PART II

TECHNICAL CHANGE: ITS NATURE AND IMPACT

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Science, Technical Change and Development*

INTRODUCTION

The view adopted by policy makers in many third world countries, including Pakistan, is that a greater expenditure on science research will lead to technical change and thereby stimulate economic development. Such an approach arises out of an inadequate understanding of the relationship between science, technical change and the production system. re will suggest in this paper that the application of modern science research to technology requires, apart from other situational changes, the establishment of machine producing industries. Only then can science research be translated into the design and manufacture of continuously improved machines. This essential prerequisite for the indigenous application of science research to technology is precluded in economy, which grows in a relationship of structural dependence on the advanced capitalist countries.

The simplistic notion that increased science research

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will lead to technical change is the basis of the over three-fold increase in the allocation for science research in Pakistan during the Sixth Five Year Plan period (1983-88) compared to the Fifth Five Year Plan ix It is also a view that has recently been propounded by Prof. Abdus Salam, the Science Advisor to successive Pakistani governments and the distinguished Nobel laureate in theoretical physics. Referring to the sultans and monarchs of successive Muslim empires in history who were desirous of Western technology, Prof, Salam writes:

> "But even while they envied and sought the technologies involved, they failed to understand the basic interrelation between science and technology. In 1799 for example Selim Eli introduced the modern studies in algebra, trigonometry, mechanics, ballistics and metallurgy into Turkey and imported French and Swedish teachers — SO as to rival European skills of gun founding. But he failed to accent baste scientific research in these subjects and Turkey .never caught up with Europe. "[2]

(Emphasis mine).

The implication of this statement is that the failure of Turkey to catch up with European technology lay in its failure to conduct basic science research. Prof. Salam goes on to formulate this more explicitly when he proposes

> ''Even to - day, when we have come to recognize that technology is the sustenance and the power we have not appreciated that there are no short cuts to it, that basic science and its creation must equally become part of our civilization as a precondition of a mastery of science in application and technology."[3]

(Emphasis mine).

Basic science research in itself would be commendable in terms of its educational value of developing the scientific attitude in our society. However, before such research can be expected to lead to technical change the industrial conditions for the application of science to technology need to be created. It is these conditions which Prof. Salam ignores when he suggests that the means to rapid technological advance in underdeveloped countries is to achieve the same level of expenditure on science research (as a percentage of GNP) as that prevalent in the advanced industrial economies. He accordingly concludes by proposing:

> "We must spend the international norm of 1 to 2 per cent of GNP — mean annual expenditure of the order of 4 billion dollars for the Islamic world— on research and development with a quarter spent on pure science."

In this paper we will suggest that the capacity of science research to contribute to technical change in the advanced capitalist countries has only been made possible by certain specific characteristics of their production system, which are currently absent in most underdeveloped countries (especially the Islamic countries). The purpose of this paper is to explore first the nature of the inter-action between science and the inventive process in the advanced capitalist countries. Second, to specify the features in the third world economics which inhibit such an inter-action between domestic scientific activity and technological change.

SECTION 1; SCIENCE AND INVENTIVE ACTIVITY

In this section we will discuss: (a) The relationship between science and inventive activity and the way this has changed with the changing structure of industry. (b) We will analyze the factors that have determined the sequence and timing of inventive activity during the process of the development of capitalism.

(a) Science and Technical Change

Historically, science could be systematically employed in the service of industry only when certain changes had occurred in the industrial structure, i.e. when the production system had moved from the state of manufacture to that of machine- based industry.

At the manufacturing stage the sequence of operations which at the earlier handicrafts stage were performed by the same craftsman, were now divided into separate steps each performed by specialized workers. Although this division of labour raised labour productivity, yet the growth of productivity was still limited by the physical capacity of the individual worker. The manufacturing period shared with the earlier handicraft stage, this essential feature that it was a tool using economy where the tool was manipulated by the worker. Hence the maximum speed at which the tool could be operated was determined by the limits of the hand-eye co-ordination inherent in the design of the human anatomy. The machine stage spelled a decisive break from the past in the sense that the speed at which the tool could be operated was no more limited by the human anatomy, i.e. the shift from the hand-operated process to the machine-operated process enabled the design of the productive process to be determined not by the physical characteristics of the human being but by scientific research embodied in machine design. The possibilities of labour productivity were thus greatly enlarged because the efficiency of machines now became a function of the ability to apply scientific knowledge to industry. It is in the context of the extent to which science can be applied to industry that another feature of modern industry acquires critical importance: The engineering and capital goods sector, i.e., the sector in which machines are produced by means of machines. Thus the growth of capitalism to the stage of modern industry allowed continuous and indefinite increases in labour productivity because it created the conditions for the systematic application of science to industry.

With the further development of capitalism two additional changes have occurred in the industrial structure of the advanced capitalist economies which have made the link between science and industry in those economies even more 1ntense. These changes are:

i) The growing importance of the so-called "high technology" industries (example computors and electronics) which depend for their survival on constantly extending the technological frontier through the acquisition of the most advanced scientific knowledge. Consequently such industries have to establish their own R and D departments where scientific research and product development are inevitably closely linked as well as maintaining close links with other sources of knowledge such as universities and research centres.

ii) The introduction of flow processes in the Chemical industries and of electronic control and automation in other industries. These have necessitated an understanding of the production process as a whole as well as a grasp of the theoretical principles before any improvements can be brought about. Here again the need to maintain specialised R and D departments has emerged.

The discussion above suggests that the link between science and technology is not the simplistic one that technical change flows out of science research, nor even that science provides what industry- demands. There is in fact a much more subtle relationship where by the systematic application of scientific knowledge to industry becomes possible only when the industrial structure itself has acquired certain specif1c characteristics.

b) The Growth of inventive activity: Supply Side versus Demand Side constraints

Let us consider now the relationship between the growth of scientific knowledge and the pattern and timing of inventive activity.

It could be argued that in a general sense, the direction in which science develops is influenced by social need as expressed in the sphere of production. However, the particular time at which any particular scientific discovery b available for the needs of inventive activity is a function of the degree of complexity of the scientific problem itself, These internal dynamics of scientific disciplines therefore condition the specific timing of inventive activity. For example it has been argued that one of the reasons why inventive activity in industry was faster than that in agriculture in late 18th and 19th centuries was that the scientific disciplines (mechanics) on which industrial invention was based were available earlier, while the scientific disciplines like chemistry geology and physiology on which inventive activity in a agriculture was based, developed much later.[7]

Not only is the pace and sequence of development of scientific knowledge influenced by the degree of complexity of the conceptual problems, but may also be constrained by the complexity of the instruments of observation, which iii turn depend on the level of development of the engineering industry. For example the development of the biologic Sciences depended critically on the microscope, just as the study of the atomic structure of molecules depended on X-Ray Crystallography.

Schmookler claims that the pattern of inventive activity in industries producing various classes of commodities can be explained in terms of the composition of demand for these commodity classes.[9]

In studying the issue of what determines the pattern of ii activity, Schmookler considers two specific questions.

How to explain:

1. Variations in inventive activity in any particular industry over time.

2. Variations in the rates of inventive activity between industries at a given moment in time. Taking new patents as a measure of inventive activity, Schmookler gives evidence to show that for many American industries both time series as well as cross sectional data show a high correlation between volume of sales and inventive activity (in the case of time series correlation a lagged correlation between in creases in volume of sales and increase in inventive activity was observed). Schmookler concluded from his evidence that the major determinant of the changes in the distribution of inventive activity was the changes in the demand for various classes of inventions as manifested in the demand for goods.

In his analysis, supply side factors (growth of scientific knowledge) are relevant not in influencing the rate of inventive activity, nor its distribution amongst various commodity classes, but in determining the particular scientific disciplines (mechanical, electrical chemical or biological) upon which inventor will draw. Thus the growth of scientific know e will determine the specific characteristics of inventions Lie the purposes for which inventions are undertaken and time at which they occur will be determined by the demand for various commodity classes.[10]

There is an important assumption underlying this argument that the inventive activity is determined primarily by demand and that the development of scientific knowledge is relevant only in determining which particular discipline the inventor will draw on. The assumption is that there is in some sense substitutability amongst the various scientific disciplines in providing the knowledge base for a new invention.

According to Rosenberg' such substitution between the various sub-disciplines of science is frequently absent and is usually imperfect. In fact in many cases there is a complementarity between the sub discipline a upon which the inventive process draws. For example the development of the new "High Yielding Varieties" of wheat and rice depended primarily on biological research but had a high degree of complementarity with chemical inputs (e.g. fertilizers and pesticides).

If the various sub-disciplines are not perfectly substitutable knowledge bases for particular inventions, then the fact that the sub-disciplines grow at uneven rates would affect the pattern of inventive activity over time. Thus as Rosenberg suggests, many important human wants remained unsatisfied despite a high demand for them. For example although there was demand for the cure of infectious diseases and medicine attracted many trained scientists, yet improvements in the treatment of infectious diseases required breakthroughs in the field of bacteriology.

Accordingly Rosenberg concludes that although demand factors have determined the direction of inventive activity yet the timing and pattern of inventive activity has operated within the constraints imposed by a body of scientific knowledge growing at uneven rates among its component sub-disciplines.

SECTION II: WHY SCIENCE RESEARCH FAILS TO RESULT IN INDIGENOUS TECHNICAL CHANGE IN UNDERDEVELOPED COUNTRIES

We have discussed in the previous section the relation between science and inventive activity in industry in the advanced capitalist countries, and have suggested the importance of the growth of scientific knowledge as one of the factors influencing the timing of inventive activity. We have also seen that this link between science and industry and the growing intensity of this link is because of two fundamental features of the industrial structure in advanced capitalist economies:

1. The existence of a machine-making and engineering industry which enables both the systematic application of science to the needs of industry as well as the orientation of the direction of scientific development by the needs of industry.

2. The increasing degree of connectedness between science and industry may (as Freeman argues)' be due to the growing importance in the industrial structure of technology intensive industries which depend for their survival on extending the techno logical frontier.

In this section we will analyze the factors explaining the absence of a link between science and industry in under developed countries.

The explanation for the absence of a link between sciences and industry in the third world countries is rooted in the structural dependence of these economies on the metropolitan economy.

In the post colonial era state power in these countries came into the hands of the landlords and the comprador bourgeoisie who were politically aligned to the metropolitan bourgeoisie. The industrial development which was instituted this ruling alliance had two important characteristics from the perspective of our present analysis:

1) It was an "assembly plant industrialization" i.e. it consisted of a shift of certain processes and activities from the metropolitan to the under developed economy. Consequently the under

developed economy.[13] Consequently the under developed countries in many cases lacked an industrial base of machine-building and engineering industries which as we have seen is a prerequisite for a link between domestic science and industry.

2) Given the highly unequal distribution of income and the influence of metropolitan culture, consumer demand in underdeveloped countries was dominated by the demand for Western, luxury goods. Industries in underdeveloped countries naturally used imported technology in the cases where they were directly owned by foreign capital. But even domestically owned enterprises used imported technology. The reason for this was that once the demand for specific products had been established there was usually little choice in the techniques required to produce them. 14 However even when given the product, choice of techniques did exist, there was a tendency in many under developed countries, to employ capital-intensive imported technology. There are three reasons for this:

   i) The overvaluation of the exchange rate and the provision of government subsidized loans to industrialists (which were policies associated with import substitution industrialization during the 1950s and 1960s) 'distorted' relative factor prices making capital relatively cheap. This induced entrepreneurs to select capital-intensive imported technology even when an efficient-labour intensive substitute was domestically available.

   ii) In the contemporary period under pressure from international loan giving agencies, many underdeveloped countries have been obliged to go in for exchange rate devolution and withdraw subsidies to bring the domestic price of capital closer to the international market price. However in spite of the increased price of capital, entrepreneur in underdeveloped countries continue to choose the capital- intensive technique in order to avoid ''labour Problem" In countries where extremes of wealth and poverty co-exist the urban labour force in many cases is often well - organized and capable of putting pressure on the management. Under these circumstances entrepreneurs prefer to go for automation in order to achieve greater control over the production process, even if the imported capital— intensive technique is relatively more expensive than the local labour - intensive one. In such cases where the entrepreneur selects imported technology, the entrepreneur is obliged to import the entire technology package because of the form in which techno logy is marketed internationally. The result is that the technology package imported is often more expensive than if the entrepreneur had imported the individual components from different sources.[15]

iii) In countries where foreign aid finances the import component of development projects there is a tendency on the part of the local elite to select projects which are capital-intensive and which use imported technology. Apart from this, projects financed by foreign aid are in most cases 'tied' to importing the technology from the aid - giving country.[16]

The result of the above features of dependent industrialization was the divorce of domestic scientific institutions in underdeveloped countries from the process of industrial development. Domestic scientific activity could not be applied to industry, nor could the demands of industry influence the orientation of domestic scientific effort as they had done in the case of advanced capitalist countries. (See Section II). Under these circumstances, as Charles Cooper' suggests, the direction of domestic research is mainly determined by the decisions of the individual researcher, who in turn takes his cue from the concerns of international academic research. Hence "scientific communities in underdeveloped countries are outposts of advanced country science with very limited links with economic and social realities which surround them." [18]

Amilcar Herrara[19] has argued that the failure of science to serve industry in underdeveloped countries cannot be entirely explained in terms of the nature of the production system in underdeveloped countries. He argues that the ruling classes deliberately refrain from instituting those changes in the production system which would be necessary for a link between science and industry, because such changes (example radical re-distribution of income and assets, and disassociation of the economy from the structure of dependence) would undermine the political power of the ruling class itself. Herrara goes beyond this to suggest that even autonomous scientific institutions, that are separate from industry, are not tolerated by the ruling class, for such institutions become centres for free discussion and criticism of government policy. This is regarded as subversive and governments therefore take active measures to undermine the autonomous science centres by reducing grants and repressing free discussion. In this way, given the political context within which separation of science institutions from industry occurs, there is a tendency for these science institutions to cease being "scientific".

CONCLUSION

We have suggested in this paper that the large increase in the funds allocated for science research n Pakistan is based on a misconceived premise That increased science research will lead to technical change within the country We have argued that the systematic application of science research to 1 technology requires a particular kind of industrial characterized by highly-developed ‘machine-pro g industries. Such an industrial structure does not exist underdeveloped countries like Pakistan which have experienced an ”assembly plant industrialization” within a framework of structural dependence on the advanced capita- countries.

In Section I, we examined the nature of the relationship science research and technical change We indicated that in the case of the European economy it was only when ad reached the machine-producing stage t scientific research could be systematically applied to industry In the temporary economy of the advanced capitalist countries relationship between science research and technology has particularly intense as the result of the emergence new characteristics in their industrial structure, which are nonexistent in underdeveloped countries

a) The growing importance of “high technology” industries such as computers and electronics.

b) The introduction of flow processes in chemical industries and electronic control.

These new industries require for their development, the application of knowledge at the frontiers of science research.

We suggested further, that in the course of the development of the advanced capitalist countries, there was a two way inter-action between science research and industry, i.e. the application of science research to the development of the engineering industry, in turn made possible the development of new instruments of observation (e.g. electron micro scope, etc.) which stimulated the growth of science research. The ‘absence in under-developed countries of the institutions and industries which link science research with industry, results in the science establishments in these countries becoming “outposts’ of advanced country science with little relevance to the needs and concerns of the local society.

In Section II of this paper we examined some of the characteristics of economic growth in underdeveloped countries, and pointed out that the nature of dependent industrialization, was such that the necessary conditions for an inter-action between domestic science research and technology, have not emerged in these countries. Given the highly unequal distribution of income in U.D.C. the demand pattern for goods is oriented towards luxury consumer goods which tend to be either imported, or assembled locally with imported technology. Thus the pattern of consumer demand itself limits the choice of technology to that available abroad. However given the product, whatever flexibility exists with respect to using indigenously developed technology is further restricted by the conditionality clauses of foreign aid on which most U.D.C. are dependent. The nature of technology transfers, and the phenomenon of “technology packaging” further limits the ability of U.D.C. to introduce locally-developed technological ideas to imported technology. Under these circumstances, we have argued that science research in U.D.C. while it may fulfill a long term educational objective of developing “The scientific attitude” cannot be expected to induce indigenous technical change, unless fundamental structural changes are brought about in the economy and society.

Notes and References

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    Also see: 1) Baran, P.A., Political Economy of Growth. M.R. New York, 1966.
    2) Frank, A.G., Capitalism and Underdevelopment in Latin America. Pelican 1969.

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14. Stewart, Frances, "Choice of Technique in Developing Countries," in Charles Cooper (ed.) Science, Technology and Development, Frank Case, London, 1974.

15. For an analysis of technological dependence associated with packaging, See: Vaitsos: Inter Country Income Distribution and Transnational Corporations. Clarendon Press, Oxford 1974.

16. By far the largest proportion of aid received by Pakistan, for example, was in the form of project assistance (73% in 1979-80). Such aid is tied in most cases to the source, i.e. the item involved In the project have to be purchased from suppliers In the aid- giving country:

See: Pakistan Economic Survey, 1979.80, Government of Pakistan, Economic Advisor's Wing, Islamabad, 1980, p. 155.

17. Charles Cooper, op. cit.

18. Ibid.

19. Herrara, Amilcar, Social Determinants of Science Policy in Latin America In Cooper (ed.) op. cit.