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CHOICE OF TECHNIQUES AND TECHNOLOGICAL
DEVELOPMENT IN UNDERDEVELOPED COUNTRIES:
A Critique of the Non-neoclassical Orthodoxy

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1. INTRODUCTION

When, after the Second World War, the development of underdeveloped economics emerged as a separate branch of economics, it was widely agreed that techniques used in many fields of activity, particularly modern industry, were in some sense too capital-intensive. Criteria of choice which would either bypass the market mechanism or supplement it were suggested by Buchanan and Polak, Kahn and Chenery (for a survey of the literature upto the end of the 1950s, see Sen, 1957, 1960). These criteria generally took only one single period into account. A necessary element of intertemporal choice was added by the paper of Galenson and Leibenstein (1955). In fact, attacking the problem from a Marxist perspective and with Soviet experience in mind, Dobb reached a very similar solution and embedded it in a comprehensive planning model (Dobb, 1951a, 1951b, 1954, 1956, 1960); Sen followed Dobb in his tracks and, while providing a more elegant formulation of the same criterion, also suggested a generalization of the Dobb-Galenson-Leibenstein approach, which effectively merged it with the emerging literature on optimal growth (Sen, 1960, 1969). Actually, the Soviet economist, S.C. Strumilin (1946) had already posed the problem of choice of techniques explicitly as a problem of choice over time, but his influence was to be filtered through the work of Dobb and Sen.

*For penetrating comments on an earlier version of the paper, I am indebted to Amit Bhaduri, Ajit Biswas and Suzanne Paine. The earlier version of the paper had been completed while Maurice Dobb was still alive, and I was looking forward to receiving his comments. But death deprived me of that opportunity. I would like to dedicate this paper to his memory.

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Galenson and Leibenstein focussed on the problem of maximizing output per capita at a "determined future time", and concluded that the correct criterion for allocating investment must be to choose for each unit of investment that alternative which all give each worker greater productive power than any other alternative. To achieve this result we must maximize (a) the amount of capital per worker, and (b) the quality of the labour force, i.e., its skill, knowledge, energy and adaptability. From this objective they derived what they called the criterion of the marginal per capita reinvestment quotient : "The best allocation of investment resources is achieved by equating the marginal per capita reinvestment quotient of capital in its various alternative uses". (Galenson and Leibenstein, 1955, p.351). But this criterion was essentially a microeconomic one and was not anchored to any model or models of growth. Since the Dobb-Sen development of the implications of the same type of objective was embedded in complete, though aggregative, models of growth in underdeveloped economies, it won a greater degree of attention in the later literature. So in the sequel, I shall be concerned almost exclusively with the collateral branch across the Atlantic.

The Dobb-Sen approach easily blended with the literature on efficient and optimal growth, particularly since Sen coined a name for the general class of criteria of choice over time, viz., "the time series criterion", without, however, offering an explicit solution. (Sen, 1957, 1960). Yet the victory of this approach over the older, neo-classical treatment has remained a Pyrrhic one. For a start, many of the analytical constructs within the Dobb-Sen corpus can be accommodated within the neo-classical or extended von Neumann framework with neo-classical frills (Bagchi, 1962; Solow, 1962). What is more damaging, this approach has proved no more fruitful either as a predictive device or as a guide to

policy prescriptions in underdeveloped countries than the neo-classical approach, as adapted to particular situations. Least of all has it proved its usefulness as a surgical tool for laying bare the contradictions with which actual choices of techniques by underdeveloped countries are fraught.

In this paper, I have almost entirely ignored the neo-classical approach. Most of the criticisms that can be made of the Dobb-Sen approach will apply *a fortiori* to the neo-classical treatment. The burden of my critique of the Dobb-Sen formulation of the problem of choice of techniques is that it misspecified the 'problematic' (for explanation of the term see Althusser and Balibar, 1972) in this area and thereby wrongly specified a whole series of issues in the field. Instead of formulating the problem as one of the highest level of development of the basic resource of the Third World countries, viz., labour, with a view to enabling it to control the other resources for achieving certain social goals (including, but extending beyond, the attainment of a basic standard of living within a short period of time), Dobb and Sen took over the problem of maximising output or surplus as such (either over a short period or in the long run) as the major objective of policy-making. From this basic misdirection followed the other mistakes which are simply enumerated here. First, the problem of investment of the surplus or saving in typical mixed economies of the Third World was ignored, and it was assumed that whatever incomes accrue to the share of capital will be invested. The criterion for maximizing the surplus over the very long run (when only it can be reduced to the problem of maximizing the rate of growth) can be positively pernicious when this surplus is systematically-wasted. From a social point of view, it may be useful to invest in relatively labour-intensive mass consumption goods in the underdeveloped countries. But this is not

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where the bulk of the surplus is generated. The bulk is generated in trading activities, to which manufacturing is simply an adjunct, or in moneylending, or in the form of rent from land. This surplus can only be used profitably to serve the needs of the rich : the mode of utilization of the surplus is not independent of its mode of its generation. (For a similar point, see Robinson, 1976)

Secondly, the problem of providing a non-contradictory description of states of transition or of comparison between one "equilibrium" state and another "equilibrium" state in the presence of a positive rate of profit was simply sidetracked by Dobb and Sen. This was done by assuming all capital to be fully malleable and constructible by unaided labour. A unique measure of the rate of surplus was also obtained by taking consumption to consist either of one good or of a fixed basket of goods. These capital-theoretic problems were adroitly handled by Mathur (1965), but Mathur's work remains subject to all the other strictures which supply to the Dobb-Sen approach. One consequence of the high degree of aggregation adopted in the Dobb-Sen approach was that disproportionality crises which compound the effective demand problems in mixed economies were swept under the carpet. (Dobb did deal with the question of balance between investment in the capital goods and in the consumer goods industries, but the discussion remained confined within the central planning assumptions of the Feldman-Mahalanobis model). Thirdly, in this approach (and a fortiori in the neo-classical-approach) the function of advances in technology in capitalist countries in controlling the workers and effectively depriving them of any creativity is completely missed. A technology, which is an advanced capitalist setting, is an instrument for controlling workers while raising their measured productivity, when translated to the Third World countries, becomes an instrument for controlling industries in the latter. It thus provides the basis of the so-called technological dependence of the Third World countries. Fourthly, the choice of technology and

of technological development is misconceived in the Dobb-Sen approach : it is essentially a process of learning and diffusion, and not a sequence of one-shot choices. To look at it from another angle, the productivity associated with particular techniques is not entirely independent of the path traversed for arriving at those techniques. In the less developed countries, the learning process is arbitrarily truncated by the intervention of foreign capital in its various manifestations, but that is all the more reason for not sanctioning apparently highly productive, capital-intensive, techniques imported from abroad, in the name of advances in technology.

X Finally, the Dobb-Sen approach shares the characteristic with much of neo-classical economics that it remains entirely agnostic about the class character of the state; even when mentioning central planning, there is little discussion of how the technocrats' choices can be influenced by signals from, and activities at, lower levels of decision-making. A state which would reverse the whole history of non-optimal choices of products and techniques in Third World countries has to provide a framework for re-integrated learning processes in order that control may be restored to the producers. The example of Chinese practice shows that alternative routes can be taken for the development of more rational, less alienating technologies in a state with a socialist class character. But, of course, these routes can be very different in detail in other underdeveloped countries.

II. THE MAIN FEATURES OF THE DOBB-SEN APPROACH : THE LURE OF FORMALIZATION

Dobb's work in the field of choice of techniques directly stemmed from his study of Soviet experience and his attempt to apply its lessons to the problems of growth of underdeveloped

countries (Dobb 1951a, 1951b). In his Delhi lectures, Dobb formulated many of the propositions which he developed later on or for which major credit was given to other economists (Dobb, 1951b). These include (i) the demonstration that with surplus labour in the economy, given other things constant, investment can be increased without depressing the average consumption level (cf. Kahn, 1972); (ii) the recognition that decisions about the rate of investment also involve decisions about (a) the horizontal structure of that investment (as regards its allocation between light industries which Dobb identified with consumer goods industries, and "heavy industries" which he identified with capital goods industries) and (b) the time-dimension of the investment, in the sense of the sequence in which inputs are used, stored or "congealed" and outputs are produced. In this connection, the crucial role of capital goods industries and of committed investment in general was emphasized, thus reminding us of the earlier Feldman model (now translated into English in Spulber, 1964) and foreshadowing the Mahalanobis-Domar formulation (Mahalanobis, 1953, and Domar, 1957). Dobb also emphasized that mobilization of resources is not a financial but an organizational problem. That is, what is needed is the redirection of resources to productive use and the prevention of waste through unemployment of labour and underutilization of capital, and the limiting of consumption to the available consumption goods, rather than the simple balancing of aggregate values of saving and investment by traditional devices. In this context, Dobb distinguished specifically between shortages of specific resources and of resources in general (Dobb, 1951b).

To Dobb, economic development was synonymous with industrialization and that in its turn was equivalent to an actual transfer of population from agriculture to industry and from the country to the city. The problem of feeding and clothing workers in industry was taken as equivalent to that of raising the marketed surplus of foodgrains

and of agricultural goods in general. In these assumptions Dobb was recapturing the experience of the Soviet Union. Although it was recognized that the "advanced sector" for which techniques are consciously chosen by the planners might as well be a part of agriculture, it was taken for granted somehow that choosing a more advanced technique would involve the migration of people to new locations.

The Soviet problem of constriction of the marketed surplus arose not just because the Soviet Union embarked on an ambitious programme of expansion of her industrial base. It also arose because while the Bolsheviks had succeeded in politicizing the industrial workers, the smytchka between the peasantry and the working class which Lenin had striven for in his lifetime was far from being an active and dependable reality in the 1920s. Stalin's collectivization programme was unduly harsh partly at least because it had to be imposed from above (Lenin, 1968). This need not be so in countries which attain socialism through a much more active alliance between peasants and workers. On the other side, the Soviet Union enjoyed an endowment of a capital goods capacity per capita which far exceeds the endowment of typical underdeveloped countries today. This made an emphasis on centralized capital goods industries in a country of vast open spaces and sparse population all the more natural.

When Dobb in 1954 embarked on a full-dress treatment of the problem of choice of techniques, he built the constraints and advantages of the Soviet experience into the ground work of his analysis (Dobb, 1954) and retained the same framework in his later work (Dobb, 1956, 1960). Most of the strength of the analysis - the emphasis on the primacy of the rate of saving and investment as a determinant of growth, on the capacity of the capital goods industry as a possible constraint in different phases of growth, on the prime necessity of feeding and

clothing the workers transferred to the advanced sector - sprang from his presuppositions derived from study of the Soviet experience. But some of the weaknesses are also due to his effort to formalize his theory with the help of these presuppositions only. While in the 1954 paper, Dobb recognized the importance of the compounding effect of the use of the surplus from projects with short gestation lags in cancelling the advantages of relatively capital-intensive projects (Dobb, 1955, pp.147-148), and of the availability of labour with requisite skills in making viable techniques with apparently large surplus-generating capacity (Dobb, 1953, pp.152-153), these at best sank into matters of secondary importance in his later work. He never saw that in labour-abundant Third World economies of large sizes, small and locally controlled projects could eliminate many of the costs of centralization (including the cost of long gestation periods) and help train workers in new skills, besides utilizing the skills traditionally acquired.

Dobb's 1956 paper in many ways completed his theoretical framework for choice of techniques. Here he posited a functional relation between P_c (the productivity per worker in the consumer goods industry) and P_i (the productivity per worker in the capital goods industry) and showed that, if the supply of labour is taken to be unlimited at a given wage rate W (on which the planning authority by assumption has no control), then the technique maximizing the surplus is the one for which $P_i (P_c - W)$ is a maximum. He also obtained a condition for choosing between different time periods which was analogous to the Jevons-Wicksell condition for the optimum age of wine or trees, viz., that the marginal product of lengthening the life by one period equals the interest cost on the value of the capital invested (see Wicksell, 1954, pp.120-144).

The major theoretical additions in Dobb's 1960 book (written in 1959) consisted of the exploration of the alternative assumption

that the main determinant of investment was the capacity of capital goods and of the problems of price-relations in a socialist economy (the problem of decentralized decision-making was explored primarily in relation to this economy). One disturbing feature of this book by the leading Marxist economist of Britain was that there was hardly any discussion of class relations and their bearing on the choice of techniques, investment projects, etc. The only way in which the concept of class enters into the analysis is through the assumption that the level of wages in the advanced sector is practically independent of the total volume of consumption goods available in the economy. Yet in all other respects, the will of the planning authority is taken to be binding. This is a straightforward translation of the Soviet experience into the framework of a planning model.

Dobb (and Sen) uses the simplifying assumption that unassisted labour could be employed to produce at least one kind of capital good, which could be used, in combination with labour, to produce all other kinds of capital goods. If gestation or production lags are ignored, this leads to the result that the different kinds of capital goods could be collapsed into one homogeneous capital good. The whole problem of surplus maximization could then be formulated in terms of a neo-classical model containing an aggregate production function and embodying the "classical" savings assumption, viz., that all profits are saved (and invested) and all wages are consumed. Soon after the publication of Dobb's book, Solow derived the Golden Rule of Accumulation in a Dobb-type model (Solow, 1962). The formal demonstration that the Dobb model can be cast in terms of an aggregate production function was given by Liviatan (1966).

However, as soon as time enters the model in any essential way, so that there are varying gestation lags in the construction of capital goods, or there are varying fruition lags in the final production of the

consumer good, or there are possibilities of different degrees of utilization of capital the comparison between different equilibrium states can lead to a multiplicity of solutions, depending on the rate of interest used (Robinson, 1953-54, 1956; Bagchi, 1962; Garegnani, 1966; Bhaduri, 1970). What applies to comparisons of equilibrium states, applies a fortiori to the problem of giving a logically consistent account of transition from an initial state to a different final state. All these capital-theoretic problems are multiplied when the essential heterogeneity of capital goods and labour are recognized from the outset. If the consumption basket is allowed to change over time, then the maximal rate of balanced growth is not necessarily intertemporally efficient either (Malinvaud, 1959; Bagchi, 1962). This is, however, a much less serious objection than the stricture that by skating over the problems of transition to the national balanced growth path Dobb (and Sen) ignored the problems of learning by doing, and the problems of deciding who is to be delegated the power of choosing between accumulation and consumption, including their form and sequence.

In a class-divided society, different types of consumer goods are consumed by different groups of people, and the problem of choice of techniques is confounded by the problem of choice of commodities (Stewart and Streeten, 1973; Stewart, 1974). Thus the concentration of Dobb and Sen on the production of homogeneous wage-goods and of malleable capital goods allowed many of the actual problems of technological change in mixed economies to escape their analytical net.

III. THE DOBB-SEN FRAMEWORK COMPLETED : GAUTAM MATHUR'S TOUR DE FORCE

In a book completed in 1962 but published in 1965, Gautam Mathur took the Dobb-Sen approach probably as far as it can be taken, integrating it with the Robinson-Sraffa developments in the field of

capital theory (Mathur, 1965). Mathur used the von Neumann model (von Neumann, 1945), as extended by Gale (1956) and Kemeny, Morgenstern and Thompson (1956), as the basic scaffolding for his theoretical structure. Perhaps the best way to appreciate both the remarkable achievement and the limitations of the book is to take seriously Mathur's own characterization of it as an attempt to present "an ordered engineering picture of the whole economy" (Mathur, 1973, p.139).

Since Mathur's book is very difficult to read, and people might be put off by the extravagant claims he makes for it (cf. Mathur, 1973, p.xvi), it is necessary first to state clearly what its achievements are. First, by treating the technology from the beginning as consisting of durable, fixed capital goods, a la von Neumann and Sraffa (1960), Mathur has got rid of many of the oversimplifications that render usual growth models merely simple-minded meccano sets. Secondly, by deriving the prices of capital and consumption goods integrally from models determining the rates of growth and of profit of the whole economic structure, and by bringing the effects of changes in prices, processes and combinations of processes (as between two balanced configurations) under the general rubric of Wicksell effects (positive, neutral or reverse), Mathur is able to treat both problems of technique reswitching and of violation of monotonicity of the value of capital with changes in the rates of interest (or in the rates of real wages) within the same theoretical framework. Thirdly, Mathur contributes a brilliant treatment of the purely technical or "engineering" (i.e., in respect of quantities and proportions of techniques and commodities needed) aspects of adjustment between one path of steady growth (without or with full employment) and another. He does this by distinguishing between different orders of bottlenecks (again, mainly in terms of commodities) and by postulating that any actual or potential economy can be looked upon as a composite of several admissible subeconomies, each of which

can reproduce itself and grow on its own and can produce the basic consumption good, corn. Such subeconomics are called eligible subeconomics (Mathur, 1973, p.41). Eligible subeconomics may than be combined in different proportions depending on which particular commodities are regarded as the first-order, second-order, third-order bottlenecks, etc.

The aim of planning is taken to be to reach the golden age where for a given rate of accumulation, "production per man employed is the highest steadily maintainable", and where full employment rules (Mathur, 1973, p.184). It can be shown easily that in such a golden age, all the surplus must be invested. The strategies that are eligible are those which allow the economy to reach this "optimum golden age" in the least possible time. Mathur does not try to solve this problem exactly: once the economy is assumed to be decomposable into a number of different subeconomies, some of which are capable of growing at a maximal, positive rate, the choice among the number of feasible paths to the optimum golden age would require rather involved mathematical methods. Instead, Mathur tells the story in terms of a combination of strategies which are characterized by different goods as the fastest growing ones (such as "corn", "tractors" and "dams"), and suggests various possible solutions, depending on the initial degree of unemployment (or, as Mathur calls it, attributing all of it to shortage of capital equipment or other material inputs, "nonemployment"). The problem of comparison of growth rates on different paths is solved by using the basic consumer good, corn, as the numeraire throughout. Even when only a few subeconomies are chosen for explicit discussion, the number of cases to scrutinize becomes very large. But they include some very interesting possibilities. The strategy of a relatively primitive sub-economy subsidizing advanced processes producing only capital goods is shown to be distinctly plausible (Mathur, 1973, Chapter VIII). The "bang bang" solution (in which only the capital goods sector or the consumer goods sector receives investment

in one phase and only the erstwhile deprived sector receives investment in another phase, and the two sectors receive investment in balanced proportions only in the optimum golden age) emerges as a plausible solution in several strategies (Mathur, 1973, Chapters XI-XIII).

Mathur also discusses the problem of choice of techniques when technical progress takes place. However, it remains confined to a generalization of the usual Harrod-Robinson classificatory scheme to the many-capital-goods-technology, and does not shed any light on how technical progress is achieved, and how it is embodied in men, machines and institutions.

Throughout Mathur's analysis there is a bewildering tendency to confuse categories of logic and entities from the real world. Quite often, this is a rather harmless expression of the author's exuberant faith in the validity of his own approach. But often also it leads him to commit analytical errors. One important case occurs when Mathur would want to count any consumption out of the surplus generated by the state as part of the wage (and therefore necessary consumption) and thereby save his basic assumption that the thriftiness of the state is unity (Mathur, 1973, pp.192-3). This is surely wrong, for from the planner's point of view, it is important to know whether the state can be regarded as a saver or a squanderer of resources, and whether or not actual consumption is equal to, or greater than, that strictly necessary at a certain stage of development. The problem cannot be conjured away by redefining all

wasteful consumption as necessary consumption.¹

Mathur's is an extreme case of an error which is often committed by practitioners of capital theory (and general equilibrium theory) : because it is difficult to provide a non-contradictory description of a non-stationary economy, it is assumed that the task of analyzing any such an economy is over once an internally consistent description has been concocted. Conversely, it is assumed that if it is difficult to describe the planning process in a socialist economy in capital-theoretic terms, then that model of planning must be "irrational". As Nuti (1970) has rightly pointed out, a socialist economy may well get by without using at all the notion of the value of capital.

Mathur's concern for getting his models right in terms of capital theory is not shared by most of the conventional analysts of the choice of techniques problem. But his explicit claim that his analysis can be easily extended to mixed economies, despite the probability that actions of individuals (or groups) would often run counter to the intentions of planners (Mathur, 1973, p.11), is shared explicitly or implicitly by other "development economists". Sometimes this is achieved through a

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1. To take another example, Mathur compares his own method of representing production possibilities on a production function with Joan Robinson's method, and concludes that Joan Robinson's presentation has relevance only "for individual entrepreneurs unable to see the interdependence of prices, interest rates, wages and techniques used in the economy as a whole" (Mathur, 1973, p.153). He then goes on: "an individual-dominated technique has no internal contradictions, and if blue-prints of others were not available to competitive entrepreneurs, a dominated technique, organised as a segment, would be viable by itself" (Mathur, 1973, p.154). Surely, the correct conclusion is not that it is not the Robinsonian method of representing a production function which is at fault, but that the specification of the conditions for survival of such a dominated technique must be at fault. The survival of the dominated technique may be due to some element of imperfection in the competitive framework, or if we are considering a steady growth model with certainty and no element of monopoly - to the fact that the rate of growth is lower than the rate of profit (which is equal to the maximal rate of balanced growth permitted by the technical conditions) (cf. Nuti, 1970).

kind of political innocence, refusing to specify the exact class basis of the planning exercises (cf. Sen, 1960). Sometimes there is a more dogmatic belief that socialist economies must share the property of "rationality" which characterize smoothly functioning, purely competitive economies, after corrections for external economies and diseconomies of various kinds, and distributional imperfections have been made (cf. Meier, 1970, pp. 743-749).

However, the rules of planning derived from a model of central planning in practically classless societies (but with explicit or implicit market mechanisms) can be either irrelevant or seriously misleading when applied to actual class-divided societies of Third World. We have already alluded to the problem of investment of the surplus that can emerge in such societies. Other problems that would crop up would be disproportionality in rates of growth between broad economic sectors such as agriculture and industry, disproportionality in the rates of growth of capital goods and consumer goods sectors, and finally disproportionality in the rates of growth of different types of consumer goods and capital goods themselves. Some recent papers have concentrated on what has been regarded as non-optimally high rates of growth of sophisticated goods (see Stewart and Streeten, 1973, and Stewart, 1974). However, this kind of disproportionality is only one aspect of the patterns of underdevelopment that characterize the Third World countries. Although some of the other aspects of underdevelopment are revealed in cyclical phenomena of the Kalecki-Keynes type, not all the aspects that are relevant for us can be put under the rubric of cyclical fluctuations or short-term crises of disproportionality (for an exposition of the demand problems that can surface in apparently planned mixed economies, see Bagchi, 1970 and Tendulkar, 1974). It is to these longer-term aspects of underdevelopment processes with a bearing on the problems of choice of techniques and technological development that we now turn.

IV. ANTINOMIES OF CAPITALIST DEVELOPMENT : DE-INDUSTRIALIZATION, TRUNCATED LEARNING PROCESSES AND SEGMENTED DEVELOPMENT IN THE THIRD WORLD

Capitalist growth in the epoch until 1914 produced almost exactly opposite effects on the camp of advanced capitalist countries from which the main impulses for change were being propagated. On the one hand, and on the colonies and semi-colonial countries dominated by the west European countries and their overseas offshoots on the other. In particular, it led to the displacement of vast numbers of artisans in Third World countries such as India, China, Indonesia, Egypt, Argentina, Peru and Mexico. This process was superficially similar to the displacement of artisans and small commodity producers in western European countries. But in the latter, the displacement was soon compensated by the rapid growth of factory industry and the overseas migration of vast numbers of people. In the Third World countries, the growth of factory industry was on a minuscule scale, overseas migration was insignificant in relation to their populations and in relation to the numbers of people displaced (Bagchi, 1976).

When the artisans in Third World countries lost their trades, they also lost their traditional skills. Again, the process was superficially similar in Britain, France or Germany. But in the latter, the workers in factories acquired new skills, and the state or public authorities came forward to provide elementary education to everybody. In Third World countries, the number of persons acquiring factory skills in this way remained very small, partly because the factory employment itself was small, and partly because in colonies such as India the really skilled occupations in factories controlled by Europeans (or Americans) remained closed to the "natives" (Bagchi, 1972a, Chapter 5). Furthermore, while artisans lost their skills, they did not become more literate than before. The meagre educational facilities available

in the Third World remained open primarily to the upper classes, and produced a new type of dependence on foreigners, which we shall note in a moment.

While industrialization on the basis of use of machinery and non-biological sources of power was not attained on a large scale in the Third World, the advance of technology in the developed capitalist countries under the logic of capitalism produced new problems for Third World countries (for a brief review of the contrasts between developments in advanced and underdeveloped countries in the area of technological change, see Cameron, 1975). From the beginning of factory enterprise, managers and capitalists wanted to secure control over the work processes and division of labour within the enterprise. With the advent of technology bred by research laboratories maintained by large corporations, and of Taylorism for controlling minutely the labour of workers within the factory, the control of working methods and processes which had been retained even by the craftsmen in early capitalist enterprises passed to the management and its immediate supportive structures (Braverman, 1974; Marglin, 1974).

When this method of control was superimposed on the colonial and semicolonial economies of the Third World, the increasing degree of control of workers by the management and its supporting research, sales and financial organizations was transformed into the increasing degree of dependence of Third World enterprises on the techniques of production, marketing, finance and management of the advanced capitalist countries. This increased degree of dependence was qualified by the countervailing efforts of the nation states and processes of import substituting industrialization from the 1930s onwards, but only to a minor extent. To understand why such countervailing processes were necessarily weak, we have to refer back to several aspects of underdevelopment produced by the processes of capitalist colonialism and imperialism.

We have already referred to the lack of educational opportunities for the vast majority of the people in the Third World. For a tiny minority, educational facilities were made available so that they could serve the colonial authorities in subordinate positions. In nominally independent countries also, because of the weak growth of autonomous capitalism (a weakness that was at least partly caused by the predatory nature of advanced capitalism itself), no need for mass education was felt by the rulers who educated themselves for positions in government, law and in the upper ranges of society in general. When import-substituting industrialization created a need for new skills, again the recruitment was strictly selective, being confined to the sons (and daughters) of members of the ruling strata. The international transmission of general university and technical education supported by state subsidies on a huge scale, proved to be an easier proposition than the international transmission of technology. This had the paradoxical effect that many of the science and technical graduates emerged as eminently exportable capital goods : in effect, the ruling classes of the Third World chose this method of exporting their capital to the metropolitan countries where capital in other forms was also gravitating all the time (cf. Sen, 1973; and Bagchi, 1927b).

This export of brains was rationalized by the relative (and sometimes absolute) impoverishment of the vast masses of people in Third World countries, and by the developments in the fields of technology and science in the advanced capitalist countries. The de-industrialization process combined with lack of any large-scale investment in agriculture in Third World countries had meant that vast numbers of people were simply selected out of the development process. This trend was sustained by (a) the development of products in advanced capitalist countries that were aimed at richer and richer groups of people, (b) advances in processes of production involving the use of increasing

amounts of capital (however measured) per head of population, and (c) the higher rate of productivity growth for those groups of manufactures which were directed towards satisfying the demands of richer groups of people (see Kennedy and Thrilwall, 1972, for the relative importance of product and process innovations; and Kendrick, 1973, for differences of rates of productivity growth as between manufactured products).

The objection may be raised that we have now strayed far from the problem of the choice of optimum techniques for Third World countries. In fact, the point we are leading up to is that the specification of the range of efficient techniques or rational choice among them cannot be independent of the social system or the mode of production in which the techniques are born. What is rational for an advanced capitalist country is not necessarily rational for an underdevelopment country with a very different set of supporting institutions and learning processes. At the very least, the rational choice of techniques in any particular industry is neither a one-shot affair nor unconnected with the choice of techniques in other fields. This last point was well recognized by Dobb and Sen. But the neglect of the first point led them to de-link the problem of choice of techniques from ^{that} ~~the problem~~ of technological development or social change in general, and this neglect has been partly responsible for the resulting irrelevance or perverseness of the theoretical results. Even orthodox economists have had to recognize that choice of techniques and products involves considerable research problems, and choices of apparently superior techniques may be postponed in the expectation of further improvements in techniques, so that the failure to adopt "best practice technique" can be explained as a rational lapse (Nelson and Winter, 1974, 1975; Rosenberg, 1976). The above criticism of the usual posing of the problem of choice of techniques would remain valid whether we take the surplus maximizing,

output-maximizing or employment-maximizing criteria, or even a generalised "time-series criterion".²

Recommendations derived from the Dobb-Sen framework become definitely pernicious when the criterion for surplus-maximization is singled out for policy prescriptions. In general, this established a presumption in favour of relatively capital-intensive techniques developed in advanced capitalist countries. However, as we have remarked above, the surplus generated thereby may not be invested in a productive form at all : it may be consumed, used to develop real estate, or remitted abroad (such remittance, is probably greatest in the case of foreign subsidiaries, but is also usual in the case of companies with some foreign collaboration). Furthermore, the need for so-called capital-intensity in the advanced countries also arises out of the need to control workers who are faced with equipment and processes which act as their masters. Advanced capitalist countries have developed a whole set of institutions, besides coming up with giant transnationals, in order to control and develop these techniques (see Freeman, 1974, for a concise description of the logic and apparatus lying behind technological developments in advanced countries).

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2. In the last case, a generalization may be suggested in which the rate of technical progress itself becomes a datum in the problem. But this will remain an empty, formalistic extension, for, the rate of technical progress will be dependent on the path of production and learning that are followed in the particular industry, on the general advance in learning processes and on technological developments in other industries. Perhaps some simulation models can be developed to take care of these problems, but until some demonstration to the contrary is forthcoming, I should hazard that such models will remain only illustrative exercises with none of the hectoring potential of the criteria that have been bandied about in the literature.

The attempt by the ruling classes of the Third World to duplicate such efforts has led generally to peripheral development and segmental development. The decision of the Turkish government, for example, to guide and subsidize research in the universities through an apex body has merely strengthened the present pattern of peripheral research within the university network or marginal research subservient to the import of foreign technology (Cooper, 1974). The concentration of research and development on the development of products and techniques in advanced capitalist countries, or on scientific problems picked out in such countries, leads to much of the research becoming essentially fruitless or catering only to the needs of the already favoured few. In all capitalist countries, the educational system has been geared to the maintenance and reproduction of current patterns of inequality (See Bowles, 1971; and Carnoy, 1971). But in ex-colonial, de-industrialized Third World countries the problem is especially severe, because in their drive for centralizing and exporting the surplus of these countries, the colonial authorities had rendered the whole pattern of development segmental and outward-orientated, and in the process had filtered the majority of the people out of the enclaves in which some growth takes place. (Incidentally, the extreme differences in measured productivity of agriculture and industry and of average rural-urban incomes, ~~is a~~ ^{is a} colonial heritage and long predates the process of import-substituting industrialization to which they have been wrongly attributed by Little, Scitovsky and Scott, 1970, among others). This has led, among other things, to much greater differential returns to skills and education in Third World countries than in advanced countries (see Kothari, 1970). The optimism that was once there about the easy and cheap transferability of technologies to the underdeveloped countries has suffered a blow from the realization that the overwhelming proportion of the usable patents in Third World countries is held by foreign nationals or foreign

companies to pre-empt certain markets without necessarily utilizing the patents (Vaitsos, 1972; O'Brien, 1974; Patel, 1974); that a large fraction of such patents is held by giant transnationals who have proved more adept at playing one national government against another than the latter have proved at playing foreign companies against one another; that a large fraction of the essential knowhow is no longer even patented and remains confined to certain key personnel or departments of companies (Schmookler, 1966); and that transnationals with worldwide operations generally use transfer prices for inputs and technology which are far higher than their true costs (Vaitsos, 1974, and Lall, 1973). Soviet bloc assistance may have led to some decrease in the dependence of Third World countries on the developed capitalist countries, but only in some fields, and it has in turn created new problems of dependence. Thus the failure of self-reliant research and development in the Third World has contributed to the exclusion of the majority of the people from any positive development and has accentuated the dependence of the ruling class on developed capitalist countries. In this paper I have highlighted the first aspect rather more than the second because it is a relatively neglected aspect.

Because the whole process of technological and scientific development in the Third World remains dependent on developments in advanced capitalist countries, the learning processes which might otherwise overcome some of the difficulties of advancing technology autonomously and according to the logic of the internal situations of Third World countries themselves, get truncated all the time. At the bottom end of the scale, unskilled or semi-skilled workers lose their jobs, with the advent of a different, usually less labour-intensive, technology. At the top end of the scale, the top technicians and scientists decide to leave their country or work for foreign companies,

because they find their particular skills better utilized there, or because they get better pay (the resignation of a large number of top managers and technicians from the Indian public sector oil-exploring organization, ONGC, in late 1976, is a notorious case). Thus in neither case can learning on the job lead to a significant technological advance in the country. The emphasis on "modernity", on capital-intensity, on the "advanced" character of techniques rather than on the internal logic of development through continuous learning (either on the job or outside), if necessary by making mistakes (see Cooper and Maxwell, 1975), helps to rationalize an ever-fragmented, ever-segmented, process of development of technology in Third World countries.³

V. ILLUSTRATIVE CONTRASTS BETWEEN TECHNICAL CHOICE
IN THIRD WORLD COUNTRIES AND IN THE SOCIALIST
FRAMEWORK OF CHINA

While it is relatively easy to figure out in what ways the development of techniques in Third World countries fails to meet the requirements of their autonomous development, it is not at all easy to see how to go about correcting the failures. That the corrections cannot

3. In a paper presented to the Kandy Conference, Mathur put forward a logical analogue of the Dobb-Sen-Mathur approach to the problem of choice of techniques for educational planning (Mathur, 1970), and was strongly criticised by Sen, among others, for the major results obtained by Mathur were patently unacceptable. It could be argued that Mathur's paper showed up one basic deficiency of the Dobb-Sen approach in assuming techniques to be immutable at the moment of choice, and in excluding the effects of learning and experience on both techniques and manpower.

be effected by piecemeal methods should be clear from our analysis.⁴ At least one Third World country seems to have overcome many of the difficulties associated with the adoption of apparently sensible techniques, and that is China. Instead of trying to analyse the whole process of technical choice and innovation in that country - a task which is beyond the power perhaps of any single person and particularly of any person who knows about the process only at second hand - I shall take up three illustrative cases and show how very sensible recommendations produce very different results in China and in capitalist Third World countries.

The use of second-hand machinery by Third World countries has been extensive in the past, and the logic of use of such machinery under competitive conditions has been brought out by Sen (1962). If the streams of gross outputs produced by the same piece of machinery are the same in advanced and underdeveloped economies, then the effective economic life of the machine would be longer in the lower-wage economies. The

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4. This is one major reason why I do not discuss the merits of the so-called "intermediate technology". Where intermediate technology is viable with existing prices of capital goods and labour, often capitalists on their own make the needed adjustments, particularly in the subsidiary operations. Sometimes a so-called intermediate technology involves wastage of labour and raw materials and becomes viable only through excessive exploitation of peasants and workers by the capitalists involved, and through government subsidies. This was true, for example, of the Khandsari method of sugar production in India. (Cf. Bagchi, 1972a, Chapter 12; the otherwise admirable analysis of C.G. Baron, "Sugar processing techniques in India", in Bhalla, 1975, is seriously deficient in that it fails to consider the implications of the locally monopolistic control exercised by Khandsari-owners on sugarcane producers). Attempts to introduce intermediate technology invented in laboratories or experimental projects when the other basic limitations on the adoption of self-reliant technology are still fully active, are bound to meet with disappointment.

reason is that the time period within which quasi-rents would become zero and then negative would arrive earlier in higher-wage economies, since wages can be taken to be the major component of the direct and indirect operating costs of the machinery. An even stronger result can be derived : if new and old machines are priced so as to reflect the conditions in advanced capitalist countries where the rate of profit and the rate of interest are lower than in the poorer country, and if older machines have shorter working lives (in a physical sense) than newer machines, then it will pay the poorer, higher profit economy to buy older machines rather than new. These results can be easily extended to the transfer of older machines from more highly developed regions of a country to the backward regions.

In applying this logic to actual cases of transfer of older machinery, the first problem that is faced is the pricing of the machinery - because of the usually superior bargaining power and a more extensive store of information available to the more developed countries and regions, and because of the higher degree of uncertainty characterizing the performance of older machines (see Cooper, Kaplinsky and Turner, 1974, pp.49-39). Furthermore, second-hand machinery is typically bought by businessmen in the less developed areas of a country, and since these businessmen generally find it difficult to keep up - in respect of finance, management and standards of maintenance - with the more established business groups, the low-wage areas often lose their competitive advantage, and are saddled with many "sick" enterprises with inefficient management and outmoded machinery, which involves enormous running and maintenance costs (see Bagchi, 1972a, pp.272-273.)

In a valuable study of the use of second-hand machinery in jute-processing in Kenya, Cooper, Kaplinsky and Turner (1974) concluded: (a) that second-hand machinery used in developing countries is often just obsolete and its use is non-optimal from both the private and the

social point of view; (b) that the installation and reconditioning costs of second-hand machinery can be high, so that the nominal price of second-hand machinery is a poor index of its capital-saving effect; (c) that, as has already been mentioned, the real productivity of second-hand machinery in a new location can be extremely variable; and (d) that the problems of spare part availability can be acute once the machines are installed.

As against all this, in China, the transfer of second-hand machinery from modern large-scale enterprises to small, communal level or regional enterprises has been successfully used as a vehicle for the transfer of technical knowledge (Sigurdson, 1973, pp.216-218). In the field of manufacture of bearings and machine tools, old machinery has been transferred from the larger national enterprises to local plants, and new types of equipment have been installed in the national enterprises. The modern equipment in larger enterprises is often specialized to the needs of other national level enterprises, whereas the local enterprises cater to the local needs and thus serve as complementary units. Workers are trained in the national enterprises to man the equipment in the local enterprises. These in their turn will generally be expected to pass both technical knowledge and equipment still lower down to serve the needs of rural industry and agriculture. Such a link is possible between large and small enterprises in socialist China because their relationship is not one of dominance, and neither the capital market nor the price mechanism - necessarily working in favour of the larger enterprises and better-developed regions in capitalist countries - plays a crucial role in determining what will be produced where and how.

This is the critical difference between the phenomena of "transferring down" (with or without the aid of second-hand machinery) in China and of subcontracting in Japan, where it is supposed to have

succeeded splendidly in utilizing scarce capital and abundant labour. In Japan also, the large enterprises often utilized smaller enterprises, including cottage enterprises, for getting ancillary inputs or products made for them. But in return for credit, marketing facilities, technical knowhow and even supply of machinery, the smaller enterprises were completely dominated by the larger business combines of whom the Zaibatsu were the most prominent. (Pelzol, 1965; Lockwood, 1960, Chapter 4) Furthermore, Japan differed fundamentally from most Third World countries in being able to stretch her investible resources to the fullest extent almost from the beginning of the Meiji restoration, and in being able to acquire a colony which would absorb many of the shocks of technical change, besides applying her with additional resources. The difficulty in most Third World countries including India is that their "large enterprises" are not large enough, and their rate of growth is not high enough, for the larger and smaller enterprises to enter into subcontracting relations on an enduring basis (Watanabe, 1974).

The second example concerns the role of engineering units and repairshops in the design and construction of sophisticated products. In China, many engineering units which had come up as repairing shops, and as units ancillary to ship-building, etc., particularly in the area around Shanghai, slowly graduated to become manufacturing works on their own, and turned out equipment for the petroleum industry, compressors, machinery for producing artificial diamonds and ships, with very little outside assistance. She has also built up factories producing motor vehicles in many parts of the country. Some of these units have apparently proved far more innovative than giant Soviet-aided complexes (Heymann, 1975; Rawski, 1975b). While China has not abjured the import of foreign technology, this has never been allowed to dominate the pace of progress even in technology-intensive fields. Struacious attempts have been made to internalize the imported technology.

Self-reliance and mobilization of local resources have been stressed in all fields, so that tractor-manufacture, for instance, is now widely dispersed in the country. It has been claimed that China's own production of machinery and equipment is now so large that imported technology represents only a small fraction (perhaps 6 to 8 per cent) of its overall technology accretion". (Heymann, 1975, p.679.)

The experience of India in this respect provides a vivid contrast. India had a larger steel industry than China in 1947, when she obtained independence from British rule. Several engineering industries also had grown up to a considerable size by that time (Thomas, 1948, Chapters 13-20; Bagchi, 1972a, Chapters 9-10). Yet India has remained dependent on foreign firms and on continued and repetitive import of foreign technology in such crucial areas as transport equipment, design of complete iron and steel plants, metals and metal products, machinery and machine tools, and electrical equipment, both in the government and in the private sector (for a general survey, see Reserve Bank of India, 1968 and 1974; for characteristics of collaboration agreements in particular fields, see Reserve Bank of India, 1974, pp.119-131; and Subrahmanian, chapters 5-7; and for the situation in the field of iron and steel technology in India, see Roberts and Perrin, 1975). India has been able to export the products of even some technology-intensive products. But this has been done often by foreign firms based in India, or by Indian firms acting as subcontractors for foreign firms. Her dependence in these technology-intensive fields is shown by the number of foreign collaboration agreements in operation, their duration (often going up to 10 years at a time), the renewal of the agreements decade after decade, the general excess of imports over exports in the case of foreign subsidiaries and other firms with foreign collaboration agreements, the remittances in the forms of dividends, patent and

licence fees and payments to foreign technicians, and the volume of foreign currency loans extended to the firms with foreign connections. (For details see Reserve Bank of India, 1974).

An enquiry into the causes of these differences in Indian and Chinese performance will have to range over most of the differences in their socioeconomic patterns and historical experience since 1949. For our purpose, it is enough to indicate that two at least of the basic conditions for continued and assured learning and indigenous innovation have been lacking in the Indian case. The first is the assurance that indigenous innovation will not be sabotaged by a sudden decision to allow a new and apparently more sophisticated technology to be imported. The second condition is that the skill generated will not be made infructuous through unemployment of the skilled persons due to lack of effective demand. In West Bengal in India, for example, the whole regional economy was thrown into a long-term crisis by the massive recession in the engineering industry starting in 1966, so that the skills accumulated earlier have been dissipated in the later years. (In their eagerness to stress the importance of learning by doing in small enterprises, both Heymann and Rawski seem to have underplayed the role of the ^{larger} ~~larger~~ framework of Chinese policy in sustaining such learning by doing).

The third example which illustrates contrasts between Chinese practice and practice in Third World countries concerns the diffusion of agricultural innovations. In Mexico, the Green Revolution has increased the degree of inequality between different regions, favouring wheat growing, irrigated regions in comparison with maize growing, unirrigated areas. One of the main reasons for the relative lack of success of the high-yielding varieties of maize in comparison with the high-yielding varieties of wheat has been that the former are much

more difficult to reproduce under relatively uncontrolled farming conditions than the latter, whereas, it is precisely the maize-growing districts which are less well-connected by transport, so that they are more difficult to cover from a few central seed-farms (Myren, 1970). In China, the problem of diffusion of seed varieties and agricultural innovations has been sought to be solved by locating research stations and experimental farms in every commune, if not in every brigade, wherever possible (Alley, 1973; Science for the People, 1974, pp.50-51; Crook, 1975). China's agricultural developments may come up against hindrances which are of a national scale, but the diffusion of innovations or inputs down to the level of the production team does not seem to pose a major problem. This is a highly significant achievement in a world in which the putative gains of the Green Revolution have faced various barriers in the process of diffusion and have aggravated problems of unequal development.

VI. CONCLUDING REMARKS

The Chinese examples are illustrative of the general methods that may be adopted to reverse the typical processes of retardation in an underdevelopment economy, and to prevent the emergence of new inequalities during the process of growth. This experience is relevant for the problem of choice of techniques on at least three counts. First of all, it illustrates how in an underdeveloped (as well as in an advanced) economy the real desideratum is not the choice of the optimum degree of capital-intensity or mechanization at any moment of time, but the pursuit of a package of policies that allow the development of techniques and the diffusion of the better techniques. The Chinese emphasis on walking on two legs is well-known (see, for example, Riskin, 1969); this implies not simply the possibility of choice of different degrees of mechanization at any moment of time, but the

possibility of development of techniques at several levels of organization and with differing degrees of mechanization.

Secondly, the Chinese experience illustrates that although learning processes are involved both in advanced capitalist countries and in socialist countries with a poor capital and skill endowment, they must be fundamentally different if the typical characteristics of underdevelopment - such as lack of articulation of development between different sectors, the creation of vast masses of deskilled people along with the growth of a tiny technological and scientific elite, the emergence of vast backwaters of stagnation along with a few nodes of growth - are to be reversed. The hierarchical control of learning processes in capitalist enterprise, the rigid differentiation between social classes in respect of opportunities of access to education, learning and control of production can merely aggravate the processes of underdevelopment in an already underdeveloped society. The apparatus that acts as a means of centralization of resources for further development - whose fruits are nevertheless unequally distributed - emerges as an impenetrable barrier against diffusion of development and helps to securely tie the underdeveloped economy to the advanced capitalist countries. Seen in this light, the brain drain from the Third World countries emerges as the inevitable result of imitating the educational and learning processes in advanced capitalist countries.

The third aspect of the Chinese experience that must be stressed is that in order for learning and development processes to succeed in the long run, available resources must be fully utilized for the purposes of production and productive consumption. It is no use creating new skills or a larger potential surplus on the basis of a higher degree of mechanization unless those skills and that potential surplus can be actually used to produce capital goods or goods catering to the

consumption of ordinary workers. If such utilization cannot be guaranteed, the creation of new cadres of educated or skilled people or of a potential surplus can lead to waste in several ways. Part of the skilled manpower may remain unemployed or employed in jobs not really requiring the skills acquired by it, and part of the new capacity may remain unutilized. This latter involves not only the wastage of domestic resources or foreign resources embodied in the "human capital", but also the piling up of claims of foreigners where the new, higher degree of mechanization is associated with the import of foreign technology or capital. If the skilled manpower and the sophisticated capacity are utilized, they are quite likely to cater to luxury consumption of the rich. Such luxury consumption will generally require the import of foreign capital and technology and involve the drain of foreign exchange resources. Finally, of course, the skilled manpower may be exported to advanced capitalist countries; and less frequently, the new capacity may produce goods for the advanced capitalist countries more cheaply than the latter could produce. This last development may mitigate the problem of waste if the returns are used to augment domestic investment or productive consumption at home. But such a development is still quite atypical in Third World countries.

Given the fact that capitalist countries of the Third World are endemically subject to problems of effective demand, of the diversion of potential saving into luxury consumption, of creation of educated manpower on the model of advanced capitalist countries, and of drain of foreign exchange resources for the import of foreign capital and technology for producing a whole range of goods, to stress the optimality of the degree of capital intensity judged by the criterion of generation of potential surplus to the exclusion of its utilization is positively misleading. The Dobb-Sen approach was fashioned to combat certain falacious orthodoxies of the early 1950s. At that time, economic

research with learning and diffusion processes even in advanced capitalist countries was still in its infancy (almost the first theoretical formulation occurred in Arrow, 1962). The Chinese experiment was still in its first phase. And finally, few economists were willing to recognize that typical Third World countries, in spite of all talk of planning, were likely to suffer from most of the ills of the advanced capitalist countries and some additional afflictions. Now that the experience on all these counts has given us some sobering thoughts and some new hopes, it is time to change the problematic altogether.

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