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MARX'S SOCIAL DYNAMICS AND NEUTRAL TECHNICAL PROGRESS: A CONTRADICTION?*

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I. Introduction

Marx's approach to society and economics is a dynamic one. The driving force in his system are the continuous improvements in the method of production or, in his terminology, the development of production forces. This feature of Marx's economics has long been recognized. According to Sweezy (1968), "it is hardly possible to evade the conclusion that Marx was the first economist who saw and foresaw the significance of technical change for economic development". Joan Robinson (1973) goes a step further and, in evaluating his contribution, writes that, "the main message of Marx was the need to think in terms of history, not equilibrium". It needs to be understood that 'history' refers to the dynamic and changing aspect of the economic system.

Modern economic theory after Hicks (1932) and Harrod (1939) has considered these dynamic aspects under the heading of technical change. It, too, has concerned itself seriously with the problem of innovation – adoptions of improvements in the techniques of production – and their effects on economic growth. Although in 1960 Blaug (1960) could still write about Marx's theory of economic development that, "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", modern theory has long since made attempts to remedy the shortcoming for which the antidote was meant. It has involved itself with serious discussion of the process of technical change.

One of the useful contributions of modern growth theory is the classification of innovations into labour-saving, capital-saving and neutral technical change. These concepts attempt to specify the effects of the introduction of new techniques on the relative employment of the factors of production and, thereby, on the distribution of the product among them.

Can the process of accumulation in Marx be neatly pigeonholed into one of the above categories? Specifically, is the concept of neutrality compatible with Marx's model of technological change? The purpose of this paper is to show that neutral technological change is incompatible with the Marxian theory of accumulation and income distribution, and that models which posit such neutrality reach conclusions that differ from the Marxian view of social dynamics.

*We express our appreciation to two anonymous referees for their helpful remarks.

To consider this question we first review the meaning of neutrality and its implications for the distribution of income, and examine, in turn, the two best-known definitions of neutral technical change – that of Hicks (1932) and of Harrod (1948, 1961). We then discuss the Marxian theory of accumulation and its implications for the distribution of income. To test the compatibility of the concept of neutrality with the Marxian model of the capitalist economy we apply Hicks's and Harrod's definitions to Marx's theory of technical change. Finally, we analyze two models of the Marxian process of accumulation (Samuelson-Heertje and Robinson) to determine to what extent these models, which use the *concept of neutrality*, correspond to the Marxian conception of technical progress.

II. Neutrality of Technological Change

Modern theory describes the various types of technical change as labour saving (or capital using), capital saving (or labour using), or neutral. A technical change (and we are restricting ourselves to positive changes) results in increased output per unit of input. If inputs are expressed in terms of capital/labour ratios, K/L, the higher output may be associated with a higher K/L, a lower K/L, or the same K/L, but in all cases with less of the inputs employed. It is the relative amounts of the factors thus saved that determine the type of technological change.

Different theories define neutral technological change differently. The common feature of all of them, though, is that the effect of such a change is to leave the income distribution between the factors of production (between labour and capital in the models with which we are concerned) unchanged. In fact, Blaug refers to 'the test of relative shares' as the criterion for neutrality of technical change (1963, pp. 13-33).

A neutral innovation poses – as does any technical change – a problem of measurement. The innovation causes the output of the product to rise by a certain percentage. If we assume the market price of a unit of output to remain unchanged, then the value of the output and the price of the equipment (in terms of the product) rise in the same proportion. The equipment, however, includes both the old and the new equipment. It would be unreasonable to assume that the productivity of the old equipment increases at the same rate as that of the new equipment. This raises a serious problem of aggregation when we deal with the entire stock of capital equipment: capital stock cannot be measured in physical units since the old and the new machines must be considered separately. This question of measurement seems to be insoluble.

The neoclassical pricing principle requires a knowledge of the aggregate production function for the determination of the price of capital (= rate of profit). This necessitates a knowledge of the amount of capital. But because of the hereogeneous nature of the means of production, the amount of capital can be expressed only in value terms.

This results in circular reasoning: To determine the price of capital we have to know its quantity, but this amount cannot be determined without a prior knowledge of its price. On the other hand, to determine the amount of capital and be logically consistent, its value must be independent from the rate of profit. However, the aggregation process indicates that the same physical means of production change their value when different rates of profit are applied, thereby causing different slopes of the production function. Therefore, different levels of value and rewards for the same physical means of production are achieved. This means that the relative prices of the factors and their shares are affected by the income distribution – for the determination of which they are used.

To be scientifically acceptable, neoclassical theory must provide a measuring unit which is completely independent of the income distribution. The Cambridge controversies proved that neoclassical theory failed to provide such a unit. Therefore, all measures of capital independent of the distribution of income were rejected by J. Robinson and the non-neoclassical participants of the Cambridge controversies (except in the extreme case of a fully malleable one-commodity economy) (*cf.* Garegnani, pp. 407-36; Harcourt, pp. 15-29).

For the current discussion, the above methodological problem is not an insurmountable obstacle. The current paper deals with the different interpretations of the effect of technological change on the income distribution. Since the attempt to use the production function in its own units has been shown to be unacceptable, the analysis can be couched in the physical units of output.

1. *Hicks's concept of neutrality*

Hicks bases his definition of neutrality of technical change (1932, p. 121) on the production function

$$Y = f(K, L, t) = A(t)f(K, L)$$

where Y is output, K and L are capital and labour inputs all measured in physical terms, and t is the technological change parameter. $A(t)$ is any rising function of t.

Hicks defines neutral technical change as the change in the production function which, at a given level of $k = K/L$ leaves the ratio of the marginal products of the factors unchanged. This is usually understood to hold for all values of k.

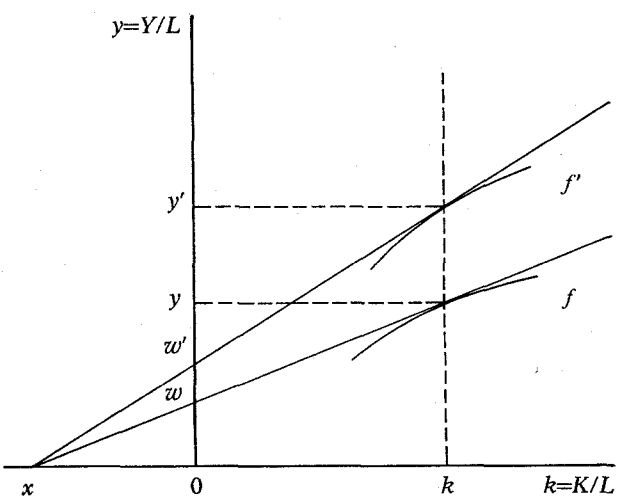

FIGURE 1
Neutral technical change according to Hicks

In Figure 1, f is the production function. At the given k, output $y = Y/L$ is produced. The slope of the tangent to f measures the marginal product of capital, MP_K, or the rate of profit. Hence, y-w represents the share of output going to capital, and the residual w – the share of output going to labour. Since the variables are measured in 'per worker' terms, w represents the wage rate. The segment $0x$ measures the ratio MP_L/MP_K, *i.e.* the income distribution.[1]

We introduce Hicks-neutral technical change by drawing f'. Diagrammatically, this requires a shift in the production function which, for any given k leaves $0x$ unchanged. Therefore, $(y'\text{-}w')/w' = (y\text{-}w)/w$ and the distribution of income is unaffected by the technical change.

2. *Harrod's concept of neutrality*

Harrod's definition is based on a production function which exhibits labour-augmenting characteristics:

$$Y = f(K, L, t) = f(K, A(t)L)$$

He classifies technical change by comparing production functions at levels of output where the marginal product of capital, *i.e.* the rate of interest, is the same. This implies a rise in k. Harrod defines neutral technical progress as the change in the production function which, at a given level of MP_K, leaves the capital/output ratio unchanged. This is usually understood to hold for all values of k/y.

In Figure 2, the tangents to the two production functions f and f' are drawn parallel to each other representing a constant return to capital. Points y_1 and y_1' lie on a ray from the origin representing a constant output/capital ratio. The move from y_1 to y_1' thus represents neutral technical progress according to Harrod's definition.

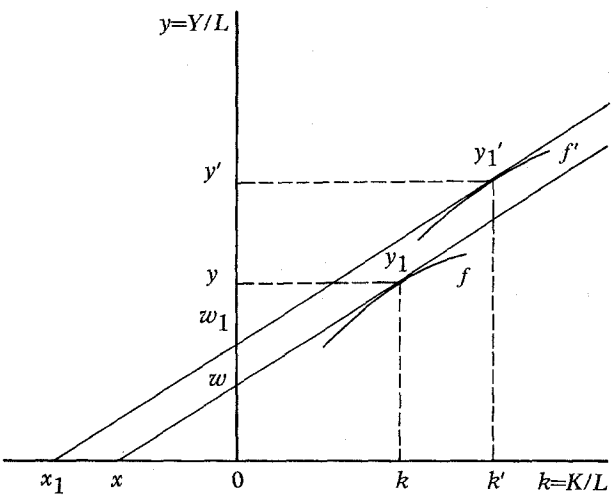

FIGURE 2
Neutral technical change according to Harrod

[1]Dividing $0w$ $(= MP_L)$ by $0x$, we get $0w/0x = \tan \alpha = MP_K$. Hence, $0x = MP_L/MP_K$.

The two definitions we investigated are devised in such a way as to meet the test of constancy in the distribution of income. This test, however, though couched in economic terms carries social implications. Both Hicks's and Harrod's definitions reflect situations of social stability and lack of change – if not lack of conflict.

III. The Marxian Model of Social Dynamics

This social stability does not fit the Marxian model which is built on social contradictions derived from the economic positions of the social groups engaged in the productive process. Marx writes: "What, then, is *the general law which determines the fall and rise of wages and profit in their reciprocal relation? . . . Profit rises to the extent that wages fall; it falls to the extent that wages rise.*" (1977, p. 219)

Marx's economic analysis is based to a great extent on his social theory and his historical approach to different economic systems and modes of production. The best-known exposition of the essential points is given in the Preface to the *Critique of Political Economy* where he discusses the forces and relations of production. Forces of production refer to the material means of production and the active capability of the entire working labour-force. Relations of production form the prevailing economic system – the 'economic base' – which expresses the socio-economic relations between the members of the society engaged in the process of production and the historical development of these relations.

The summary of the theory in the Preface of the *Critique* is couched primarily in sociological rather than economic terms. The economic significance of the theory is analyzed mainly in *Capital* I, chapter 7, *Capital* III, part 7 and in *Results* (pp. 948-1084). It is this economic interpretation which is relevant to the topic of this paper.[2]

According to Marx, the production process must be considered under two headings: The labour process, which deals with the forces of production and produces the output (*use-value as wealth*) of the society, and the valorization process, which focuses on the economic relations and the income distribution of the system by means of evaluation.

1. *The labour process*

As in any other system, so under capitalism the production process represents the production of the material conditions of human existence as a process performed under a particular interplay of the economic and historical relations of production. This process Marx calls the labour process.

Marx is very explicit about the features of the labour process and is consistent in stating this view throughout his entire scientific activity in his various works: "The labour-process . . . is the necessary condition for effecting exchange of matter between man and Nature; it is the everlasting Nature-imposed condition of human existence, and therefore is independent of every social phase of that existence, or rather, is common to every such phase" (*Capital* I, pp. 183-184)[3].

[2]For a discussion of the effects of technological change on the rate of profit see Groll and Orzech (1987).

[3]See also *Results* p. 998, p. 951, p. 975, pp. 981-82, pp. 996-97, pp. 1021-22; *Capital* III, pp. 814-16, p. 818, p. 825, p. 883; *Theories of Surplus Value* III, 264-65; *Grundrisse*, pp. 257-58.

2. *The valorization process*

According to Marx, capitalist production is characterized by the following features:

1) The production of commodities becomes a *dominant* form of the products produced. The form of commodities is not unique to capitalism, but only capitalism transforms the commodities into a dominant and general shape in which the products are produced (*Capital* III, p. 879).

2) The *differentia specifica* of the capitalist mode of commodity production is the transformation of living labour into wage-labour, *i.e.*, its transformation into a commodity or labour-power: "Wage-labour is then a necessary condition for the formation of capital and remains the essential prerequisite of capitalist production" (*Results*, p. 1006; see also *Capital* III, p. 879).

Like other commodities, labour-power has value and use-value: "The daily cost of maintaining it [the labour-power], and its daily expenditure in work, are two totally different things. The former determines the exchange-value of the labour-power, the latter is its use-value" (*Capital* I, p. 193; see also *Theories of Surplus Value* I, p. 156; *Theories of Surplus Value* II, p. 90, p. 178; *Results*, pp. 1016-17).

The only commodity the labourer possesses is labour-power, and by selling it receives its value and relinquishes its use-value. The latter, as in every sale, becomes the property of the buyer. The 'consumption' of this use-value takes place, as in every other form of consumption, outside the market. For the capitalist, the use-value of the labour-power is that part of the working day which remains after deducting the necessary labour time: "The use-value of labour-power for the industrial capitalist is that labour-power creates more value (profit) in its consumption than it possesses itself, and than it costs. This additional value is use-value for the industrial capitalist" (*Capital* III, p. 351; see also *Theories of Surplus Value* I, p. 398, p. 400). On the other hand, "the value of labour-power resolves itself into the value of a *definite quantity* of the means of subsistence" (*Capital* I, p. 172; emphasis added). Thus, the use-value of labour-power exceeds the value of labour-power and creates a positive residual for the capitalist.

3) The extraction of surplus-value is the other essential feature of the capitalistic mode of production, and is "the direct aim and determining motive of production" (*Capital* I, p. 880; see also *Capital* I, p. 331, p. 335; *Capital* III, p. 259; *Results*, p. 976). Production of surplus-value is therefore conditioned by the existence of the wage-labour system: "Without a class dependent on wages . . . there can be no production of surplus value; without the production of surplus-value there can be no capitalist production, and hence no capital and no capitalist" (*Results*, p. 1005).

These three characteristics constitute the essence of the valorization process and are certainly the most important features of the relations of production of the historically determined capitalistic system of production. The distinction between the labour process and the valorization process represents the central axis of the capitalist system, as Marx saw it.

The above enumerated features express the essential difference between the various models of modern growth theory and the theory of dynamic development in Marx. In the former, it is the increase in output as a function of the capital/wage-labour ratio which expresses the contribution of capital and the wage-labourer. It therefore entitles

the owners of capital to their share in the income distribution as everlasting, fully justified partners. For Marx, on the other hand, the increase in output is rather a function of the $\frac{\text{means of production}}{\text{entire living labour}} = \frac{\text{embodied past labour}}{\text{living labour}}$; *i.e.*, it is the result of the labour process. Under capitalism, however, the valorization process imposes on the labour process a distribution of income which transforms the surplus-value into the property of the owners of the means of production.

The income distribution constitutes an essential part of the relations of production and bears their character as an historically determined social form of the organization of production (*Capital* III, p. 883). Already in *Grundrisse* Marx emphasizes that every set of social relations of production possesses its specific type of distribution of income as determined by its mode of production. "The wage presupposes wage-labour, and profit-capital. These definite forms of distribution thus presuppose definite social characteristics of production condition, and definite social relations of production agents. The specific distribution relations are thus merely the expression of the specific historical production relations" (*Capital* III, p. 882; see also p. 883).

3. *Income distribution and technological change*

The income distribution is determined by the impact of the capitalist valorization process on the labour process. The driving motive of capitalistic activity requires technological change as a means of increasing the level and rate of profit. But, as we have seen, technological change, by its very nature, refers to the labour process since it relates the net changes in output to the change in $\frac{\text{means of production}}{\text{entire living labour}} = \frac{\text{embodied past labour}}{\text{entire living labour}}$. However, the impact of the technological change on the income distribution is via the valorization process. Marx's dynamic analysis deals with the process of accumulation specifically as a method of producing relative surplus-value. Both accumulation and surplus-value are essentially rooted in the valorization process and therefore necessarily affect the distribution of income between the factors.

According to Marx, technological change is always labour-saving or capital-using. This generally accepted view is mainly based on chapter 25 of *Capital* I, "The General Law of Capitalist Accumulation", where the theory of the reserve army and unemployment is presented, and on chapter 13 of *Capital* III, "The Law as such", where Marx analyses the theory of the falling rate of profit and the increase in the organic composition of capital.

The increased output due to technological change (if given in physical units as is customary) affects the distribution of income in the following manner: Labour receives the same amount of products as before the change, which represents the necessities required for the reproduction of the labour-power, and capital receives a larger amount of products which represents the increased share of the surplus-value. This increase in surplus-value reflects the capitalistic reason for the introduction of the technical change.

Assuming a technological change but a given length of the working day, the *mass* of output increases but the size of the *value added* during this working day remains constant. As a result, the value of each unit of product decreases. This change represents a change in the income distribution, for changes in the amount of surplus-value are always inversely related to changes in the value of labour-power (*Capital* I, p. 520). Since the value of the

labour-power is determined by the value of a given quantity of products (the necessities required for its reproduction), the value of labour-power can change only as a result of the change in labour productivity, *i.e.*, technological change. In Marx's words, "every change of magnitude in surplus-value arises from an inverse change of magnitude in the value of labour-power . . . It is the value and not the mass of these necessaries that varies with the productiveness of labour" (*Capital* I, pp. 522-23). It follows that the maximal change is fixed by the constant amount of the necessities, *i.e.*, by the changed value of the labour-power (*Capital* I, p. 522). Surplus-value need not assume the new level immediately, but may fluctuate between the old, higher level and the new, lower level until the new level is reached.

Marx mentions the possibility that the increase in productivity may leave the income distribution unchanged, *i.e.*, that the increase in output may be divided proportionately between wages and profit. Does this mean that he accepts the possibility that the worker may benefit even in the short as a direct result of the introduction of the new method of short-run production? How do such benefits accord with his view of the normal functioning of the capitalist economy?

Marx believes that only special circumstances can bring about such an occurrence. In each case where the labourer receives an increased amount of the means of subsistence, the price of the labour-power (wage) deviates from its value. This is especially true in the extreme case where the increase in output is distributed proportionately between necessary labour and surplus labour. "In such a case, although labour-power would be unchanged in price, it would be above its value" (*Capital* I, p. 523). The magnitude of the deviation "depends on the relative weight, which the pressure of capital on the one side, and the resistance of the labourer on the other, throws into the scale"[4] (*Capital* I, pp. 522-23). Ultimately, though, Marx's model emphasizes, the deviating price *converges with the new value of the labour-power.*

Until the new value is achieved the worker may be rewarded with more means of subsistence. This, however, does not change the basic impact of the valorization process since "even in such a case, the fall in the value of labour-power would cause a corresponding rise of surplus-value, and thus the abyss between the labourer's position and that of the capitalist would keep widening" (*Capital* I, p. 523).

If we exclude these extreme cases and deviations, the labour-power maintains its value and the entire difference between the old and the new value of labour-power becomes part of surplus-value. Technological change under capitalism is, therefore, always in favour of the increase of surplus-value, otherwise no technological change would be introduced: "For capital, however, the use [of machines] is still more limited. Instead of paying for the labour he only pays the value of the labour-power employed. Therefore, the limit of his using the machine is fixed by the difference between the value of the machine and the value of labour-power replaced by it" (*Capital* I, p. 392).

This is the ultimate condition for the introduction of a machine and technological

[4]In the French edition of *Capital*, vol. I, which is the final and, in our view, the most decisive version (see Groll and Orzech, pp. 592-94), we find at the place we cited the following addition by Marx: "Néanmoins, cette lois d'après laquelle le prix de la force de travail est toujours réduit à sa valeur . . ." (vol. I, tom 2, 194, Editions Sociales, Paris, 1977).

changes. The valorization process changes the income distribution in favour of the surplus-value. In Marx's words: "Hand-in-hand with the increasing productivity of labour goes . . . the cheapening of the labourer, therefore a higher rate of surplus-value, even when the real wages are rising. *The latter never rise proportionately to the productive power of labour*" (*Capital* I, p. 604). (Emphasis added).

Technological changes that are labour-saving or capital-using decrease the number of workers per unit of output. Therefore, with capital-deepening, unemployment may rise and wages fall relative to the new value unit. Capital-widening may also cause a deviation of the wage from the new value. In either case, these market phenomena are independent of the labour process which, as we have seen, always changes the income distribution in favour of the capitalists. Neutral technological change is therefore not a concept applicable to the Marxian model.[5] To test this conclusion we impose the Hicksian and Harrodian models of neutral technological change on Marx's theory of accumulation and technical progress.

4.1 *Hicks-neutral technological change and Marx*

In Marxian terms, the segment y-w, or y'-w', (see Figure 1) represents surplus value S (per worker), and w the payment of labour, or variable capital V (per worker). $(y\text{-}w)/w$ is, therefore,the rate of surplus value $s = S/V$ which expresses the distribution of income between capital and labour.

Hicks's definition in Marxian terms requires technical progress to be such that, at constant k (and therefore falling capital/output ratios K/Y) the rate of surplus value remain the same. This is equivalent to a constant distribution of income. Also, in contrast to the Hicksian rate of profit which rises since the slope of f' is greater than that of f, the rate of profit as defined by Marx, $\pi = s/k$, remains constant in this model since both its components (in physical terms) are assumed constant.

Does this construction make sense in Marxian terms? In Marx, as we have seen above, the real rate w, which represents the quantity of physical products necessary to reproduce the labour-power employed, is assumed constant at any point of time. Speaking of w, Marx says, "The quantity of these necessaries is known at any given epoch of a given society, and can therefore be treated as a constant magnitude." (*Capital* I, p. 519)

In the diagram, with w constant, the tangents to both production functions must pass through point w. With rising output, this necessarily raises s. So long as we use the Hicksian assumption of a constant k, the profit rate must then also rise. But in Marx, accumulation with technical progress in general implies not a constant, but a rising k.[6] In that case, whether the rate of profit rises or falls then depends on the relative magnitudes of the changes in s and k. It is clear however, that in any case the ratio of income shares does *not* remain constant. The income distribution changes in favour of capital (*cf.*, *e.g.* 1967, I, p. 645).

[5]One could argue that Marx implicitly defines neutral technical change in *Capital* I, chapter 25, section 1, where accumulation is accompanied by constant organic composition, rate of surplus value, and profit rate. This, however, is only a point of departure for his analysis.

[6]In *Capital*, Vol. I, pp. 612-21, Marx analyzes a case of accumulation without technical progress, *i.e.* with constant k. But there, w increases at the expense of S and accumulation ceases because of the falling rate of profit. This case, then, too, does not fit the Hicksian concept of neutrality.

4.2 *Harrod-neutral technical change and Marx*

Harrod's definition, too, results, as we have seen above, in a constant distribution of income. His definition, moreover, also implies a constant distribution of income in Marxian terms. The ratio $(y\text{-}w)/w$ (see Figure 2), which corresponds to the rate of surplus value and expresses the relative income shares, remains constant. The rate of profit, however, changes. Given a rising k, the constancy of s causes the rate of profit to fall. Thus accumulation with neutral technical change and constant output/capital ratios, which in Harrod are compatible with constant rates of profit, result in the Marxian model in a falling rate of profit.

4.3 *Marx's technical change*

For Marx, technical progress is fundamentally labour-saving. He says, "the use of machinery . . . is limited in this way, that less labour must be expended in producing the machinery than is displaced by the employment of that machinery". (*Capital* I: p. 390, p. 392. See also, *Capital* III: p. 108, pp. 255-57, p. 262, p. 265) (In value terms, technical change requires constant capital C to increase faster than variable capital V, *i.e.*, requires a rise in the organic composition of capital.) The production function applicable to the Marxian model is one which portrays technical change as capital augmenting:

$$Y = f(K, L, t) = f(A(t)K, L)$$

We can represent the Marxian model by using a diagram similar to the ones we used for Hicks and Harrod.

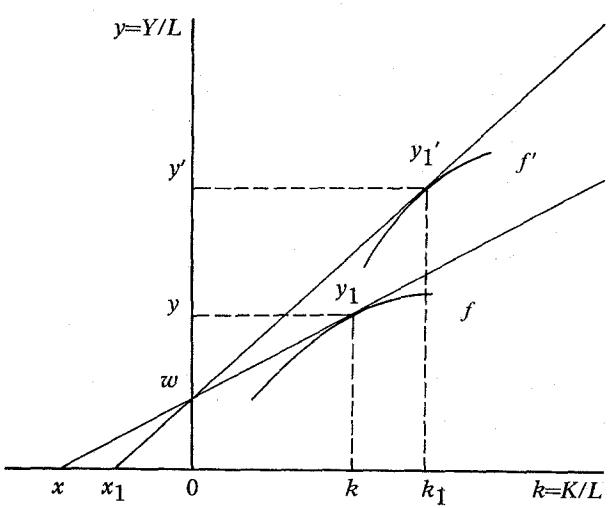

FIGURE 3
Technical change according to Marx

In Figure 3, the real wage rate w is held constant and the tangents to the two production functions pass through point w. In general, point y_1' lies to the right of y_1, which is tantamount to an increase in k. (In value terms this is an increase in the organic composition of capital.) Surplus value increases from y-w to y'-w and the rate of surplus value from $(y\text{-}w)/w$ to $(y'\text{-}w)/w$. The income distribution is therefore changed in favour of capital, which is graphically represented by a shortening of segment $0x$.

It can be argued that Hicks and Harrod were not concerned to assert that technical change is in fact neutral, but to attempt to define neutrality so that the actual path of technical change could be investigated. Still, in comparing different models of Marxian accumulation the answer to the question whether the model leads to neutral or non-neutral results must be one of the touchstones of the theory.

IV. Heertje

To that purpose we first discuss Arnold Heertje because he addresses the concept of technical neutrality in Marx directly. In his model (1972, 1977), he follows Samuelson's early interpretation of Marx (Samuelson, 1957). Although he quotes the famous passage in *Capital* I, that, "Accumulation of wealth at one pole is, therefore, at the same time accumulation of misery . . . at the opposite pole, *i.e.*, on the side of the class that produces its own product in the form of capital" (*Capital* I, p. 645), he arrives at the conclusion that accumulation in the Marxian model corresponds to neutral technical change.

Heertje uses a two-sector economy in which sector I produces homogeneous capital goods K, and sector II consumption goods Y. The inputs are homogeneous labour L and capital K, such that $L_1+L_2=L$, and $K_1+K_2=K$, respectively. Further he uses Leontief-type technical coefficients a_1, a_2, b_1, b_2, all > 0, such that:

$$L_1 = a_1K \qquad K_1 = b_1K$$

$$L_2 = a_2Y \qquad K_2 = b_2Y$$

He assumes a constant rate of interest, r, and, after some manipulation, derives the relationship

$$\frac{p_1}{w} = \frac{a_1(1+r)}{1-b_1(1+r)}$$

where p_1 is the price of a unit of K and w is the wage rate.

Heertje then derives the expressions for the organic compositions of capital for each of the sectors and for the total economy:

$$\frac{C_1}{V_1} = \frac{p_1K_1}{wL_1} = \frac{b_1(1+r)}{1-b_1(1+r)}$$

$$\frac{C_2}{V_2} = \frac{p_1K_2}{wL_2} = \frac{a_1b_2(1+r)}{a_2[1-b_1(1+r)]}$$

$$\frac{C}{V} = \frac{C_1+C_2}{V_1+V_2} = \frac{p_1K}{wL} = \frac{a_1b_1(1+r)}{\{1-b_1(1+r)\}\{a_2(1-b_1)+a_1b_2\}}$$

He now introduces technical change by allowing the productivities of capital and labour to grow at various rates and in various combinations, and calculates the effects of these changes on the organic compositions of capital (both sector and total) and on the capital/output ratio for the system. We summarize his results in three cases.

Case 1: He increases labour productivities in both sectors ($1/a_1$ and $1/a_2$) at equal rates. He does this while assuming, in turn, that the partial organic compositions of capital are equal to one another, and differ from one another. In both instances, as can easily be seen from the above expressions, the a_1's and a_2's cancel out and the organic compositions as well as the capital/output ratio remain unaffected by the technical change.

Since his assumptions correspond to Harrod's definition of neutrality (*i.e.* constant rate of interest and constant capital/output ratios b_1 and b_2), Heertje classifies the technical change he introduced into the Marxian model as Harrod-neutral.

Case 2: In this case, Heertje again increases labour productivities in the two sectors, but at different rates. He assumes different partial compositions of capital for the two sectors. He finds that, if $1/a_2$ rises faster than $1/a_1$, the organic compositions of capital for sector II and for the economy as a whole increase. The composition for sector I remains unchanged as does the capital/output ratio for the economy (the partials b_1 and b_2 are constant by assumption).

Here again, the changes introduced meet the conditions of Harrod-neutral technical change.

Case 3: Heertje introduces technical change only into sector II, by letting the productivities of labour and capital ($1/a_2$ and $1/b_2$) grow at equal rates. (In this case, he does not require the equality of the partial compositions of capital.) As in Case 1, he finds no effect on either of the compositions of capital, but finds a decrease in the capital/output ratio for the economy as a whole. (This latter result is not surprising since the total capital/output ratio is composed of the two sector ratios, the first of which, b_1, is assumed constant, and the second, b_2, is assumed to increase.)

Since in this case Heertje assumes a constant ratio of a_2/b_2 and a constant K/L (as part of the constant organic composition of capital), he finds the results of Case 3 to correspond to Hicks' definition of neutral technical change.

How is it possible that Heertje arrives at results so different from ours? The answer lies both in the structure of the model and in the changes he introduces into it.

Inspection of the expressions for the sector compositions and total compositions of capital reveal that:

a) The expression for the composition of capital for sector I does not contain the variables a_1 and a_2; *i.e.*, the organic composition of capital for the capital-goods producing sector is indepedent of the labour productivities in the economy.

b) The expressions for the compositions of capital for sector II and for the total economy

contain the variables a_1 and a_2 in their respective numerators and denominators in such a way that the a's cancel each other when we set $a_1 = a_2$.

c) The same structural characteristics and, therefore, results as in (b) hold true when we set $a_2 = b_2$.

Given the above specifications of the model, the very particular changes that Heertje introduces into the system (*i.e.*, equal rates of growth of a_1 and a_2 in Case 1, and equal rates of growth of a_2 and b_2 in Case 3) together with his assumption of a constant rate of interest, result in constant compositions of capital. Moreover, the growth rates he uses point by necessity to neutral technical change and a constant division of the national product.

Case 2 differs from the first two cases in that the productivities of labour in the two sectors are allowed to rise at different rates. Yet, since again neither b_1 nor b_2 are affected, we again have no change in sector I nor changes in the capital/output ratios. Accumulation in this case is therefore also, necessarily, Harrod-neutral.

Besides the problem posed by the assumption of equal growth rates in Cases 1 and 2, two additional questions arise about the conformity of Heertje's model to that of Marx. 1) Is it possible to have an increase in the productivities of labour without having *par passu* increases in the productivities of capital? and 2) is it possible to have an increase in the productivites in sector II without affecting those of sector I?

The answer to both questions must be negative. For Marx, there is a close interdependence between changes in labour productivities and changes in capital productivities. Of the many instances where he discusses the reciprocal relationship between labour and capital we quote only one: ". . . it can in fact be shown that *all* human relations and functions, however and in whatever form they may appear, influence material production and have a more or less decisive influence on it." (*Theories of Surplus Value* I, p. 288)

It is equally impossible in the Marxian schema for the productivities of one sector to change without affecting those of the other sector. Marx is very explicit about the interrelationship between the sectors. In discussing the impact of machinery on the post-Industrial Revolution era he writes: ". . . as the use of machinery extends in a given industry, the immediate effect is to increase production in the other industries that furnish the first with means of production" (*Capital* I, p. 443; see also p. 388).

V. Robinson

Joan Robinson (1978) presents a different model of the Marxian process of accumulation. In her paper she compares the effects of the introduction (in turn) of four different techniques of production. We focus on the technique she characterizes as Marx's 'normal case', a technological change that is capital-using or labour-saving, *i.e.*, that represents a rise in the organic composition of capital.

Robinson presents each technique as a straight line in a modified version of Sraffa's wage-profit diagram: (The straight lines are for convenience of exposition only.)

$$w = (Y/L) - (K/L)r$$

In Figure 4, line 0 refers to the original and line 1 to the new technique.

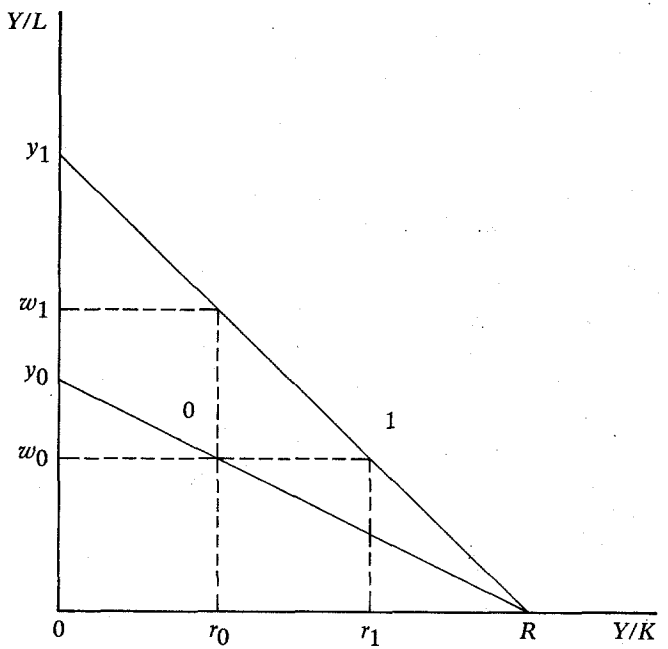

FIGURE 4
Technical change according to Robinson

Technique 1 gives a higher net output for the given labour force than technique 0. It therefore represents a higher capital to labour ratio as shown by its steeper slope. The capital to output ratios of the two techniques are identical. Hence the increase in the value of capital is in the same proportion as the increase in output. Robinson refers to the relation of these two techniques as 'neutral'.

The term 'neutrality' in this case defines only a technical relationship and does not refer to the constancy of factor shares after the introduction of the new technique. Only at one level of wages, w_1, will the distribution of income with technique 1 be the same as it was at the original wage level, w_0, with the original technology. In the rest of the 'feasible' region, the distribution of income changes in favour of the capitalists.

The feasible region – or region of interest to the capitalist – extends from w_0 to w_1. Wage rates cannot fall below w_0 which represents subsistence and will not rise above w_1 for beyond that point the rate of profit declines and the new technique will not be introduced.

Factor shares in this model are expressed as follows: the share of output going to capital is the rate of profit times the amount of capital, rK, and the share of labour is the wage rate times the number of workers, wL. Hence, the relative shares going to the factors are indicated by the ratio rK/wL, which corresponds to the rate of surplus value, s. We rewrite the ratio, $s = (r/w)k$, to investigate the changes in the distribution of income assuming various wage rates.

i) With constant wage rate w_0, the profit rate increases from r_0 to r_1. Since k increases, $s > s_0$ (the subscript refers to the original technique); the total increase in output is absorbed by the capitalists.

ii) As the wage rate rises above w_0, r_1 declines toward (though well above) r_0. $s > s_0$ though declines as w increases.

iii) At the upper end of the region, w has risen to w_1 and r has fallen to $r_1 = r_0$. At this point $s = s_0$, relative factor shares have not changed from what they were under the original technique; the technological change is neutral in its distributive effects.[7] This case also corresponds to the Harrodian definition of neutrality because it meets the two criteria of constant capital-to-output ratio, and constant marginal product of capital (or profit rate).

Except for the limiting case, Robinson's model is a better representation of Marx for all along the region where capitalists are expected to invest in new technology, not only does the profit rate rise, but, despite the fact that wage rates rise as well, the distribution of income changes in favour of capital.

VI. Conclusion

To preserve the essence of Marx's theory of growth of the capitalist economy, we must focus on the impact of technical change on the factors of production. Neutrality of technical change and its congruent constancy of income distribution are not adequate to this task. There exists a basic contradiction between Marx's economic dynamics of the social relations of the income distribution and the concept of a neutral technological change. Whereas the former imposes changes that are advantageous to the owners of the means of production, the latter, by definition, preserves the distribution of the total product between labour and capital unchanged. Neutral technological change is incompatible with Marx's theoretical structure. An unchanged income distribution as a result of technological change is not acceptable in the capitalistic system as understood by Marx.

[7]The proof that the distribution of income remains unchanged where the profit rate $= r_0$ is straight forward. Referring to Figure 4, with technique 0, the distance y_0–w_0 respresents surplus value S_0 (in Marxian terms); $(y_0-w_0)/w_0$ therefore is the rate of surplus value s_0, or the ratio of factor shares D_0. Likewise, for technique 1, $s_1 = (y_1-w_1)/w_1$. For technique 0, we can write: $(y_0-w_0)/y_0 = r_0/R$ and for technique 1, $(y_1-w_1)/y_1 = r/R$. Where $r = r_0$ the left sides of the equations also equal one another, and the ratios of the distributive shares are identical.

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