoclassical economic theory is a matter of faith." Statisticians, though with a very coarse mesh, can catch evidence of the capital-output ratio in terms of dollar values, and the shares of wages and profits in value added, over a particular period in a particular economy, and so they can offer an estimate of the ex-post, over-all rate of profit being realised. They cannot say what expectations of profit were in the minds of the managers of firms, or whether alternative schemes were on the drawing boards of engineers, when the investment decisions were taken that brought a particular stock of capital equipment into existence. Still less can they say what decisions would have been taken if present and expected prices and wage rates had been different from what they were. Professor Ferguson expects too much.

[12] *The Neoclassical Theory of Production and Distribution*, 266.

Consider a run of figures for a prosperous period of development in a modern industrial economy which conform more or less (as they often seem to do) to what Kaldor calls the "stylised facts." The capital-output ratio and the wage and profit shares are fairly constant over time, while the dollar value of output per man employed and the dollar value of capital per man have a strong upward trend. This would lend itself to interpretation as an approximation to the story of accumulation on a Harrod path, as in the vintage model, with neutral technical progress and a fairly steady over-all average rate of profit (fluctuations in effective demand being smoothed out).

This will not do for the neo-neoclassicals. They want to separate out increases in the quantity of "capital" from the effects of technical progress. To find this distinction, they puzzle themselves with their leets. Leets can absorb technical progress without any investment being required. An "invention" raises the output per head of a set of workers equipped with a given quantity of leets. But output also consists of leets, so that if the share of saving in income is constant, leets per man employed begins to rise as a result of the invention. Is this to be attributed to accumulation or to the invention? To attribute the growth of leets per man to saving, it would be necessary to define as saving, refraining from consuming so much of additional leets as to keep leets per man constant.[13]

In any case, the statistics are in dollars, not in tons of leets. Whether technical progress is embodied in new types of equipment or affected by a rearrangement of existing equipment or comes from "learning by doing" by workers without any change in equipment at all, the figures would be the same. The difference would appear only in the amount of gross investment required to keep the economy going.

Output of capital equipment must be reckoned not in tons of any metal or in lists of items (a bus is a bus and a lathe is a lathe) but in terms of productive capacity. Over-all, wages in terms of product are rising in step with output per head, and the rate of profit is constant. The capital-output ratio, over all, does not change much, either way. For embodied technical progress, therefore, the cost per unit of productive capacity is rising at the same rate as output per head.

Equally, the value of equipment absorbing disembodied progress (if there is such a thing) would rise at the same rate. Profit per man employed rises with output per head (since the real wage rises at the same rate) and no depreciation is required. Capitalise the profits at a rate of interest equal to the over-all rate of profit and the value of the equipment rises at the same rate as output per head.

Professor Jorgenson uses just this procedure to account for the rise in the value of capital shown in his statistics but then he attributes its growth entirely to accumulation and maintains that no technical progress has occurred in US industry since 1945.[14] More often a set of statistics is used to draw up a produc-

[13]Cf. T. K. Rymes, "Professor Read and the Measurement of Total Factor Productivity," this JOURNAL I, no. 1 (May 1968).

[14]D. W. Jorgenson and Z. Griliches, "The Explanation of Productivity Change," *Review of Economic Studies*, 34 (July 1967), 249–83.

tion function in terms of "capital" and labour and to separate the growth of the value of output per head into the part due to the increase in the quantity of "capital" and the "residual" due to technical progress. This requires the statisticians to find out from the record of what actually happened, what the growth of output *would have been* if the value of capital had grown as much as it did without any technical progress having taken place. (It must have needed an even tougher hide to survive Phelps Brown's article on "The Meaning of the Fitted Cobb-Douglas Function"[15] than to ward off Cambridge Criticism of the marginal productivity theory of distribution.)

No doubt Professor Ferguson's restatement of "capital" theory will be used to train new generations of students to erect elegant-seeming arguments in terms which they cannot define and will confirm econometricians in the search for answers to unaskable questions. Criticism can have no effect. As he himself says, it is a matter of faith.

[15]*Quarterly Journal of Economics*, 71 (November 1957), 546–60.

NOTES

CAPITAL THEORY UP TO DATE: A COMMENT ON MRS ROBINSON'S ARTICLE*

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I have long since abandoned the illusion that participants in this debate actually communicate with each other. Robert M. Solow[1]

I feel distinctly honoured that Mrs Robinson read my recent book[2] and wrote a review article on one-half of one chapter of it.[3] One could not hope for a more distinguished or less unbiased reviewer.

Despite the admonition in the lead quotation, I should like to address a few comments to her review in the hope of establishing some ground for mutual communication. As a *caveat* I should add that "I still have the faith," although that ill-begotten clause did not convey adequately what I have faith in.

1. My book was intended chiefly to be an exposition and extension of the *microeconomic* theory of production, cost, and factor demand (i.e. a theory applicable to single firms or single entrepreneurs). I assumed a production function relating physical output to the physical inputs of heterogeneous labour, heterogeneous machines, and heterogeneous raw materials. As a first approximation, I further assumed that the *definition* of the output required the various raw materials to be used in fixed proportions. Thus, attention was directed to the first two heterogeneous categories of inputs.

Assuming variable proportions,[4] each physical input has a well-defined marginal physical product. If profit maximization is also assumed, which does not seem to be objectionable to any of the participants in this debate, each entrepreneur will hire units of each physical input until the *value* of its marginal physical product is equal to its market-determined and parametrically-given input price. In essence, this is what I called the neoclassical, or the marginal productivity, theory of input pricing.[5]

*The author acknowledges financial assistance from the National Science Foundation, GS-2430. I wish to thank Martin Bronfenbrenner and Robert Solow for helpful letters received before and after this manuscript was written. The usual *caveat* applies.

[1]Robert M. Solow, "Substitution and Fixed Proportions in the Theory of Capital," *Review of Economic Studies*, XXIX (1962), 207–18.

[2]C. E. Ferguson, *The Neoclassical Theory of Production and Distribution* (Cambridge, 1969).

[3]Joan Robinson, "Capital Theory Up to Date," *Canadian Journal of Economics*, III (1970), 309–17. In addition, Mrs Robinson reviewed the book in *Economic Journal*, LXXX (1970), 336–9.

[4]Chapters 2 and 3 of Ferguson, *The Neoclassical Theory of Production and Distribution*, are devoted to fixed-proportions production functions.

[5]Ferguson, *The Neoclassical Theory of Production and Distribution*, contains numerous embellishments based on monopoly or monopsony, which are derivative from Joan Robinson, *The Economics of Imperfect Competition* (London, 1933). One of these should not have been there. Indeed, pp. 181–5 should be totally ignored inasmuch as input demand functions cannot be derived when input prices are variable to the firm.

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Following the leads of J. B. Clark and Hicks, I extended this well-established microeconomic theory by analogy to an aggregate economy. This, I take it, is where the controversy arises. Capital is not merely *leets* that are used with homogeneous labour to produce *leets*.[6] Rather, commodities are produced by means of commodities and labour. Thus capital valuation is not independent of distribution; the neoclassical system is undetermined and some factor price must be given exogenously.[7] So goes the marginal productivity theory of distribution at the most highly aggregated level, or so Mrs Robinson would have it go.

However, it does not. Neoclassical theory, whether aggregate or micro-economic, is general equilibrium theory. The marginal product equations are merely input demand functions in inverse form. Taken alone, there are more unknowns than equations; hence the marginal product functions determine nothing. But there are market-clearing equations for inputs and all sorts of equations for the commodity markets. In addition, there may be added a time preference function or, alternatively, some type of demand-for-wealth equation. Taken together, the system is not underdetermined.[8] There may be a capital valuation problem; but as I shall later point out, this does not damage the corpus of neoclassical theory.

There seem to be many areas of discord. I shall attempt to cover some of these briefly and in more or less random order.

2. In commenting on my book, Mrs Robinson wrote that "we can learn from him what it is that the neo-classicals believe neoclassical theory to be."[9] In my exposition I erred in at least two ways. First, I implicitly imputed my view of neoclassical theory to all neoclassical theorists. Second, and worse, I implicitly assumed that readers would not take the "Clark parable" as the ultimate statement of neoclassical theory.[10] Parables, whether of the Clark or Biblical variety, are only intended to emphasize tendencies. Very few Fundamentalists believe that Adam literally plucked an apple off a tree.

To avoid possible confusion, let me state what I (possibly alone) believe neoclassical theory to be. First, and most important, it is a microeconomic theory of pricing – a theory of how all input and output prices get to be what they are because of the equilibrium adjustments of firms and markets. As a by-product, this yields the marginal productivity theory of input pricing. Such general equilibrium models have little empirical usefulness unless some simplifying assumptions are made.

Second, therefore, neoclassical theory deals with macroeconomic aggregates, usually by constructing the aggregate theory by analogy with the corresponding microeconomic concepts. Whether or not this is useful is an empirical

[6]I see no more justification for assuming homogeneous labour than homogeneous capital. If one did not, what would happen to the Wicksell-Robinson diagrams?

[7]See Joan Robinson, *The Accumulation of Capital* (London, 1956), or C. E. Ferguson and Donald L. Hooks, "Wicksell Effects and the 'Cambridge Criticism' of Neoclassical Capital Theory," to appear in *History of Political Economy* (Fall, 1971).

[8]On this score, I am particularly indebted to Robert Solow for pointing out an ambiguity that appeared in the first version of this manuscript.

[9]Robinson, "Capital Theory Up to Date," 309.

[10]Even a very perceptive Cambridge Critic apparently took me literally. See G. C. Harcourt, review of Ferguson, *The Neoclassical Theory of Production and Distribution*, *Journal of Economic Literature*, VIII (1970), 809–11.

question to which I believe an empirical answer can be given. This is the "faith" I have, but which is not shared by Mrs Robinson.[11] Perhaps it would be better to say that the aggregate analogies provide working hypotheses for econometricians.

"Aggregation by analogy" is most easily achieved within the framework of the Clark real-homogeneous capital model; and it has the further (desirable?) characteristic that the marginal productivity theory of input pricing has its analogue in the marginal productivity theory of distribution. This model describes a leets-labour-leets world in which none of us believe. But it also offers some *parables* that many of us believe are important to those who are interested in empirical work at the aggregate level.

3. Aggregation by analogy also leads to much more "realistic" or "complicated" models in which some of the "parable relations" do not necessarily hold. In these models the "unobtrusive postulate"[12] does not appear; a higher value of capital per man does not necessarily correspond to a higher real wage rate. The only relation (under debate) these models imply is equality between the rate of interest and the rate of return.[13]

4. The paragraph above raises another issue. In light of the *general* neoclassical model, which is readily to be found in the works of Samuelson, Solow, and others,[14] why have the Cambridge Critics concentrated solely upon the "J. B. Clark neoclassical fairy tale"? There are probably numerous explanations, only two of which I shall suggest. First, the empirically oriented Critics have probably chiefly read the neoclassical empirical studies. These rely upon Cobb-Douglas or CES production functions, which do at least imply the "unobtrusive postulate." That is, they yield all the neoclassical relations and the marginal productivity theory of distribution. There is no capital valuation problem and all Wicksell effects are non-negative. Second, the theoretical Critics seem to wish to build a strawman they can easily destroy rather than to attack the more formidable foundations of neoclassical theory.[15]

It is almost inconceivable, yet almost inevitable, to say that the Critics have imputed total ignorance of the Wicksell effects to neoclassical economists. Since Mrs Robinson and others made such a to-do about the Effects,[16] they

[11]Robinson, "Capital Theory Up to Date," 315–7.

[12]L. L. Pasinetti, "Switches of Technique and the 'Rate of Return' in Capital Theory," *Economic Journal*, LXXIX (1969), 508–31. To the extent of my reading of neoclassical authors, Pasinetti's "unobtrusive postulate" has never been postulated by anyone. In one-commodity models, the question simply cannot arise. In two- or multi-sector models, whatever happens to the value of the capital stock in terms of a consumption numeraire just happens.

[13]Robert M. Solow, "On the Rate of Return: Reply to Pasinetti," *Economic Journal*, LXXX (1970), 423–8.

[14]This is not the place for documentation. However, I might cite Paul A. Samuelson and Robert M. Solow, "A Complete Capital Model Involving Heterogeneous Capital Goods," *Quarterly Journal of Economics*, LXX (1956), 537–62, and Robert Dorfman, Paul A. Samuelson, and Robert M. Solow, *Linear Programming and Economic Analysis* (New York, 1958).

[15]To paraphrase Solow, some of the Critics appear to write their comments just as oysters make pearls – out of sheer irritation.

[16]For relevant bibliography, see G. C. Harcourt, "Some Cambridge Controversies in the Theory of Capital," *Journal of Economic Literature*, VII (1969), 369–405, or Ferguson and Hooks, "Wicksell Effects."

have certainly been well known. Both the price and real Wicksell effects can be negative, or they can be offsetting with the negative effect dominating. In these cases, the Cambridge Criticism is valid in the sense that there is not a one-to-one correspondence between factor and commodity markets.[17] Further, the *aggregate* marginal productivity theory of distribution may not hold.[18] But neoclassical theory, conceived as a general approach to economic analysis, does not live by marginal productivity alone.

5. The Cambridge Critics seem to equate the *aggregate* J. B. Clark marginal productivity theory of distribution with the entire corpus of neoclassical theory. Such is not the case. While the Clark-Hicks aggregate marginal productivity theory of distribution is a special case of general neoclassical theory, it is neither a necessary nor sufficient criterion by which to judge it. The criterion, I would suggest, is whether the rate of interest is equal to the rate of return.[19]

6. The last point of issue I wish to discuss here is the long run *versus* the short. Some Critics[20] charge that neoclassical theory is concerned only with the Keynesian long run "in which we are all dead." They emphasize a short run in which there are output and factor price rigidities, less than full employment of all resources, and zero or severely limited factor substitutability. At any moment in time this is apt to be an accurate characterization of the economy. But is this what capital theory is all about?

For myself only, I answer *no*. Capital theory concerns trends or tendencies, or how the present situation might change given a set of current disequilibrium phenomena. Capital theory had its origins in the stationary state and, I think, has its best current representations in what Mrs Robinson calls "Golden Age" models. To be sure we live in a living present in which there are fixed proportions or very limited factor substitutability, discontinuous marginal product functions, and all sorts of price rigidities and market imperfections.

In the planning horizon, however, entrepreneurs can make investment decisions that change factor proportions in accord with the prevailing or expected factor price ratios. Because of real or price Wicksell Effects, the results of these independent decisions may have an "aggregate" impact that is sometimes different from what is to be expected on the basis of simplistic neoclassical theory. This is what the Cambridge Critics have brought forward.

[17]Murray Brown, "Substitution-Composition Effects, Capital Intensity Uniqueness and Growth," *Economic Journal*, LXXIX (1969), 334–47 has shown, in effect, that if all factor-price frontiers are linear, the price Wicksell effect is zero and the real Wicksell effect is positive. This is, of course, the "normal" case treated by neoclassical theorists (not linearity, but a positive real Wicksell effect). For some extension, see C. E. Ferguson and Robert F. Allen, "Factor Prices, Commodity Prices, and Switches of Technique," *Western Economic Journal*, VIII (1970), 95–109.

[18]On a disaggregated level, it does. See Ferguson, *The Neoclassical Theory of Production and Distribution.*

[19]This statement needs some modification and elaboration. First, there are many maturity structures of interest rates. The rate of return on social saving obviously cannot equal all of these. Second, an equally important test is the equality between the real wage rate and the marginal product of labour. Finally, one should distinguish between the logical consistency of neoclassical theory and its empirical relevance. Mrs Robinson, of course, would have it that the theory is logically inconsistent and empirically irrelevant (see especially, Robinson, "Capital Theory Up to Date," 315–7). The chief object of this note is to argue the opposite view.

[20]See especially Harcourt, review of Ferguson.

As a neoclassical theorist I can only reply that the relevant question is what is relevant: should we make our predictions on the basis of what Mrs Robinson has called perverse technical behaviour or on the basis of the relations that have repeatedly been observed?

7. In the short run I am willing to accept any kind of rigidities the Critics wish to impose. In the long run I believe that the leets-labour-leets world of investment decisions made in light of known or expected factor prices is an adequate characterization of the economy. If "rational" behaviour occurs, the rate of return will equal the rate of interest; and neoclassical theory is validated by the behaviour of people none of whom any of us control.

CAPITAL THEORY UP TO DATE: A REPLY

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It is natural for Professor Ferguson to dislike being teased about his "faith," but I fear that this comment will not save him. It is nothing but a repetition of several confusions that are only too sadly familiar in this tedious and unnecessary debate.

The main confusion is between a Walrasian supply-and-demand system and "production of commodities by means of commodities." For Walras, there is an arbitrarily given stock of specific capital goods which is somehow already in existence. In the other system, only the techniques of production are specified in advance; the stock of capital goods is brought into being by profit-seeking investments. In Walrasian general equilibrium, the prices of commodities are determined by supply and demand and prices of "factors" are derived from them. In the other system, wages and prices have to be known before the appropriate stock of capital goods can be chosen. (The composition of the labour force in respect to skill etc., is also assumed to be adjusted, in an equilibrium position, to the requirements of production.) Professor Ferguson, indeed, agrees that "some factor price has to be given exogenously." But here he is only making a pun. In one sense, a "factor" is a piece of productive equipment such as a blast furnace or a field of wheat. In another traditional usage the "factors of production" are "land, labour, and capital." Professor Ferguson's whole argument consists in solving, to his own satisfaction, the problem of relative prices with given "factors" in the first sense and then proclaiming that he has solved the problem of the distribution of the total net output of industry between wages and profits. (This is where faith comes in.)

When the "factor price" that is "given exogeneously" is the over-all rate of profit on capital, then all prices and wage rates are settled according to the technical relationships in the system of production of commodities by means of commodities. Then, of course, the micro-equilibrium conditions can be specified for perfect and imperfect competition. Professor Ferguson takes the case where "each entrepreneur will hire units of each physical input until the *value* of its marginal physical product is equal to its market-determined and parametrically-

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given input price" (his italics). Here, evidently, the selling price of the product and the purchase prices of the services of the "factors" are given to the individual firm. But then he jumps from value products from the point of view of individual firms in a perfect market to real products from the point of the economy as a whole. The argument merely consists in a play upon words.

A second prevalent source of neo-neoclassical misunderstandings is the nature of a pseudo-production function. A book of blueprints representing a "given state of technical knowledge," is not something which exists in nature. In real life techniques are blueprinted only when they are going to be used. The co-existence at a moment of time of a number of techniques that would be eligible at different rates of profit is conceived only as a logical device to disentangle the ambiguity of "substitution between labour and capital."

Each point on a pseudo-production function is intended to represent a possible position of equilibrium. Time, so to say, is at right angles to the blackboard on which the curve is drawn. At each point, an economy is conceived to be moving from the past into the future with the rate of profit and the technique of production shown at that point.

We can run an eye up and down the curve, observing backward and forward switch-points and changing values of capital, *comparing* possible equilibrium positions, not tracing *movements* that could actually take place. Professor Ferguson seems to think of a process of accumulation as pushing an economy from technique to technique along the pseudo-production function. Presumably it is for this reason that he defiantly maintains that his faith is unshaken by "the Wicksell Effects." And it is evidently the reason why he now attaches so much importance to Professor Solow's slogan that "the rate of interest is equal to the rate of return," for this is connected with the concept of a pseudo-production function. At a switch-point two techniques are yielding the same rate of profit at the same level of real wages. The technique which has the higher value of capital per man, at the ruling rate of profit, has a correspondingly higher value of output per man. The "rate of return" on this additional value of capital is the rate of profit (which neo-classicals prefer to call the rate of interest). Professor Solow's proof of this proposition amounts to proving that a switch-point is a switch-point. Professor Ferguson maintains that this is the essence of the neo-classical theory of distribution. If so, he is welcome to it.

But he does not really want to leave it at that. He thinks that there is something in this slogan that throws light on "relations that have been repeatedly observed." It seems that he is no longer asking the econometrists to find out whether "there is sufficient substitutability within the system to establish neo-classical results." Now he wants them to tell him whether the rate of interest is equal to the rate of return. I think that they had better first ask him to say what these magnitudes would look like when they are different.

All this sophistry, of course, is just a smoke screen. The point of the neo-neoclassical argument is to restore the pre-Keynesian view of modern capitalism according to which accumulation is governed by society's desire to save, full employment is guaranteed except when the workers are so foolish as to demand more than the equilibrium level of wages, and the rate of interest (or is it the rate of return?) guides investment into the form that maximizes welfare for

society as a whole. The old defence of *laissez faire* was badly knocked about by the great slump. The new one is being still worse knocked about by the arms race, inflation, pollution, the persistence of poverty in the rich nations and growing misery in the Third World. The object of Professor Ferguson's rigmarole is to prevent his pupils from thinking that economics has anything to do with the problems of the economy that they are living in. It is strange that he should be the one to say that "the relevant question is what is relevant."

Postscript

I am very much interested in the paragraph added with the aid of Professor Solow, as I have long wondered what he intended his theory of profits to be. We can now see that it is a mixture of the two systems; the prices of commodities and specific factors are in Walrasian static equilibrium while at the same time there is a general rate of interest equal to the "reward of waiting" as in Pigou's ultimate stationary state. Professor Ferguson certainly needs all his faith: *Credo quia impossibile.*

THE MEASURE OF CAPITAL: THE END OF THE CONTROVERSY

THE meaning of capital as a factor of production has been in dispute ever since the concept was first formulated. In the pre-Keynesian orthodox tradition there were two distinct concepts—one of capital as a list of machines, stocks, etc., all specified in physical, engineering terms, embodying particular techniques of production; the other, of a fund of " waiting " embodying the savings accumulated over the past history of the economy.[1] In one department, associated with the name of Walras, the return on " capital " was made up of the rentals of particular machines, derived from the demand prices for commodities which they could help to produce; in the other, associated with the name of Marshall, there was a " normal rate of profit " which, in long-run competitive conditions, would be received on the value of investments being made in all the various lines of production. After Keynes, it was recognised that accumulation results from the decisions of profit-seeking firms and public authorities and that the relation of money prices to money wage rates reflects the level at which gross margins are set.

[1] Cf. L. Robbins, " On a Certain Ambiguity in the Conception of Stationary Equilibrium," ECONOMIC JOURNAL, June 1930.

These distinctions seem to have been lost in the revival of orthodoxy after the Keynesian revolution. In particular, the econometrists did not pay any attention to them. A convention was adopted of interpreting statistics of the performance of industry, for instance in the United States since 1945, in terms of a production function with labour and capital as inputs, and discussing the remuneration of these factors in terms of their marginal productivity.[1] This seems to have been widely held to justify the argument, associated with the name of J. B. Clark, that the " marginal productivities " of labour and capital from the point of view of the economy as a whole (" land " being given) provide a satisfactory account of the determination of the distribution of the product of industry between rent, wages and profits, or, as Ricardo put it, between the classes of the community.

The statistics in themselves are certainly valuable. The rate of accumulation, the capital to income ratio and the share of wages in the value of net output are relationships of the greatest interest, whatever difficulties there may be in presenting them accurately. But what they have to do with a production function has never been explained comprehensibly and the method of measurement of the quantities of the inputs has never been satisfactorily specified.

" Labour " obviously is not a homogeneous input and the meaning to be attached to the concept of " the marginal productivity of labour " in an industrial economy is by no means clear, but in principle " labour " is measured in a physical, technical unit—a man-hour of work. In what unit is " capital " to be measured? The figures in the time-series are collected in the first instance in terms of dollars; however they may be deflated or adjusted, the amount of capital in the statistics is a sum of value. How can this be made to correspond to a physical factor of production?

Attempts to answer this question followed two main lines. The first was in terms of a parable. Imagine that there is a physical substance which has the characteristics of capital in a well-behaved production function, and that the price of a unit of this stuff in terms of final output never changes. This was first suggested by Professor Swan, with his sets of Meccano.[2] He appears to have offered this concept in a satirical spirit, saying that it " would deceive no one," but it was taken, apparently, quite seriously by a number of writers.[3]

From this point the argument went off at a tangent. One of the notions that had been taken over from the old orthodoxy was that of substitution of capital for labour " in a given state of technical knowledge." This was interpreted in terms of a pseudo-production function or factor-price frontier, showing what techniques, each with its appropriate stock of capital goods,

[1] *E.g.* R. M. Solow, " Technical Progress and the Aggregate Production Function," *Review of Economics and Statistics*, August 1957.

[2] See " Economic Growth and Capital Accumulation," *Economic Record*, November 1956.

[3] Cf. J. E. Meade, *A Neo-Classical Theory of Economic Growth* (London 1962). The most recent elaboration of the parable is by R. M. Solow, *Growth Theory: An Exposition* (Oxford, 1970).

would be eligible at various levels of the rate of profit and of real wages. After the so-called " reswitching " debate, Professor Samuelson admitted that it came as a shock to him to find that, in terms of a pseudo-production function set out on quite acceptable assumptions about technology, a lower rate of profit (with a higher real wage) is not necessarily associated with a less labour-intensive technique, so that the principle of substitution does not work.[1]

This all arose from a misunderstanding. The presumption that " more capital " must be associated with a higher real wage was drawn from the notion of capital as a stock of machines, and of prices derived from supply and demand. In this setting, to have more machines with the same labour force must entail higher wages and lower rentals. The pseudo-production function is set out in terms of the other system of prices. At each point, a different rate of profit is conceived to be ruling (with the corresponding level of real wages) and the prices of all capital goods are governed by their costs of production including an allowance for profits at the normal rate. In this system a " quantity of capital " cannot be identified with the value of the stock of capital goods, since the identical stock of physical capital will, in general, have different values at different rates of profit. Nor is there any presumption that the relative values of different stocks of capital should be such that, at every point, a more mechanised technique, providing a higher rate of output per man employed, is always eligible at a lower rate of profit.

Professor Samuelson took a false step when he tried to identify the quantity of capital-stuff in the parable with the value of capital on a pseudo-production function.[2] To postulate a well-behaved pseudo-production function (as he tried to do by confining the argument to the case of labour-value prices) did not really make the argument any better, nor did the discovery of " re-switching " make it much worse.

The whole trouble arose from mixing up two concepts of capital. But neither concept has anything to do with the interpretation of actual statistics. The time-series over a prosperous period for modern industry show a process of accumulation going on with, on the whole, rather small variations in the overall ratio of value of capital to value of output and rather small variations in the share of wages in net output. That is to say, they show a more or less constant overall *ex-post* rate of profit on capital. The rising ratio of " capital " to labour is evidently not associated with a movement along a pre-existing production function, but with increasing productivity. Clearly a pseudo-production function has nothing to do with the point. It purports to compare different rates of profit with the same technology, while here we

[1] See " Paradoxes of Capital Theory: A Summing Up," *Quarterly Journal of Economics*, November 1966.

[2] For the history of this affair see Joan Robinson, " Capital Theory Up to Date," *Canadian Journal of Economics*, May 1970.

are evidently presented with the same rate of profit and changing technologies. The " reswitching " argument that made Samuelson lose faith in his parable was just as irrelevant as the parable itself.

The second line of argument about the meaning of capital in a production function was to seek for an index of physical capital to which the concept of marginal productivity could be applied.[1] In conditions of perfectly competitive equilibrium, it is argued, the individual entrepreneur has adjusted the proportions of the factors of production that he employs in such a way that the marginal product of each is equal to its cost. Then the marginal products of the factors in output as a whole can be derived from their prices.

No one, presumably, would claim that the statistics of modern industry depict an economy in equilibrium with perfect competition and correct foresight. But even in the purest of pure theory the argument does not hold. Micro-marginal-productivity analysis requires the postulate that each entrepreneur seeks to produce a given output at minimum possible cost or to ensure the maximum possible return on a given investment. When he contemplates using any particular capital good—say a machine of given specification—he must consider its cost in terms of his own product in order to decide whether it is to be preferred to some other method of production. To make his calculation he must know the pattern of prices of many kinds of machines and other inputs, wage rates and the prospective prices of his own products. In short, the rate of profit in the economy as a whole has to be known before the micro-marginal productivities can be calculated.

Professor Leontief confused the issue by maintaining that his input–output tables correspond to a picture of Walrasian equilibrium:

> How does this system operate? How does it solve its problems? It solves them by a trial-and-error method. A competitive economy can be viewed as a gigantic, natural computing machine which tirelessly grinds out problems automatically fed into it. It allocates labor, capital, and natural resources among all the different branches of production. It determines automatically which industry should expand and which contract its output, which corporation should invest and which go out of business.[2]

This is evidently misleading. The input–output matrix may be filled in with sums of money depicting the flows of actual transactions among businesses and between businesses and households. In that case all the prices are already in the picture—competitive prices, monopoly prices, profitable prices or disappointing prices, just as they happened to be. Or each row of the matrix may depict the output of a near-enough homogeneous product, distributed between its uses as an input, in physical units—tons, pints or yards. Then, to sum up the columns, composed of a variety of products, a consistent

[1] See L. R. Klein, " Macroeconomics and the Theory of Rational Behaviour," *Econometrica*, 14 (1946).

[2] *Input–Output Economics* (New York, 1966), p. 5.

set of prices has to be found. There is one possible set of prices corresponding to each rate of profit (or share of wages in the value of output). The rate of profit cannot be derived from the physical matrix. It must be supplied from outside it. Moreover, there is no scope for substitution between factors of production in an input–output table. It purports to show the proportions of inputs actually used to produce an actual output. When the requirements for an increase in any output are calculated, the assumption is made that inputs will be needed in those same proportions. This is a useful first approximation, say for a planning authority, but it does not give any support to the concept of substitution or to a marginal-productivity theory of prices.

All these confusions were recently swept away by Professor Franklin Fisher.[1] Working within the conventions of micro-marginal-productivity theory, he made a careful examination of what would be involved in an index of physical capital and showed that it cannot be found. He concluded that there is no such thing as a quantity of aggregate capital; in a later note, he summed up the argument by saying that " aggregate production functions are not generally even good approximate descriptions of the technical possibilities of a diverse economy . . . "[2] On his authority, the pursuit of the will-o'-the-wisp of an index of physical capital should be called off.

This leaves the question where it began. " Capital " in the statistics is a sum of money. Estimates of the dollar value of capital represent equipment, stocks and work in progress committed to industrial production, reckoned at dollar prices. A piece of equipment or a stock of raw materials, regarded as a product, has a price, like any other product, made up of prime cost plus a gross margin. These costs (direct and indirect) are composed of wages, rents, depreciation and net profit. The amount of net profit entering into the price of the product is, obviously, influenced by the general rate of profit prevailing in the industries concerned. Thus the value of capital depends upon the rate of profit. There is no way of presenting a quantity of capital in any realistic manner apart from the rate of profit, so that to say that profits measure, or represent or correspond to the marginal product of capital is meaningless.

At this stage in the argument, however, Professor Fisher was still in some doubt. The sentence quoted above ran on. Although aggregate production functions are meaningless, yet " the question of what lies behind their apparent success at explaining factor shares is not a trivial one." That is to say, the fact that Cobb–Douglas functions can be fitted to the time-series of statistics must have some significance.

This question was taken up more than twelve years ago by Professor Phelps Brown.[3] He pointed out that the evidence from time-series cannot,

[1] " The Existence of Aggregate Production Functions," *Econometrica*, October 1969.

[2] *Econometrica*, March 1970, p. 405.

[3] " The Meaning of a Fitted Cobb–Douglas Function," *Quarterly Journal of Economics*, November 1957.

in the nature of the case, detect a production function. The figures " can describe the relations between historical rates of growth of labour, capital [that is, in terms of value] and the product, but the coefficients that do this do not measure marginal productivity." " Any coefficients," he says, " found to agree with actual distribution shares, do so only by coincidence."

Professor Fisher has since found out what the coincidence was. He carried out an investigation by means of a simulation model and came to the conclusion that a Cobb–Douglas fits any series of figures in which the share of wages in the value of output is fairly constant.

> Whether such an argument or such results have much bearing on a real world in which underlying relationships are more complicated and aggregation takes place over labor and output as well as capital is necessarily a somewhat open question. The suggestion is clear, however, that labor's share is not roughly constant because the diverse technical relationships of modern economies are truly representable by an aggregate Cobb–Douglas but rather that such relationships appear to be representable by an aggregate Cobb–Douglas *because* labor's share happens to be roughly constant.[1]

It seems then, that the controversy is over. We must agree (though mumpsimus will continue in the textbooks) that marginal productivity of capital in industry as a whole has been shown to be a meaningless expression. We must look somewhere else to determine the laws which regulate the distribution of the produce of the earth among the classes of the community.

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