TECHNICAL CHANGE AND MARXIAN ECONOMICS

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Marxian economics claims to provide an analysis of "the laws of motion of capitalism". Orthodox economics in recent decades has devoted much attention to explaining the hitherto sucessful performance of the capitalist system so as to discover what light past trends may shed on future prospects. For the first time in a century of debate between Marxian and orthodox economics the nature of the central issue is not in dispute. In the past, fruitful discussion was impeded by fundamental differences in approach: the two schools of thought were simply interested in different things. This is no longer true, and the recent flurry of articles on Marx suggests that there is still something to be learned from the Marxian theory of economic development. Its persistent emphasis upon technical change as an inherent feature of the process of capital accumulation provides a healthy antidote to the static bias of received doctrine. Even Marx's mistakes are extraordinarily instructive. But the one great merit of the Marxian system—a merit which supplies the rationale of this paper—is that criticism of it leads one to consider all the difficulties which have so far stood in the way of a satisfactory theory of technical change. The central point I wish to make is that Marxian economics, despite its prescient insights into the nature of technological progress, contains no systematic theory of the factor-saving character of technical improvements. It is for this reason, and not because of any logical errors, that it failed correctly to predict the evolution of capitalism.

I

The basic axiom of Marxian economics is the proposition that surplus value (profit plus interest plus rent) is unearned income, in the strict Marshallian sense of the phrase; for Marx, capital has no supply price and property income is purely a function of the private ownership of the means of production. Since the argument proceeds in the context of a perfectly competitive economy, we might

think that the individual entrepreneur—whose contribution to total output is too small to influence price—would expand output in the effort to reap more surplus value, until wages are bid up so as to reduce the surplus to zero. What is it that holds wages down? Having abandoned the Malthusian theory of population, Marx could not assume that population growth would preserve wage rates at the subsistence level. Instead, he postulated the existence of "the industrial reserve army" of the unemployed, providing unceasing competition for vacancies. Booms deplete the reserve army and slumps replenish it, but secular growth at full employment levels is conceptually impossible, according to Marx. Unemployment arises initially from inappropriate factor endowments combined with limited possibilities of factor-substitution: full capacity use of the capital stock is insufficient to absorb the available labor supply. When this ceases to be true at some levels of the capital stock, further accumulation must involve a sufficient flow of labor-saving innovations so as to produce chronic unemployment. Thus, the Marxian conception of mature capitalism is predicated upon a bias towards labor-saving technical change.

It is not difficult to demonstrate that if the underlying production functions show either diminishing or constant returns to scale, a persistent labor-saving slant in technological progress must lead to a rise in capital requirements per unit of output. And, unless the property share of output rises proportionately, this will cause the rate of profit to fall. Marx' law of the falling rate of profit is, in fact, based upon exactly this kind of reasoning.

The argument is in principle very simple. Since most of Marxian economics thrives under a cloud of terminological confusion, the first step in translating Marx is to agree upon a set of definitions. Writing small letters for flows and capital letters for stocks, Marx's "constant capital" c is defined as the sum of depreciation charges on fixed capital and inputs of raw materials. Adding the wages of production workers v, Marx's "variable capital", we get the flow of outlays k. Dividing the components of k by the appropriate rates of turnover, we get the stock of capital invested K. $K = C + V$, where C stands for the value of the stock of durable equipment and inventories of raw materials and V stands for working capital required to meet weekly payrolls. Following Marx, surplus value s is defined on a flow

basis as the excess of gross revenue over variable and fixed costs. For the economy as a whole this amounts to the excess of net national product over the wages bill. The rate of surplus value s' is s/v. The rate of profit p', as Marx defined it, is s/k; on a stock basis it is s/K[1].

Marx himself never explicitly defined the so-called "organic composition of capital". What he had in mind, however, is clearly the ratio of embodied labor to current labor or of machine costs to labor costs: C/v[2]. When multiplied by the wage rate, and ignoring V as negligibly small, this becomes the amount of capital per man, i.e. $K/v \cdot v/L = K/L$. At all times Marx shuffled freely between stock and flow definitions without warning the reader. His expression for p' is actually the share of profits in the turnover of capital; it is equal to profits per unit of capital on the assumption that the whole of capital turns over once a year. Marx was aware of variations in the turnover rates of v and c and to that extent he recognized the distinction between stocks and flows[3]. Still, he put no stress upon the point and it soon dropped out of sight in the Marxist literature.

So much for definitions. The rate of profit p' varies inversely with "the organic composition of capital" Q and directly with the ratio of surplus to wages[4]. Taking into account variations in wages per man, p' may be said to vary inversely with the capital/labor ratio and directly with the amount of surplus per man, i.e.

$$p' = \frac{s}{v} \cdot \frac{v}{L} \Big/ \frac{K}{v} \cdot \frac{v}{L}$$

As far as Marx was concerned this established the law that the rate of return on capital must fall with the increased mechanization of

1. The expression s/K ist still not the rate of profit as conventionally understood; this is given by $\bar{s}/K$, where $\bar{s}$ stands for non-labor income minus administrative overhead, sales and advertising expenses, rents and indirect business taxes. Marx himself includes administrative and sales expenditures in the numerator of the expression s/v but excludes salaried personnel from the denominator.

2. Some commentators interpret him to mean the capital/output ratio which seems far-fetched or the ratio c/K which varies through time in much the same way as c/v.

3. See *Capital* (Chicago, 1909), II, ch. 16; III, ch. 4.

4. Marx writes the gross profit rate as $s/(c+v)$, which is identically equal to $s'/(q+1)$, where $q = c/v$. Strictly speaking, this should be amended to $p' = s'/Q$ where $Q = q \cdot t$, t being a weighted average of the durabilities of c and v.

industry. Having concluded that the wage rate rises little, if at all, in the course of capital accumulation while technical change constantly raises the stock of equipment per worker, he thought it obvious that the organic composition of capital must show a steady upward trend. It is true that this will not lower p' if the rate at which s' is rising exceeds that of Q. And as mechanization raises the productivity of labor it can hardly fail to raise s'. Marx realized that there was some functional connection between Q and s', but, after satisfying himself that s' could rise only within "certain impassable limits", he assumed it to be constant. He did recognize the influence of autonomous increases in s', which he handled under the label of "absolute and relative surplus value", but these too he dismissed with more justification as having definite physical limits[5].

The constancy of s' was only a simplifying assumption but, as both Sweezy and Robinson have pointed out, it was a particularly clumsy simplification for the Marxian system. Since wages and profits exhaust total income, a constant s' for the economy as a whole implies constant relative shares. This means that real wages rise as fast as the average productivity of labor, i.e.,

$$s' = \frac{s}{v} = \frac{s}{o} \Big/ \frac{v}{L} \cdot \frac{L}{o}$$

But not only did Marx frequently imply that labor's share would decline but it is the function of "the reserve army" to keep wages at subsistence. However loosely interpreted, this presumably means that wages do not rise as fast as the average productivity of labor. And so long as this is true, every increase in output per man raises s'. *A fortiori*, if real wages are constant, s' will rise sharply as K/L increases. thus, tendency for p' to fall is indeterminate: it all depends on the nature of the explicit function $s' = f(Q)$. Marx's attempt to demonstrate the existence of an upper bound to this function involved him in a horrible confusion between physical-productivity and value-productivity[6]. On his own terms, the only relevant question is whether productivity is likely to increase faster in the wage-goods industries

5. For references to Marx's writings on this point, see H. D. DICKINSON, "The Falling Rate of Profit in Marxian Economics", *Review of Economic Studies*, February, 1957, p. 123 n.

6. *Capital*, III, p. 290.

than in other sectors. If so, this will mean a fall in the value of the Marxian measuring rod of labor-hours with the result that p' will tend to rise. The law of the falling rate of profit, therefore, calls for some denial of this effect, be it on logical or on empirical grounds.

It is possible, however, to make out a case for Marx's law on orthodox grounds. Assume that the aggregate production function shows constant return to scale, the obvious assumption for the Marxian two-factor case. By the properties of the function, output rises for every increase in capital per man along the given function but less than proportionate to the increase in capital. As the capital/output ratio rises, the increase in capital will entail a fall in p' even though $s' = f(Q)$[7]. Innovations as such are not enough to upset this conclusion. If technical change does not work to reduce capital per unit of output, p' will nevertheless fall. This is because the capital-absorbing effects of the innovational process governs the degree to which wages rise as capital increases. If wages rose as fast as output per man, relative shares would be unaffected and the rising capital/output ratio alone would lead directly to a fall in p'. In the Marxian system labor's share is alleged to fall through time; therefore, a rising capital/output ratio here does not necessarily imply a falling p'. But this is only to say that the Marcian law of the falling rate of profit is predicated upon a very rapidly rising capital/output ratio, which implies in turn that technical change is heavily slanted towards labor-saving improvements. For the claim that capital per man rises faster than profits per man, or in Marxian terms that Q rises faster than s', is tantamount to claiming that the capital/output ratio rises faster than the property share in output:

$$p' = \frac{s'}{Q} = \frac{s}{L} \Big/ \frac{K}{L};$$

dividing through by L/o, we get

$$p' = \frac{s}{o} \Big/ \frac{K}{o}.$$

7. This rather obvious point is proved indirectly in Dickinson's recent paper, *op. cit.* By itself it provides no support for Marx's law since Marx denies that capital can increase without technical change. Dickinson's defence of Marx's argument, however, abstracts from innovations.

The fact that the aggregate capital/output ratio has remained practically unchanged in advanced economies over the last 75 years is fatal to the Marxist schema. Together with the observed long-run stability in relative shares, it leads directly to the conclusion that profits per man have risen as fast as capital per man and hence that p' has not declined. In the American case, the rate of return to privately owned physical capital has in fact shown a slight tendency to fall in the 20th century. But the reason for this is not that technical change has been excessively labor-saving; on the contrary, the evidence suggests a mild capital-saving bias in the American economy over the last four decades[8].

The facts make it unnecessary to consider the deeper contradictions in Marx's argument. After all, a labor-saving slant in technical change implies that the rise in man-hour productivity is concentrated in the finishing stages of production: all cost-reducing improvements in the capital goods industries are capital-saving for the economy as a whole. Hence, the prices of consumer goods fall faster than machine prices. In terms of the labor theory of value, this means that the value of v declines faster than the value of c or s, so that it is not at all certain that Q or s' will increase. The Marxian law of the falling rate of profit, even when accepted on its own grounds, is caught up in a bewildering mesh of opposing forces whose outcome is not deducible from elements supplied by the theory.

II

Given the weaknesses of Marx' argument, it is hardly surprising that his predictions failed to materialize. Even Marxists have now conceded the point. A recent book by an American Marxist for the first time submits the law of the falling rate of profit to a statistical test[9]. Using census data for American manufacturing over the period 1849 to 1939, the author, J. M. Gillmann, starts out by accepting Marx' categories on a flow basis. The results are very disquieting: although q showed a fairly strong tendency to rise until the turn of the century, the trend-value through 1919–1939 was constant. Since s' rose per-

8. For a discussion of the evidence, see W. Fellner, *Trends and Cycles in Economic Activity* (New York, 1956), pp. 246—257.

9. J. M. Gillmann, *The Falling Rate of Profit* (London, 1956).

sistently, the trend in s/k was decidedly upward over the whole of the 90-year period.

When the ratios are converted to a stock basis, however, the data breaks clearly into two historical phases[10]. Until 1919 capitalism in manufacture behaved very nearly as Marx had predicted: Q rose significantly and s' did not increase sufficiently to prevent p' from falling. Then something went wrong. The organic composition of capital stabilized in the 1920's at levels reached in 1919 and fluctuated counter-cyclically in the 1930's; it fell all through World War II and had risen little by 1950. If the decade of the 1930's is excluded, there is in fact some indication of a secular decline in Q. In addition neither s' nor p' showed any definite trend[11].

Gillman has nothing to say about the average productivity of capital. But his findings are complemented by studies of the capital/output ratio in American manufacturing: measured in current prices, it rose through 1880–1909 and then fell continuously until 1948. When capital and output are estimated in 1929 prices, the peak is reached in 1919. Furthermore, the downtrend since 1919 holds both for the ratio of fixed capital and of working capital to output[12].

Thus, Marxists and orthodox economists do not disagree about the facts. Not so long ago some Marxists were predicting an even sharper tendency towards labor-saving technical change[13], but

10. In the absence of data on the rate of turnover of raw materials before 1922, and neglecting V as too small to matter, K is calculated on fixed capital only, i.e. the value of plant and equipment estimated at their reproduction cost in current prices net of depreciation.

11. Since production workers declined as a fraction of the total labor force in manufacturing, GILLMAN infers that the rate of net profit $\bar{s}/K$ did fall very slightly over the years 1910–1950 (*Ibid.* p. 98). But in fact the regression line estimated by the method of least squares shows no trend component whatever on the 5 per cent level of significance. The same negative results are shown by MANN's nonparametric ranking test for trend which makes no assumption about the mathematical properties of the trend line or about the character of the population distribution.

12. D. CREAMER, *Capital and Output Trends in Manufacturing Industry* (NBER, Occasional Papers 41, 1954). The fall in the capital/output ratio since 1919 is all the more remarkable if it were true, as Marxists allege, that late-stage capitalism reveals a chronic tendency towards under-utilization of capacity. As the denominator is usually measured, a fall in the utilization of capacity should, everything else being the same, increase the capital/output ratio.

13. P. M. SWEEZY, *The Theory of Capitalist Development* (New York, 1942), p. 276.

Gillman adduces evidence of the increasing importance of capital-saving innovations[14]. This is where agreement ends, however. Gillman seems to regard capital-saving improvements as novel manifestations of a complex technology which Marx could not have foreseen. Apparently, labor-saving innovations are induced by rising real wages eating into profit margins but capital-saving innovations just happen, for technical reasons, to occur only in late-stage capitalism. Capital-saving innovations play the same role in Gillman's book as trade union pressures in the works of other Marxists: they enter into the analysis as exogenous variables which reconcile the theory with reality.

Ironically enough, Gillman here adopts an attitude which not so long ago was widely shared by most orthodox economists but, as we shall see, not by Marx himself. A brief digression will help to place the matter in perspective. Economic development was traditionally said to involve continuous capital deepening in the sense of increased capital requirements per unit of output; capital-saving innovations were regarded as only becoming important when an economy was already richly endowed with capital. The temptation to draw unwarranted from the historical increase in capital per man proved irresistible[15]: technical innovations lighten human toil by substituting mechanical power for hand labor; therefore, technological progress as such is necessarily labor-displacing and, in the absence of sufficient capital-widening, will lead to chronic unemployment. The constant preoccupation with the problem of technological unemployment, out of all proportion to its actual importance, testifies to the hold of this line of thought. Implicitly, it will be noticed, technical change was being discussed as if it consisted mainly of inventions in the narrow sense of the term rather than of any change, for whatever reason, in the technical horizon of producers[16].

14. *Op. cit.*, pp. 74–79.

15. This ignores the fact that changes in the capital to labor ratio over time reflect not merely technical change or even factor-substitution without technical change, but also autonomous changes in the supply of savings and in the growth of population.

16. See e.g. J. R. Hicks, *The Theory of Wages* (London, 1932), pp. 123–125, and the comments by G. F. Bloom, "A Note on Hicks' Theory of Invention", *American Economic Review*, March, 1946; for recent version of Hicks' argument, see K. W. Rothschild, *The Theory of Wages* (New York, 1954), pp. 117–119.

With hindsight it is hard to believe that anyone could ever have doubted that capital-saving improvements are as normal a feature of technical change as labor-saving innovations. It is difficult now to appreciate how quickly and how recently economists have changed their minds on this question. In 1937 Joan Robinson declared that:

> It appears obvious that the development of human methods of production, from the purely hand-to-mouth technique of the ape, has been mainly in the direction of increasing "roundaboutness", and the discovery of short cuts, such as wireless, are exceptions to the general line of advance.

But in 1956 she concluded:

> There is no reason to expect technical progress to be exactly neutral in any one economy, but equally there is no reason to expect a systematic bias one way or the other. Capital-using innovations raise the cost of machines in terms of commodities and give entrepreneurs an extra motive to find ways to cheapen them. Capital-saving innovations tend to produce scarcity of labour in the consumption sector and give entrepreneurs an extra motive to increase productivity. Each type of bias tends to get itself compensated by the other[17].

Capital-saving innovations fall into two classes, those that save fixed capital and those that save working capital. Apart from cheaper and better machines, any improvement that widens the scope of auxiliary instruments, reduces floor space, or lengthens the physical life of a plant, belongs to the first class of innovations. Economies of working capital, on the other hand, release operating funds by reducing the stock of goods which must be carried for given output. Typically, they take the form of lower freight charges, faster handling of materials, reductions in delivery-time, and fuel savings through recovery and use of waste-products. Put this way it would be surprising indeed if capital saving innovations had not proved important even in the earlier phases of capitalist development. A good many of the crucial inventions of the Industrial Revolution on balance released rather than absorbed capital: the smelting of iron with coal, Cort's puddling and rolling process, chlorine bleaching, Watt's vacuum engine, Neilson's hot blast, Woolf's compound engine, not to speak of the transport revolution associated with the names of Macadam and Bridgewater[18]. The canal era, or for that

17. J. ROBINSON, *Essays in the Theory of Employment* (London, 1937), p. 135; *The Accumulation of Capital* (London, 1956), p. 170.

18. For the most part, the economic history of the period has been written with other questions in mind. But see the works of T. S. ASHTON, *The Industrial*

matter the replacement of the stagecoach by railroads, certainly drew heavily on capital resources. But its effect in reducing the prices of coal, timber, and iron in which the cost of carriage weighed heavily, was such that it is doubtful whether it raised capital requirements per ton-mile of freight carried[19].

Capital-saving innovations *may* involve such revolutionary inventions as explosives for mining, radio, telegraphy, and airplanes, but they need not. Frequently, they consist of minor but not necessarily routine improvements in technique and for that reason they tend to escape recognition. Indeed, awareness of the very existence of capital-saving innovations came late in the history of economic thought. Even the classical economists realized that time-saving improvements raise the rate of profit by increasing the turnover rate of capital funds; when railways were first introduced, their advantages in economizing working capital were thoroughly canvassed[20]. But such ideas were not systematized and economies of fixed capital were never seriously contemplated Sidgwick in 1883 seems to have been the first to hint at the general concept of a capital-saving innovation; Taussig and J. B. Clark made references to it in their writings. But none of them doubted that technical change had been overwhelmingly labor-saving in the past[21]. The growing influence of the Austerian theory of capital around the turn of the century, emphasizing as it did capital formation which increases the durability of plant and equipment, further encouraged the belief that capital deepens as it grows[22].

Revolution (London 1948), pp. 91–92; *An Economic History of England: The Eighteenth Century* (London, 1955), pp. 90, 100, 108–113. No historian has done more to attract attention to the importance of capital-saving improvements in the eighteenth century.

19. W. T. JACKMANN, *The Development of Transportation in Modern England* (Cambridge, 1916), I, pp. 404–451; II, pp. 724–729.

20. *Ibid.*, II, pp. 490, 543–544.

21. For page references to the neo-classical authors see A. GOURVITCH, *A Survey of Economic Theory on Technological Change and Employment* (Works Project Administration, Philadelphia, 1940), pp. 93–95.

22. BÖHM-BAWERK maintained that while some inventions do reduce roundaboutness, the capital so released tends to be applied to lengthening the period of production elsewhere. Only if the innovation is both capital-saving and product-replacing will the average period of production be shortened. This he dismissed as exceptional, citing the secular increase in physical capital per head as presumptive evidence of the greater frequency of time-increasing inventions: "Industrial ex-

Marx, on the other hand, was not only aware of capital-saving changes but spoke of them as the product of automatic market forces. "Capitalist production", he writes, "enforces economies in the employment of constant capital" which tend "to check the fall in the rate of profit." "This shows once more", he concluded, "that the same causes which bring about a tendency of the rate of profit to fall, also check the realisation of this tendency[23]." Chapter five of the third volume of *Capital,* written by Engels in the early 1890's, elaborates upon the tendency of certain inventions to shorten the time of production, thus raising profits by saving goods in the pipelines. This contention is richly illustrated with examples drawn from British industry. Engels notes that "the revolution in the means of communication in the last fifty years..." have more than doubled or trebled "the productive capacity of the capital engaged in world commerce." These comments, however, were merely suggestive and even as such they were confined to innovations which save working capital; neither Marx nor Engels considered the effects of technological progress concentrated in the capital goods industries. In the final analysis, Marx too remained a victim of the myth of a labor-saving bias in technical change.

III

Technological progress acts to offset diminishing returns to the faster growing factor. When innovational investment is insufficient to offset diminishing returns it is possible that both profits and wage rates decline as capital per man increases. But if technical change is strongly biased it would require a very low level of innovating activity to produce the perverse result of unfavorable trends in both profit and wage rates. Viewed in this light, the Marxian view of capital ac-

perience will verify two propositions... first, that with the larger capitalistic equipment, the product per unit of labor increases; and second, that this increase in product does not go on *pari passu* with the addition of capitalistic equipment." "The Positive Theory of Capital and its Critics", *Quarterly Journal of Economics,* January, 1896, p. 150. It is worth noting that WICKSELL's famous discussion of the effect of inventions upon wages in the *Lectures on Political Economy* does not consider the possibility of capital-saving improvements.

23. *Capital,* III, pp. 103 and 277.

cumulation seems almost deliberately paradoxical. Marx draws no distinction between movements along production functions and shifts in the production functions themselves: capital can not be invested without altering the state of the arts. Hence, there is no question in the Marxian system of insufficient offsets to diminishing returns. At the same time, Marx assumed that innovations would be heavily slanted in the labor-saving direction. Yet, he concluded that capital accumulation will depress the rate of profit without necessarily raising real wages per man. The mechanism that is supposed to produce this result is entirely independent of any third factor receiving an increasing residual. It is solely due to what Marx liked to call "the passion for accumulation". An excessive rate of capital formation lowers the profit rate while the innovations embodied in the increments of capital hold down wage rates by being largely labor-saving.

The Marxian situation is theoretically possible[24]. Events have not turned out that way, but is there any reason to think they could have done so? If a given rate of accumulation depressed the yield of capital (say, by hastening the rate of obsolescence or driving down the prices of finished goods), what prevents the system from settling down to a slower rate of growth? After all, if capitalists accumulate wealth for reasons of prestige and status irrespective of the rate of profit, so long as it is positive, and this is what Marx implies, a rate of accumulation so rapid as to depress the rate of return must defeat itself[25]. Putting this aside, it is still true that if capital is being incessantly invested in labor-saving improvements, the capital/output ratio must rise. This means a higher share of depreciation and interest charges in total costs with consequent pressures to affect economies in the use of capital. Likewise, "the passion for accumulation" should lead to a chronic excess demand for capital; consequent

24. See W. FELLNER, "Marxian Hypotheses and Observable Trends Under Capitalism: A 'Modernised' Interpretation", *Economic Journal*, March 1957; but see the elliptical comments of P. A. SAMUELSON, "Wages and Interest: A Modern Dissection of Marxian Economic Models", *American Economic Review*, December, 1957, pp. 893–894.

25. In other words, the demand for capital is *less* elastic in the long run than in the short run: all savings come out of profits and the capital stock is used to capacity; hence, a lower profit rate depresses savings not because it affects the willingness to save and invest but because it affects the ability to do so.

difficulties in obtaining finance, expressing itself in an upward sloping supply curve of funds available to the firm, should be enough to induce capital-saving innovations. No matter how we look at it, the investment-demand function must be of a very peculiar shape to sustain the Marxian case.

Under perfect competition innovations as such can not *for long* lower both profit and wage rates. Any sharp trend in factor-returns will generate a stabilizing shift in technical change. This is not to imply that innovations can be said to have a unique effect upon rates of return to productive agents: without knowledge of the underlying production functions nothing specific can be inferred[26]. Nevertheless, if technical progress is plentiful and yet produces a fall in the rate of return to capital it does suggest that the factor-saving slant of innovations is out of line with relative factor scarcities. In an economy in which capital is the scarcer factor, a persistent bias toward labor-saving improvements must erode the profits which each individual producer expects to reap from an improvement; this is the case Marx had in mind. When labor is the scarcer factor, as in advanced Western economies, a bias towards capital-saving improvements likewise works to reduce the yield of capital. The reason that technical change has not exhibited either bias to any marked degree is that the long-term pattern of innovations is the outcome of successive adjustments to differential rates of growth in the factor supplies as reflected in relative prices. Producers in a perfectly competitive market face infinitely elastic supply curves in factor markets; hence, the perfectly competitive market seems to provide no signal to induce the "appropriate" factor-saving innovation. But the factor-supply curves do shift through time and

26. Innovations may be conveniently classified in terms of their effect upon relative shares (see FELLNER, *op. cit.*, pp. 212–213). A capital-saving innovation raises labor's share and, of course, tends to lower the capital/output ratio; the effect upon the rate of profit, however, depends upon which of the two consequences predominate. A spate of capital-saving innovations occurring together will engender commodity-substitution towards capital intensive goods which fall in relative price; this stimulates the demand for capital and, the capital/output ratio may actually rise. Indeed, to predict the effect of an innovation upon rates of return and upon relative shares it would be necessary to know the elasticity of demand for every product and the elasticity of supply of ervery factor-input in addition to the changes in the marginal rates of substitution of factors.

there is nothing in the static theory of the competitive firm which leads us to deny that firms will learn to adapt themselves to a persistent trend in the shifting of factor-supply curves. Producers simply become conditioned by experience to avoid disappointment by choosing improvements which save the relatively scarcer factor. This process of adjustment damps down sharp cumulative changes in factor returns and thus works to stabilize the relative shares[27].

It is not necessary to assume that factor-prices have a *conscious* redirecting effect on firms: the familiar "realistic" objections to marginal productivity theory are irrelevant in this context. The argument rests essentially on competitive survival, regardless of the nature of individual motivation and foresight[28]. Firms adopting, say, capital-using devices in the light of falling wage rates and rising interest charges will not prove viable. The successor innovator will be saving capital and absorbing labor and the economist looking on will find the system as a whole adapting technical change to relative factor scarcities.

This response mechanism is not likely to operate very smoothly, as the existence of business cycles will testify. At the crude aggregative level adopted here, objections crowd in from every direction. Technical constraints may not permit enough substitution of other factors for labor to prevent a rise in total labor costs as wages rise; when labor costs bulk larger in total costs than do capital charges, the effect of a change in wages is not symmetrical with the effect of a change in the rate of interest. Moreover, scarcity of capital is not adequately reflected by the rate of interest owing to the practice of capital rationing.

In addition, indivisibility of capital in some industries may cause capacity to be installed far ahead of the market. Such industries may be impervious, for relatively long periods of time, to changes in wages and interest rates. Capital-saving improvements are often the result of external economies generated by the growth of social over-

27. See *ibid.*, pp. 220–222. Professor Fellner notes that under conditions of monopsony, in which the firm necessarily affects the price of the input it purchases, producers are made directly aware of relative factor scarcities by the respective gaps between average and marginal factor costs.

28. See A. A. ALCHIAN, "Uncertainty, Evolution, and Economic Theory", *Journal of Political Economy*, June, 1950.

head facilities. Since external economies are not reflected in the price system, improvements so originated form an important exception to the theory of market-induced innovations. Then too, it has been tacitly assumed up to this point that all innovations are cost-reducing. What of product-replacing or demand-creating innovations for which there is no basis of comparison with previous cost-outlays? These are certainly as significant nowadays as process-improvements and yet little can as yet be said about them. Variations in the level of inventive efforts raise further questions but we need go no further to make the point. Nevertheless, these reservations do not destroy the notion that the innovational process as a whole is the outcome of responses to market pressures: rational optimizing behavior precludes the possibility of any pronounced bias in technical change over long periods of time.

IV

The idea of an adjustment-mechanism governing the innovational process goes back to Marx. But Marxian economics provides only a truncated theory of factor-saving innovations. Changes in factor-prices are said to affect the choice of new techniques but capital-saving innovations are not treated on the same footing as labor-saving innovations. Yet Marx recognized that a falling rate of profit will induce entrepreneurs to economize upon fixed and working capital. The failure to consider the consequences of such tendencies is the fatal weakness of the Marxian theory of capital accumulation. It results in a theory of economic growth in which investment-prospects dry up not because there have been too few labor-saving improvements but because there have been too many. This conclusion is hard to justify in any competitive economy and has certainly proved to be irrelevant to the experiences of developed capitalist countries. Marx erred in not envisaging the possibility that labor might become the relative scarcer factor. It is only fair to say that this was in fact a common error of all 19th century economic thought. It matters more for Marx, however, because he alone claimed to predict the historical evolution of capitalism.

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SUMMARY

The Marxian system attempts to predict the course of technical change in a capitalist system on the basis of standard profit-maximizing assumptions. But despite Marx' prescient insights into the nature of technical change, he failed to provide a systematic theory of the factor-saving character of technical improvements. It is for this reason, and not because of any serious logical errors, that the Marxian system breaks down.

Technical change, however, is still typically treated as an exogenous variable in economic theory. A criticism of Marxian economics may serve as a steppingstone to the construction of an adequate theory of technical change. The outline of such a theory is sketched at the close of the paper.

Marx' argument for a falling rate of profit and a labor-saving bias in technical improvements is set forth with some care and then translated in the language of orthodox economics. His case is shown to be predicated upon a rapidly rising capital-output ratio; this tendency is not only contradicted by the available evidence but cannot persist under the Marxian model of investment behavior. Although Marx was one of the first writers to recognize the phenomenon of capital-saving innovations, treating them indeed as the product of automatic market forces, he minimized their importance, as did all economists after him. The idea that capital-saving improvements are as normal a feature of technical change as labor-saving innovations has won acceptance only recently. Capital-saving innovations are defined and some examples are offered. It is argued that the long-term pattern of innovations is the outcome of successive adjustments on the part of "learning" producers to differential rates of growth in factor supplies as reflected in relative prices. This process tends to damp down sharp cumulative changes in factor returns and thus to preserve approximate neutrality of technical change.

ZUSAMMENFASSUNG

Im marxistischen System wird versucht, den Verlauf des technischen Fortschritts vorauszubestimmen, indem von der üblichen Annahme ausgegangen wird, dass eine Gewinnmaximierung angestrebt wird. Obwohl Marx den Charakter des technischen Fortschritts erkannt hatte, ist es ihm nicht gelungen, eine systematische Theorie des produktionsmittelsparenden Charakters des technischen Fortschritts aufzustellen. Wenn das marxistische System in sich zusammenbricht, so ist in diesem Mangel – und nicht etwa in irgendwelchen schwerwiegenden Denkfehlern – der Grund zu suchen.

Der technische Fortschritt wird in der Wirtschaftstheorie immer noch als exogene Variable behandelt. Eine Kritik des marxistischen Systems kann jedoch den Grundstein für den Aufbau einer adäquaten Theorie des technischen Fortschritts bilden. Eine solche Theorie wird in grossen Zügen im vorliegenden Artikel entworfen.

Die marxistischen Argumente für eine fallende Profitrate und den produktionsmittelsparenden Charakter des technischen Fortschritts werden hier sorgfältig dargelegt und in der herkömmlichen Sprache der Nationalökonomie ausgedrückt. Im Verlaufe dieser Erläuterungen stösst man auf die Annahme eines rasch ansteigenden Kapitalkoeffizienten. Diese Tendenz wird aber nicht nur durch offensichtliche Fakten widerlegt, sondern kann im marxistischen Modell des Investitionsverhaltens schon gar nicht bestehen. Wenn Marx auch einer der ersten Autoren war, die das Phänomen der kapitalsparenden technischen Fortschritte erkannten, und er sie als Ergebnis der automatisch wirkenden Kräfte des Marktes behandelte, schätzte er ihre Bedeutung doch gering ein, wie es auch nach ihm alle Ökonomen getan haben. Der Gedanke, dass der technische Fortschritt ebensogut Kapitaleinsparungen wie Arbeitseinsparungen mit sich bringen kann, hat erst seit kurzem allgemeine Anerkennung gefunden. Kapitalsparende Neuerungen werden definiert, und einige Beispiele dafür werden gegeben. Es wird argumentiert, dass die langfristige Struktur der Neuerungen aus den sukzessiv erfolgenden Anpassungen der Produzenten an die verschiedenen Wachstumsraten des Faktorangebotes resultiert, die sich in den relativen Preisen widerspiegeln. Dieser Prozess dämpft tendenziell scharf kumulative Veränderungen in den Faktorerlösen und lässt auf diese Weise den technischen Fortschritt nahezu neutral bleiben.

RÉSUMÉ

Le système marxiste se propose de prédire le cours du progrès technique dans un système capitaliste en partant de l'idée communément admise que le but poursuivi est de maximiser le profit. Malgré sa préscience de la nature du progrès technique, Marx n'est pas parvenu à établir une théorie systématique du progrès technique en tant que facteur permettant de réaliser des économies sur les moyens de production. C'est pour cette raison et non à cause de quelque faux raisonnement que s'écroule le système marxiste.

Le progrès technique continue cependant à être considéré comme étant un facteur exogène dans la théorie de l'économie. Une critique de l'économie marxiste peut conduire à l'établissement d'une théorie adéquate du progrès technique. Une telle théorie est tracée en grandes lignes dans le présent article.

Les arguments de Marx pour un taux de profit allant en diminuant et la tendance des améliorations techniques à déterminer des économies de travail sont repris ici et formulés dans le langage usuel des économistes. De déduction en déduction, nous parvenons à l'idée marxiste d'une croissance rapide du cœfficient de rendement du capital. Or, cette tendance est contredite par les faits les plus évidents; de plus, elle ne saurait subsister dans le modèle marxiste du comportement des investissements. Bien que Marx ait été l'un des premiers à reconnaître le phénomène des innovations permettant la réalisation d'économies de capitaux, innovations qu'il considérait cependant comme étant le résultat de forces automatiques du marché, il en a minimisé l'importance, ainsi que l'ont fait après lui tous les économistes. Il n'y a pas bien longtemps que l'on admet de manière

générale que les innovations techniques permettent tout aussi bien de réaliser des économies de capitaux que des économies de travail. Les innovations de nature à permettre la réalisation d'économies de capitaux sont définies et un certain nombre d'exemples sont indiqués. Quant à la structure des innovations d'une période de longue durée, elle est considérée comme étant le résultat de l'expérience des producteurs procédant à des ajustements successifs aux taux de croissance de l'offre des facteurs de production, tels que les reflètent les prix relatifs. Ce processus modère la tendance aux brusques changements cumulatifs du revenu de ces facteurs, permettant ainsi aux modifications techniques de rester pratiquement neutres.