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THE CREATION OF TECHNOLOGY IN THE ARGENTINE MANUFACTURING SECTOR

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INDEX

List of Tables and Diagrams

I. INTRODUCTION

The aim of this monograph is to examine the phenomenon of technological creation in the context of the Argentine manufacturing sector. It is of interest to study the magnitude of overall expenditure on tasks direct at creating technological knowledge, its composition from one industry to another, the effect which this knowledge has on the growth performance of the industrial establishments which undertake such expenditure, the nature of the kind of knowledte produced, etc.

Although this is a subject written about with relative frequency, it is surprising to note both that the available micro-economic research is very limited and that the theoretical generalizations which attempt to provide an interpretative model for the technological position of the Argentine industrial sectors are very few.

Three papers, written some time ago, are the only sources of statistical information presently available. The first one is the study by the Undersecretariat for Science and Technology, carried out in 1969 and published in 1971, in which it is estimated that expenditure on scientific and technological research in the manufacturing sector is around 2,300 million pesos - approximately 6 million dollars of that year 1/.

A second paper is the research carried out in 1969-1970 by the present author which, after a study of the technological behavior of 200 relatively large industrial firms, concludes by stating that towards the end of the 1960's the firms sampled spent annually nearly 30 million dollars on research and development activities 2/.

Finally, there is the study carried out in 1972 by the National

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1/ Argentine Republic, Undersecretariat for Science and Technology, Potencial científico y técnico nacional, Vol. 1, National Presidency, Buenos Aires, 1971, p.102.

2/ J. Katz, Importación de tecnología, aprendizaje e industrialización dependiente, Fondo de Cultura Económica, México, D.F., 1976. (A preliminary mimeographed version was first published by the Instituto Di Tella, Buenos Aires, 1971).

Institute of Industrial Technology (INTI), in which it is shown that expenditure on research and development by the 220 firms in their sample that year reached 26 million dollars 3/.

If we bear in mind that the estimate made by the Undersecretariat for Science and Technology is not the result of a specific field study, but an indirect approximation prepared on the basis of secondary evidence 4/, and if at the same time it is noted that there is a significant similarity between the other two indicators 5/, we can begin our exploration of this field assuming that towards the beginning of the present decade Research and Development activities in the manufacturing sector were worth around 30 million dollars annually. This consideration opens up a series of questions, among them the following: What significance must be attributed to this flow of internal technological expenditure in the context of a country whose industrialisation strategy has been almost entirely based on the subsidised inflow of foreign capital and the unrestricted reception of foreign technology? What is the nature of the flow of technological knowledge generated by this expenditure? What differences between industries can be observed with respect to the size and nature of the inventive-innovative activity carried through on the basis of such domestic technological expenditure? What effect does this expenditure have on the growth performance of the firms which undertake it? What relation exists between the flow of internal technological expenditure and such macro-economic variables as the level of employment, income distribution, the pattern of comparative advantages with which the country operates, its degree of external dependence, etc?

3/ INTI: Aspectos económicos de la importación de tecnología en la Argentina, Buenos Aires, 1974, p.61.

4/ Undersecretariat for Science and Technology, op. cit., p.101.

5/ Differences obviously exist and should not be minimized, since they arise from different conceptual appraisals which it is useful to keep in mind. In our view, the conventional definitions of research and development activities fail to pick up important forms of technological knowledge created at plant level. For conventional definitions, the reader may refer to the Frascatti Manual (OECD, Paris, 1962); criticisms of such definitions can be seen in J. Katz, op. cit.

In the second part of this paper some of these topics are examined, using for this purpose some of the micro-economic empirical evidence resulting from the field study already mentioned.

In the final section, one possible interpretation of the observed facts is attempted. It places special emphasis on the concept of the relative technological gap which separates Argentina from the group of industrially more advanced countries. In this section, it is argued that the technological gap seems to be decreasing in specific areas of manufacturing production, due to two main factors: on the one hand, a relative slow down in the rate of expansion of the international technological frontier in comparison with the immediate postwar years and, on the other, the parallel increase in the level of the local technological capacity.

II. IMPORTATION OF TECHNOLOGY AND DOMESTIC RESEARCH AND DEVELOPMENT EXPENDITURE

Conventional reasoning starts from the assumption that there is an inverse relation between importing technology from abroad and generating technology locally. On the basis of such a premise it is then taken for granted that in a country which bases its industrialisation strategy on the reception of foreign capital and technology - this is a characteristic feature of the Argentine industrialisation strategy throughout the postwar period - there is little to be expected in terms of domestic generation technological knowledge.

Such reasoning oversimplifies modern industrial reality 6/. There is no doubt that the larger part of the technology presently employed by Argentine manufacturing has basically been conceived in more developed countries. But that is not sufficient reason to assume that the domestic utilisation of such technology can take place without the mediation of local technological efforts, which to a great extent occurs through the creation of technological knowledge which is complementary to the imported products and processes' designs.

Approximately two thirds of the 200 manufacturing firms examined in one of the three studies mentioned previously 7/ operated, at the time they were approached, on the basis of a license agreement signed with one or more foreign firms. The remaining 30% of the sample was found to be operating with domestically designed technology. In both such groups, however, significant activities aimed at producing local technological knowledge were detected. The reasons for this are set out below.

6/ The Japanese case is a good example in this respect, since it shows the great complementarity that exists between importing technology and generating it. See T. Uzawa, Transfer of Technology from Japan to Developing Countries, Unitar, New York, 1971. Also, H. Kitamura, "Foreign Aid and Investment. New Challenges to Japan", The Developing Economies, Vol. X, Nº 4, Tokyo, December, 1972, and Y. Tsurumi, "Japanese Multinational Firms", Journal of World Trade Law, no date.

7/ J. Katz, op. cit., Fondo de Cultura, México, 1976.

Whereas for the economist the technology of a particular industrial plant is thought to be a fixed factor, the engineer visualises a more flexible world in which the designs of products and productive processes gradually improve through time, adapt to the circumstances peculiar to their utilisation in the context of a specific plant, etc.

In other words, the industrial engineer is used to the idea that no two industrial plants in the world are alike, even when one of them tries to replicate the other 8/, something which is also often the case with respect to the design of a given product 9/.

There are a number of circumstances which may lead to the need to adapt, adjust, improve etc. a particular process or product. Among them are the following: better or more appropriate use of industrial waste 10/; better adaptation to the needs of

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8/ In the literature on industrial engineering there are abundant examples of technological designs intended to be carbon copies of existing designs, but which when put into operation showed the need for a substantial parallel engineering effort aimed at achieving a satisfactory performance of the copied design. See for example M. C. Clarck, E. M. Forest and L. R. Steckley: "Aches and Pains of Plant Start-up", Chemical Engineering Progress, Vol. 67, Nº 12. This case analyses what happened with a chemical plant belonging to the Vulcan Material Co., designed "as a copy of the Wichita plant, but three times the size". Despite the similarity of the technology two years were required to get the new plant into full operation. There are frequent cases of this sort in the industrial sphere.

9/ The Ford Taunus manufactured in Argentina, despite being a copy of the German design introduced on to the European market a year before, took 230,000 hours of Argentine engineering efforts - nearly a year and a half's work of a group of approximately 50 people - before it went on the market. Very few parts were not redesigned and adapted to local conditions, although the central design of the German Taunus was not altered.

10/ Many examples of this kind can be found in chemical production, where plants operating locally are barely 10% of the sizes used internationally. These plants, which began by burning economically valuable gases, later shifted towards using those locally with the consumer in the country in question or to the way in which the product is locally employed 11/; the removal of bottlenecks in the production line; technical assistance to suppliers of raw materials, parts, etc.; mechanization and/or streamlining of specific sections of the productive process; adaptation to new inputs, or the need to substitute imported raw materials for local near equivalents (never exactly the same), etc.

All these circumstances have been observed in the Argentine context, so that the day-to-day operation of the major manufacturing plants has required the parallel production of a certain flow of technological knowledge, a task usually undertaken by a department known in manufacturing firms as Process Engineering Department, Technical Assistance to Production Group, Trouble Shooting Department, etc. This professional team usually works separately from the production staff of the industrial plant and its main function is to produce an incremental flow of technological knowledge which can be used both by the Production Department, by the Quality Control Laboratory, etc. 12/. Now, it seems reasonable a priori to expect that different manufacturing sectors will differ in their propensity to undertake R & D expenditures to create technological knowledge of this sort. On the one hand, this may arise for purely technological reasons; for example, the age of the product design, or of the productive process employed, which seems to be significantly associated with the amount of non-routine engineering

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the aid of domestic technological designs. Duperial, Pasa, etc., are examples in this respect. See D. A. Orsi, Optimización de procesos sin perturbar la operación. Third National Petrochemical Congress, Salta, June, 1974 (the author is on the staff of Pasa Petroquímica).

11/ It is not only some firms in the automotive industry that are proverbial in this respect. In the non-electrical equipment sector, as well as in the electronic industry, there are many significant examples.

12/ It is common to find Maintenance personnel who, with the passage of time, have developed skills to act in Quality Control Departments and, somewhat later, in Technical Assistance to Production or Research and Development groups as such.

work demanded by a particular manufacturing plant 13/.

On the other hand, the differences between industries with regard to their propensity to undertake domestic R & D expenditure may also arise from circumstances more closely related to economic considerations, such as the differences in the relative profitability of such expenditure in various manufacturing sectors, or from factors inherent in the market structure of different industrial markets - basically the degree of oligopoly - or the relative share of local subsidiaries of multinational corporations. Table 1 presents the differences between industries which prevail in the Argentine manufacturing sector, as far as R & D expenditure is concerned. The information has been gathered by means of a study which covered firms accounting for almost 40% of the country's manufacturing product towards the end of the 1960's. In a methodological appendix to this paper, the conceptual definition of the different variables and the procedure followed in their calculation is discussed 14/.

The interindustry differences regarding R & D expenditure are seen to be quite substantial. Both the electronic goods industry and the chemical and pharmaceutical sectors appear to be relatively intensive sectors in this respect. By contrast, the food and beverage industry, textiles, vehicles and the metals sector show a much lower propensity, in relative terms, to carry out R & D expenditure locally 15/.

13/ The papers written by R. Vernon, S. Hirsch, G. Hufbauer, and others, in the context of the theory of the production cycle, are strongly based on the concept of historical "maturity" of products and productive processes. See, as an example, R. Vernon, "International Investment and International Trade in the Product Cycle", Quarterly Journal of Economics, May, 1966, Vol. 80.

14/ J. Katz, op. cit.

15/ It is interesting to emphasise that the three industries in which a relatively high level of R & D expenditure is observed are those in which the major part of the patenting activity of multinational corporations operating locally is concentrated. Approximately 60% of foreign patenting involves the chemical sector, including the pharmaceutical branch, while a further 20% of foreign patents belong to the electrical and electronic area. If we note that barely 15% of the flow of foreign patents applied for

Table 1. Argentina: Accumulated Expenditure on Research and Development and Growth Performance of Nine Manufacturing Industries, 1960-1968 (at 1960 pesos)

Industrial Areas	Accumulated Expenditure on R & D Activities (Thousands of 1960 pesos)	Increase Between 1960 & 1968: Level of Production (%)	Increase Between 1960 & 1968: Productivity Level (%)
Pharmaceutical Industry	106.7	123.9	104.3
Machinery and electrical equipment	112.0	200.0	150.4
Vehicles	40.1	106.7	67.2
Metals	44.6	225.0	122.6
Chemicals	106.4	197.6	120.2
Oil and Derivatives	85.0	65.0	42.0
Textiles	40.8	40.0	30.1
Food and Drink	33.6	107.0	50.7
Machinery and non-electrical equipment	63.6	114.3	76.0

Source: J. Katz, op. cit.

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in this country reach the stage of effective utilisation in production, and if at the same time we observe that foreign patenting is concentrated in those areas in which local technological efforts tend to be greater, the role of foreign patenting emerges fairly clearly as a mechanism for blocking domestic technological efforts. See in this connection J. Katz, Patentes, la Convención de París y los países de menor desarrollo relativo. CIE, Instituto Di Tella, Also J. Katz, "Patentes, tecnología y corporaciones multinacionales", Desarrollo Económico, June, 1972.

Quite apart from the intrinsic interest of this result - which questions the so frequently postulated absence of domestic technological efforts - it opens the way for the examination of a subject which may be of vital importance both from the academic point of view and with respect to the design of instruments of technological policy. This subject is, on the one hand, the relation between the flow of R & D expenditures and the growth performance of the industrial firms which undertake such expenditures and, on the other, the macro-economic significance of such expenditure with regard to employment, comparative advantages etc. These points will be examined below.

Micro-economic Aspects of the Domestic Technological Effort

Throughout recent years, and beginning with a much quoted article by K. Arrow written in 1962 16/, economists have started to give more attention to the matter of technological learning, and to its relation to productivity growth rates attained at plant level. The first empirical studies in this field still bear the original imprint of Arrow, Haavelmo 17/ and others, to the extent that they are based on the assumption that the increase in productivity arising from the accumulation of experience at plant level appears as a by-product of the firm's productive activity itself, without there being an explicit search or without resources being explicitly allocated to that purpose. In this respect the studies on learning curves in aeronautical production and other branches of the American manufacturing industry are well known 18/.

16/ K. Arrow: "The economic implications of learning by doing", Journal of Economic Studies, 1962.

17/ See K. Arrow, "Classificatory notes on the production and transmission of technological knowledge", American Economic Review, (Papers and Proceedings), 1970.

18/ Among others, the following articles are often quoted: W.Z. Hirsh, "Firm Progress Ratios", Econométrica, April 1963; K. Hartley, "The Learning Curve and its Applications to the Aircraft Industry", Journal of Industrial Economics, March 1965; H. Asher, Cost-Quantity Relationship in the Air-frame Industry, Rand Co. Monog. R-291, July 1956.

Relatively recently, however, the subject of technological learning has been approached from a different angle: learning is no longer a simple by-product of the production process, but is a vital part of the resource allocation strategy of the firm. It is now recognized that the generation of technological knowledge has a cost (wages and salaries of the Engineering staff, depreciation costs of experimental capital, prototypes, etc.) and a benefit (lower costs, improved products and processes, etc.), and that it is appropriate to ask which is the optimum technological strategy of knowledge creation for any given industrial plant 19/. In other words, it is now recognized that the firm learns not only "by doing", but also through an explicit expenditure on engineering activities.

The statistical material in Table 1 provides initial information for the examination of the topic under discussion. At the aggregate level of the sample it seems clear that both effects, that of "learning through experience" and that of "learning through engineering", are positively associated with the growth rate of overall factor productivity.

This result also seems to be valid at the industrial sector level, and in this case with cross-firm data pertaining to individual establishments.

In both cases - at the aggregate level and in individual branches of industry - a simple regression model of the following type has been estimated by least squares:

$$\lambda = \text{constant} + \alpha \frac{\Delta Q}{Q} + \beta \sum_{1960}^{1968} \frac{\text{Expenditure R\&D}}{L}$$

Where:

λ is the growth rate of overall productivity throughout the

19/ Along these lines, the work of W. Nordhaus, Invention Growth and Welfare, MIT University Press, Cambridge, 1969, is important. Also J. Stiglitz and A. B. Atkinson, "A New View of Technical Change", Economic Journal, 1969. This author's 1971 work falls within this approach to the problem. See: J. Katz, op. cit.

period 1960-1968.

$\triangle Q/Q$ is the growth rate of the physical volume of production.

Σ Expenditure R&D/L is the annual expenditure on Research and Development activities per person employed (L) in the plant, deflated at 1960 prices and accumulated throughout the whole period 1960-1968.

α, β are the rates of change of λ (the rate of change in overall factor productivity which derives from a marginal change in the growth rate of the firm or in its accumulated expenditure on R&D activities.

Table 2 gives the results obtained, indicating also: a) the number of observations in each of the industrial sectors, b) in brackets the standard error of each one of the estimates, and finally, c) the multiple correlation coefficient for each equation.

The results of Table 2 indicate that the industrial sectors - or the individual firms in each one of the industries - which grew most rapidly and undertook larger local expenditure on Research and Development activities concomitantly achieved higher rates of increase in overall factor productivity than the average of the respective samples. Inversely, a lower relative rate of growth in output and smaller expenditure on research and development have tended to be associated with lower relative growth rates in overall factor productivity.

Rather more specifically, it is worth observing the following: Firstly, the so-called Verdoorn coefficient both at the aggregate level and in specific sectors of industry takes on values which are consistent with estimates of this parameter previously quoted in the literature both for other countries 20/ and for Argentina 21/. Verdoorn himself writes: "A stable, long-term relation

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20/ See, for example, W. Beckerman, The British Economy in 1975, Cambridge University Press, Cambridge, 1967. Also, N. Kaldor, The causes of the slow rate of growth of the U.K. Cambridge University Press, Cambridge, 1966.

21/ A. Canitrot and P. Seebess, "Algunas caracteristicas del comportamiento del empleo en la Argentina, 1950-1970", Desarrollo Económico, April, 1974; J. Katz, Production functions, foreign investment and growth. North Holland Publishing Co., Amsterdam, 1969.

Table 2. Argentina: Effects of Growth in Physical Volume of Production and of R&D Expenditure upon the Growth Rate of Overall Factor Productivity, 1960-1968

Industrial Sector	Number of Observations	Constant	"Production Effect"	"R&D Expenditure Effect"	R^2
Pharmaceutical Industry	17	-5 638 (27 520	0.316 (0.143)	0.245 (0.121)	0.75
Metals	23	-31 166 (19.067)	0.319 (0.049)	0.218 (0.112)	0.90
Food and Beverages	25	-24 016 (10 628)	0.315 (0.046)	0.313 (0.106)	0.89
Chemicals	22	-66 271 (18.671)	0.469 (0.122)	0.250 (0.075)	0.87
Machinery and Non-electrical Equipment	15	-40 306 (59 658)	0.260 (0.137)	0.558 (0.301)	0.62
Machinery and Electrical Equipment	18	-34 584 (33 478)	0.501 (0.043)	0.207 (0.150)	0.92
Vehicles and Transport Materials	14	-43 689 (27 836)	0.310 (0.207)	0.300 (0.191)	0.71
Overall Sample		-10 54 (17 63)	0.567 (0.092)	0.188 (0.082)	0.90

apparently exists between productivity and the level of production. This is confirmed by the fact that the regression coefficient between industries and countries within the range 0.45 - 0.60" 22/.

22/ J. Verdoorn, "Fattori que regolano lo sviluppo della produtività del lavoro", *L'industria*, Milan, 1949.

Secondly, the accumulated flow of local expenditure on Research and Development activities is statistically significant as an explanatory variable of the observed growth in overall factor productivity, both at the aggregate sample level and in specific sectors of industry. Despite the fact that the degree of statistical significance of this coefficient varies between productive sectors, it is important to observe that in practically all cases this variable plays an important role as an explanatory factor of the growth performance of the firms hereby studied. It is important to note that the marginal efficiency of the accumulated expenditure on plant and product engineering activities tends to fluctuate in the range of 20% - 30%, which in some ways is reassuring, given what is known today about the rate of return of this kind of manufacturing investment 23/.

We close here the examination of the relation between the growth rate of output, the accumulated domestic expenditure on Research and Development activities, and the observed productivity performance of the manufacturing sector.

The empirical evidence presented thus far suggests that both experience accumulated via the gradual increase in the physical volume of production, and the experience obtained through the accumulated flow of R&D expenditure, are central determining factors of the growth of industrial productivity.

Some macro-economic consequences of the micro-economic set of circumstances will now be examined.

23/ See, for example; Z. Griliches: Research Expenditure and Growth Accounting, paper given in 1971 at the conference of the International Economic Association, St. Anton, Austria, Science and Technology in Economic Growth, MacMillan, London, 1973. Also N. Terleckij, Sources of Productivity Growth in the U.S. Manufacturing Sector. Unpublished doctoral thesis, University of Columbia, 1959.

III. FURTHER OBSERVATIONS ON THE TOPIC OF DOMESTIC TECHNOLOGICAL LEARNING

The main purpose of the foregoing pages has been to provide the reader with an introductory glance at a micro-economic setting in which the creation of technological knowledge forms part of the day-to-day activities of a manufacturing plant.

This knowledge creation, whether it takes place inadvertently (as in the Arrowian models), or whether it arises as a result of an explicit technological strategy, must be borne in mind if the aim is to set up a theory of technological change useful for understanding situations such as those which currently prevail in Argentina, Brazil, Mexico, etc.

This is not, however, sufficient if what is desired is to locate the role of technological change within a wider interpretative framework which throws light on the general problems of economic growth. In this respect, a broader range of questions become important, apart from those aspects of a micro-economic nature previously examined. Among others, the following stand out: Are there reasons for believing that technological learning, clearly present in Argentina, Brazil, Mexico, etc., will contribute in the future to reduce the degree of technological dependence of these countries? How are the benefits arising from technological learning distributed? What is the relation between technological learning and the pattern of dynamic comparative advantages in each one of these countries?

Some of these topics are examined below, not with the intention of providing a rigorous final interpretation, but with the aim of opening up the exploration of aspects which so far have scarcely been studied within the theory of economic development.

Local Learning, New "Vintages" and Technological Dependence

It has previously been stated that the majority of the new designs for products and manufacturing processes currently employed in Argentina, Mexico and other countries are a more or less close copy of similar designs previously employed in developed countries and introduced onto the local manufacturing scene, whether through a license or as part of an overall package of direct investment carried out by a multinational corporation. It has also been argued that the opening of a new industrial area, or the incorporation of a new engineering design for a product or a manufacturing process, frequently triggers off local forms of technological learning.

We must now ask how far the domestic learning process could allow a reduction in the observed degree of technological dependende of the Latim American countries. For the purpose of examining this topic, Diagram 1 presents a simple geometric exercise 24/.

Suppose that a certain product - a television set, for example - can be characterised by three quality dimensions which are called P_1, P_2 and P_3 respectively. Taken together these dimensions form a vector $v_1 = f\ (P_1, P_2, P_3)$ which represents the technological level incorporated into a particular design. ("Vintage or "technological generation" are also common ways of referring to a particular v).

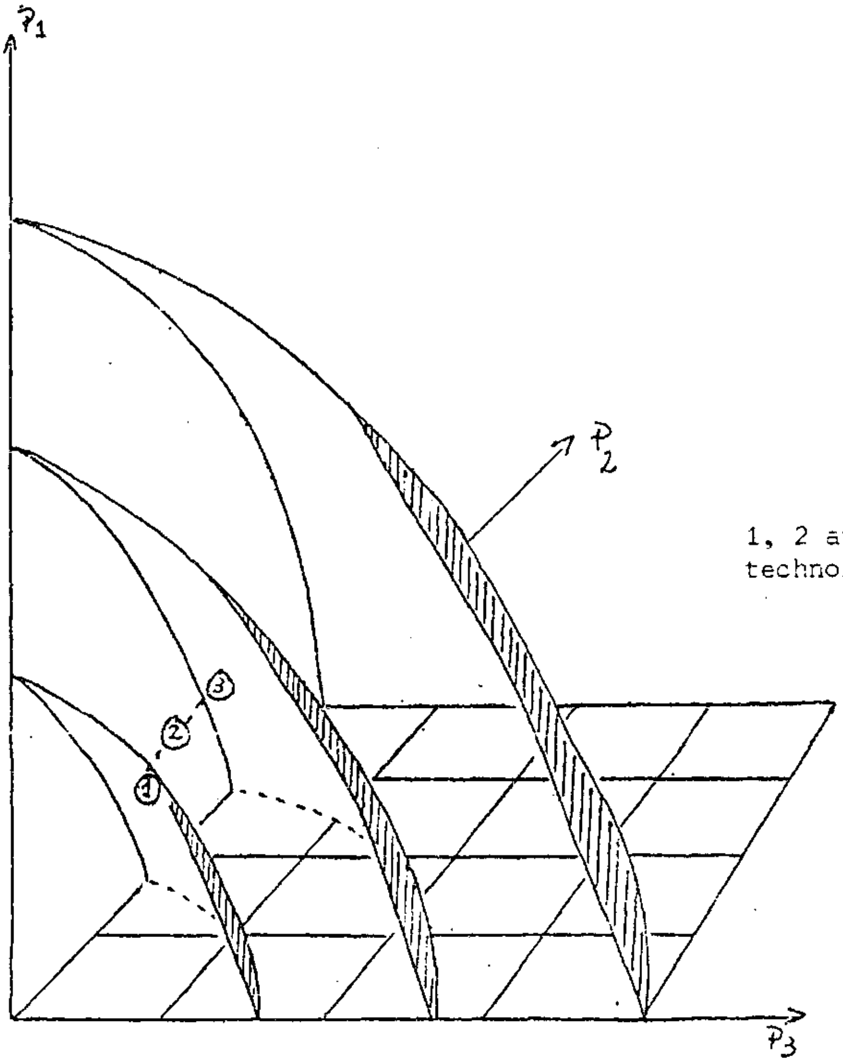
Suppose that at moment t_1 a local producer acquires, through a license, all the technical specifications needed to produce a television set whose design belongs to the "generation" t_1 25/. This design is characterised by the vector $v1$; $v_1 = f \quad P_1\ (t_1),\ P_2\ (t_1),\ P_3\ (t_1)$.

24/ An empirical exercise with a similar case can be seen in R. Shishko's work: <u>Technological Change Through Product Improvement in Aircraft Turbine Engine</u>, Rand Corporation, May 1973. This diagram comes from that study, but has been adapted to the case of a local firm which limits its technological strategy to the "production" of "adaptive" technology, while other firms at the international level introduce important modifications in the state of the art, or the world-wide technological frontier.

25/ The reader will probably notice that it is being assumed that at moment t_1, the local producer acquires, through a licence, a certain technological design which represents the 'best practice' technology available at that moment. It is obvious that the assumption is extremely unrealistic and it is only employed for the purpose of simplifying the analysis. Further on, empirical evidence is presented to support the belief that the Argentine manufacturing industry operates with a lag which may fluctuate between five and twenty years, depending on the industrial sector examined. This is the same as stating that, while the best international practice

At moment t_2 the international technological frontier has moved to v_2, that is, to a new technological vector 26/ which

Diagram 1. Argentina: Adaptive Technological Change and Shift of the International Frontier



1, 2 and 3 are points of the technological adaptation path.

is represented by v_3, the local producer acquires, through a licence, the technological design represented by v_1. This topic will be taken up again later.

26/ This representation is frequent in the electronic market where it is common to talk about designs of second, third, etc. 'generation'. Valves, transistors, micro-circuits, etc, are representatives of successive technological 'generations,' or vintages.

is characterised as $v_2 = g\ P_1\ (t_2),\ P_2\ (t_2),\ P_3\ (t_2)$. In v_2 the local producer - who has confined himself merely to technological activities of an 'adaptive' nature - is already showing a certain lag, which obviously increases when at t_3 the international technological frontier again moves out, at the same time as decreasing returns begin to operate in relation to the flow of domestic adaptive technological efforts.

Diagram 1 suggests that the relative position of the firm which acquires the manufacturing license will depend both on its rate of technological learning and on the rate of change of the international technological frontier. In those cases in which a rapid domestic learning rate coincides with a low rate of expansion on the international knowledge frontier, it is feasible to imagine that the local producer, after a few years, could find himself in a position to 'catch up' with the level of efficiency and with the best technological practice which exists, on average, in more developed countries 27/ 28/.

The reasoning so far can be complemented by several further considerations. First, it is important to note that, judging by what is known today about adaptive technological efforts, they are characteristically affected by "saturation effects, resulting from the various technico-economic restrictions imposed by the original technological design 29/. This means that very likely the expenditure on adaptive technological activity is subject to diminishing

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27/ The case is, however, not unrealistic. Various technologies are frequently quoted as examples of specific areas of the international technological frontier which have shown little progress in recent decades. The analysis of a concrete example in the pharmaceutical area can be seen in B. Cohen, J. Katz and W. Beck, Innovation and Foreign Investment Behaviour of the US Pharmaceutical Industry, National Bureau Economic Research Paper Nº 101, New York, 1975.

28/ A journalistic reference to the topic of the slowdown in the rate of innovation at the world level can be seen in "The Breakdown of US innovation", Business Week, February, 1976.

29/ S. Hollander contributes evidence with respect to the "saturation effect" of the 'adaptive' R & D efforts in The Sources of Efficiency Growth. The Case of Dupont, MIT University Press, Cambridge, 1966.

returns.

A consequence of this technical fact is that the marginal productivity of the 'adaptive' technological efforts seems to be significantly greater during the early productive history of a specific plant or industry than after several productive periods have passed.

Second, both from the theoretical point of view - because of its relevance in connection with the theory of the multinational corporation, or in relation to the theory of innovation - and from the point of view of economic policy, it is worth observing that a significant proportion of the overall effort to generate technology of an 'adaptive' nature is carried out in engineering departments of local subsidiaries of multinational groups. In this respect, it is important to see that the engineering departments of firms such as Ducilo (Du Pont), Ford, Fiat, IBM, Celulosa Argentina, Duperial, etc. are of sizeable magnitude and produce a very significant flow of new adaptive technology.

This fact has several consequences, some of which will be examined later on in this paper, especially as far as the pattern of comparative advantages of the Argentine economy is concerned, or with respect to the distribution (domestic and international) of the benefits of local technological learning. From the point of view of the specific topic of this section - i.e. the relation between technological learning and technological dependence - it may be worth noting that there is no logically necessary condition why the technological learning of a given subsidiary of a multinational group should favor its greater technological independence. Except for a limited number of exceptions in which it could be observed that the part played by the local subsidiary has increased within the multinational group as a whole, thanks to successes of its technical department taken advantage of at the level of the group as a whole, the evidence gathered throughout the field studies carried out does not seem to indicate that succeeding generations of products and plant designs used locally have ceased to be decisions and design of the head office, even when the local subsidiary has accumulated a significant amount of experience in the domestic market. 30/.

30/ It is interesting to observe that some multinational corporations have successfully used the technological and engineering capacity accumulated by the technical teams of their local subsid-

Thirdly, the reasoning so far allows us to begin to examine a subject which has received little attention in the literature on technological change; that is, the technological lag which is observed both between industries in the same country, and between countries within given branches of industry. The empirical evidence available suggests that, although it exists, the technological lag between countries of the developed world usually does not exceed two or three years.

Moreover, the whole 'product cycle' theory of international trade is based precisely on this idea, since it is merely a theory of technological learning applied to developed nations with the aim of explaining the international trade flows which exist between them 31/.

The Latin American literature is extremely poor in empirical studies concerning the technological lag with which different industrial sectors within a particular country operate, or with which the different countries of the region actually work.

In our view this must be considered an extremely important subject for the following reasons: it is a gross oversimplification to speak of the international market of a particular product, or group of products. Strictly speaking, there is a range of markets (more or less sophisticated in their levels of technical information and requirements) which demand and products which are

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iaries, when they decided to expand their operations to other Latin American countries whose technico-economic environments are more similar to those of Argentina than to their country of origin. As examples we can mention the cases of Fiat Argentina with respect to Colombia and Venezuela, Massey Ferguson with respecte to Peru, Ducilo (Du Pont) in Mexico, etc.

31/ See, for example, S. Hirsch, "The US electronics industry in international trade", National Institute Economics Review, November 1965. Also two papers by C. Freeman, "Chemical process plants, innovation and the world market", National Institute Economics Review, August 1968, and "Research and development in electronic capital goods", National Institute Economics Review, November 1965; J. E. Tilton, International diffusion of technology. The case of Semiconductors, Brookings Institution, 1971.

not strictly homogeneous or identical either, but rather allow (and demand) adjustments, adaptations and modifications. As an example, it may be pointed out that the automotive market in Chile or in the Andean Pact countries, does not have exactly the same requirements as European or North American ones. At the same time, the Argentina cars exported to those markets are not similar products to their peers of European or North American design (see Note 8). This means that the technological lag with which a particular industrial sector operates in one of the Latin American countries, taken together with the accumulated amount of internal technological efforts carried out by firms in the industry in question, is important if we are to explain the pattern of international trade which prevails today in the region as a whole. This subject will be taken up again in the following section, when we examine the relation between 'adaptive' technological change and the pattern of dynamic comparative advantages with which a particular society operates.

Technological Learning and Dynamic Comparative Advantages

Even though this subject has been examined recently at a high level of theoretical abstraction by authors like P.K. Bardhan, M. Teubal and others 32/ and despite the value which must be conceded to such analytical efforts, it may still be premature to infer behavioral patterns from the received theory.

The reasons for this are various. In the first place, the formal specifications of the learning phenomenon are, for the moment, of the "learning by doing" sort. This eliminates the possibility of examining the relative influence of alternative explicit technological strategies on the pattern of dynamic compara-

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32/ P. K. Barhan, Economic Growth, Development and Foreign Trade, Wiley and Sons, New York, 1970. Chapter VII is particularly relevant, "Optimum trade policy in a model of learning by doing". M. Teubal, "Comparative advantage and technological change: the learning by doing case," Journal of International Economics, 3, 1973, pp. 161-178. Also, by the same author: "Towards a neotechnology theory, comparative costs", Mimeograph, July 1973.

tive advantages 33/ 34/.

Second; the basic assumption is always that it is the "industries" which learn, rather than specific firms or corporations. This introduces at least two important simplifications. On the one hand, it supposes a perfect diffusion of knowledge among the various members of the industry. This implies avoiding the knowledge appropiability problem at the expense of a certain lack of realism. On the other hand, by placing the analysis at the level of the industry instead of at the level of the corporation, the controversial subject of learning and change in the dynamic comparative advantages of the multinational firms is altogether ignored. This subject, however, is obviously important both for academic as well as for political circles in Latin America.

Third; the research concentrates on matters such as the optimum rate of subsidy, its variation over time, etc., in the framework of a competitive model of international trade. Possible alternative market structures and various aspects of an institutional nature (and therefore political in character) which undoubtedly must affect the observed pattern of dynamic comparative advantages, remain examined.

The foregoing must not be interpreted as an indication that the above theory can be considered unnecessary. It is obvious, however, that there is still a long way to go in this field.

What we have observed is not industries which learn, but rather large corporations which do so, many of them subsidiaries of multinational groups, while others - even in the same branches of industry - do not learn or do so at a much slower pace. Put in

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33/ Presumably the inclusion of explicit expenditure on technological learning would reduce the number of periods required by learning and therefore the optimum subsidy calculated by the international trade models.

34/ A brief discussion of this subject in the specific framework of the local pharmaceutical industry can be found in J. Katz, Oligopolio, firmas nacionales y empresas multinacionales, Siglo XXI, Buenos Aires, 1975.

another way, Volkswagen of Brasil, Fiat of Argentina 35/, or Resistol of Mexico, are the ones that 'learn' and not the overall sector in which they operate. These firms, or others similar to them, are those which, more and more frequently, export from their local subsidiaries.

This naturally opens up several questions: What prices do these exports command? From what is known, undercharging on exports and subsequent overcharging in a tax-haven country prior to forwarding to the final market of destination is not an uncommon practice 36/. It implies, of course a hidden transfer of resources. Up to now there are no studies throwing light on this problem and evaluating its magnitude on a macro-economic scale. Is there a new pattern of comparative advantages (as distinct from a simple accounting exercise played by MNCs)? If this is the case, what is the real degree of control which each country exercises over the sources of the above-mentioned comparative advantages? Finally, to what extent is the concept of dynamic comparative advantages itself useful for understanding the new kind of situations to which exporting by multinational companies leads? It is obvious that access to markets in the developed world must be different when comparing a national with a multinational company, and that the degree of accessibility will be a function not only of those variables which are traditionally associated with the resource endowment of a particular country, but also of variables of a political and institutional nature which the model of

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35/ It is common to hear that Volkswagen Brasil has already reached an operative efficiency level very similar to that of its parent company. Further, Chart 19 of the Kefauver report shows the high level of efficiency of the Argentine antibiotic industry, a fact confirmed throughout interviews held by this author with executives of the industry. See Administered Prices. Drugs. Report of the Committee on the Judiciary, United States Senate, 27th June, 1961, United States Government Printing Office, Washington, 1961.

36/ Note that this procedure does not mean that it is the consumers of the country of final destination - the United States in the case of antibiotics - who receive the benefits of the learning of any one of the subsidiaries. These benefits tend to be absorbed by the multinational group, and not by the final user.

comparative advantages has great difficulty in incorporating 37/ 38/.

In short, it can be considered that the effect of technological learning on the pattern of dynamic comparative advantages has not received in the current literature the degree of attention consonant with its importance.

A correct approach to the subject implies, however, carrying the examination into the micro-economic level, since it is at the level of particular companies that the learning phenomenon assumes importance. It also implies encountering statistical difficulties in the examination of the flow of transactions within multinational groups, where real dynamic comparative advantages are mixed with accounting exercises of transfer price manipulation. In the author's opinion, without this kind of analysis the normative position of much of current writing on international trade lacks significance and content 39/.

37/ In a recent paper, S. Hymer and S. Resnik write: "In technical terms, the standard model of international trade must be considered as incorrectly specified, since it only concerns itself with market relations and omits very important equations connected with social and political aspects", "International trade and uneven development", Trade Balance of Payments and Growth, ed., J.Bhagwati, North Holland Publishing Co., Amsterdam, 1971.

38/ Under the general heading of "export platform" this kind of situation and the role they play within the overall strategy of multinational corporations have begum to be studied recently. Given that it is the multinational company itself which operates on both sides of the market, the existence of a market cannot really be assumed. It is to be hoped that future research willtthrow light on this controversial area. See in this connection R. Barnet and R. Muller, Earth Managers, the New World of the Global Corporation, Simon and Shuster, New York, 1974.

39/ It is surprising to observe the lack of importance which I. Little, T. Scitovsky and M. Scott assign to "technological learning" in what is supposed to be one of the greatest efforts of the 1960's in the study of international trade. Their omission is considered crucial by the present author, who believes that this seriously limits the value of the results of their research (see these authors, Industry and Trade in Some Developing Countries, Oxford University Press, London, 1970.

Appropiability of the Results of Technological Learning

Technological learning has direct economic effects - that is, those that affect the company which learns and its consumers - and indirect economic effects, derived from the fact that technological knowledge is not a perfectly appropriable commodity.

The major part of the economic effects belong to the first of the two categories. The relevant question in this field is, to what extent does the industrial pricing mechanism possess sufficient flexibility to reflect the differential learning rates between companies of a given industrial sector? This is a subject on which the sparse available research does not yet allow broad generalisations. As far as this research goes, it seems to suggest that, although not entirely inflexible, the industrial price mechanism is relatively imperfect and only reflects a relatively small fraction of the observed productivity increases 40/.

With regard to the indirect effects of technological learning, it must be observed that they arise from the quasi-public nature of knowledge as a tradeable commodity.

In the context of situations such as those prevailing in Argentina, Mexico, etc., the problems of appropiability arise more in relation to overseas licensing firms, or to the respective head offices, than with respect to potentially competitive firms in the local market. The reasons for this are examined below.

It is common to divide Research and Development expenditure between expenditure on Basic and Applied Research and on Development activities. Independently of the usefulness such a classification may have in other fields, it must be observed that there are important differences between those three forms of creative activity in the degree to which their benefits can be appropriated by their producer.

While Basic Research is by nature a creative activity with a very low degree of private appropriability, the latter increases

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40/ See J. Katz, Production Functions, Foreign Investment and Growth, North Holland Publishing Co., Amsterdam, 1969 and La industria farmacéutica argentina, Estructura y Comportamiento, Centro de Investigaciones Económicas, Instituto Di Tella, Buenos Aires, 1973.

when we move into the field of Applied Research, and it grows even more when we consider the output of development, adaptation and technological improvement.

It has previously been maintained that a large part of the creative activity found in the Argentine manufacturing sector belongs to this last group of technical activities. This leads one to think that local firms do not have much difficulty in keeping as a plant secret a large part of the new adaptive knowledge which they generate, thus blocking its internal spread. For instituional reasons - as also for contractual ones - this blocking does not occur (or is only very imperfect) in two other cases: a) the case of the local subsidiaries of multinational companies, and b) the case of the international technology purchasing contracts with explicit clauses granting usage rights to the licensing company. Important differences between the two cases mak it advisable to treat them separately.

Learning within the Framework of the Multinational Corporation

The presence of a certain flow of intra-group technological information is, in the author's opinion, a distinctive trait central to the multinational corporation which has gone relatively unnoticed up to now.

This flow of technological information - made up not only of "blue-prints", technical memoranda, operating manuals, etc., but also by a significant amount of orally transmitted experience (by frequent trips by technical personnel between subsidiaries) - is built up not only from the contributions of the head office, but also from the new knowledge arising from the learning of the various subsidiaries.

What is more, given that head office and subsidiaries can perfectly well be operating with technology from very different vintages 41/, the flow of adaptive knowledge from the various

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41/ Throughout the field study mentioned at the beginning of this paper (see Footnote 2), it has been observed fairly frequently thatthe differences in the operating scale utilised by the parent company vis-à-vis its Argentine subsidiary, and the differences in technological vintage, make the knowledge accumulated by the former subsidiaries is an important contribution within the overall group.

This situation naturally affects the rules of appropriability of the results of learning, it now being the multinational group as a whole which, through the spread of technological information, manages to internalize the learning benefits of each one of the subsidiaries 42/.

As in other aspects, it is the group as a whloe which maximises the benefits derived from learning, since there is no reason to suppose that the distribution of the benefits between the members of the group bears any relation to the contribution made by each member to the overall pool of technical knowledge. In this field, there is a great difference between the case of the multinational corporation and that of the licensing contracts with clauses concerning the transfer of information in favor of the licensing firm.

Learning and Licensing Contracts with Free Transfer Clauses

Between the different contractual clauses which make up a license agreement, it is not uncommon to find an explicit mention of the fact that the receiving firm undertakes to transfer completely free of charge all new knowledge which may arise from the adaptation or improvement of the process or the product under

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only partially useful and force the latter to learn for itself by a true local engineering effort.

42/ Note that, from the point of view of the learning function of any one of the subsidiaries, the gradual learning of the other members of the group acts as a positive factor because of the low level of private appropriability. This is, of course, not so in the case of the license contracts, in which the licensing firm's gradual increase in experience has no reason to act as an outside source for the licensee. It is obvious that only the arguments which make up the learning function in each case are referred to and not the final appropriation of benefits from it; this point is made clear in the following paragraph of the text.

license 43/.

It is important to note that the inverse mechanism - that is, the transfer of improvements by the licensing company - is not such a commonly employed legal form as the previous one.

In this case we are faced with a legal mechanism which reduces (or eliminates) the private appropriability of the learning benefits. When the above-mentioned mechanism operates in the context of a non-exclusive license, the original owner may derive monetary benefits from the technological efforts carried out by the licensed firm, if it opts to grant a new license to a third party, in that case transferring the rights to use the basic technology along with the improvements introduced by the first licensor. Situations of this kind are far from uncommon in the industrial world of today.

It is appropriate to mention a final point before leaving the subject of the appropriation of the benefits of technological learning. In those cases in which the licensed firm learns by adapting and improving over time the technological knowledge which was the subject of the original license, it seems reasonable to argue that the marginal usefulness of the original license will decrease over time as the current technological level of the firm in question moves away from its initial technological level. That being the case, it also seems reasonable to argue that the equilibrium value of the original technology should also be a decreasing function of the rate of domestic learning. This should be reflected by royalty payments as well. Put another way, as the local learning gradually detracts from the importance of the overall engineering rules which make up the original license, the equilibrium royalty rate should fall over time in order to reflect the accumulative value of local learning.

We conclude here the study of the relation between adaptive technological change and variables of a macro-economic nature, such as the pattern of dynamic comparative advantages with which

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43/ See in this regard C. Vaitsos, Transfer of Resources and the Preservation of Monopoly Rent, Harvard Development Advisory Service, 1970 (mimeo). Vaitsos here presents a long list of "standard" clauses found in the contracts he examined. Several ways of drawing up a free transfer clause were found during the present research, in which a list of 70 industrial technology sales contracts were examined.

a particular society operates, its degree of external technological dependence, etc.

IV. SUMMARY

This paper explores certain basic features of the technological situation of the Argentine manufacturing sector.

First; towards the end of the last decade, 200 large industrial firms (approximately 40 per cent of the manufacturing output) spent approximately 30 million dollars annually on Research and Development activities within the country. That figure represents about half of a percentual point of the value of sales.

Second; there does not seem to be, in the local situation, an inverse relation between importing technology from abroad and generating technology locally. There would rather appear to be a complementary relation between the two phenomena in that domestic technological efforts are aimed at the production of changes in the state of the art, adjustments and adaptations of the imported technology to the internal conditions of utilisation, etc.

Third; the flow of internal technological efforts is associated with, or caused by, one or several of the following forces: 1) the need to make better use of by-products, 2) the impossibility of obtaining, or the advisability of substituting, imported raw materials, 3) the resolution of bottlenecks in the production line, or in the design of a product, or a process, 4) the need to give technical assistance to suppliers, or to users of the end product, 5) the advisability of mechanizing or streamlining specific parts of the productive process, etc.

Fourth; significant differences between industries in domestic technological expenditure can be observed. The electrical products sector, the chemical industry and the pharmaceutical sector show a higher proponsity to carry out local technological efforts. By contrast, food and beverages, textiles, metals and vehicles and machinery, are relatively much less inclined to carry out such efforts.

Fifth; about 90% of the differences between industries, as far as overall factor productivity is concerned, are statistically ex plained by the difference between industries in two variables: a) the rate of growth of output - the Verdoorn or learning by experience effect; and b) the accumulated expenditure on research and development activities.

Sixth; within the framework of individual companies, the internal technological efforts can close the gap between a given firm and the international technological frontier. In the cases where this happens or has happened, it is feasible to expect important changes in the pattern of dynamic comparative advantages. This kind of phenomena would seem to underlie the recent expansion of manufactured exports which can be seen in Latin America, especially in the case of Brazil, Argentina and Mexico.

Seventh; a significant proportion of the internal technological effort is concentrated in the engineering groups of local subsidiaries of multinational groups. This brings up important questions related both to the appropriability of the results of technological learning in peripheral countries, and also to the degree of technical dependence with which these countries operate. It is more and more common to note that the flow of adaptive technological knowledge generated locally within a subsidiary of a multinational group, becomes useful for the group as a whole when operations are expanded to other regions of Latin America (Fiat, Massey Ferguson, etc.).

Eighth; different industrial sectors seem to be demonstrating concomitantly a) a relative slow down in the rate of expansion of the international technological frontier and b) a rapid process of technological learning in some Latin American countries, especially Brazil, Argentina and Mexico. The real significance of this fact, both as far as its internal industrial and politico-economic impact is concerned and with regard to the international position of the Latin American countries involved, is a subject which still requires detailed attention on the part of the different branches of the social sciences.

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