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# NOTES ON TECHNICAL CHANGE INDUCED UNDER CONDICTIONS OF PROTECTION, DISTORTIONS AND RATIONING

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# Notes on technical change induced under conditions of protection, distortions and rationing

## INTRODUCTION

In industrialized countries, technical change pertains to cost reduction improvements in production processes and to the creation of new products. In SICs, (semi-industrialized countries), characterized by protection, market and information distortions, and rationing, technical change consists mostly of the adaptation of imported technologies to local conditions. The firms operating in these countries try to optimize an objective function, generally of profits or net worth, under various constraints. To some extent, possibilities of substitution exist between productive and R & D activities or between investment in new capital equipment and maintenance and modification activities to keep old machinery running and even expanding output. Constraints are generally the result of import restrictions, and the relevant case seems to be, not that of a high tariff, but an outright prohibition of imports of certain materials or equipment, as this will generally demand R & D to modify the received technology. The feasibility of doing so seems to depend strongly on the availability of the required skills.

In this paper we explore first, the characteristics of the distortions prevailing in a SIC, i.e., one which has successfully undertaken production of consumer goods, intermediates and some capital goods under tariff protection, a growing domestic market, and, initially at least, with limited exports abroad. Then we review the microeconomic characteristics, i.e. those of the firm and the entrepreneur or decision-maker. In a third section we analyze the types of technical change observed under such conditions as those described above. In a fourth section we attempt to contrast the economic conceptualization of technology and technical change with the phenomena observed in SICs. The paper ends with some observations about economic welfare and T.C. in SICs.

## THE MACROECONOMIC ENVIRONMENT

Under this heading we include the industry's market structure, the extent of protection from outside competition, as well as major distortions in the prices of productive factors--including those required for investment and for R & D. In turn, some of these conditions, like market structure, may affect the firm's objective function, when due to the availability of lowly paid technical skills, substitution of R & D for machinery becomes advantageous. [1/] Additionally, the flow of general and specific (industry) information, readily accessible to the firm, also constitutes an important component of the economic environment.

The distortions mentioned have a direct bearing on the amount of R & D activity undertaken in SIC's as well as on its composition. Some of the most obvious effects resulting from such distortions are summarized below:

Import Restrictions

Restrictions may consist of steep tariffs on imported goods, quotas or an outright prohibition of importation; they could cover machinery and/or raw materials and components. The substitution of imported by local raw materials generally requires the undertaking of laboratory and plant experimentation and may also lead to modifications in product quality requirements, changes in production processes, size tolerances, etc. In the case of machinery, alternatives include the acquisition of local equipment, generally of somewhat different quality, and/or the modification or renovation of existing equipment which demands local engineering, maintenance and repair efforts. Distorted rates of foreign exchange or licenses to import equipment may have a similar effect. Alternatively, foreign exchange regulations may be such as to favor the importation of equipment by granting it preferential rates of exchange. The importation of equipment may introduce new technologies and be further stimulated by the scarcity of local skills required for repair and modification work.

Distorted Cost of Factors

A subsidized rate of interest may act as an inducement to invest, while credit rationing may have the effect of inhibiting technical choice or the development of local innovation as observed by McKinnon (1973). In some respects, the effect will be similar to that resulting from a distorted rate of foreign exchange.

A high wage for labor will inhibit the use of labor intensive techniques and may induce the adoption of capital intensive ones. 2/ On the other hand, capital using techniques may introduce new technologies and have beneficial learning effects. Skilled labor, of the engineering and technical type, may be underpriced and this will have the effect of inducing excessive demand for adaptations and modifications, etc. Such activities may, in turn, have beneficial effects derived from the learning by doing resulting from undertaking them.

The environment may also include government quotas for the supply of raw materials, (limiting the level of output), erratic supply of energy, etc., as well as various pricing policies which may have a distorting effect upon the level of output and its composition, and also generate a demand for R & D work.

## THE FIRM AND THE ENTREPRENEUR

The main entrepreneurial role in SIC's having industrialized under protection is generally in the hands of the G, since it is able to determine which will be the most profitable industrial activities through the granting of subsidies, tax exemptions and other inducements for investment, as well as public sector procurement. Having accepted the G's protection, the local industrialist then merely reacts to market signals. His response in terms of investing and beginning to manufacture is based on a perception of high profits and reduced risk due to G assurances of protection from imports and thus reduced competition. The decision to manufacture will also be accompanied by that of undertaking complementary R & D activities required to carry out the production. This will be a result of the need to adequate foreign technology and specifications to the local environment, and we shall discuss it in greater detail later on in this paper.

In this context, a key feature of the enterprise's decision-making process is that the technical innovations it must carry out are, in good measure, dictated by the prior decision to develop certain industries made by the G who is the real Schumpeterian innovator in our case. However, a distinction must be made as to the type of enterprise we are considering. For our purpose we may wish to distinguish the following: i) small local firms, ii) large local enterprises, iii) local subsidiaries of a TNE and, iv) generally large G enterprises.

One important difference between large and small enterprises results from the fact that the small firm generally cannot have resort to the internal division of labor, so as to benefit from the services of technical departments, and many times is even limited in its ability to hire technical personnel, consultants, etc. It must be added that many such technical services are not perfectly divisible and that the market fails to supply good substitutes for the lack of the enterprise's own technical personnel. Thus to the gaps in the flow of technical information prevailing in the country and market (in which the firm operates) must be added the inhibiting factor resulting from the insufficient division of labor in the small firms which restricts their access to useful technical information. Where appropriate, this may be overcome by sector level programs for technical assistance and information dissemination.

The other type of enterprises, large local firms, subsidiaries of TNE and large G enterprises are, to some extent, in a different class since they all have easy access to technical personnel and, through that, a greater awareness about the information needs prevailing in their type of business. Of course, cases exist of particularly technically oriented small entrepreneurs who may fully compensate with their technological and entrepreneurial abilities for the above shortcomings. 3/

## THE NATURE OF TECHNICAL CHANGE IN SICs

In ICs, two main types of TC take place. By means of one, new products or processes are created largely to serve needs hitherto unknown (Polaroid, Xerox, laser, transistor). Through the other type, cost reduction improvements in existing processes are attained. In contrast, in SICs, TC consists mostly of the adaptation of imported technology to the local environment and factor supplies. This includes taking care of the distortions in prices and the constraints in supply availabilities introduced by G policies as outlined above. Typical R & D efforts would be determined by the need to use different raw materials, scale-- down to smaller plant size, diversify the product mix, use simpler, more universal, less automated, lower capacity machinery, stretch out the capacity of existing equipment and introduce improvements in its design, etc.

In those cases where T.C. is undertaken to permit changes in the quality of inputs entering the production function (P.F.) and making in this way local production possible, we must either consider T.C. as part of the manufacturing sequence, or a prerequisite investment to the start of production. Thus, from the viewpoint of their time sequence and relation to the production process, the following types of T.C. take place in SICs: i) adaptation of local inputs to the P.F. requirements, generally preceding production start up, ii) continuous gradual improvement of production processes through plant and process optimization and increases in the productivity of inputs, iii) T.C. in response to changes in demand, market conditions, supply constraints, etc., iv) R & D not directly related to the production processes, but which may have an effect upon it, as carried out in experimental laboratories and technological institutes endowed with a permanent budget and assigned the task of generating new ideas, developing and testing them.

Most of the T.C. found under conditions of import substitution industrialization with various distortions and constraints, falls into categories i to iii. If we were to look at the overall optimization including, as suggested by Nelson (1978), the joint consideration of decisions about production and innovation, it would perhaps be best approached as a problem of optimal control or dynamic programming, where we try to maximize the benefits derived from a process of industrialization cum technological development.

## ECONOMIC CONCEPTUALIZATION OF TECHNOLOGY AND TECHNICAL CHANGE

It is appropriate to ask what has economic theory to say about technology and technological development, and whether this theorizing is relevant for the situation of the SICs. If that were not the case, we should investigate the discrepancies and how to proceed with the modification or adaptation of the theory. This would not be at all possible if the evidence from several microeconomic case studies, particularly those of the IDB/ECLA Program, and others also of an empirical nature, were not available to provide us with the basis for further conceptualization and generalizations.

We should also inquire, to what extent is G intervention justified in this field and whether we would not be better off leaving things as they are, to be taken care by decentralized decision-making in the market place.

From the available evidence, we reach a few preliminary conclusions which become, in turn, assumptions for further work. The first is that G intervention is, of course, justified even in ICs. Second, the received theory on TC is insufficient and inadequate, even for ICs, and third, the reality of SICs is quite different and their characteristics should be explicitly incorporated in the theoretical models used.

The contributions made so far by economic theory to this topic may be considered along two main approaches: i) the comparative-statics analysis of decision-making by the firm in the neoclassical economic theory of production and distribution and, ii) an analysis of the reasons for market failure in the allocation of resources for research activities due to the public good nature of information as the resulting product. We briefly consider them in that order.

Conceptualization of technology by the economist

The kit of tools of the economist dealing with technology has consisted basically of three concepts: technique, technology and technical change. From the point of view of their applicability to the process of technological development of SICs, they are based on highly simplified models including few of the relevant factors and have proven to be: i) excessively static in nature, ii) dependent on irrelevant assumptions, and iii) reductionistic in character. Furthermore, utilization of these concepts in SICs, has resulted in the advocacy of policies, and the focusing of attention, on those conditions which apparently signified the major departures from the assumptions that would make the model work ideally.

## Technique

In the case of technique, (the point on the P.F. defining, generally in a two factor model, the optimal factor proportions), the emphasis has obviously been placed on the existence of distortions in the prices of the factors of production leading to the adoption of wrong factor proportions in SICs. These distortions are, by and large, caused by the Gs and they take shape in the form of fiscal and monetary policies and tariff protection, which have the effect of promoting excessive use of scarce factors (capital and foreign exchange) and lesser use of the abundant one (labor).

While there is, of course, some truth in this characterization, it is albeit an incomplete and misleading picture. As it clearly emerges from the case studies analized so far, the outright prohibition of access to certain inputs may be more important in determining factor proportions than is depicted by the metaphor of an apparent choice facing distorted, but feasible, prices. Furthermore, the price of skilled labor is critical for the use of scientific and technical personnel required in R & D which, in many cases, constitutes a complementary activity of production.

More important, even when achieved, the static allocation of resources according to real scarcities does not guarantee that the economy, or activity in question, is in an optimal path taking into account the dynamic changes in factor endowment resulting from the cummulative effect of the protection of industry cum technological development. That is to say, choices looking wrong in static terms may turn out to be the correct ones when due account is made of the totality of the relevant effects, costs and benefits, as well as of their future expected changes. In fact, strict adherence to short run factor endowment may be detrimental to future growth if the incorporation of new advanced equipment or technology leads to further technical change, cummulative learning and growth.

## Technology

As far as technology, (the state of the art technical information relevant to production), the approach of economic theory has been to assume that this information is exogenous to the economic system and accessible, without delay and for free, to everybody. In this way, as Stigler (1976) has noted, the existence of a problem of technological choice was assumed away and replaced, as noted above, by that of choice of technique.

In development economics, emphasis has been placed on the cost of the acquisition of the technology to importing countries, given the existence of restrictions and undue business practices--documented by Vaitsos (1971), and others--attributable in good part to the differences in information available to the buyer and the seller.

Underlying this characterization of the transfer of technology are implicit assumptions about the existence of an adequate absorptive capacity and free access (not subject to major difficulties), as well as transfer practically in-toto, without major adaptation, given the incapacity of the importing countries to undertake technological change activities.

Technical change

As far as technical change, application of this concept has been largely restricted to ICs, and the prevailing theorizing oriented towards a type of technical change which is induced by changes in relative prices. This was first proposed by Hicks, (1932) and although refuted by Salter (1960), and others, by showing that in the neoclassical theory of production the firm minimizes total costs and not the cost of any given input, it still constitutes the prevailing neoclassical metaphor. (Binswanger and Ruttan, 1978).

While this type of technical change may in some instances be of interest also to SICs, as shown by the case studies, it does not exhaust the types of TC found in the conditions of protection, distortion and various input constraints or bottlenecks prevailing in these countries. In fact, the main lesson from these studies, as far as the nature of TC, seems to be that it is mostly conditioned by market and production demands. I am not referring merely to the existence of inducements to "look for innovations" in certan directions rather than in others (Nelson and Winter, 1977), but more to the existence of constraints and bottlenecks which must be removed to accomplish production. It is closer to what Rosenberg (1976) calls "compulsive sequences", but they operate not so much by generating demand for inventions or innovations, than as R & D efforts necessary to substitute inputs and to accomodate to different market needs, scale, and other availabilities. In his study of Taiwanese enterprise, Fei (1977) also points to the strong pull of market demands as the main determinant of TC efforts rather than productivity improvements to reduce costs (generally less important under protection), induced by changes in the relative price of inputs.

The one conclusion pervaiding all this is that the adaptation type of T.C. is complementary to production; that is, in the "pure" adaptation cases, once the decision to produce under certain constraints is made, there is really no latitude to substitute T.C. for physical inputs, as in the continuous productivity improvement case. There is then no choice but to use T.C. to accomplish certain production needs. An explicit allocation of skilled (technical) labor to accomplish such T.C. is required being consequently, clearly endogenous to the economic system.

The result of such T.C. is also quite certain. While it might be more or less costly according to the length of the process, it is really surrounded with little or no uncertainty. It may be best conceived as a preliminary investment need.

In summary, the three types of T.C. observed are: prior to, accompanying the production process, and independent of it, respectively. The first is complementary with production and little risk is involved. The second is a partial substitute, for example, to the expansion of production by increasing inputs, and some degree of uncertainty as to the expected results may be ascribed to it. The last type is uncertain and may be unrelated to the P.F., but in the most general of senses.

## Market failure and a role for the government

The reasons why the market fails to perform properly in allocating resources for T.C. are several and do not exclusively pertain to SICs being, in principle, equally prevalent in advanced economies. They are due to economic characteristics of the creation and use of technical information.

There are three principal economic characteristics of the creation of scientific-technical information which determine market failure: (Nelson 1959, Arrow 1962): i) the existence of risk or uncertainty; ii) the presence of important externalities giving rise to problems of appropriability of the results, and iii) the need for indivisible investments.

While these aspects of the economics of the creation of scientific-technical information are not new, and have already been pointed out by the students of R & D in ICs, they are also relevant to SICs.

Uncertainty

The results of basic and applied research are generally uncertain and, consequently, there is an element of risk in allocating resources to such activities. A priori, one may think that the risk would be greater the less applied the investigation, and that the risk would be increasing along a spectrum going from the more basic to the more applied kind of research, although that need not be always the case. In many of the investigations on applied research reported at this meeting, there is little or no uncertainty as to the actual achievement or the nature of the expected result. There may however exist an element of uncertainty as to the duration of the R & D effort and the total amount of resources that eventually need to be allocated to it.

It is thus conceivable, that even in such cases, there could be an element of risk aversion involved which would lead to underinvestment in the R & D uncertain activities.

Externalities and the appropriability problem

Problems of appropriability due to externalities arise in other fields, but their presence is thought to be particularly important in this one. The issue is clearly important in basic research since it is impossible, or very difficult, to appropriate the benefits of such research. In the case of applied research, it may sometimes also be very difficult to appropriate all the benefits thus leading to a reluctance on the part of private firms, to invest in R & D. It could be argued that as one moves from the more basic to the more applied research, it becomes easier to appropriate all the benefits, and that the measure of monopoly power obtained through the granting of patents will contribute to that effect, etc. However, the general conclusion of this type of theorizing is that given the presence of externalities, there is a presumption, though difficult to quantify as to the intensity of the effect, that there would be underinvestment if we leave to the market the allocation of resources in R & D.

Against the background provided by this theoretical insight, it is clear that most of the research done in the firms and industries investigated in the studies of the IDB-ECLA Program, under conditions of protection, distortion and rationing, is of a complementary nature to production and, as such, carried out to reap the extra benefits generally granted by protection. So, although external effects may exist, they are easily disregarded by private parties since the benefits to be obtained by the industrial production, made possible with the requisite amount of adaptive research, are enough to induce the necessary allocation of resources. This may of course be facilitated with low wages and ample availability of technical personnel, or be hindered by its scarcity.

Indivisibilities

This is also an aspect found in other fields besides S & T. Research requires of a series of investments which to some extent are characterized by indivisibilities. There are, or may be, minimum size constraints in the number of investigators per research team to reach a critical mass in some topics; there is need for laboratories, instruments and special equipment, etc., and this gives rise, on one hand, to economies of scale and on the other to possible barriers to entry given that substantial minimum financial resources may be required. This constitutes an already well known argument in ICs in support of G intervention, at least to supplement the investments done by private enterprises in R & D.

Less studied and known are the aspects related to the use of the technical information resulting from research already done. These economic characteristics, although similar to those observed in the utilization of other resources give a peculiar character to the utilization of information.

The received theory of the firm assumed the free access to information, that is, not subject to costs. Accordingly, it was accepted that in ICs, where markets operate more or less efficiently, firms in a given industry will all have access to the same technology and there would be no differences in the facility or capacity of accession to such information. This is now being questioned and an economy theory of the use of information is being developed.

The following economic aspects of the utilization of information might be mentioned [4/] (Arrow, 1971, 1974): i) Because of required prior investments, there exists irreversibilities that must be taken into account. The utilization of information requires investments in information receivers and channels. Such investments generally imply a committment to a certain pattern of information use and it is quite possible that future, more efficient alternatives, will not be considered because of the committment of resources previously made. [5/] ii) Once the investment on the acquisition of information is made, depreciation on it starts. On one hand, this is similar to what takes place with any investment; on the other, in this particular case, depreciation will be greater without use of the information than with it and this could lead to obsolescence. iii) There are decreasing returns to the human factor as a processor of information. The human being has limitations in the handling of information which are well established in the psychological study of perception. iv) There are increasing returns to the use of information. For example, once the investment is made, the technical information required for production can be used with any volume of production and, the greater the volume, the lower will the unit cost of its use be. In principle, it is possible to acquire monopoly power due to the increasing returns to the volume of information use. v) Propagation of information is not necessarily uniform. Information may travel easier through some channels than others, and certain information may be propagated during production itself, etc.

The implications of these economic characteristics of the use of information have not been yet fully developed (Stiglitz, 1978), in particular, with respect to their impact upon the performance of small industrial firms in SICs.

## SOME ECONOMIC WELFARE CONSIDERATIONS IN ADAPTATION-TYPE OF TECHNICAL CHANGE

Research to adapt processes to local conditions and inputs seems to be quite common in SICs, and from the various types of adaptation efforts described in the IDB/ECLA Program studies and in Teitel (1978), some useful insights have been gained about this type of T.C. As far as economic welfare is concerned, these may be summarized as follows: while there is much more T.C. going on than one would infer from the conventional wisdom, not all T.C. is beneficial to the national economy. We note below some of the main points.

i) With low priced skilled personnel, a higher than warranted (on social accounting basis) effort of adaptation takes place. "Excessive" use of such labor will lower its marginal productivity, or put another way, will lead to the undertaking of research activities with low national priority. However, proper costing would require taking full account of the learning and indirect effects of carrying out the research effort.

ii) "Excessive" adaptation of machinery, may preclude the introduction of advanced technologies embodied in capital equipment, while, on the other hand, it may have desirable skill-formation effects, i.e. the creation of repair, maintenance and engineering design skills.

iii) An upper limit should be put on the cost of technology adaptation efforts to permit the use of local raw materials. Such a limit could be based on the shadow price of the F.E. required to import the raw material originally specified plus the externalities in terms of learning effects, etc. resulting from the adaptation activities.

The above discussion had to do with adaptation to the local supply of inputs. Adaptation needs also arise from the market demand side and may include changes due to scaling down of plant size, climate, preferences of consumers, and various other particular local conditions.

Adaptation to market size, terrain conditions, climate, or even consumer preferences, seems to be compulsory once it is decided, for example, to locally manufacture cars. However, the particular adaptation needs may be difficult to predict, and their extent will of course be influenced by the nature of the import substitution undertaken as well as by the specific price and other distortions introduced.

Social cost-benefit evaluation of these adaptation efforts is complicated and many of the indirect and secondary effects present are hard to identify and assess. In the case of raw materials, as stated above, the total cost of the investment in R & D effort, in terms of its present value, should be less than the cost of the imported raw material affected by the shadow rate of F.E. cum the possible research benefits. Among the benefits of the R & D effort a factor to account for the learning by doing effects of the research could be included. Additional benefits, if any, of "compre nacional", should also be included in terms of supply development, etc., if not reflected through the price mechanism. The real cost of skilled labor should be used for the calculations.

These calculations are, of course, relevant for the G or nation which has the responsibility of controlling the importation. However, for the local entrepreneur, once committed by a previous decision to investment in establishing new production alternatives the R & D to use the local material becomes a necessary activity complementary of production. If the necessary skills were not available, among the plant's personnel, suppliers or independent laboratories, or were prohibitively costly, the entrepreneur would have no other choice but going back to the G to ask for import relief.

Firms will obviously go ahead with the R & D effort when it can be carried out under favorable conditions. The use of scientific, engineering and technical personnel will be facilitated by its availability and low cost resulting from previous G investment in public university and technical education. To analyze such a situation we must fix our assumptions. Without factor mobility, (assuming no migration) and the salaries of such personnel below equilibrium, more use than warranted of such labor will be made, and its marginal product will fall, in accordance with its lower wage, to keep optimality relationships with the returns of other factors. With perfect factor mobility, the skilled labor market would adjust automatically through migration. In the intermediate situation, we may assume that there is some mobility and that the value of such skills is at least partially determined by international flows. In the first and last cases, proper costing of skilled manpower should include utilization of border prices. For example, the salaries of Argentine physicists and engineers may be determined by the relevant Brazilian or U.S. "border" prices.

## Footnotes

1/ In a paper prepared for this Seminar Stiglitz (1978) goes even further and suggests that the allocation of resources to R & D must be considered simultaneously with that of productive factors due to the interactions between market structure and the optimal timing of innovations.

2/ While as noted by Salter and others, the entrepreneur will minimize costs of total inputs, and not those of any particular factor, and optimal equilibrium requires equalization of results per unit of expenditure for all inputs, such expenditures will generally be correlated with the salary, or unit cost of inputs, given the right elasticity of substitution.

3/ Such mavericks as Mr. De Alba, first domestic producer of furfural in Mexico (Pérez Aceves y Pérez y Peniche, 1978), and Mr. G, President of C, producer of automotive electric horns in Argentina, (Teitel 1978, c) come to mind.

4/ For a more detailed statement see Teitel, (1978b).

5/ In fact, one could look upon the ample (surplus?) cadres of Argentinian engineers and scientists, as such a previously made commitment of resources on receivers and carriers of technical information which by their mere presence (availability) have a biasing effect, through the use of their skills, on future local innovations and may deter from the addition of new (frontier) knowledge.

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