CEPAL Review

UNITED NATIONS
ECONOMIC COMMISSION FOR LATIN AMERICA

SANTIAGO, CHILE / APRIL 1983

CEPAL

Review

Number 19 | Santiago, Chile | April, 1983

CONTENTS

CEPAL REVIEW
April 1983

Technological change in the Latin American metalworking industry

Results of a programme of case studies

*Jorge Katz**

The metalworking industry is passing through a phase of out-and-out transformation in the international scenario. The rapid development of Japanese production and its penetration into European and United States markets, the gradual consolidation of the position of several 'newly industrializing countries' (NIC) like Brazil, Korea or Taiwan as manufacturers and exporters of various products of the industry in question, the dramatic irruption of *robotics* as one of the latest steps in the increasing automation of the production process, and the more and more intensive use of microelectronics in several of its phases, but above all the feeling that the changes now brewing –in the spheres of technology, organization, international trade, etc.– are of considerable magnitude, make this industry an unquestionably attractive field for economic analysis.

In the present article consideration is given to various aspects of Latin America's situation in this respect. The plants manufacturing metal products and machinery in the region are far from constituting a replica of their counterparts in developed countries. Both the production processes and the organization of production predominant in Latin America differ significantly from those observable in exactly the same fields of activity in mature industrial countries. What is more, there are also yawning gaps between the various Latin American countries, reflecting the wide diversity of situations existing in the region.

Hence it is more than obvious that a careful microeconomic scanning of different sub-branches of the metalworking industry in different Latin American countries must constitute a necessary first step towards any subsequent action or thinking, whether in the domain of theory and analysis or in that of the formulation and implementation of instruments of economic and technological policy.

*Director of the IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America.

Introduction

Since 1979 and up to the present day, four international agencies have co-sponsored a programme of research on the manufacture of metal products and machinery in Latin America, the results of which will be discussed in the course of the present article.[1] This Programme represents an attempt to supply the lack of basic information on the real situation of the metalworking industry in the region by means of a large number of case studies in which the economic and technological behaviour patterns of about half a hundred metalworking-engineering firms in Argentina, Brazil, Colombia, Mexico, Peru and Venezuela are examined in detail. The main findings of this research will be presented here, and some observations will be ventured, although only provisionally, on the major aspects of economic and technological policy to which these findings will naturally refer us.

The following pages do not constitute a sectoral study of the conventional type. First, because the sample considered by no means warrants our speaking of coverage in a statistical sense; secondly, and more important still, because the methodology used –individual case studies– enables us to shed some light on the very specific character of domestic production functions and of local industrial organization and innovative behaviour, etc., but does not allow us to arrive at analytical models or at universally applicable conclusions. It may safely be said that much of the information available in Latin America on innovative behaviour, industrial organization and the peculiar and specific character of the production functions locally current is still of a pre-theoretical nature, and that much yet remains to be studied if we are to reach a theory which –even though not formalized– will enable us to give an adequate description of the economic and technological behaviour of

[1] The IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America has given rise to a long list of working monographs. Specific references to these appear throughout the present text.

metalworking enterprises in the region and, subsequently, pass on into the domain of recommendations for public policy.

The main concern of the various case studies which serve as a basis for the present attempt at generalization has been to examine in detail the technological behaviour of the enterprises selected. The point of departure is the idea that this technological behaviour is closely associated with each enterprise's general performance, whether the latter relates to improvements in overall factor productivity, achieved in the course of time, or to changes in the firm's competitive position in the domestic and/or international scenario, etc. It is manifested in at least three major spheres of action in which every enterprise must possess both an *initial* technology —or 'package' of technical information— and a systematic flow of *incremental* technological know-how which will enable it to improve its operational performance. These spheres of action are the following: (i) product design, which embraces detailed specifications of parts, as well as plans and instructions as to manufacture, maintenance, etc., for the product or products to be made; (ii) production engineering *per se*, which involves the selection of machines to be used, the gadgets and tools accompanying them, the rules for the operation and maintenance of such equipment, etc.; and, lastly (iii) the organization and planning of production, an area which includes the employment and management of subcontractors, the control of purchases, stocks and inventories, the planning of the machine load, etc. In other words, the technological behaviour pattern of every industrial enterprise comprises both the original selection of technology and its subsequent improvement and modification through time, and relates to product design, to production technology *per se*, and, lastly, to the technology of the organization and planning of production.

The technological behaviour pattern of an enterprise is the outcome of a complex interrelationship of variables. As will be seen later, some of these variables have their origin in the techno-economic history of each individual firm; others derive from the market in which the firm operates and from its competition with rival enterprises. Lastly, yet others emanate from the overall macroeconomy in which the market in question is inserted and from the rate of general technological progress affecting the technical frontier of the branch of industry under consideration. In other words, the behaviour of entrepreneurs in general —and their technological behaviour in particular— results from a complex interaction between the strictly specific (or idiosyncratic) features of a given industrial plant, the market in which the said plant operates and the techno-economic parameters of the economy as a whole. This interaction is of a dynamic character and implies a sequential process which can feasibly be broken down by 'phases', in the course of which the firm accumulates experience, achieves successes and suffers failures, and gradually develops the possibility of using 'packages' of technological information of increasing complexity. All this constitutes the pith and marrow of a long-term maturation process which, as we shall argue, has not yet been adequately described or understood by conventional economic development theory.

The results presented below are the product of an exploratory effort at the microeconomic level which is beginning to bear fruit in terms of a novel description of the techno-economic behaviour of Latin American industrial enterprises and the sequential process of maturation which they undergo through time. The results in question shed new light on the old discussion regarding 'infant' industry, dynamic comparative advantages and the industrialization pattern, by showing that the learning of technology, and the externalities associated with it, are much more far-reaching in their scope than has often been admitted in the conventional literature of the subject in recent years.[2]

[2] With respect to what we are calling here 'conventional literature', the reader may consult Bela Balassa and Michael Sharpston, "Export Subsidies by Developing Countries: Issues of Policy", in *World Bank Reprint Series: Number Fifty-one.* Reprinted from *Commercial Policy*

The outline of the present study is as follows. Chapter II examines in some detail certain technical features proper to the technology of the metalworking industry, making a quick comparison between this and the technology of the so-called "processing industries" –typically the petrochemicals industry, steel-making, etc.–, in which the end product is more homogeneous and standardized, and in which the production process generally takes the form of a continuous flow, is executed with equipment and plant designed *ad hoc*, and is exempt from the multiplicity of subprocesses and the final assembly work which characterize the manufacture of metal products and machinery.

Several of the technical features identified here as proper to the technology of the metalworking industry influence the techno-economic behaviour of firms in the sector. Both in the original selection of technology, and its subsequent modifications through time, entrepreneurial decisions are swayed, *inter alia*, by forces and facts which stem from the very nature of the technology of the industry in question. We therefore think it important to begin the present analysis of results with a systematic review of the technical conditioning factors that affect metalworking enterprises in general.

Chapter III plunges straight into analysis of the results obtained. It is obvious at once that where the metalworking industry is concerned widely differing stages of maturity are to be found within Latin America itself. Some countries –typically Brazil– have successfully worked their way through a slow process of maturation and accumulation of experience, the duration of which must be measured in decades. In the course of this maturative process the metalworking industry has gradually broadened and diversified the fields covered, and electrical has become progressively more important than non-electrical machinery. Concomitantly, the proportion of skilled and technical personnel employed in this branch of industry has gradually increased, while at the same time a significant autochthonous technological base has little by little been developed. Other countries –like Peru and Venezuela– are only in the initial phases of a sequence which began more recently and which implies the production of simpler metal products and machinery –for example, agricultural equipment such as ploughs, harrows, etc., or machines for the construction industry, such as trailers, cement mixers and others. The case studies undertaken in the framework of the present Research Programme afford a good deal of information as to the disparaties in maturity which are seen to be associated with the difference in the age of the sector in various countries of the region. And similarly linked to the question of age is that of the technological complexity of the manufacturing establishments studied. Argentina and Brazil have been showing significant signs of development in metalworking activities since as long ago as the 1930s. Several of the case studies carried out in these countries relate to firms which have completed three (and even four) decades of manufacturing life, and whose techno-economic history embodies a wealth of experience and is representative of long-term trends and decisions. Peru and Venezuela, on the contrary, confront us with much shorter enterprise histories, in some cases of less than a year's duration. Again, Colombia and Mexico stand somewhere midway between the two extremes.

Various other features of the metalworking plants covered by the survey confirm this first impression regarding the maturative differences referred to in the context of the age of the factories concerned. These other features include, for instance, the complexity of the equipment, the employment of subcontractors, the development of the different intra-firm

Issues, Geneva, November 1977; Bela Balassa, "Export Incentives and Export Performance in Developing Countries: A Comparative Analysis", in *World Bank Reprint Series: Number Fifty-nine*. Reprinted from Weltwirtschaftliches Archiv 114, Tubingen, 1978; Jagdish N. Bhagwati and T. N. Srinivasan, "Trade Policy and Development", in *World Bank Reprint Series: Number Ninety*. Reprinted from *International Economic Policy: Theory and Evidence*, Rudiger Dornbusch and Jacob A. Frenkel (eds.), Johns Hopkins University Press, Baltimore, 1978.

engineering departments or sections, and their degree of 'sophistication' in respect of product design, process engineering and planning and organization of production.

Throughout chapter III the material emerging from the various case studies will be subjected to comparative analysis, with the aim of shedding light on the scope, determinants and implications of the above-mentioned differences in maturity.

The object of chapter IV is to pick up some of the old threats of the theoretical discussion on 'infant' industry, externalities and dynamic comparative advantages, but this time in the light of the results presented in the preceding chapter. Despite the fact that all we have before us is empirical evidence of a partial character, the material gathered in the various case studies constitutes an important asset on the basis of which it is interesting to take another look at received theory.

Lastly, the fifth and final section of the article ventures, although only briefly, into the domain of economic and technological policies. Attention is devoted here to various aspects where our findings reveal the existence of fertile ground for improving the *modus operandi* of the Latin American metalworking industry and its position in the international scenario.

I
Nature of metalworking technology

The metalworking-engineering industry embraces all those sectors of production which undertake metal-processing activities.[3] In this industrial subgroup are included not only casting and forging plants but also workshops for the stamping, cutting and welding, heat treatment, etc., of a variety of metals. Lastly, the sector also comprises establishments engaging in the assembly of electrical and non-electrical machinery, vehicles and transport equipment and miscellaneous scientific apparatus.

The technology of these branches of production has a range of features peculiar to it which undoubtedly affect the technological behaviour pattern of enterprises, both at the time of the initial selection of technology and throughout the firm's subsequent technological history. Among these special features, typical of metalworking technology, the following are worth mentioning: (i) the large number and enormously wide variety of subprocesses necessary to the manufacture of a given metalworking product; (ii) the magnitude and complexity of the 'components tree' which links up parts, subassemblies and end products; (iii) the universality, or multipurpose capacity, of a more or less substantial part of the equipment used by the sector, and (iv) the high degree of substitutibility between subprocesses, production techniques, etc.

Together with other variables of an eminently economic nature, such as market size, relative factor prices, the degree of imperfection prevailing in the factor and information markets, the level of protection, etc., the technological features mentioned above influence both the original selection of technology made for the installation of any new productive establishment, and the type of technological effort expended by the said establishment *a posteriori*, on the occasion of launching new products on the market, incorporating new machinery or lines of production, reorganizing the plant lay out, etc.

Accordingly, in view of the crucial importance which we attach here to these

[3] See United Nations, "International Standard Industrial Classification of all Economic Activities", Department of Economic and Social Affairs, *Statistical Papers*, Series M, No. 4, Rev. 2, New York, 1969.

technological features as determinants of a firm's behaviour, it seems appropriate to begin by examining them in greater detail. To this analysis the following pages are devoted.

1. *Differences between continous and discontinuous processes*

Unlike the so-called processing industries –in which, as a general rule, we can speak of the transformation of a raw material into a relatively homogeneous product, via a single subproduct, or a sequence involving a limited number of phases–, the output of the metalworking sector covers an extremely heterogeneous range of products obtained by way of a lengthy series of subprocesses. Cement production, steel-making, etc., or petroleum refining are instances of the first type of situation, whereas the manufacture of an electric motor, a passenger car or a harvester exemplify the second. The extensive range of subprocesses required for metalworking production, together with other features such as the heterogeneity of output, the labour-paced character of many subprocesses –especially during the assembly phase– and so forth, meant that the processing industries, as they are called, were those that lent themselves most easily to continuous production. Let us first consider the number and complexity of the subprocesses required and the high degree of substitutibility prevalent among them. To manufacture a car or tractor axle, the first requisite is casting –or alternatively forging–, followed by machining, then by heat treatment, etc. Here we may observe both the diversity of the subprocesses required and the technical possibility of substituting one subprocess for another. What is more, the machining process will be different according to whether the axle in question comes from a casting shop or from a forging plant, a fact which reveals not only that substitution between subprocesses exists but that it may sometimes alter the technical nature of the subprocesses used and even the plant lay out and design. So much for what is implicit in the number of subprocesses and their interdependence.

We remarked earlier that the metalworking industry is also characterized by the complexity of the 'components tree' which links up parts, subassemblies and end products. What happens is that any complex final product –for example, a passenger car– is the sum of a series of subassemblies, each of which in turn has to have its own assembly process carried out beforehand. Some subassemblies or parts may be common to various end products, as when standardized electric motors are used in the manufacture of different electric appliances and housewares. The possibility of decentralizing production of these standardized items (a possibility which arises out of the very nature of metalworking technology) has a marked incidence on manufacturing costs through the emergence of scale economies and the option of employing specialized subcontractors.

The differences between the processing industries and the metalworking branches of industry are of course not confined to the larger number of subprocesses that normally make up the technology of the latter, nor to the greater complexity and magnitude of the 'components tree' and the decentralization and specialization options implicit in this. Other equally important technical features are: (i) the universal and multipurpose character of a substantial part of the equipment used. This means that a very significant proportion of the machines and tools used by the sector can serve for the manufacture of a wide variety of end products; (ii) the immense diversity and heterogeneity of the final products made. In this context appear not only the wide variety of specifications and models often used in the manufacture of one and the same product, but also the differences in quality that may be found in products which fulfil more or less equivalent functions; (iii) in many subprocesses the calibre of the manpower available frequently determines the time spent on machine preparation, the level of tolerance attained and the rate of faults and rejects with which a given manufacturing establishment operates. We shall see later that considerable inter-enterprise differences in productivity exist side by side in a particular branch of production. These differences are partly accounted for by the disparities in the quality of the manpower employed by different firms. Let us look at all these technical features in a little more detail.

The universality and multipurpose character of some of the equipment and the heterogeneity —as regards specifications and qualities— of the products offered influence the selection of technology, inasmuch as they make substitution of one piece of equipment for another feasible at the level of individual subprocesses, while at the same time they also affect the optimum sequence of subprocesses required in manufacturing a given part or component. In its turn, the labour-paced nature of many subprocesses means that the theoretical technical coefficients are only of an indicative nature, as a wide margin exists for the learning of know-how and for inter-enterprise differences in productivity, even between close competitors.

The technology adopted by any metalworking establishment will be bound to reflect the technical features listed above; it will do so from the very moment of the original selection of equipment and lay out design with which every factory enters operation, and will then continue to do so throughout the firm's technical history, whenever the occasion arises to launch new products, to incorporate new machinery, to reorganize the plant lay out, etc.

In broad outline, and taking into consideration the *type* of product and the *volume* of output to be produced, we may categorize three basic forms of metalworking technology.

(a) *Production in large batches*

In the metalworking sector continuous production takes the form of the manufacture of large batches of homogeneous items. Typical cases in point are afforded by the manufacture of passenger cars, standard electric motors, etc. The degree of automation may vary, depending upon the number of subprocesses which are executed by hand,[4] and the degree of mechanization of the activities ancillary to production, such as transport, quality inspection and control, etc.

In continuous production plants part of the capital equipment is often specific to a given subprocess, or to several subprocesses taken in conjunction, as, for example, in the case of 'machining centres'. An extreme situation may also be reached, in the shape of a totally automated continuous production line designed for the manufacture of a single standard product (for example, simple electric motors).

(b) *Production in series of small batches*

Many metalworking sectors produce in small batches to meet a very limited number of orders per year. Their range extends from the manufacture of agricultural machinery to that of aircraft or locomotives, and includes machine-tools, etc. Establishments of this type are organized on a workshop basis, i.e., in sections or departments which carry out a given machining job and to that end group together all the equipment of a specific type: for example, the turning-shop, the grinding section, etc. Here the parts and subassemblies are conveyed either manually or by mechanized transport from one shop to another.

In this instance the equipment employed by each section is more universal and the manpower more skilled than in the preceding case. The greater versatility of the equipment and the higher level of skill of the operatives are characteristic features of discontinuous production in small batches, or to meet individual orders. In factories of this type relatively less time is spent on machine preparation —prior to machining

[4]For example, in a plant manufacturing electric motors, the winding of the rotor can be a manual, semi-automatic or totally automated process, irrespective of whether production is or is not organized on a production line basis. The same may be said of other subprocesses, or of tasks ancillary to the production process, such as transport or quality inspection and control.

itself– and, likewise in relative terms, direct machining time increases.

An establishment of a discontinuous type may or may not have undergone a technical reorganization process aimed at partly offsetting the negative effects of its fragmented character. Generally speaking, when such a reorganization is undertaken, its purpose is to linearize successive sections of the overall production process through the application of 'group technology' as it is called, organization by 'technological groups' or some other organizational technique which implies standardization and normalization efforts.[5]

(c) *Production of custom-made items or to meet individual orders*

Plants specializing in the manufacture of custom-made or individually-ordered items –for example, turbines, equipment for hydroelectric or atomic power stations, etc.–, are also organized as workshops, i.e., on a discontinuous basis. In these cases the output mix is broader than that of establishments producing in small batches, the result being a higher degree of organizational complexity.

After this preliminary characterization of the three basic types of metalworking establishments commonly found in practice, and following the observation that production both in small batches and to meet individual orders takes place in discontinuous plants, organized on a workshop basis, we shall pursue our analysis in greater depth by concentrating on two basic types of organization of the production process: (i) production in long series, organized on a production line basis; and (ii) production in short series, or of custom-made items, organized on a workshop basis. For the purposes of detailed understanding of the fundamental differences between the two forms of organization, we shall divide the production process into activities, as is normally done in industrial engineering;[6] this will enable us to track down the source of the most striking differences in operation and productivity between the two types of organization of work.

Every industrial establishment carries on the following five 'activities':[7]

Symbol	*'Activity'*	*Meaning*
⇨	Transport	Implies the transfer of an object from one place to another, except in those cases where the said transfer is part of a machining operation.
○	Operation	This is the physical or chemical modification of an object, its assembly with another or disassembly, or its preparation for a subsequent operation.
△	Inspection	This is the examination of an object to identify the quantity or quality of any of its properties.
D	Delay	Delay occurs when conditions –other than those intentionally introduced– preclude execution of the next activity provided for in the production process.
□	Storage	Storage exists when the object is kept in store while awaiting an authorized transfer.

[5] E.A. Arn, *Group Technology*, New York, Springler-Verlag, 1975. In particular: "The Group Technology Flow Line", pp. 9 *et seq.*

[6] See, for example, *Introduction to work study*, the ILO, Geneva, 1969, p. 180.

[7] In this connection we wish to express our appreciation of the help given us by Mr. Angel Castaño, who afforded us access to general bibliographical information on this subject, and also to an unpublished manuscript of his own in which he discusses the use of numerical control in the metalworking industry on the basis of categories similar to those adopted here.

The sum of these five activities constitutes the production process of every industrial plant, including those manufacturing metal products and machinery. If a comparative study is made of factories organized on a production line basis and discontinuous production plants organized as workshops, it becomes clearly evident that out of the total number of hours worked in each case, the proportion of direct machining time —or 'Operation' hours— is significantly less in the discontinuous process plants organized on a workshop basis. In these the operatives spend much more time on: *Delays and Transport* of materials, tools and special devices; *Looking up and Interpreting* technical information; *Repairing* machines and tools (outside normal Maintenance hours), etc. In other words, it is in the very nature of metalworking technology that discontinuous production processes organized on a workshop basis are as much more 'dead time'- and transport time-intensive,[8] as a plant organized on a production line basis minimizes *ex ante* the duration of the manufacturing cycle. In a production line technical activities and machining processes succeed one another in balanced and co-ordinated fashion down to the micromotion level. The stocks and storage points of materials undergoing processing, parts, subassemblies, etc., are located and sized in accordance with the general balance of the line. For all this to happen, the end product must be highly standardized and part of the capital equipment must be of a specific nature, i.e., specially designed for the performance of a particular job or combination of jobs.

In contrast to this picture, discontinuous plants organized on a workshop basis are much less carefully planned entities. The workshops are not bound to occupy one particular spot in the physical space, nor is their location constant through time. Several different products are manufactured simultaneously, since it is now the product that circulates from one workshop to another, not the factory lay out that is designed in correspondence with the successive technical operations required by a given product. In the present case great flexibility exists in respect of the way in which production is organized. Since all the machines of a certain type can perform a particular task, the job is assigned to whatever machine happens not to be in use at the time. It is on this account that a crucial role is played by the organization of the (weekly, daily) machine load programme, since upon that will depend the higher or lower degree of utilization of the available capital equipment.

To sum up: there are obviously major structural differences between the technology of a continuous production plant organized on a production-line basis and that of an establishment going in for discontinuous workshop-based production. The physical structuration of the plant, the capital equipment used, the organization of the production process, etc., will be significantly different in the two cases. The choice between one option or the other —i.e., whether to install a continuous-process plant operationg on a production-line basis, or whether to set up a workshop-type factory— is conditioned by: (i) the type of product to be manufactured; (ii) market size (or the volume of output envisaged); (iii) relative factor prices, etc. In its turn, the selection of one or the other way of organizing the production process will infallibly condition the entire techno-economic history of an enterprise from the very moment of its installation. In the course of the present study we shall argue that in a long list of metalworking industries the typical mode of production in the Latin American region is of the workshop-based discontinuous order, whereas in developed countries production is based on continuous-process production lines with a high degree of automation. The differences in global productivity deriving from

[8] The existence of these spells of 'dead time' is not a necessary and sufficient reason for a continuous production line to be more efficient than workshop-based production. The difference in the wages of the operative personnel employed in each case and the differences deriving from the other inputs will also have to be taken into account in order to arrive at a comparative appraisal. See Howard Pack, "The Capital Goods Sector in LDCs: A survey" (mimeographed text), Washington, April 1979.

this dissimilar organization of the production process are extremely important and determine the actual viability of Latin American producer enterprises, if this is supposed to be evaluated in a framework of openness to international competition. In this context we shall have occasion, later in the present article, to note how in a great many instances the initial technological decision to set up a small plant, organized on a discontinuous basis, inevitably marked out and restricted not only the technological paths subsequently accessible to a given enterprise, but also the actual viability of the firm's subsistence in an atmosphere of increasing international competition.

As up to now we have shown how the very nature of metalworking technology conditions the technological behaviour pattern of enterprises, we shall next consider how this pattern is influenced by other determinants, including the volume of output, relative factor prices, etc.

2. *Type and volume of output, available supply of skilled manpower and other determinants of the production process adopted in the metalworking industry*

The production process adopted by a given metalworking plant –continuous or discontinuous, automated or manual, etc.– is clearly associated with the type of equipment used and the skills of the manpower employed. At one extreme, the equipment may be constituted by universal-type machines and tools and by a manual system of handling, transport and control of materials, parts, etc. In this case the organization of the production process is highly flexible, but it also accumulates various spells of 'dead time' and diseconomies of scale. At the other extreme, equipment may consist in a set of transfer lines especially designed for manufacturing specific families of parts in large batches. Here flexibility almost entirely disappears. All sorts of intermediate options are conceivable, such as, for example, conventional machine-tools combined with automated (or semi-automated) systems of handling and transport of parts, or 'islands' of programmable machines, manipulated by robots and designed to produce families of parts in large batches, but, unlike transfer lines, susceptible of reprogramming should it prove necessary. Each of these models for the organization of the production process calls for skills of a particular type on the part of the operatives employed by the plant and the equipment it uses.

The kinds of equipment and, therefore, the continuous or discontinuous nature of the production process, the level of automation and the type of manpower chosen by a given manufacturing establishment will depend upon different technical and economic variables. These include: (i) the type and volume of output to be produced; (ii) relative factor prices; (iii) the prevailing flaws in the labour, financial and other markets; (iv) the look of the cömpetition which the firm will have to face, etc. The incidence of some of these variables will next be reviewed, beginning with the type and volume of output. To that end, let us look in detail at the internal structure of what is termed direct machining or 'operation'.[9]

Machining (or 'operation') implies:

(a) *Machine preparation*

This comprises the execution of all the activities necessary to carry out the machining or assembly operation. It includes selecting and installing the appropriate machine-tools, determining feed and speeds of metal chipping, etc. What is involved is a series of *given* activities –their incidence being therefore *fixed*– which are consequently proratable among all the parts to be machined. The longer the series, the greater the amount of prior effort that may justifiably be expended on machine preparation –including the

[9] In some of the firms studied under the present Programme, machining operations absorbed from 20 to 25% of the total time covered by the industrial process. In establishments with continuous production the machining (or 'operation') time tends to be realtively less, inasmuch as the 'dead time' inherent in discontinuous production and in small batches is to some extent reduced.

manufacture of masks and special gadgets—, inasmuch as the unit machining (or 'operation') time proper can thereby be reduced.

(b) *Loading and unloading of part into and from machine*

(c) *Machining (or 'operation') proper*

This comprises metal chipping, welding, etc., *per se*. The speed of execution will be a function of: (i) manual constraints, which depend upon the skill of the operative; and (ii) technical constraints, which depend upon: the machine (its age, motive power, etc.); the type of metal that is being worked; the tool employed; the lubricant used;[10] the complexity of the job to be carried out; the acceptable level of tolerance, etc.

(d) *Inspection and control*

This covers the controls effected by the operative, over and above the quality controls programmed in the production process.

Generally speaking, it may be said that industrial engineering has at its disposal standard estimates of the time which has to be spent on machine preparation, loading and unloading, machining (or 'operation'), etc., in order to perform a specific type of activity, given the equipment and operational conditions of the process (lubricants, cutting tools, etc.).[11]

For the purposes of the present analysis —where what concerns us is to show the relation existing between the equipment to be chosen by a given metalworking plant and the type and volume of output envisaged—, the essential fact to be stressed is that machine preparation time, which may come to constitute a significant proportion of total 'operation' time, is a fixed charge independent of the size of the batch, upon which, precisely, its incidence on the unit cost of production will therefore depend, i.e., upon the number of parts —or in other words the size of the batch— that will be manufactured once the machine is prepared.

How does the size of the batch influence the type of equipment used by a given plant?

If we assume that one or two units of a fairly simple part are to be produced, a hand-operated machine of a universal type —for example, an engine lathe, a drill, etc.— would be sufficient. Machine preparation time would be comparatively short, but a longer time would be spent on machining proper. In view of the low relative cost of the machine involved in the technique in question, this latter may probably be the most justifiable choice, inasmuch as it certainly minimizes the unit cost of capital.

This extreme situation —in which the selection of equipment is relatively simple— would undergo modifications in correspondence with at least two specific facts. Firstly, in response to the complexity of the part to be manufactured and, secondly, in relation to the size of the batch and/or the number of annual orders for the same part.

A well-known example of the first of these cases is the airspace industry, where many items were practically impossible to produce successfully on the basis of an operative and a conventional tool. Here the application of sophisticated numerically controlled equipment and of programmable manipulation and control machinery proved justified in relation to the technical complexity of the parts to be made and the limits of tolerance required. Similarly, a significant expansion of the volume of output —due to an increase in the size of the batch and/or a larger number of annual orders for the same part— warrants, in the first place, a greater machine preparation effort in the shape of the manufacture of masks and special devices, and, secondly, if

[10] "Water-based Cutting Fluids Cut Machining Costs. Switching from Neat Cutting Oil to Water-Based Coolants Helps to Reduce Production Costs —and Conserves Oil", in *Machine Tool Review*, Vol. 63, Nos. 363 and 365, Coventry, England, 1975.

[11] See for example, A.S. Manne and H.M. Markowitz (eds.), in *Studies in Process Analysis. Economy-Wide Production Capabilities*, Cowles Foundation for Research in Economics at Yale University, New York, John Wiley & Sons, Inc., 1963.

the volume of output so permits, the incorporation of equipment at a higher level of complexity and automation. At the upper extreme –in cases of mass production– there is justification for the use of a highly automated machine, specially designed for the purpose of manufacturing a particular part or component.[12] This might be a transfer machine or a reprogrammable 'island' of numerically-controlled machines.

So much for the relation between the complexity of the product manufactured, the volume of output and the selection of technology in given metalworking plants. Another variable which significantly influences the nature of the equipment used is the availability and cost of skilled manpower.

Simple equipment, of a universal type, makes intensive use of skilled manpower, some of it being of a quasi-artisan character. With automated equipment and transfer lines, on the contrary, these skilled operatives –whose training may take four or five years– can be replaced by much less skilled personnel, who can be trained in rather less than a year. In the course of interviews conducted under the present Programme, one case was recorded in which, as the result of introducing numerically controlled equipment, it was possible to replace 44 skilled workers by approximately 20 operators of automatic equipment; while in another instance, 21 operators of numerically controlled equipment today do the work that was formerly performed by 63 skilled turners.[13] In addition to the operatives directly in charge of it, this numerically controlled equipment called for qualified instructors and programmers. In approximate terms, it is estimated that from 6 to 8 numerically controlled machines are served by one instructor and one programmer. Consequently, the change from one technology to the other also involves a change in the nature of skills –indirect instead of direct– and reduces employment of skilled direct operatives.

From analysis of the preceding paragraph it can be inferred that automatic and semi-automatic equipment acquires greater relative importance in those countries where the supply of skilled workers is relatively small and their wages are therefore relatively higher. Influence in the same direction –that is, in favour of relatively greater use of automatic equipment– is exercised by the various possible flaws in the labour market which may prevent or hinder continuous operation with night shifts. Situations of this type are relatively commoner in European countries (the United Kingdom, Sweden, etc.) than in Latin America, although there are obviously considerable inter-country differences within the Latin American region itself.[14] We shall revert to this topic in the last section of the present article.

In addition to the type and volume of output, the supply and cost of skilled manpower, the institutional conditions prevailing in the labour market, etc., there are obviously other factors which have an incidence on the kinds of equipment, the nature of the production process and the level of automation chosen by a specific metalworking enterprise. Among these it is worth while to mention the following: the rate of interest or cost of capital; the greater or lesser availability of financing; the degree of uncertainty prevailing in the economy, etc. In combination with the variables mentioned above, these will affect the capital recoupment period or planning horizon by which a given productive unit is swayed at the time of making its choice of production techniques.

So much for what is inherent in the relation between kinds of equipment, type and volume of output and relative prices and

[12] See A. S. Manne and H.M. Markowitz (eds.), *op. cit.*

[13] S. Jacobsson, "Technical Change and Technology Policy. The Case of Numerically Controlled Lathes in Argentina" (mimeographed text), Lund, Sweden, July 1981, p. 12.

[14] Berth Jonsson, Corporate Development AB VOLVO, "Corporate Strategy for People at Work. The Volvo Experience", International Conference on the Quality of Working Life, *QWL and the 80's* (mimeographed text), Toronto, Canada, 30 August-3 September 1981.

available supply of factors. Another crucially important feature of metalworking technology is that it opens up the possibility of decentralizing production through the employment of subcontractors. The following pages are devoted to discussion of this topic, which will reappear later when —in section III— we present the several findings obtained in the various field studies. It will also crop up again at the end of the present article when we refer to possible official policy measures.

3. *Subcontractors*

Another of the basic characteristics of metalworking technology is the broad spectrum of subcontracting relationships which it permits. They have their origin in the complexity of the 'components tree' and subprocesses that go to make up the sector's activity, with the result that plants and workshops can exist which specialize not only in the manufacture of particular parts and components but also in the execution of specific jobs, such as casting, heat treatment, etc.

We shall now explore the economic content of these subcontracting relationships.

The existence of such relationships reveals the presence of flaws of various kinds in the operation of the market mechanism. In a perfectly competitive world, where large numbers of undifferentiated buyers and sellers operate, every economic agent obtains all the requisite information through the price system. In such a model there are no transactional costs, and each firm maximizes its operations without resorting to any data other than those provided by the market.

In contrast, there is obviously a large number of markets for intermediate products —as there are many in which subcontracting relationships figure in the metalworking field— where various forms of inter-firm co-ordination emerge whose economic content it is of great interest to explore. In a recent study, S. Lall remarks that there are two possible alternatives. The first is that the costs of co-ordination of independent firms are so high as to warrant the complete internalization of the market by way of vertical integration. The second implies that the advantages of commercial independence outweigh that of complete internalization, but that recourse to co-ordination is justifiable as a means of surmounting the imperfections of the market.[15] And he adds that vertical integration is the result of a complete failure of the market mechanism, whereas the several forms of inter-firm co-ordination derive from its partial failure.

In order to go more deeply into this subject we must ask what are the underlying economic facts or features here.

The subcontracting relationship presupposes the presence of at least two economic agents. One of these, the firm engaging the subcontractor, must be able enough to co-ordinate its external supplies of parts, components, etc., in such a way that getting them from outside is profitable. This necessarily means obtaining prices, standards of quality, guarantees of punctual delivery, etc., at least similar to those implicit in producing its own inputs. The other contracting party —the subcontractor— must be in a position to meet the requirements in question reliably and systematically.

It is readily understandable that subcontracting relations may involve technical, financial, organizational and other aspects, and may have a fundamental incidence on rights of ownership over technical information, on the subcontractor's entrepreneurial capital, etc.; and, furthermore, that problems will necessarily arise in connection with the appropriation of entrepreneurial profits deriving from the productive activities of the subcontractor. In principle, because these are contractual relations in which the rules of competition are only very imperfectly operative, there is a wide margin for negotiation between the interested parties, by means of which all sorts of different agreements can be reached, given the more or less extensive

[15] S. Lall, "Linkages Revisited" (mimeographed text), Oxford, 1980.

range of possible situations of equilibrium.[16]

Let us take a look at some of the aspects normally present in subcontracting relationships.

(a) *Technical aspects*

It often happens that the subcontractor's work calls for an *initial* technical information component –plans, design specifications, standards of quality, etc.–, as well as an *incremental* flow of such information that will enable the subcontractor to work in unison with the technological changes introduced by the subcontracting firm. Co-operation and co-ordination between the two is necessary here in order to make up for deficiencies in the diffusion of know-how. There is literally no way in which the market can provide the necessary information in time for the operations of the two firms to take place efficiently in default of prior agreements.

Obviously, apart from questions inherent in the diffusion of technical information, important problems also arise relating to the appropriability of its benefits. The subcontracting firm may (or may not) hand over to the subcontractor intangible assets in the form of technical information. The sales price of such assets may differ substantially from their purchase price, and this opens up a wide margin for negotiation between the contracting parties and a similarly broad spectrum of possible situations of equilibrium. Given the highly specific nature of each contractual relationship, all sorts of cases are conceivable in which the implicit profits are divided differently between the subcontracting firm and the subcontractor, depending upon the structure of the subcontractors' market, the bargaining power of the terminal firm *vis-à-vis* its own customers, etc.[17]

It can also be seen that in their turn the ownership relations existing between the terminal firm and the subcontractor, and the degree of control which they allow, will likewise exert a decisive influence on the nature of each contractual relationship. In general terms it may be assumed that a 'captive' subcontractor will have better access to the subcontracting firm's stock of technological information –with the consequent generation of greater externalities– than an independent subcontractor who can operate freely in the market. But having better opportunities of obtaining externalities in terms of technological information does not necessarily imply enjoying the possibility of appropriating its benefits, inasmuch as this will depend upon the price formation mechanism in operation between the two firms, and upon the underlying ownership relations.

(b) *Economic and financial aspects*

Over and above the strictly technological plane –which we have described as the segment of technical information involved in plans, formulae, manufacturing instructions, engineering handbooks, etc.–, the relation between a terminal firm and a subcontractor may also have regard to financial matters –loans of share and/or working capital–, production questions, investment flows –amount and nature of the subcontractor's output mix–, etc. Here again we have the extreme case of the 'captive' subcontractor, who has to consider himself an operational appendage of the terminal firm, which in reality is the taker of decisions as to volume of output, conditions of sale, etc. At the other end of the scale we find the situation of the independent subcontractor who operates freely in the market and who decides upon his own plan of production, investment, etc., relatively regardless of the subcontracting firm.

A fair-sized metalworking firm which decides to operate on the basis of subcontractors may normally do business with scores (or even hundreds) of workshops supplying parts and components, or with plants responsible for carrying out specific

[16] J. Katz, *Importación de tecnología, aprendizaje local e industrialización dependiente*, Mexico, Fondo de Cultura Económica, 1974, pp. 24 *et seq.*

[17] In an earlier study we have presented a simple geometric model which may be applied to the present case. See J. Katz, *ibidem*, 1974.

subprocesses such as casting, heat treatment, and others.

There is no reason whatever why the contractual terms stipulated in any one agreement should be reproduced in the other agreements entered into by the firm.

In each individual case the morphology of the specific submarket where the subcontractor operates, the difference in costs between supplies obtained from internal and external sources, the greater or lesser importance of the part, component or subprocess and the degree of dependence which it entails, etc., will have a bearing on the relative bargaining power of the two parties, on the final price and on the several other terms in accordance with which the operation is finally agreed upon. Since on many occasions a reference price simply does not exist, and the range of possible situations of equilibrium is wide, the result of each subcontracting arrangement is not easy to decide *a priori*. In some cases the subcontractor is a mere 'price-taker', transferring a good deal of his profit to the terminal firm, while in others the situation may be reversed and the relative weakness of the terminal firm is thrown into relief.

It is precisely because of the diversity of possible situations that the management of a global subcontracting policy constitutes a complex problem of organization and planning of production from the standpoint of the terminal firm, which often needs a specialized technical department capable of simultaneously concluding a large number of extra-firm production agreements, and balancing the deliveries of external suppliers in such a way as to minimize unnecessary costs of stocks, risks of supply shortages, etc.

In developed countries the employment of subcontractors is common practice. And in contrast it is much less frequent in the semi-industrialized world, an assertion which holds good even in the case of local subsidiaries of transnational corporations.

Thus we bring to a close the present section dealing with some of the outstanding features of metalworking technology. We have noted that perhaps more often than the processing industries the various branches of metalworking admit of discontinuous organization of the production process, the use of equipment of a universal and multi-purpose type, the employment of highly-skilled quasi-artisan labour that it takes a long time to train, the utilization of specialized subcontractors, etc. Obviously, the fact that this is feasible from a technical standpoint does not necessarily indicate that these technical options are actually turned to account. The type and volume of the output to be manufactured, relative factor prices, the prevailing flaws in the labour, financial and other markets, the look of the competition that the firm has to face, the level of protection that it enjoys, etc., will necessarily be powerful determinants not only of the technology originally chosen by every manufacturing establishment, but also of the modifications in it which the establishment in question will introduce through time.

In the next section we shall have an opportunity to look into the incidence of these structural features of metalworking technology in different production scenarios in Latin America. Radical evolutionary disparities exist in the region and are clearly apparent in the differing production, organizational and other technologies adopted by the manufacturing establishments studied in the course of the present research.

II
The Latin American technological scenario in the metalworking field. Empirical evidence arising out of a programme of case studies

Metalworking plants in Latin America are far from constituting a replica of the manufacturing establishments producing similar goods in mature industrial countries. To explore the most striking differences and their implications both at the theoretical level and at that of the formulation of instruments of public policy, attention will have to be devoted to such aspects as: (i) the size of the factory; (ii) the nationality of the enterprise and its organizational 'model'; (iii) the age of the firm and the degree of technological maturity of its technical departments; (iv) the morphological characteristics of the supplier market –monopolistic or competitive, in the latter case with alternative supplies of domestic and/or foreign origin–; (v) the factor markets where inputs are obtained; (vi) the legal and institutional framework in which the enterprise operates, etc.

As stated in the preceding chapter, these variables –since metalworking technology so permits– have brought about the emergence and consolidation in Latin America of a metalworking sector –which in the more developed Latin American countries accounts for practically one-third of the industrial product– formed by factories with a very specific lay out, with equipment which includes a high proportion of machinery of their own manufacture, with a mode of organizing production that is little inclined to the use of subcontractors, and so on. The purpose of the present chapter is to describe some of the key features of these metalworking plants. This will later enable us to speculate as to the possibility –and the public and private measures through which it might materialize– that some of these industrial establishments may subsist on competitive terms under less protectionist international trade régimes.

The differences in maturity within the Latin American region are extremely marked. Some countries –such as Argentina and Brazil– began to develop their metalworking industry relatively early, near the beginning of the present century, and during the 1920s activities like casting and forging, welding, etc., were started.In these countries the following decade already saw the emergence of plants of some importance manufacturing machine-tools, durable consumer goods, etc.; many of these grew up from maintenance and repair shops run by distributors and importers of products from abroad. At that time the said countries' parks of motor vehicles, durable consumer goods, etc., were large even in comparison with those of countries in the developed world, and the maintenance infrastructure they required permitted the appearance not only of local repair shops but also of the first attempts at domestic manufacture of the simpler capital goods needed in that connection.

During the 1930s various subsidiaries of metalworking groups in developed countries settled in Argentina and Brazil. They were not, at that time, production units proper, but distribution and commercial representation branches, many of them concerned with durable consumer goods and with capital goods for the food, textile, and other industries. Obviously, several of these firms set up departments for providing technical assistance to customers, as well as for repair and maintenance of the corresponding local park. The gradual increase in the index of incorporation of domestic production, in respect of spare parts first and later on components, and the derived demand for metalworking products which this triggered off, constitute another of the important historical background data which must be borne in mind when studying the early development of the metalworking industry in Argentina and Brazil.

In other countries of the region the emergence of metalworking activities is of more recent date, being traceable to the 1950s in Mexico, Colombia and Chile and the close of the 1960s or the beginning of the 1970s in Venezuela or Peru.

These differences in the 'age' of the region's respective metalworking industries are reflected in significant disparities in maturity. This explains why, on an average, the Brazilian or Agentinean metalworking industry is nowadays in a position to operate on the basis of a package of technical information more sophisticated and complex than can be handled, for example, again on an average, by the metalworking branch of industry in Venezuela or Peru.[18]

The age of the plant and the degree of technological maturity of its technical and engineering cadre are not the only sources of disparity between the technical and economic results achieved by Latin American firms. Equally important is the size of the local market, in so far as it influences, as we have already seen, the selection of production techniques. In Argentina and Brazil, and to a lesser extent in Mexico and Colombia, there are various branches of the metalworking industry in which continuous-process plants exist, where the work is organized on a production-line basis as is appropriate to mass production programmes geared to large markets. The degree of automation of these production-line plants, however, is significantly less than in comparable establishments in the developed world. The most striking examples of production lines are connected with durable consumer goods and with the motor-vehicle industry and its subsidiary branches supplying parts and subassemblies. With differing degrees of vertical integration —higher in Argentina and Brazil and lower in Mexico and Colombia— these are the only countries in the region where domestic manufacture of passenger cars in undertaken. Assembly of vehicles on the basis of imports of disassembled units, and with very little incorporation of domestically produced elements, can also be found in other Latin American countries such as Venezuela, Peru or Chile.

Apart from what has already been said —i.e., from the fact that Argentina, Brazil, Mexico and Colombia are the countries where continuous-process plants organized on a production-line basis are most numerous—, the empirical evidence collected also suggests that these are the countries where greater domestic technological efforts are observable in the direction of linearizing segments of the production process in factories originally organized on a discontinuous basis as a succession of 'islands' or workshops. As we shall have occasion to observe a little farther on, this reveals a by no means negligible advance in terms of local technological maturity, inasmuch as the technological effort required to linearize a discontinuous process may be considerable in respect of product design engineering (for example, normalization and standardization of parts and subassemblies), as well as in the fields of process engineering and industrial organization (employment of subcontractors, etc.). The important point at this stage of our argument is that only in a few countries in the region —typically Brazil, Argentina, Mexico and Colombia— has the metalworking industry gradually developed, in different plants, enough domestic engineering capacity to explore, on the basis of domestic technological effort, ways of linearizing a factory lay out initially conceived as discontinuous.

In short, when we attempt to examine metalworking technology in the Latin American region we find ourselves faced with a complex mosaic of technical differences between manufacturing establishments; and

[18] Two interesting examples afforded by the case studies on which the present article is based clearly reveal the significance of this matter of maturative differences. The first relates to the technological effort made by a Venezuelan firm to design a sugar-cane harvester; the second to a method —by welding— chosen by a Peruvian plant to manufacture the revolving drum of a cement tipper. In both cases the firms concerned had a short production history and were faced with serious technical problems not only in the product design area but also in that of process engineering; and in both the technical problems in question had been resolved several years before by Brazilian and Argentinean metalworking firms.

these differences are significant not only within each country and between Latin American countries, but also between establishments in the region and industrial plants in the developed world. At all three levels the differences in question call for careful scanning.

Semi-automatic or manual in-factory transport; manual or semi-automatic coil-winding of motors; manual, loading and unloading of parts and tools; relatively greater use of conventional equipment instead of numerically controlled equipment (and, therefore, a different distribution of personnel between skilled operatives and programmers); longer spells of time allowed for the product engineering department to arrive at a new design ready to put on the market; a high degree of self-sufficiency as regards supplies of parts and subassemblies, etc.; all these are characteristic features of Latin American plants which significantly differentiate them from one another and from their counterparts in developed countries.

1. *Production lines*

We shall begin this analysis of results by considering continuous production plants, organized on a production-line basis, before going on to review discontinuous-type establishments, i.e., those organized as a succession of workshops. Within the framework of the case studies on which the present attempt at generalization is based, the plants that we had an opportunity to look at include several that run on a production-line basis. To this subgroup pertain: Perkins (motors) and Metalúrgica Tandil (casting) in Argentina; Metal Leve (pistons) and Romi (engine lathers) in Brazil; Sofasa (passenger cars) in Colombia, etc.

Continuous production lines constitute a 'mode of production' whose history in Latin America is relatively brief. The amount of know-how accumulated with respect to the management of this type of organization of production is therefore still modest, and difficulties of various kinds are encountered. For example, as the result of an over-diversified output mix, a continuous production line designed to produce a flow of highly standardized items is often used in Latin American countries to manufacture short series of relatively differentiated products, so that substantial economies of scale are lost through an increase in the number of stops, in machine preparation time and in dead time arising out of any change in the production plan. Perkins Argentina, or Sofasa in Colombia, are eloquent cases in point. The first of these firms gained a great deal in labour productivity during the second half of the 1970s when it decided to introduce an additional production line and specialize the output mix produced by each individual line; while much the same thing happened in Sofasa when this firm standardized engines, gearboxes, brake systems, etc., as between the Renault-4 and the R-6, thus eliminating dead time and stops.

It may be said that there are few cases in which the factory lay out was originally designed for continuous production of an only slightly diversified output mix, or a single individual product, so that immediate and full advantage could be taken of the economies of scale proper to this mode of organization of production.

The small size of the domestic market, an economic policy which compelled terminal firms to operate with a high and increasing degree of vertical integration, the lack of reasonably efficient subcontractors, etc., are all circumstances inherent in the Latin American metalworking environment which may have influenced the fact that the original output mix was unduly wide in its range and thus gave rise to inefficient use of continuous technology.

Much of the domestic technological effort of factories of this type is marked by concern with how to obtain greater economies of scale for the respective manufacturing establishments. In some cases, this has stimulated efforts in the field of product design engineering aimed at standardizing parts and subassemblies, as in Sofasa, Colombia, while in others the same end has been pursued through planning and organization of production, for example, by way of rationalization of the output mix and more specialized use of the available equipment.

Whichever the way chosen, it is important to stress here that adequate exploitation of the advantages of continuous production is neither *immediate* nor *automatic.* Far from it. Attainment of the economies of scale inherent in a design for a continuous-type plant generally takes time and calls for domestic engineering efforts on the part of the various technical departments which make up the enterprise.

In this respect the nationality of the firm may come to play a significant part. The Latin American subsidiaries of foreign enterprises have at their disposal a plentiful stock of technical information belonging to the parent firm, and this information may make it easier for the local subsidiary to take greater or more rapid advantage of the economies of scale implicit in every continuous-type technology.

There are, however, exceptions to this rule, especially when the Latin American subsidiary operates with a more diversified output mix than that of the parent firm itself (which generally possesses production lines, or even complete plants, specializing by product), or with a process technology which, although organized on a production-line basis, is far from resembling that applied by the parent firm as regards the degree of automation of the production process. In this last case, obtaining the economies of scale implicit in the technological design locally used will probably necessitate a substantial amount of 'made-to-measure' technological effort.

Table 1 summarizes various technological and economic features of the continuous metalworking plants, organized on a production-line basis, that were studied under the IDB/ECLA/IDRC/UNDP Research Programme.

These plants produce, on the one hand, durable consumer goods, such as, for example, passenger cars and the various subassemblies (for instance, motors) or individual parts (pistons, camshafts, cylinder blocks, intake manifolds, etc.) required by the terminal establishments, or, on the other hand, certain capital goods sufficiently simple and standardized for them to be manufactured on a production-line basis: in this case, conventional engine lathes.

Three of the five firms forming this subgroup started out as ventures undertaken by national entrepreneurs on the basis of domestic capital, and entered operation in the post-war years. In one of these three cases the enterprise was subsequently purchased by a terminal firm which is a subsidiary of a multinational group, for which reason it must nowadays be regarded —from the standpoint of the legal ownership of capital— as a foreign enterprise.

The two remaining firms are of more recent date —1961 and 1970, respectively— and both have belonged from the outset to foreign enterprises.

In relation to this whole group of firms, which are organized on a production-line basis, we shall next examine the sources of the product and process technologies locally applied, the sources and nature of the embodied technological change introduced by enterprises in the course of time, the magnitude of the technological effort they tackle, etc.

Let us first look at the origin of the embodied technology, beginning with product engineering and going on to the technology of the production process *per se.*

In the two subsidiary firms owned by foreign capital product design engineering is almost entirely provided by the corresponding parent firm; the enterprises in question are Perkins Argentina and Sofasa in Colombia. The external origin of product design is no bar to either local firm's introducing adjustments, changes in parts, gradual improvements in the performance of the original design, etc., but it can safely be said that in both situations product engineering primarily stems from outside the enterprise and outside the Latin American region.

In the case of the other three firms that make up the group of production-line enterprises —i.e., the three which were at first owned by domestic capital—, consideration of the source of product technology raises a question of morphology which cannot be disregarded, i.e., whether the firm concerned produces a final good or an intermediate input. One of these three firms manufactures a final good; this, as has been stated, is a simple engine lathe, of conventional type. In this instance product technology is entirely local and is the outcome of a long process of evolution which started with copying a similar product of European origin, more than two decades ago. The other two are subcontractor enterprises manufacturing intermediate inputs for terminal firms that produce vehicles. By their very nature as suppliers of subassemblies and parts, both firms are bound to work with a product technology largely pre-specified by the corresponding terminal firm. However, this does not prevent one of them —Metal Leve, Brazil— from maintaining a sizeable product engineering team, supported by a Research and Development Office concerned with questions relating to physics, chemistry and metallurgy. This office carries on an active interchange with universities in Brazil and abroad and participates in the designing of new products both for the terminal firms themselves and for other well-known international enterprises. The fact that this firm does a great deal of business in the international market undoubtedly obliges its product engineering department to be constantly updating technology. Thus, even though the product engineering with which it operates is often pre-specified by the product design of the terminal firm for which it is working as a subcontractor, the firm may safely be said to be in close contact with the world technological frontier in the field of product engineering.

If we briefly revert to the topic of product technology in the enterprise based on domestic capital which manufactures a final good —i.e., Romi, Brazil— it may be noted that the firm uses domestic technology for a wide range of conventional-type machine-tools in which the state of the art has evolved slowly in the last few decades. In contrast, and despite the fact that the enterprise is heavily committed to R&D spending —as we shall see later— it is of interest to observe that when we pass on to the designing of numerically controlled equipment —where the world technological frontier is advancing rapidly in our time— the enterprise has encountered various difficulties, in consequence of which it has recently been looking into the viability of reaching a technical assistance agreement with an Italian firm, a world leader in this field. In view of the importance attaching to this subject from the standopint of the design and implementation of economic policy instruments, we shall revert to it in the last section of the present paper.

If we now turn our attention to the source of the process technology used by the five firms studied, we shall again observe a number of interesting facts.

Three of the five firms came to apply a production-line technology in the course of their evolution, after having operated for several years on the basis of a discontinuous technology. In the other two cases —Perkins Argentina and Sofasa, Colombia— the plants started out straight away with a continuous-type plant design, although in both instances, owing to the unduly broad output mix chosen, it became difficult to take immediate advantage of the economies of scale implict in the original technology.

In these two cases, when a continuous-type technology was used from the very outset, plant design was provided by the corresponding parent firm —both are subsidiaries of foreign enterprises— and a factory design in which the parent firm concerned already had experience elsewhere was reproduced locally.

Conversely, in the three cases in which continuous technology was reached by way of evolution, local product engineering played a much bigger part. It must not be forgotten that these three firms were originally owned by domestic capital. In two instances it was the rapid expansion of the local market, following upon the installation of the motor-vehicle industry, that provided the inducement to switch over to the continuous process. In the third it was the decision to export *en masse* a standardized and homogeneous product —engine lathes— that fig-

Table 1

SOME TECHNO-ECONOMIC FEATURES OF THE CONTINUOUS PRODUCTION PLANTS STUDIED UNDER THE IDB/ECLA/IDRC/UNDP PROGRAMME

Enterprise	Product	Nationality and ownership	Source of technology: Product design	Source of technology: Production process
1. *Perkins Argentina* Argentina, 1961	Motors	United Kingdom, foreign enterprise	Design furnished by terminals and parent firm in UK. Little local engineering effort	Very specific, with a great deal of 'home-made' equipment. The plant is European, rehabilitated
2. *Metalúrgica Tandil* Argentina, 1948	Casting Blocks Camshafts Intake manifolds	*Initially:* Domestic capital *Today:* Subsidiary of foreign firm	Given by terminals. Little domestic effort. Product design undertaken for third parties	Conventional process replaced by Shell moulding or 'hot mould'. Technical information from Germany
3. *Metal Leve* Brazil, 1950	Pistons	Domestic capital. Private enterprise	Designs given by terminals but plenty of local technical effort in respect of designing for foreign firms	Automated production line opened in 1976 which puts out 600 parts per hour as against 200 from the conventional production line
4. *Romi* Brazil, 1941	Engine lathes	Domestic capital. Private enterprise	Conventional design improved in the course of the years. Much local effort in product design for other lines	Firm has 60 machining centres. Own casting. A great deal of 'home-made' equipment
5. *Sofasa* Colombia, 1970	Passenger cars	50% public enterprise and 50% subsidiary of foreign firm	Design given by parent firm adapted locally. New parts locally designed. Standardization of motors, brakes, gear-boxes	Equipment provided by parent firm. Only a few changes and one or two local designs

Source: Prepared by the author on the basis of the different field studies. See Appendix.

ured as the primary incentive to set up a continuous production line.

It is important to note that these three firms experienced very significant increases in overall productivity on passing from organization on a discontinuous basis to a continuous-type production process. The time saved in the subprocesses of core-making and trimming after the introduction of the continuous conveyor belt in Metalúrgica Tandil, the virtual trebling of the number of parts per hour obtained by Metal Leve from its continuous production lines, and a similar development in the history of Romi, reflect the tremendous impact implied by the transition from one mode of production to the other. In contrast, in the two cases in which continuous production was introduced straight away the misuse of the potential advantages implicit in this way of organizing production is blatant; over-diversification of the output mix seems to have been responsible in both instances for an initial phase laden with examples of operational inefficiency.

In all five cases studied the continuous production line was set up on the basis of equipment primarily brought from abroad, though nevertheless, in four of the firms at least, the design and self-supplying manufacture of machinery within the firm was important in the past, even for

Nature of technological change		Scale of engineering and research and development (R&D) efforts	Morphological features of the market		
In product design	In process and organization		Type	Protection	Exports
(1) Different uses of the motor manufactured (2) Improvements of quality in water-tightness, mechanical strength in blocks, crankshafts, etc.	Important equipment in the 1970s and embodied technical change. Flexibility of production line reduced. Greater integration	Engineering effort takes up 8% of total hours	Concentrated Oligopoly	Special régime favourable to high degree of vertical integration and low import content	
	(1) Significant increase in productivity in core-making and trimming shops, through time-saving (2) Rejects drop from 13% (1976) to 5% in 1980/1981		5% of total market and 10% of major enterprises.		Very few
		1.5% of sales spent on R&D. Approximately 60 persons. Exchange with universities and support from FINEP	70% of pistons market		
		7% of sales. Since 1979 R&D independent of product engineering offices and plant technical assistance	70% of domestic market		17% of sales in 1979
(1) Design of new parts for R-18 (2) Increases in R-4 cylinder capacity (3) Improvement in quality (for example, crankshafts cast instead of forged)	(1) Great improvement in planning of production, management of stocks, etc. (2) Substitution between subprocesses	2% of sales. 13 persons in the plant and 45 in all 35% of time spent on process engineering	Concentrated oligopoly		

setting up the continuous production line.

So much for the origin of the product and process technologies used by the firms under consideration; let us now go on to study questions inherent in technological change in these enterprises.

The resolution of problems associated with the technology originally embodied, the fact that these are enterprises manufacturing final products or intermediate goods, the quest for improvements in quality and/or for ways of cutting costs, the substitution of subprocesses (casting instead of forging, for instance) or of raw materials, the more efficient management of stocks and inventories, the development of subcontracting, etc., constitute some of the key elements that must be taken into account in examining the technological behaviour pattern of the five firms studied.

As previously pointed out, the two plants that were originally installed with continuous-type technology seem to have made very poor use at first of the economies of scale implicit in the technology chosen. In one of these cases the technological response to this initial state of affairs involved the standardization of parts and assemblies and the rationalization of the output mix. At the same time, the firm significantly improved the organization and planning of production, management of stocks, etc. Here technological change is largely 'disembodied', and includes aspects relating both to product engineering and to organizational techniques. In the other enterprise —Perkins Argentina—, utilization of economies of scale necessitated an intensive equipment programme which the firm put into practice almost ten years after its installation. Unlike the foregoing instance, this is a case of 'embodied' technological change which reduces the flexibility of the plant, increases its degree of production line specialization, and by this means improves the use of time in the establishment.

Of the three remaining cases, in which the installation of a continuous production line is reached by a process of evolution, two exhibit a more marked domestic technological effort in the field of process engineering. The first is a 'captive' casting shop which works almost entirely with product designs from the terminal firm which it supplies, while the second is the firm manufacturing conventional engine lathes, an item with a high degree of standardization and universality. In both cases domestic efforts in respect of process engineering were substantial and significantly more important than in product engineering. This must be interpreted, however, not as a general neglect of product engineering on the part of the firms in question, but as an indication that the production line under discussion here called for little technological effort in that direction. It should be borne in mind that the firm manufacturing engine lathes possesses several other adjacent establishments organized on a workshop basis, in which it produces a wide range of engine lathes, turret lathes, etc., and miscellaneous machine-tools. The group as a whole earmarks 7% of the value of its annual sales for research and development activities, and although the product engineering required by an engine lathe run off a production line is only a very small part of the overall technological effort undertaken by the enterprise, it should not be forgotten that the firm does product engineering work in many other additional directions. Similarly it seems worth while to note that in the case of the 'captive' casting shop the firm proves to have engendered an independent economic group —Ingeniería Santander— engaged in the design and construction of equipment and machinery for third parties. In other words, even though the 'captive' character of the casting shop's production line significantly limits requirements in respect of product engineering, the increase in design capacity displayed by this firm reveals the powerful synergic element implicit in the accumulation of engineering capacity in general.

The foregoing paragraphs summarize the empirical evidence gathered as to the nature of embodied technological progress in the five production-line plants that have been studied under the present research programme. A striking feature is the wide diversity of situations recorded. While in one case the bulk of technological change is disembodied, and involves product design engineering and organization of production, in another it is primarily embodied, and is based on the technology of the production process *per se.* In the subcontractor firms technological change seems to have been related more to process than to product engineering, a situation which is apparently reproduced in the case of the firm manufacturing a relatively standardized and multipurpose final good.

A wide variety of situations also reappears when we attempt to classify the motivations accounting for the incorporation of the technological changes observed. Exploitation of economies of scale, improvement of quality, substitution between subprocesses or of one raw material for another, cutting costs by reducing direct machining ('operation') time, more efficient management of inventories, etc., are the motives most commonly in evidence.

Generallly speaking, the production-line plants are comparatively large in proportion to the specific market in which they operate. While Metal Leve and Romi supply about 70% of their respective markets, Perkins Argentina and Sofasa, Colombia, are also clear instances of concentrated oligopoly.

Given the relatively large size of all the production-line firms considered here, it is not surprising to find that they all maintain sizeable engineering departments that employ a staff ranging from about half a hundred technicians and professionals in Sofasa to twice (or three times) that number in Metal Leve or Romi. It becomes understandable that production scales of that magnitude can cope with the maintenance of cadres specializing in the various branches of engineering, and even of R&D offices more directly concerned with exploratory tasks that have a greater basic science content. In this context there can be no by-passing the fact that the two firms with the clearest R&D commitments are Brazilian, are owned by domestic capital and have received and still do receive definite State support in the field of technology. Again, both are integrated in the international market, maintain plant scales closely resembling or similar to those current in the developed world, and in various respects rise above the narrow-minded concentration on production for the domestic market which prevails in most of the manufacturing establishments born of import substitution strategy. We shall revert to this topic when discussing comparative advantages, technology and official policy.

2. *Discontinuous production organized on a workshop basis*

Here we pass on from analysis of the five continuous-process establishments organized on a production-line basis to consideration of the other metalworking plants studied under the IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America. The factories in question number about a score, most of them of smaller dimensions, and operating with a discontinuous production process and a plant lay out organized on the basis of 'islands' or workshops.

Within this group of firms those that manufacture custom-made goods to meet individual orders exist alongside those producing in small batches.

As was pointed out in section II, a metalworking establishment producing custom-made items or in small batches represents a mode of production substantially different from that considered hitherto. The enterprise of family type and origin, set up on the basis of the mechanical ability of an immigrant, showing a marked predominance of product design engineering over process engineering and organization of production, and still taking little —but gradually increasing— advantage of the economies of scale deriving from standardization and normalization, etc., is the representative firm in this subgroup.

Two or three decades of sustained operation seem to have been necessary in some of these cases for the initial factory —often a mere repair workshop for imported machinery— to attain the category of a reasonably equipped and organized industrial plant, in which accounts are kept by 'cost centres' so that the standard manufacturing costs can be reconstructed, in which the 'follow-up' of parts is effected through the various subprocesses, in which a stable routine of quality control and preventive maintenance of the available equipment is carried out, etc.

In many of the cases examined the physical volume of output has been quintupled —and even increased tenfold— in the course of a few years, and consequently the whole character of the industrial operation has altered. Inter-temporal analyses of productivity must be approached with the greatest caution, inasmuch as the output mix has normally changed, as has likewise the quality of each of the items in the mix; the schedule and nature of the subprocesses used has been modified *pari passu* with the equipment incorporated and with the subcontracting to third parties; the proportion of direct to indirect workers has decreased; the skills and qualifications of the personnel have altered, etc.

Admittedly, in many respects the manufacturing establishments in operation today still bear the indelible stamp of their initial technical structuration —which at different points of time limits the possible techno-economic options open to them—, but at the same time they superimpose upon it a complex history of expansions, changes of strategy, and gradual development of domestic technological capacity. In the following pages we shall endeavour to describe the historical sequence of this process.

To this effect, we shall divide the history of the firm's evolution into 'phases' or 'stages'. The first of these —which we shall term the phase of 'original installation'— combines a number of quasi-artisan characteristics, typical of a family-style productive organization. There is no functional specialization, the equipment is of a universal and rudimentary type, and the product manufactured is elementary, often merely the parts and spare parts for pre-existing equipment imported from abroad or a reproduction of some 'old' model of a capital good or a durable consumer good, likewise brought from outside the region.

The second phase or stage comprises the transition from this artisan workshop to a more modern factory. This transition must not be thought of as an organic plan in any way assimilable to what would be an optimum situation such as is commonly described in conventional textbooks. It is frequently characterized by: (i) a move to a different physical location; (ii) intensive expansion of equipment; (iii) rapid recruitment of direct operatives. At this stage there is not yet much order or rationalization in the successive steps taken by the enterprise. As a general rule the new building or factory is not specially designed in relation to the firm's specific tasks, so that the plant lay out is the offspring of chance rather than of programming. The equipment and operational personnel are not seldom selected and incorporated in the light of extra-economic criteria based on extremely imperfect information. Errors of excess and defect abound in a situation where the focal point is rapid expansion of the physical volume of output. The quality of the product begins to improve in consequence of the new equipment, but there are still no organic criteria that are applied as a matter of routine in relation to quality control.

The third phase is characterized by the development of plant engineering in association with a gradual process of 'digestion' of the installed capacity and the operative and technical personnel. At this stage the ratio of direct to indirect workers varies substantially as the firm brings in technicians and professionals and rationalizes the use of its productive resources. Formal criteria begin to supersede oral tradition, and management of technical information becomes more orderly; thus, plans per part, machine maintenance manuals, quality control routines, etc., make their appearance.

The fourth phase —the last in the evolutionary sequence which we shall describe in the following pages— definitively incorporates organization and methods engineering in connection with a global operational programme for the firm which embraces not only the plant itself but also the other complementary functions such as buying warehousing, technical sales services, etc. At this stage a start is now made on linearizing various segments of the production process by the application of organizational engineering methods such as studies of 'families of parts', 'technological groups' and several other techniques which facilitate standardization and normalization and, in more general terms, make it possible to obtain economies of scale by improving batch sizes, and reducing machine stoppages and dead time. Time and motion studies, development of subcontracting, etc., are proverbial features of this fourth phase, reflecting a relatively sophisticated stage of operation and organization of the firm's various engineering departments.

The evolutionary sequence described above does not occur overnight; rather, we must not be surprised if it takes something like 15 to 20 years. Nor is it any wonder if there is no sign of linear or balanced-expansion characteristics in a specific situation. Lastly, neither is it impossible that an individual firm may be unable to pass from one phase to another, or may simply fail in the attempt to subsist as a productive organization, dropping out at some point in its history. The firm should be envisaged as moving through successive situations of disequilibrium in which, by too much or too little, it misses the optimum, and has to seek a more rational allocation of resources. As at the same time the environmental variables are changing (the market, the macro-economy), this adjustment lag is a recurring process.

There is of course nothing obligatory, or logically necessary, in the functional relations and the phases described here. Other sequences taking exactly the same (or a different) length of time seem logically viable in less protectionist contexts, or in scenarios where the factor markets operate in accordance with rules of the game different from those that are proverbial in the Latin American region. (Particularly significant cases in point are those of Japan, Korea, etc.).

A few —but only a few— of the firms studied here have succeeded, during their evolutionary history, in moving through the four phases described; in particular, this is true of Argentinean, Brazilian and Mexican enterprises. To a lesser extent the statement holds good for Colombia. The great majority of the metalworking plants considered may be located at some point corresponding to phases two and three of the sequence propounded (see table 2).

Many of the enterprises forming the subgroup under study enjoy a measure of 'natural protection' deriving from the existence of locational advantages or from better technological adaptation to specific requirements of demand, etc. This natural protection weakens the role of external competition and must be taken into account both in examining the techno-economic behaviour pattern of the firms considered, and in proposing public policy measures and instruments.

It is perhaps this very thing that may explain the basic importance that seems to have been attached to product engineering in the very origins of many of the firms making up this subgroup. The problem consisted more in meeting existing demand than in doing so at a cost or with a quality specification which could have stood up to external competition.

This original product engineering stemmed in a good many instances from a copy of a similar foreign good, as can be seen to have happened in the case of agricultural machinery, machine-tools, flour or rice mills, etc. At first this copy was generally made from a relatively old 'technological vintage' of the product concerned. This occurred, for example, when Turri[19] and Romi[20] copied a European back-geared lathe on first entering operation in the 1940s, or when Zaccaria[21] began to produce rice mills in the 1930s in the region of São Paulo, Brazil. The practice was partly due to the limitations of the capital equipment available —extremely rudimentary at that time—, but account must also be taken of significant information lags in these initial attempts at product design and copying.

In the great majority of these cases, it would not appear that process engineering —and far less still that of production organization— played a meaningful role until one or even two decades after the original entry into operation. The initial equipment abounded in secondhand and 'home made' machinery. Plant lay outs arrived at by accident or chance are much commoner than those deriving from production programming. There are major technical imbalances between one section of a plant and another —see, for instance, among the factual evidence collected under the Programme, the spectacular imbalance between the forging, machining and die-sinking departments which characterizes the original plant design in the case of Forjas, Colombia.[22] Obviously, these workshops have no technical

[19] See A. Castaño, J. Katz, F. Navajas, "Etapas históricas y conductas tecnológicas en una planta argentina de máquinas-herramienta", *Working Paper No. 38*, IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, January 1981.

[20] See H. Nogueira da Cruz, "Relatório Parcial Parte II. Firma E" (mimeographed text), IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, January 1981.

[21] See H. Nogueira da Cruz, "Evolução Tecnològica no Setor de Máquinas de Processar Cereais. Um Estudo de Caso", *Working Paper No. 39*, IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, July 1981.

[22] See D. Sandoval, M. Mick, L. Guterman and L. Jaramillo, "Análisis del desarrollo industrial de Forjas de Colombia, 1961-1981", *Working Paper No. 50*, IDB/ECLA/

Table 2

SOME TECHNO-ECONOMIC FEATURES OF PLANTS ORGANIZED ON THE BASIS OF DISCONTINUOUS PRODUCTION IN SMALL BATCHES OR CUSTOM-MADE

Manufacturing enterprise and country	Product	Ownership, nationality	Source of technology	
			Product	Organization process
1. *Gherardi* Argentina (1937)	Agricultural machinery. Stock	Argentina. Family enterprise	Adaptation of imported designs	Forging, machining and welding are the most capital-intensive
2. *Zaccaria* Brazil (1920)	Agricultural machinery. Custom-made	Brazilian. Family enterprise	Copies of similar imported products, simple at first, later more complex	Secondhand equipment. First factory, workshoptype, set up in 1943. Equipment and machine-tools made in the factory itself. Equipment becomes more sophisticated in the 1970s
3. *Forjas* Colombia (1950)	1. Caterpillar mounting for tractors 2. Parts for passenger cars 3. Currently: crankshaft forged for Renault 4. Flanges and grinders	Colombian, 30% domestic, 60% foreign. Management German, then Italian and subsequently Instituto de Fomento Industrial (IFI)	First phase: a great deal of diversification and small batches of caterpillar mountings for tractors. Second phase: increase in diversification with the incorporation of FIAT products, but more subcontracting. Third phase: IFI reduces diversification	Initial studies made by a German consultant. German management up to 1970. IFI management since 1980 but by now there are many instances of obsolescence. There has always been an imbalance between forging and machining and between forging and die-sinking
4. *Ramo* Mexico (1941)	Flour mills. Almost all products custom-made. For repairs some equipment made for stock	Mexican. Family enterprise	Derived from a family tradition in milling. Firm began by repairing old equipment and manufacturing spare parts. Is diversifying output, introducing other products	Moved to new premises in 1961. There entered upon the manufacturing phase. Has its own casting-shop
5. *Rota-Agro* Venezuela (1961)	Agricultural machinery. Produces for stock	Venezuelan. Family business started in Cuba	Rotary harvester copied from a United States model. Efforts at adaptation to the local environment. Possession of its own casting-shop influences product design	In 1963 set up its own quite simple workshop. Since 1968 also has a casting-shop

Source: Prepared by the author on the basis of various field studies. See Appendix.

standards or proper costing systems until many years later. Similarly, in view of the lack of subcontractors, plus a family tradition of self-sufficiency, vertical integration is almost complete, including casting, the civil engineering connected with the erection of new buildings, etc.

The evolution following upon this first phase of an enterprise, based on extremely rudimentary and informal process and production organization engineering, must be viewed as a historical sequence marked by the dynamic interaction of variables inherent in: (i) the firm, within which changes take place in the skills of the personnel, technical functions are developed and specialized and new equipment is introduced, and the whole enterprise goes through a gradual learning process; (ii) the market, of which, at the same time, the morphology and competitive climate alter; and (iii) the macroeconomy of each individual society.

So much for what is inherent in the origin and characteristics of the initial

IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, June 1982.

Description of technical change		Subcontractors and suppliers	Patents taken out	Increases in productivity, their source and magnitude
In product design	In process technology			
Emphasis on product engineering. Demand plays important role in second phase. Seeding equipment absorbs a great deal of innovation	Time saving in machine preparation	Boom in subcontracting. Greater degree of internal processing in the more complex models (70%). Gear boxes designed, and manufactured in the plant	Yes, and especially in the 1970s	Increase in economies of scale due to reduction of machine preparation time. Output increases with innovations
Cereal huller incorporated in 1948. The new generation (1970) begins to go in for machine-tools	A start made only recently on producing in small batches. Goods previously made to meet individual orders. Second generation introduces a proper costing system, installs a computer, etc.	1. Total vertical integration. 2. 1944 - casting-shop and rubber section set up. Subcontractors' delivery times, prices and quality unsatisfactory. 3. Casting dropped in the 1970s and replaced by buying from third parties	Yes. Firm has some 20 product patents, pertaining to recession period. Patents not taken out during expansion	No major increases. Measurement problems posed by breadth of mix and changes in quality and in subprocesses covered.
As from 1975, in association with FIAT, more FIAT-designed passenger-car parts produced. Renault design used since 1977	1. Die-making a key area in which improvements are effected with the introduction of new machinery 2. Attempts to make the furnace forging machine stage continuous in order to reduce fuel costs 3. Batch sizes increased	During the FIAT phase recourse is had to subcontracting to reduce the negative effect of the greater diversification due to FIAT designs. IFI increases subcontracting and reduces diversification	No	High degree of underutilization at all times. In the past, almost 50% in forging; 60% in machining
Wide diversification of uses of similar equipment	A few up-to-date machines purchased in 1979. At first 90% of every plant constructed was imported. Later on production by the firm itself gradually increased		First patent registered in 1965	An embodied effect observable in the 1970s
Close contact with farmers provides indications of adaptations needed. Output mix subsequently broadened, still on the basis of copying reinforced foreign models	Attempted to increase its degree of vertical integration by incorporating casting and manufacture of plough disks. Organization more defective than that of Tanapo or Nardi. Improving nowadays through imitation of others	At first, the introduction of casting enabled the firm to reduce costs. Not so today, since there are better subcontractors. Develops a range of 'outside shops' which enable it to lower costs and face up to the recession	No	Productivity improves with reduction of degree of diversification. Rival firms are beginning to use numerical control. Rota-Agro not yet

package of technology with which many of the discontinuous metalworking enterprises examined under the IDB/ECLA/IDRC/UNDP Programme seem to have entered operation.[23]

The time has now come to turn our attention to technological change, i.e., to all the above-mentioned modifications of the initial package of technical information handled by each of the firms under discussion. What concerns us is to study the determinants, nature and implications of these changes.

Product engineering was undoubtedly

[23] Obviously this is not the only possible situation, although it is the commonest in the present universe of case studies. A different model, with an original product and process design much more external to the local society, can be seen in the study on Forjas of Colombia (*op cit.* (1982)), a firm to which initial packages of technical information on both types of design were provided by a German firm. Other examples in which foreign technology also forms a predominant part of the original package of technology can undoubtedly be found in the group of metalworking firms organized on the basis of workshop-type discontinuous production, but these are definitely in the minority in the sample considered here.

Table 2 (conclusion)

Manufacturing enterprise and country	Structural features of growth	Exports	Concentration	Macro-influences	Manpower skills
1. *Gherardi* Argentina (1937)	Two periods. 1. Up to 1972; 2. 1972-1978. Latterly obliged to simplify during recession. Innovations in 1974 prove a failure and complexity is lessened	Yes, a great many to adjacent countries. May reflect adaptation to demand	Four enterprises account for two-thirds of the total in five families. Share is a function of new orders	Subsidy to farmers	A bigger field for informal characteristics. Length of service and seniority
2. *Zaccaria* Brazil (1920)	Fluctuations of demand lead to diversification. Demand changes appreciably in the 1970s and induces the firm to improve the product	Only in the years 1965 to 1970 does the firm begin to export, again in response to a recession	From the first held about 20% of the market	In times of recession simpler versions are launched and the firm takes to exporting; this more recently	Only with the expansion in the 1970s are techniques incorporated that require higher skills and expensive and specific machinery
3. *Forjas* Colombia (1950)	Three clearly defined stages. German: ball bearings manufactured and design engineering undertaken. Italian: intra-FIAT group passenger-car parts are produced. IFI: an agreement is concluded with Renault which increases batch sizes and exports	15 to 18% at recent dates (1975)	Monopsony at first. Only buyer General Electric	Imports opened up in 1965, just at the time of entry into production. Devaluation increased the debt in marks and brought about bankruptcy	During the German phase the technical team (undertaking product and methods design) comprised 40 persons. In the Italian period all this was done away with. IFI reverts to the previous organization
4. *Ramo* Mexico (1941)		As early as 1959 began to export to the United States. Sold complete plant in Costa Rica. Today exports 15% of output	Holds 50% of the domestic market. 40% held by the other competitor (foreign)	1. High degree of protection 2. Subsidized credit	Training school since 1966
5. *Rota-Agro* Venezuela (1961)	The climate of competition gradually changes through time, after a monopolistic start. Today the firm has to imitate its competitors since it feels itself left behind	Does not export	For almost a decade the only firm in the sector. Then two competitors appear on the scene: one a subsidiary and the other a licensee of foreign enterprises	1. Subsidized credit to farmers is main source of expansion of demand 2. The 1977-1981 contraction affects this firm more than the other two	Few improvements introduced until the recent incorporation of the 'professional generation'

the first thing to attract domestic technological effort in the group of firms analysed here, and it implies: (i) the design of successive 'vintages' of the product manufactured; (ii) the broadening (and, on some occasions, the narrowing) of the output mix offered; and, lastly, (iii) an improvement in the quality of individual items in the mix.

The first step in product engineering often seems to have been a move to get away from the external model or models originally copied, in an attempt to reduce the technological gap existing between the products offered locally and internationally and at the same time adapt more closely to the needs of domestic demand.

An autonomous technical component, endogenous to the firm, and deriving from the learning of technology in its design offices, together with a component exogenous to the enterprise, relating to changes in the morphology of the market and in the nature of demand, may be traced as the main determinants of a greater domestic technological effort in the field of product engineering during the early years of the enterprises reviewed here. Let us take a more detailed look at these components in the light of the empirical evidence collected.

From one of the studies carried out under the Programme, we extract the following information on the determinants of the

Raw materials	Role of the State and externalities	Nature of technological change	Other specific features
Greater thicknesses are used in sheet for reasons of quality, and this gives it more weight and strength	Significant role played by INTA in diffusion of information. Hybrids, biological innovations and characteristics of demand	More complex machinery launched in 1974. This was a failure and a simpler design had to be made. Technical information on a French machine used	1. Frame welded instead of bolted as before. Increase in output leads to changes of process 2. Contradiction between specificity of user and economies of scale through standardization 3. Normalization between one generation and the next 4. Active producer and active user
Substitution between metal and wood at first	Virtually no State intervention other than protection	Great improvement in quality. 'Natural sequence' in treatment of cereal to be processed	1. After 1970 the 'second generation' comes on the scene. Great changes in management of firm 2. In 1966 firm engages services of consultants on organization and management. This is proposed by a member of the second generation 3. In the 1970s producers group themselves in co-operatives and begin to insist on better products
Borum steel substituted for chrome steel in ball bearings and production cycle reduced	1. Training and mobility of personnel 2. This is a public enterprise	In die-sinking, several capital-saving advances (through saving of time and cost of new dies). This change is embodied via a milling-machine, a glass pulverizer, etc. Also many changes in crankshafts	1. Completion of installation coincides with a drastic slump in demand 2. In 1971 the firm goes bankrupt and closes down 3. FIAT manages it from 1974 to 1980. The engineering department is closed and emphasis is placed on sales of parts for passenger cars 4. This is an interesting case of training of human resources and rotation of personnel. 5. Furnace constructed in 1975 for small parts designed in the plant 6. Many bottlenecks in the machining-shop
	A great deal of subsidized credit	A production technology already familiar put to new uses	1. At first self-financed with resources brought from Spain 2. Expansions in 1961 entirely on a family basis 3. Even today satisfactory bookkeeping and general records are lacking
This firm has less capacity for analysis of materials and use of substitutes than its competitors but the latter operate under external licenses	Incidence of credit policy on the agricultural sector is very marked	The bulk of technological change relates to product design engineering	1. Recently an important 'generational change' seems to have begun which implies the emergence of a technically qualified stratum. This poses the question of overhauling methods of work and ways of facing up to competition 2. Interesting experience in the development of 'outside shops' on the basis of piece work. Since 1976 'inside shops' are also being developed, in an attempt to evade labour laws

early expansion of product engineering: "With regard to the firm, we have pointed out that ... the change in its staple product from an engine lathe that was a copy of the Czechoslovakian Mass model to a copy of the URSUS model –which is significantly more sophisticated and complex–, together with the increase in equipment and technical personnel which is associated with the modification of the product (given that the scale is maintained in 10 to 12 monthly shifts on an average), constitute the first step in the transition process ...".

The study goes on to show that this change is induced on the one hand by the appearance on the scene of the motor-vehicle industry, and, on the other by the autonomous development of the firm's internal design engineering capacity. The motor-vehicle industry brings about "... a differentiation between two types of demand on the lathes market. One, already traditional, represented by repair, maintenance and machining shops manufacturing low-quality products; another, formed by enterprises with a large output that demand automatic and semi-automatic lathes as well as more quantitatively and qualitatively serviceable universal machines. In the first segment ... the work to be done induced demand for low-price and low-quality universal lathes, copied from European models of the 1940s —for example, the back-geared lathe or the Czechoslovakian model produced by Mass in the 1950s. In contrast, the firms in the second group called for better-quality and higher-productivity machinery. In this connection the URSUS engine lathe represents a great advance on what the firm was producing before".[24]

With reference to this same enterprise, and to our previous argument regarding the determinants of the technological effort in design engineering, the study points out that the copy of the URSUS model dates from 1958 —i.e., from three or four years before the real beginning of the motor-vehicle boom in Argentina, which may be placed in the very early 1960s— and is clearly associated with the building of a new factory, with the introduction of new and better equipment (a new copying lathe, a radial drill, etc.) and, above all, the arrangements made to include a specific product design office in the firm's organizational chart. All this reveals the existence of an autonomous technical component, stemming from learning within the plant, as a determinant of the improvement in design engineering, over and above the signals emanating from the market, which in this case are also present and call for a more complex and sophisticated product to satisfy a new type of customer.

In this specific instance —and in several others in the sample of firms examined here— the changes in market morphology and the gradual enhancement of the role of competition from third enterprises, do not begin to play a significant part in inducing innovative behaviour until at least a decade later. In other words, and still with reference to the initial development of engineering capacity and the greater relative effort in product design by which this seems to have been marked, outstanding importance attaches to the autonomous technical factor —within the firm— and the messages emanating from demand, while at the same time the negligible rule of competition in inducing innovative behaviour is also revealing.

[24] A. Castaño, J. Katz, F. Navajas, *op. cit.*, 1981.

Notwithstanding that the available empirical evidence confirms the earlier development of design engineering, it also shows the high degree of linkage existing between this and production engineering. From the very first a relation is apparent which becomes closer after the lapse of a few years, when the development of the climate of competition so warrants: namely, that existing between the quality of the product and the equipment used to manufacture it. Even though in its infancy the firm may lack a specific technical department concerned with production engineering —a department which in many cases comes into being as the plant scale grows larger, the output mix is diversified and the equipment becomes more complex— it seems obvious that the improvement in the quality of the product originally offered, or the release of better and better 'vintages' of that initial product, calls for the introduction of new and superior machinery, and the emergence of new subprocesses not applied before (such as, for example, grinding or heat treatment of parts). This incorporation of additional equipment and activities frequently entails tackling problems of plant design, process engineering, etc., which, although they do not necessarily involve the creation of a specific department or office for the purpose, must infallibly absorb some of the working hours of the technical and engineering personnel.

Hitherto we have considered questions relating to the designing of new vintages of the original product and to the gradual improvement of quality embodied in the product concerned. Entrepreneurial strategy based on early development of product design engineering also partly consists in the broadening and diversification of the output mix. Obviously, this must of necessity call for technological effort in respect of product design, just as does the improvement of quality or the launching of successive vintages of the original product referred to above. But as regards the determinants and implications of the broadening and diversification of the output mix offered on the market, it seems worth while to revert to the empirical evidence collected in so far as it reveals additional interesting features.

In many cases the decision to broaden and diversify the output mix seems to have been associated with: (i) the limited size of the domestic market; (ii) recessions at the level of the economy as a whole, reflected in slumps in demand on the specific markets served by the firm under consideration; and (iii) the entry of new competitors into the market.

In this context, the material gathered shows that it is not uncommon for new families of products[25] to be started or less complex versions of known products to be launched in response to slumps in demand or to relatively high indexes of gluts on the market,[26] or to releases of similar products on the part of competitors.

In one way or another, as regards the implications of diversification, the broadening of the output mix necessarily entails changes in the production plan, a larger number of stops and machine preparation hours and, in general, a heavier incidence of unproductive dead time. In other words, there is clearly a negative statistical relation between the firm's degree of diversification and its exploitation of economies of scale.

We may now attempt a brief summary of what has so far been said with respect to the determinants, nature and implications of the technological change emerging in the initial stages of operation of the metalworking establishments studied. The available evidence suggests that domestic technological capacity tends, in the factories covered by the Programme, to develop early on in the area of product design engineering; this area encompasses the designing of new products, improvement of quality in those already familiar and, lastly, the broadening of the mix offered on the market. Among the determinants of this early development of domestic design capacity are variables inherent in the initial technical level and subsequent learning of new technologies observable in the firm's professional and technical team, as well as forces emanating from the demand side and, to a lesser extent during the initial phases, from the climate of competition prevailing in the specific market in which the firm operates. As regards the implications to which allusion has been made, we know, in the first place, that the launching of new products and the improvement of quality are usually linked to the incorporation of new equipment and subprocesses in the factory, with the consequent necessity for physical investment in plant and for certain efforts in the field of process engineering, concomitant with those made in product design engineering. Lastly, we know, too, that any design engineering effort which ends by broadening the output mix —given that the available equipment remains the same— will probably exert a negative influence on the technical efficiency of the plant, by increasing the number of machine preparation hours, stops and spells of dead time, and thus reducing the economies of scale obtained by the firm.

The next step in the development of domestic technological capacity seems to be the strengthening of process engineering. It has already been said that primary forms of process engineering generally emerge from the very outset of manufacturing activity even when there is no formal department responsible for this work. What it is here of interest to identify, however, is the set of circumstances surrounding the consolidation of these functions and, once again, the nature and implications of the technological change —or new technical information— emanating from such a department.

The creation of a process engineering department, and its consolidation in the firm's organizational chart, generally seem to be connected with a significant change in the scale of operations of the enterprise. This, in turn, necessarily involves an equipment programme, the redistribution and

[25] See J. Berlinski, "Innovaciones en productos y aprendizaje (El caso de una planta argentina de implementos agrícolas)", *Working Paper No. 43*, IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, January 1982.

[26] See M. Turkieh, "El cambio tecnológico en la industria venezolana de maquinaria agrícola. El caso de Rota-Agro S.A. El caso de Tanapo S.A. El caso de Nardi C.A." (mimeographed text), IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, 1982.

partial or complete alteration of the plant lay out, the incorporation of new operative and technical skills in the manning-table, etc.

Both the initial equipment and the quasi-artisan factory of the early years become constraints on potential development in many of the enterprises considered here. The existence of surplus demand and the opening-up, in some of the cases studied, of new markets linked with the installation of the motor-vehicle industry, hold out optimistic prospects of expansion, which on a good many occasions set in train a change of location, the designing or purchase of a new factory and the contacting of international suppliers of equipment.

Special attention must be paid to questions relating to the financing of the plant expansion which ushers in the second phase of the sequence traced here. The various case studies show that access to the subsidized credit granted by the official banking system, the receipt of external private investment, credits and joint venture agreements with international suppliers of equipment, the firm's own family resources, etc., make plant expansion feasible at this stage. The possibility or impossibility of obtaining financing in one or other of these alternative ways, the specific terms on which it is extended, etc., indubitably affect the probability of one individual firm's gaining an advantage over its immediate competitors at the very time when the market is taking shape,[27] with the result that the latter assumes morphological features which thenceforward have far-reaching repercussions.

Proverbial in this phase, in addition to the rapid growth of the physical volume of output, are the following developments: (i) improvement of the quality of the product, in association with the incorporation of new subprocesses (and the equipment necessary for the purpose) such as tempering or heat treatment, grinding, etc.; (ii) a rise in the index of vertical integration; (iii) the introduction of new skills among the operatives and technical personnel, etc. Explicit references to these topics are to be found in some of the case studies carried out under the Programme. Thus, H. Nogueira da Cruz writes of the Zaccaria plant: "In 1943 the plant was moved to a site belonging to the firm and the workshop characteristics which had marked the production process began to make way for those of a factory endowed with a larger quantity of equipment and better organization of the available space. Manpower productivity, and factor productivity as a whole, increased ... Owing to the underdevelopment of the industrial infra structure the enterprise took pains to find ways of increasing its vertical integration. In 1944 it set up its own casting-shop and in 1945 created its own rubber-processing section".[28]

In their turn, A. Castaño and others state in the study on Turri S.A.: "Outstanding, in the first place, is the substantial investment placed in the construction and equipment of the new plant. It is interesting to note the way in which the plant was prepared to produce the new goods and then to enlarge its scale of operations. To begin with, the bulk of investment in machinery and equipment is earmarked for the machining section, with a twofold purpose: to increase production capacity and to improve the quality of the product". A little farther on in the same study it is explained that of the equipment incorporated at that time, the most important machines are the following: (i) a grinder, which makes it possible to quadruple the number of lathes per month that the plant can manufacture, at the same time improving the quality of the gears, a vital part of the lathes in question; (ii) a broaching machine, which takes over the work of a relatively old slotter that also represented a manifest bottleneck in the equipment of the old factory; (iii) a planning tool, which permits of appreciable improvement in the quality of the equipment manufactured, especially as regards the preparation of the engine-lathe bed.

[27] A. Castaño, J. Katz, F. Navajas, *op. cit.*, 1981.

[28] See H. Nogueira da Cruz, *op. cit.*, 1981.

It is also surprising that among the equipment incorporated at that time a set of special blowpipes appears, manufactured by the enterprise itself. This enabled the firm to introduce tempering of the lathe bed several years before its closest competitors, and thus to become an important leader in respect of quality in the domestic market.

To sum up: significantly to increase the physical volume of output and improve the quality of the product manufactured are initially the key objectives of the second phase described here.

Notwithstanding that in correspondence with these objectives the physical volume of output and the quality of the product make significant progress at the beginning of this second phase, it is a notable fact that for several years an optimum situation is not reached. Instead, the available evidence shows that complete digestion of this expansion process takes time and requires domestic technological effort both in the field of process engineering and in that of methods and organization of production. Once again the study on Turri S.A., is enlightening on this point:

"At the subsections level no instructions whatever as to methods and timing were given to the operative other than those provided by foremen or supervisors on the basis of their own experience. There was also a notable shortage of gadgets, masks and tools in every machining and assembly job, in addition to a marked lack of plans, routines to be followed, etc. At the level of the process as a whole programming tasks were carried out by the plant supervisor on very simple lines. The matter became more complicated when —with the increase in the scale of the enterprise— the planning of purchases and the follow-up of the product grew beyond the plant supervisor's power to cope with ... (yet) technical experts in method and programming were not to be incorporated until 1968". (Note that this is a date almost ten years after the introduction of the equipment mentioned in the first part of the preceding paragraph.)

In other words, the enlargement of the scale of operations and the improvement in the quality of the product manufactured which were implied in the expansion of the original artisan-type workshop called for an intensive equipment programme and the introduction of new skills and engineering routines. The global package of process engineering and organization and methods engineering technology which this involves is not available *ex ante* nor can it be obtained without an effort in respect of made-to-measure domestic technology. Some of these technological efforts must necessarily emanate from the plant engineering department itself, which will be responsible for the design and construction of devices and tools supplementary to the key equipment associated with plant expansion, as well as for the instruments of quality control, etc. Another part of the local technological effort will have to come from the organization and methods department —generally somewhat later in the evolutionary history of the 'type' establishment considered here— which will have to deal with time and motion studies, with systems of incentives to improve upon standard times, with control of stocks and, more comprehensively, with the global programming of the entire product operation.

The empirical evidence collected depicts this second phase in the history of enterprises as fundamentally associated with the expansion of the factory, which is far from being based on a harmonious programme. And on this account all sorts of technical imbalances and situations of disequilibrium are generated. It is precisely the process of 'digesting' this accelerated expansion that is covered by the third phase of a firm's evolutionary history.

'Digesting' plant expansion may take several years and require major adjustments in factor endowment and in the whole of the operational routine. The macroeconomic framework within which each individual firm operates is by no means unconnected with the speed and nature of this adjustment process. In the context of an expansionist situation where surplus demand exists, the 'digestion' of a significant increase in plant scale —see, among the studies carried out under the Programme the case of Aceros Chihuahua in the Mexican milieu[29] must necessarily differ from what happens in a scenario of recession. Examples of this latter type of situation may be seen in the Argentinean cases of Turri S.A. or Gherardi Hnos. during the 1966 depression, or in those of the Venezuelan plants manufacturing agricultural machinery –Rota-Agro and Nardi– when, in 1978, they had to face a sharp contraction in demand just when they had completed their respective plant expansions.[30] [31]

At all events, an interesting point, apart from the form and duration of the process of 'digesting' factory expansion, is that it calls for a considerable amount of technological effort both in the field of process engineering and in that of organization and methods engineering. It is also important to note that almost certainly the enterprise will have to formulate a strategy for tackling the various technical problems posed by its day-to-day operation and that this approach will be closely related, firstly, to the size, rate of recruitment and type of skills of the technical staff; and, secondly, to the nature of the activities and subprocesses undertaken, the equipment used, etc.

It is our impression that this approach strategy passes from the simple to the complex, and from machine-paced jobs –i.e., those for which technical information exists to indicate the theoretical standard of performance of the machine– to the labour-paced tasks which are more difficult to systematize. Similarly, the evidence collected suggests that the technical problems connected with the operation of the machinery, and with process engineering in general, are usually tackled before questions of organization and methods. The gradual embodiment of new specialities and skills in the firm's technical and engineering personnel reflects the existence of an evolutionary process of the type postulated here.

The fourth and last phase of the evolutionary sequence traced involves the growth and consolidation of organization and methods engineering. Once the plant can be classified as middle-sized, and the rapid incorporation of factors has been 'digested', further spectacular expansion can hardly be expected. This does not preclude the introduction of new equipment, especially in so far as it implies a higher degree of automation in specific subprocesses –welding, coil-winding of motors, etc.–, or the establishment of machining centres, whereby several subprocesses can be combined in a single machine; this at the same time raises the degree of automation of the operation as a whole. In our opinion, however, the key feature of this technological phase is the gradual expansion of technical effort aimed at rationalizing and optimizing the operation of the firm as a whole. Studies of 'families of parts'; the reorganization of the factory lay out by technological groups; studies of methods by sections, beginning with the machine-paced sections and moving on subsequently to those of assembly, which are much more labour-paced than the machining sections; standardization and normalization programmes; studies of optimization of stocks; the development of subcontracting, etc.; all these constitute the typical output of new engineering know-how produced by the organization and methods department in the course of this phase.

Up to a point this flow of technical know-how is of a 'disembodied' nature, but since putting it into practice often simultaneously entails the use of new and better equipment and/or the redesigning of the product, it is virtually impossible to separate the embodied from the disembodied part of the total technological progress achieved by the enterprise.

Hitherto we hace discussed the nature and characteristics of the technological changes –i.e., of all the modifications of the initial package of technical information– introduced in the course of time by the metal-working firms included in the present

[29] See A. Mercado, "Estudio sobre la Empresa Chihuahua", IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America (mimeographed text), Buenos Aires, 1981.

[30] See A. Castaño, J. Katz, F. Navajas, *op. cit.*, 1981; and J. Berlinski, *op. cit.*, 1982.

[31] See M. Turkieh, *op. cit.*, 1982.

sample. We have devoted particular attention to its sequential character –product engineering first, followed by process engineering and lastly by organization and methods engineering– and to the complex set of variables of a strictly microeconomic nature which affect the changes in question. We have shown that the development of engineering capacity in the establishments studied may be viewed as a succession of phases in which both the size and the composition of the staff of engineers and technicians at the firm's disposal are gradually modified as the requirements of 'digestion' first, and later of optimization of plant expansion, make it necesssary. This enables the firm to operate on the basis of an increasingly sophisticated and specific package of technical information. We have also shown that this succession of phases takes time and involves various kinds of learning of know-how in different branches of engineering. It means that the development of these firms must not be envisaged as a situation of dynamic equilibrium; rather is it characterized by errors of excess or defect, and their subsequent correction as the result of a new technological input emanating from the plant engineering departments.

Our description of the evolutionary process has concentrated hitherto on what has been observed in the manufacturing establishments studied. On their account we have paid less attention to another process likewise sequential, collateral to the one just considered, and closely related to it: i.e., the evolutionary process that is concurrently undergone by the market, in respect of its morphology and its climate of competition. As we shall see next, the development of plant engineering activities is not independent of what is happening in the sphere of the market.

Both the morphology of the market and the climate of competition prevailing in a specific branch of industry are subject to modifications through time. Two major 'type scenarios' can be described in the light of the information gathered in the various case studies on which the present article is based. The first of these corresponds to those situations in which a monopolistic régime was *initially* predominant. The motor-vehicle industry, or some of its subsidiary branches, exemplifies, in various Latin American countries, this type of original morphological conformation of the market.

At the very outset, the industry consists exclusively of a single producer, who is protected from external competition either by tariff barriers or by direct import prohibitions. Surplus demand exists in the domestic market, where periods of waiting for deliveries are chacracteristic. In the postwar years a situation of this type can be seen in various metalworking markets in Argentina and Brazil, while similar trends appear in Peru and Venezuela only in the 1960s and 1970s.

In view of these initial conditions, it is not surprising that during its earliest years the firm earns abnormally high profits, considerations of costs and/or quality taking no prominent place among its immediate concerns. Setting aside the moment of the plant's entry into operation, which may have required a significant amount of engineering efforts aimed at resolving problems of assembly, balancing of the production line in the case of continuous production, etc., it seems reasonable to assume that in these instances the firm's priority objective should be the attainment of a satisfactory level of utilization of installed capacity.

As the conventional models suggest, a situation of this type is apt to induce the entry of new producers into the market with an eye to the existence of differential profits. Such profits may likewise be conducive to rapid expansion of the installed capacity of the original firm. In each of these two cases, both the morphology of the market and the climate of competition prevailing in the branch of industry concerned will pursue a different path, and this will carry implications for the technological behaviour of the sector. Obviously, if new producers do actually enter the market the share of the original monopolist is bound to diminish. The climate of competition may or may not reflect this inflow of new producers. If external protection remains at a high level and the domestic market affords room both for the original firm and for the new enterprises, a division of markets may well occur without the participants' engaging in practice, in a competitive struggle which comes to be reflected in prices, quality, etc. Should the opposite happen, the pressure of competition may act as an inducement not only to engineering efforts aimed at reducing costs (and prices) but also to attempts at differentiating products, at broadening the mix offered on the market, and at improving not only the quality but also the 'age' or 'technological vintage' of locally manufactured designs.

The growth of plant engineering departments —and the incorporation of new skills in the professional and technical team— will indubitably reflect the market situation. Where the quality of the product, the output mix or the age or technological vintage of the product offered play a more important part than a price cut, design engineering may be expected to develop early, as described in previous pages. In contrast, in cases where the price-elasticity of demand is greater, and where the quality or age of the product do not assume so essential a role —as for example, in the case of simple machine-tools of a universal type used in repair and maintenance work— there are grounds for expecting a bigger relative effort in the area of process engineering, aimed at bringing down production costs and prices.

The picture would be somewhat different —as regards both market morphology and technological behaviour— if the original surplus demand were to induce expansion of the single plant existing at the beginning of the analysis, and a monopolistic régime were thus perpetuated. In this situation it is less feasible to expect efforts to be made in the field of design technology with a view to differentiating the product, broadening the mix or manufacturing newer vintages of the original design. Greater relative attention might be paid to process engineering and subsequently to organization and methods engineering, with the aim of taking advantage of the economies of scale implicit in the production process, or permitting more efficient plant utilization when under-utilization of equipment is due to technical problems, intersectional imbalances, etc.

As stated before, there are several branches of the Latin American metalworking industry which began to operate in monopolistic conditions and later gradually found themselves doing so in differentiated oligopolies. The available empirical evidence suggests that transitions of this kind may cover the history of a specific market for ten years (or more), during which period both market morphology and the climate of competition prevailing undergo a succession of changes. The scale and nature of the technological efforts undertaken by firms and consequently the development of engineering departments and the pattern of utilization of skilled human resources will be closely associated with the above-mentioned market characteristics. These, in their turn, will gradually alter in proportion —*inter alia*— to the technological efforts made by the different enterprises. Thus technological behaviour and market morphology and competitiveness simultaneously interact as mutual determinants.

The second of the two 'type' situations observed in the course of our field studies is initially characterized by the presence of various small and undifferentiated producers. The manufacture of agricultural machinery or of different types of machine-tools approximates closely to this typology.

The existence of various small and undifferentiated producers is not enough to warrant the assumption that there are competitive elements in the market. Both in the manufacture of agricultural machinery and in that of machine-tools, our research revealed the presence of a certain degree of 'natural protection' deriving from the geographical location, from the technological adaptation of the designs offered on the market, etc. The aforesaid fragmentation of supply and the lack of competitive elements are initial features of the market, preceding plant expansion on the part of any of the firms operating in it. In other words, since we have described the evolutionary history of the 'type establishment' as comprising four successive phases or stages, the second of which implies the rapid expansion of the factory, it should now be noted that this initial state of the market –in which the fragmentation of supply and the lack of competitive pressure are predominant– pertains to a point in time when all establishments are in the first phase or stage of their evolutionary sequence.

Factors exogenous to the market –partnership with a foreign investor, subsidized credit from the official banking system, an innovative success, generally in the area of product design, or some other equally fortuitous circumstance– seem to have helped to explain why at some time or other one of the several undifferentiated producers should have acquired a measure of preponderance over the group of metalworking establishments, and thence moved on into the second phase of its evolutionary history, through the rapid expansion of its factory.

As we have already seen, plant expansion implies both an increase in the physical volume of output and an improvement in its quality, the latter by virtue of the incorporation of new and better capital equipment. Consequently, in the first place, the initial morphology of the market is bound to change inasmuch as there will be an increase in the relative share of that one-time small-scale and undifferentiated producer who is most beforehand in undertaking the expansion of his factory. Secondly, and simultaneously, the better quality made viable by the new equipment will consolidate the position of leadership which the producer concerned will be able to establish. This change in the morphology of the market does not necessarily involve –at any rate straight away– a greater pressure of competition in the industry. Firstly, if there is surplus demand on the market or if, concomitantly with the increase in supply, demand is rapidly growing –as happened in the case of many of the metalworking industries associated with the introduction of the motor-vehicle sector in countries such as Argentina, Brazil, Mexico–, the above-mentioned plant expansion can be absorbed without its meaning that the said increase in supply must necessarily displace established producers. Secondly, given the improvement of quality attained in conjunction with plant expansion, it may feasibly be assumed that the leader enterprise will cover the more sophisticated segments of demand, leaving the rest to the group of small and undifferentiated firms. In either case, however, competitive pressure is bound to build up as the years go by; and this for several different reasons. Firstly, because it is not unlikely that other producers may attempt to expand their own plants, attracted by the existence of surplus demand or of differential profits in the more sophisticated submarkets. Secondly, because in cyclical downturns the leading producer will probably cope with the slump in demand in his own submarket by invading those of the smaller enterprises, even at the cost of lowering quality or modifying the output mix offered, as can be seen in the study on agricultural machinery carried out in Argentina.[32] Thirdly, because of the gradual dissemination of technical information throughout the branch of industry concerned, which will gradually erode the technological advantages of the leader enterprise. In particular, those advantages that do not depend upon new equipment on a massive scale will be bound to spread in a few years' time to the whole group of firms making up the industry.

For each and all of these reasons –entry of new producers or expansion of those already in existence through the broadening of the output mix, slumps in overall demand in cyclical recessions, gradual diffusion of technical information throughout the industrial branch, etc.–, the pressure of competition may reasonably be expected to increase through time. Thus, in the first place, the morphology of the market is bound to change when the most advantaged producer expands his plant, and, secondly, the climate of competition prevailing in the industry will likewise alter in relation to the above-mentioned variables. Accordingly, the initial situation characterized by the presence of various small and undifferentiated

[32] See. J. Berlinski, *op. cit.*, 1982.

producers, faced with little regular and systematic pressure from competition, ultimately becomes, in the course of time, a differentiated oligopoly, similar in several respects to the case previously discussed.

Here, again as in the preceding case, we must expect a clear connection between the technological behaviour pattern of enterprises and the morphology and competitiveness of the market. The two latter conditions will affect, and be affected by, not only the rate of development of plant engineering departments —including here the nature of the firm's new technical activities and professional skills and the pace at which they are introduced— but also the relative importance attached to engineering efforts bearing on the quality of the product or the breadth of the output mix *vis-à-vis* those others that are concerned with ways of reducing costs (and prices).

Here we conclude our study of the relation existing between market variables and the technological behaviour of individual firms. Hitherto we have devoted attention first to what is strictly specific to the individual enterprise —i.e., to the microeconomic determinants of the evolutionary sequence followed by a given firm's engineering capacity—, and, secondly, to market variables —morphology and competitiveness— as forces influencing the said sequence. At the macroeconomic level, too, messages are recurrently generated which have repercussions on the technological behaviour of entrepreneurs. In the framework of the IDB/ECLA/IDRC/UNDP Programme, we have had an opportunity to record technological responses to various incentives deriving from official policy, whether concerned with technology or with other matters. Some of these responses are summarized below.

Instruments of economic policy aiming at the management of aggregate demand —exchange, credit, fiscal, monetary measures— influence the technological behaviour of firms both in the demand side and, in some cases, on the supply side. Let us take a quick look at both situations.

A policy of expansionist (or recession) throughout the whole of economic activity indubitably unleashes trends in the same direction —although not necessarily on the same scale— in individual markets. Several of the studies carried out under the Programme show that a common recourse in periods of recession is to launch new product designs, of a realtively less sophisticated and more multi-purpose character.[33] Similarly, another typical reaction to a recession consists in reducing the subcontracting coefficient, and bringing back into the firm subprocesses or activities that had been handed over to third parties in times of normal operation.[34] Conversely, the expansionist phase of the cycle —often associated with fiscal and credit policies that subsidize equipment— seems to be linked to an opposite trend in respect of subcontracting and to the launching of new products with a higher level of complexity and sophistication.

It seems needless to point out that any reaction which implies changing the output mix —*inter alia,* recourse to the launching of new designs not necessarily available in the firm's output records—, altering the degree of vertical integration, substituting subprocesses (to enhance the quality of the product manufactured), etc., involves correcting the plant operation routine, the machine-load chart and, more generally speaking, the organization of the production process. Each of the engineering functions —product design, process and organization engineering— is required to play a part in a contingency of this type, until a new operational routine has been established. In other words, the firm will necessarily reflect at the technological level —among others— its reaction to the displacement of the demand curve that results from a programme corresponding to expansion (or recession) in the economy as a whole.

Some of the instruments for the management of aggregate demand —for example,

[33] See J. Berlinski, *op. cit.*, 1982. Also A. Castaño, J. Katz, F. Navajas, *op. cit.*, 1981.

[34] See J. Berlinski, "Innovaciones en el proceso y aprendizaje en una planta argentina de fundición", *Working Paper No. 45*, IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, April 1982.

the rate of interest or the exchange rate— also have repercussions on the technological behaviour of firms on the supply side, inasmuch as they increase (or lessen) the costs of plant equipment and organization programmes, of maintaining inventories of parts, etc. Our field research is enlightening at this level too. The rise in interest rates induced Turri S.A. —like many other metalworking firms in Argentina— substantially to curtail the duration of the production cycle, while at the same time it led to the postponement of equipment programmes and the stepping-up of efforts to rationalize the production process. The latter included work on standardization and normalization in the area of design, application of the technological groups and 'families of parts' methodologies with the aim at increasing batch sizes, etc. In this sense, the rise in the interest rate may be said to have induced the substitution of local engineering effort for new equipment.

The exchange rate in its turn also seems to be related with plant equipment and modernization programmes, especially in so far as these imply the incorporation of imported equipment. In this connection, there are several technological implications that we have been able to observe in the course of the studies carried out. In the first place, it is clear that the gradual reduction in the cost of foreign currency has influenced the propensity of firms to automate specific subprocesses, particularly in the machining area, where the introduction of numerically controlled equipment figures as a recent trend in the Latin American scenario. [35] We had occasion to remark earlier on the demand for engineering efforts relating to 'digestion' of the plant expansion process in the transition from the second to the third phase of the evolutionary sequence described in the present article; something similar occurs as a result of the trend towards automating specific subprocesses by the incorporation of numerically controlled equipment. We have noted in several of the studies carried out that the machining centres, the numerically controlled equipment, etc., introduced in response to the relative fall in their prices require their own 'digestion phase'. This, of course, must be thought of as closely associated with made-to-measure engineering efforts corresponding to the specificity of the plant incorporating the automatic equipment in question. The study on Perkins Argentina sheds a great deal of light on the subject of the 'digestion' of numerical control and machining centres, although this is obviously not the only case in point covered by the present research.[36]

Apart from policies relating to the management of aggregate demand, there are many other public policy instruments which in one way or another influence the technological behaviour of enterprises, and have repercussion on both the amount and the nature of the engineering efforts tackled by individual firms. Among these, mention should be made of all the sectoral instruments that affect: (i) the rate of investment; (ii) the climate of competition; (iii) the framework of regulations; (iv) the greater or lesser ease with which advantage can be taken of externalities deriving from public R&D work —done by universities, official laboratories,[37] etc.— that are prevalent in a particular market.

As in the case of the instruments of macroeconomic policy mentioned above, these measures of a more sectoral nature, but also emanating from the public authorities, undoubtedly influence the process

[35] See S. Jacobsson, "Technical Change and Technology Policy. The Case of Numerically Controlled Lathes in Argentina", *Working Paper No. 44*, IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, March 1982.

[36] See J. Berlinski, "Productividad, escala y aprendizaje en una planta argentina de motores", *Working Paper No. 40*, IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, August 1981.

[37] With reference to the study on Gherardi (J. Berlinski, *op. cit.*, 1982), special mention should be made of a complementary paper by the same author, "Algunas notas sobre los usuarios de maquinaria agrícola, el Instituto Nacional de Tecnología Agropecuaria (INTI) y la Comisión para el Desarrollo de la Maquinaria Agrícola (CODEMA)" (mimeographed text), Buenos Aires, January 1982.

of technological exploration that takes place within a given industrial firm.

Here we close the present section, of which the object has been to review, even though only provisionally, the material collected in the course of the various field studies carried out under the IDB/ECLA/IDRC/UNDP Programme on technological change in the metalworking industries of several Latin American countries.

In the two following sections —the last in this paper— we shall use the material reviewed up to now as the basis of a body of considerations both in the theoretical domain of industrialization and dynamic comparative advantages, and in that of economic and technological policy in the field of the manufacture of metal products and machinery.

III
Protection, technological behaviour patterns and maturative phases in the area of Latin American metalworking production

The material presented hitherto depicts a 'type' enterprise and a competitive scenario bearing little likeness to the conventional images usually formed on the basis of textbooks. In neoclassical tradition: "Firms are the key productive actors, transforming inputs into outputs according to a production function. The production function, which defines the maximum output achievable with any given quantity of inputs, is determined by the state of technological knowledge. Technological knowledge is assumed to be public, or at least this is implicit in models based on an industry or an economy-wide production function. Firms choose a point on their production function to maximize profits, given product demand and factor supply conditions. Generally these markets are assumed to be perfectly competitive, so that a firm treats prices as parameters... Over time output grows as inputs increase and firms move along their production functions, and as technology advances. ... There clearly are some strong presumptions here. The view of firms and markets is very stylized —not much room for incompetent management ...or oligopolistic rivalry. Technological advance, while acknowledged as a central feature of growth, is treated in a very simple way, and the Schumpeterian proposition that technological advance (via entrepreneurial innovation) and competitive equilibrium cannot co-exist is ignored".[38]

In contrast to so stylized a microeconomic world, the empirical evidence presented suggests that the metalworking sector which we are studying is characterized by: (i) disequilibria and periods of 'digesting' them that are more or less prolonged and complex, depending upon the general macroeconomic context; (ii) by firms that go ahead with innovating and improving their relative position in the market, while others suffer failures and lose ground, or simply drop out altogether; (iii) by entrepreneurs that are better off for information or financing than others; (iv) by different technological strategies even in one and the same market —firms that systematically innovate as against others that systematically imitate; (v) by technical and engineering teams of different quality; and, above all, (vi) by radical changes through time in the relative position of the firms operating and in the climate of competition prevailing in the market.

Whereas in the neoclassical world there are, as R. Nelson says in the study quoted above, few interesting questions that can be

[38] See R. Nelson, "Research on Productivity Growth and Productivity Differences, Dead Ends and New Departures", in *Journal of Economic Literature*, Nashville, Tennessee, September 1981, p. 1031.

explored and settled by studying the behaviour of individual firms, in a world such as that depicted by the material presented in the foregoing pages, the subjects that must be approached by studying the inter-firm differences in behaviour are many and complex. First and foremost we shall attempt to construct a typology of metalworking enterprises to assist us in the task of describing differential behaviour patterns in the markets concerned.

Several 'ideal types' of firm emerge from our investigation and can be described in terms of the following characteristics.

1. *The family enterprise, based on the mechanical ability of an individual (or group of individuals)*

This type of productive organization is characterized by the narrowness of its sphere of reference and by the predominance of a number of extra-economic criteria in its day-to-day operation, at least during the first two or three decades of its existence. A strong propensity to self-sufficiency and self-financing, the preponderance of skill in mechanics and design over capacity for the organization of productive activity, the application of extra-economic criteria in the recruiting of technical personnel and the selection of equipment (loyalty to the original nationality of the owner, or to relatives in the case of immigrant entrepreneurs),[39] one-man management with paternalistic criteria, etc., are all typical features of firms in this category.

Perhaps a somewhat more careful scrutiny of this 'ideal type' should lead us to recognize the existence of moments or phases within the group in question. In this sense, we should probably differentiate family enterprises that have already undergone an 'opening-up' process and a change of generation in their management cadres, from those others that are still rigidly subject to the original family hierarchy. Whereas the former are sure to be characterized by a higher degree of professionalization --deriving from the incorporation of "the generation of engineers, lawyers and graduates in business administration"[40] in their management teams–, the latter probably still retain something of the Schumpeterian 'animal spirits' that characterized the elder generation. In each of these two cases we must expect different attitudes towards taking risks, towards the relative evaluation of technical and mechanical aspects as against business and financial matters, to specialization in the domestic market *vis-à-vis* the external market, etc.

The material gathered highlights another interesting subject likewise relating to the family-enterprise group: this time, a cross-section not by age or generation of the management teams but by differences in the behaviour of firms of this type in relation to the country where they are operating. In this connection it is worth while to point out that –doubtless in response to the larger absolute size of their domestic market and the more stable and favourable framework of overall economic policy in which they have had to operate– the family-type firms located in Brazil exhibit a stronger propensity than their counterparts in Argentina or Mexico to (i) advance towards international plant scales; (ii) spend on R&D activities; and (iii) seek access to international markets.

We shall revert to these topics a little farther on when we refer to possible measures in the field of public policy.

2. *Subsidiaries of foreign firms*

Obvious as are their efforts at mimetic assimilation with the local environment,[41] firms of this type differ significantly from

[39] A similar case has been described in the bibliography of recent years in relation to the extra-economic ties underlying the movement of capital, technology, etc., between Hong Kong, Taiwan and Continental China.

[40] See H. Nogueira da Cruz, *op. cit.*, 1981.

[41] These efforts at mimetic assimilation have already been identified by other researchers, not only in the Latin American environment but also in remoter contexts, such as, for example, Southeast Asia. See B.I. Cohen, *Multinational Firms and Asian Exports*, Yale University Press, 1975. In his study on the Brazilian case Helio Nogueira da Cruz says:

the preceding category as productive organizations. To begin with there are the initial differences in technological, financial, organizational and other respects deriving from their structuration as an appendage to their parent firm. These differences, which may be an important asset when they are turned to good account, may also become burdensome hindrances and constraints when it is not understood that the operational norms and standards proper to developed countries must necessarily pass through a period of acclimatization and adjustment which will be all the more prolonged and complex, the more specific is the recipient environment.

Apparently acclimatization difficulties are greater in the case of industrial plants designed for continuous-process production on a production-line basis. An unduly broad specification of the output mix, or an attempt to maintain a high degree of flexibility in the production line —an attempt undoubtedly motivated by the small size of the domestic market and the need for diversification which it implies— have permitted an initial misuse of this particular form of organization of the production process.

In addition to the initial differences relating to the typology discussed above, there is also the fact that over the years the firms that are subsidiaries of transnational corporations continue to have access to the resource pool of the parent firm, but generally enjoy less freedom of decision and elasticity of movement than local enterprises. In a variety of particular submarkets this situation has enabled national concerns —of family origin or others— gradually to strengthen and consolidate their position, especially when innovative agility of mind is a key feature of the operation of the market.[42]

3. *Public enterprises*

Although there are not many cases of metalworking production in the hands of public enterprises that we have had occasion to look at in the course of the present Research Programme, they obviously constitute a type of enterprise different from those described above. As is suggested, for example, in the study on Forjas, Colombia,[43] it is reasonably safe to assume that when the State acts as a producer, there may well be an association between public ownership and the original selection of technology, the timing and nature of new investment, the magnitude and duration of situations of disequilibrium, the manner of coping with the process of 'digesting these', etc.

As in the other two groups mentioned above —family firms and local subsidiaries of transnational corporations— the public enterprise constitutes a typology with objectives and constraints of its own, little resembling those of the other 'ideal types'.

Viewing the field of metalworking production in Latin America, it may be observed that certain branches of the industry —for example, production of agricultural machinery or machine-tools— are typically composed of family-type firms, with many of the characteristics previously attributed to this 'ideal type'. Others —for example, the motor-vehicle industry or the manufacture of tractors— comprise almost exclusively subsidiaries of foreign firms and, lastly, a third category —the manufacture of parts for passenger cars, for example— combines enterprises of both types. Given such heterogeneity as regards firms, it is difficult to accept that a single model of 'the' firm —for instance, the conventional

---

"The fact is that production and market conditions compelled these firms (the foreign ones) to adapt to local patterns". See "Observaçoes sobre a Mudança Tecnològica no Setor de Máquinas Ferramentas do Brasil", *Working Paper No. 47,* IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America, Buenos Aires, May 1982, p. 35.

[42] An interesting example of greater innovative agility in the group of family firms than in the sector consisting of subsidiaries of transnational corporations can be seen in the case of the Argentinean pharmaceutical industry. See J. Katz, *Oligopolio, firmas nacionales y empresas multinacionales. La industria farmacéutica argentina,* Buenos Aires, Siglo XXI, 1974; and J. Katz, "Estadios de desarrollo e industria químico-farmacéutica", in *Desarrollo Económico,* Vol. 21, No. 83, Buenos Aires, October-December 1981. See also Helio Nogueira da Cruz, *op cit.,* 1982, pp. 23 and 24.

[43] See D. Sandoval *et al., op. cit.,* 1982.

neoclassical paradigm– could prove equally useful as a research instrument in all cases. Similarly, in our opinion, rather than eliminating inter-firm differences *a priori* on the basis of more or less restrictive assumptions –for example, equal access to information, the presence of a perfect capital market, etc.– it is more appropriate in some cases to construct alternative behaviour models which explicitly incorporate these differences, since with them the real operation of the market is probably closely linked.

So much for the matter of 'the' typical metalworking firm. Equally serious doubts arise when we have to introduce assumptions relating to the firm's objective-function –maximization of profits, margin of profits over costs, share in the market, etc.–, and to the look of the competition current in the market. While in this last connection we have had occasion to discuss in earlier pages the changeability of the climate of competition predominat in many of the metalworking markets studied, as regards the objective-function of the enterprises considered, it can hardly be assumed that in extremely imperfect markets, protected against external competition, and operating with multiproduct and multiprocess plants displaying varying and generally high degrees of underutilization of the available equipment, firms will do much more than resort to general indicative parameters –rules of thumb– in their adoption of decisions. In a great many cases, the intra-plant information system we have found would barely enable the firm to calculate some simple indicators of costs and productivity per hour on which to base its day-to-day operation.

In short, the neoclassical paradigm seems too simplistic to further our understanding of the behaviour of firms in the Latin American metalworking scenario. The existence of several different types of firms within the sector, with dissimilar objectives, organization and constraints, with varying access to technical information and to factor markets, etc., plus a climate of competition changing through time, a macroeconomic scenario overloaded with imperfections, a high level of protection, etc., seem to us essential features that any exploratory attempt to shed light on long-term trends in this sector of production ought necessarily to take into account.

On the basis of this reformulation of the conceptual framework within which we consider that the study of the Latin American metalworking sector may usefully be approached, let us now return to the subject of technological change, its sources, nature and implications, and endeavour to analyse the long-term role played by this sector in Latin American industrialization. In other words, given the various types of firms comprised by the sector, the features assumed by competition and what we now know of the evolutionary stages or phases of the typical metalworking establishment, it seems desirable to revert to the time-honoured –but not yet settled– question of protection, dynamic comparative advantages and the pattern of industrialization. In our opinion, the empirical evidence gathered gives us something new to say on the time that protection should last, as well as on the criteria in the light of which the maturative process of a firm or an infant branch of the industry must be judged.

Although the body of literature assembled does not prove that the pattern of industrialization is in any sense accounted for by the pattern of protection, there is little doubt that protection in itself induced industrial development. This idea is clearly expressed by J. Bhagwati and T.N. Srinivasan in their well-known article on "Trade policy and development", when they say that although it is in fact true that protection for the manufacturing sector *in toto* buttresses the industrial development of the relatively less developed countries (RLDC), it does not thence follow that the pattern of industrial production is explained by the pattern of protection, as this is measured in the RLDC (these authors are referring to the case studies on effective protection carried out under the NBER Project in 1975 and 1976, and covering Turkey, Israel, the Philippines, Ghana, South Korea, India, Egypt, Colombia and Chile).[44]

[44] See J. N. Bhagwati and T.N. Srinivasan, *Trade Policy and Development ...*, *op. cit.*, 1978, pp. 1-38.

Once the premise is granted that protection eventually causes a budding industry to spring up where it did not exist before, several new questions arise. Among them: In what conditions is protection justified to induce the development of an industrial sector? How much protection must we provide, and for how long? To what end? All these questions bring us back to the essence of the 'infant industry' argument, as it appears in the work of John Stuart Mill, and thereafter throughout the writings of the classical school.[45] We shall tackle the analysis on the basis of two kinds of material: firstly, the theoretical argument on protection, returns to scale, etc., mentioned in the passage referred to above; and secondly, the empirical evidence collected in the course of the present research programme, which will be used as a background of reference for the discussion that follows.

In what conditions is protection justified for the sake of developing a branch of industry? Mill's reply speaks of 'naturalizing' a foreign industry. But, according to him, this industry must be adapted perfectly to the country's circumstances. The country concerned should preferably be young and expanding, and protection should be temporary. The principle is valid when the only difference between the country in which the industry already exists and the country which wishes to acquire it centres in the individual experience and level of skill of their nationals, so that the superiority of one or the other country is only a question of the acquisition of this experience or level of skill, to which process there are presumably no obstacles other than the cost of learning itself.[46]

What is meant by an industry's being adapted perfectly to a country's circumstances? The above-mentioned study by R. Soifer clarifies this point, re-creating Mill's line of argument: the country introducing the new branch of production should ultimately become better fitted for that activity than the society where it originally came into being.[47]

In the foregoing pages of the present paper plenty of light has been shed on the main features —technological, organizational, etc.— of the industry of whose 'naturalization' in Latin America we are speaking here, i.e., the metalworking industry. We know, for example, that this is a branch of production in which it is possible to identify continuous-production plants, organized on a production line basis and highly automated, together with discontinuous-production workshops, producing small batches or even custom-made items, 'made to measure' for the individual buyer. We also know that between the two modes of organization of the production process there is an enormous difference in respect of scale economies, relative incidence of dead time, etc. Furthermore, we have learnt that this industry is made up of a large number of family-type firms, subject to specific rationale criteria, along with domestic subsidiaries of transnational corporations which operate on the basis of the package of technological information provided by the parent firm concerned, and with a greater or lesser degree of flexibility and adaptation to the scenario of the recipient country. It is not worth while to lay further stress here on other structural features of the metalworking industry, regarding which enough information has been furnished in earlier pages.

It is this industry —not a hypothetical sector of production deriving from the neoclassical paradigm— which is to be naturalized in the Latin American context. We should therefore ask ourselves in what conditions the various organizational and enterprise typologies that characterize the sector in question can 'be adapted perfectly' to the circumstances of the recipient societies, so that once the cost of training and

[45] In the course of the following pages we shall cite an unpublished study by Ricardo Soifer, who rigorously analyses the discussion on protection and infant industry in "Some Aspects of Trade, Development and Protection", London, September 1978. J. S. Mill's argument appears in *Essays on Some Unsettled Questions of Political Economy*, Essay I, London, 1844 (reprint).

[46] Mill, *op. cit.*, according to R. Soifer, *op. cit.*, 1978.

[47] Mill, *op. cit.*, according to R. Soifer, *op. cit.*, 1978.

learning of know-how has been covered –i.e., once domestic technological capacity has been developed– the resulting industrial firms could continue to operate on a competitive footing without requiring additional support.

The material gathered in the course of the present Research Programme enabled us to formulate the concept of maturative stages or phases in the evolution of a 'type' metalworking plant. On the basis of this concept it should be possible, in our opinion, to confer a concrete meaning –useful, therefore, for the purposes of designing instruments of public policy– on the idea of acquisition of domestic technological capacity –accordant with received theory– by a given industrial enterprise (or branch of production). We have argued that a complete maturity sequence can be defined as permitting the development and consolidation of the different plant engineering departments –i.e., product design engineering, plant (or process) engineering *per se*, and the organization and planning of production. Various studies show this maturation process to require that the firm be joined by a considerable number of professionals and technicians with different specialities and levels of skill, ranging from the expert in design engineering to the specialist in organization and methods. The same studies indicate that it often takes two or more decades for a given firm to work its way through the complete cycle.

Not all the countries studied under the present Programme nor all the organizational patterns adopted by the metalworking industry have successfully completed the maturative cycle. On the one hand there are those branches of metalworking in which production is continuous and is organized on a production-line basis both in countries of the developed world and in the Latin American scenario. In this subgroup of metalworking branches, the firms examined here reveal results that differ widely when different countries are compared: firms in Brazil, for example, are much more successful than those installed in Argentina or Colombia. On the other hand, we find metalworking plants organized, both in Latin America and in the developed world, on a workshop basis and producing to meet individual orders. This is a set-up quite different from the foregoing case, and therefore in order to analyse whether protection to enable the internal maturative sequence to proceed is or is not justified, other variables and arguments must be invoked. Lastly, there are also those sectors of metalworking production in which plants in the developed world operate on a continuous production-line basis, while Latin American establishments do so in discontinuous-process workshops organized to produce in small batches. These situations, too, call for independent consideration of whether it is or is not reasonable to protect domestic development of the industry, since the probability of nationalizing it after a certain number of years depends upon variables that differ significantly from those figuring in the preceding cases.

First and foremost, let us take the continuous-production branches of metalworking. Here the Brazilian situation calls for remark. Among the several production-line enterprises studied under the Programme, two Brazilian firms are those most closely approaching results favourable to the protection thesis. These are Romi, producing conventional engine lathes, and Metal Leve, manufacturing pistons. In these instances the firms studied: (i) have progressed towards international plant scales, introducing production line principles in branches where it is this form of organization of production that prevails in the developed world; (ii) have strikingly expanded their research and development efforts, closely approaching the international frontier of technology; and (iii) have significantly increased their exports to international markets, actively competing in countries of the developed world.

There seem to have been three reasons why the above-mentioned firms were relatively more successful than their counterparts in Argentina, say, for example, Turri S.A. and Perkins Argentina. In the first place, the great size and dynamism of Brazil's domestic market, whith its high and steady rate of growth over several decades (setting aside brief spells of contraction) have enabled the firms to rely on a large and protected domestic market on which to base their expansion. Secondly, and this perhaps in consequence of the foregoing circumstance, in both cases there is a definite propensity to install plants on an international scale —a tendency absent in other countries of the region— which has made it possible for adequate advantage to be taken of economies of scale. Lastly, there is the important fact that both firms are operating in branches of industry whose world technological frontier has not been advanced by very spectacular leaps and bounds in the last few decades; this has permitted a gradual closing of the relative gap existing between the firms in question and their counterparts in the developed world.

In other words, where the size of the domestic market has allowed of the establishment of plants on an international scale —which do not suffer from disadvantages of size in relation to enterprises in developed countries— for the purpose of manufacturing metalworking products whose world technical frontier has not been very rapidly extended through time, an official policy of protection, systematically maintained for several decades, may well be justified in so far as it not only enables firms to nurse along a vigorous process of capital formation, but also promotes the consolidation of a satisfactory level of domestic technological capacity.

It is important to note that, as the classic 'infant industry' argument contends,[48] what we have said in the preceding paragraph assumes the state of the art to be given and constant at the international level. If we admit that in reality it is perpetually changing —the numerically-controlled lathe tends partly to supersede the conventional engine lathe, and the same thing happens with pistons manufactured on he basis of new metal alloys— the situation becomes more complicated and calls for a dynamic analysis which takes into account these changes in the state of the art. In the first place, if the 'new' product is not a perfect substitute for the 'old' one —i.e., if there is still a sufficient market for the 'mature' product— there is no reason why its manufacture on a production line basis should encounter problems, even if the same firm does not tackle the manufacture of the 'new' product, but specializes exclusively in the 'mature' product. In terms of the Brazilian case, as long as demand (national or international) for conventional lathes and pistons subsists, our previous opinion as to the justification of protection in both situations does not seem to come up against any difficulties.

A further dynamic question rises when we postulate that sooner or later the mature product should disappear altogether and be entirely superseded by the new product. In this event, it may happen that the development of domestic technological capacity stemming from the production of the mature good has given rise to a set of technological specialities and skills which are not necessarily the most appropriate for closely following (or even leading) the process of change in the world frontier of technology. This latter may well call for a different group of technological skills which the production of the mature good perhaps does not afford (or require), or does so too partially and inadequately for the firm to tackle the transition from the mature to the new products.

Something like this, we think, is happening in the case of Romi, Brazil, in its transition from conventional engine lathes —an area where the firm has successfully traversed the various stages or phases of the maturative sequence— to numerically-controlled lathes, where apparently the firm has recently come up against technological difficulties which led it seriously to consider the necessity of operating on the basis of an Italian licence. The State has again intervened in this instance, once more raising the issue of the need to grant protection to a new maturative sequence, this time in the field of numerical control. Clearly, the case is somewhat more complex than that posited by the classic argument. Must

[48] See, for example, M.C. Kemps, "The Mill-Bastable Infant Industry Dogma", in *Journal of Political Economy*, February 1960. (Quoted by R. Soifer, *op. cit.*, 1978.)

society shoulder the burden of protecting a succession of maturative sequences to prevent a reopening of the technological gap which has been successfully closed in respect of a given product, or should it be the profits of the first maturative cycle that finance the dynamics of the process? To this and to other associated questions we shall revert in the last section of the present paper, when we refer to matters of official policy.

As regards the other metalworking establishments organized on a production-line basis that are studied here –i.e., the non-Brazilian firms in the present sample– there is virtually not one that can be viewed as favourable to the infant industry thesis. Clearly, in each and all of them the various forms of domestic technological capacity have appeared and developed –Perkins Argentina or Sofasa, Colombia are cases in point– while at the same time export capacity has expanded, although the exports concerned are to 'captive markets' in the multinational integration framework of their respective parent firms. Nevertheless, whether because they are local subsidiaries of transnational corporations, whose original design and location were directed towards satisfying the domestic market, or because they imply plant sizes and modes of organization of production relatively far removed from international standards, or because they have less operational flexibility than the firms owned by domestic capital which were examined above (Romi and Metal Leve), the fact is that these production-line establishments are a long way from constituting examples of successful naturalization in the Latin American environment.

The situation changes appreciably when attention is turned from continuous production organized on a production-line basis to workshops producing small batches or custom-made items to meet individual orders.

Let us consider first the case of production of custom-made items, or to meet individual orders, which is undertaken in discontinuous workshop-type plants, both in the developed world and in the relatively less developed countries. It was previously shown that metalworking industries of this kind involve much greater heterogeneity of output, a far less important role for intra-factory scale economies, a certain degree of natural protection –deriving from the heterogeneity of output and the specificity of the customer–, etc. It is in this new setting that we must endeavour to ascertain whether protection is or is not justified in terms of the probability of naturalizing this specific form of metalworking production in Latin American scenarios.

Whereas in discussion on the foregoing case –production lines– market size and its relation with the viability of installing industrial plants on an international scale were the heart of the matter, here a crucial role is assumed both by the development of design engineering and by the complexity of the available equipment. Reference is intended here to metalworking plants required, for example, to produce complex equipment for nuclear or hydroelectric power houses and power stations, large turbines and generators, heavy boiler equipment, etc.; these being establishments in which design capacity and the possibility of moving and machining big and highly complex parts impose a number of minimum requisites on the necessary equipment and the team of design specialists required.

Here there are two problems: one relating to the minimum scale of operations on the basis of which the unit incidence of design department costs can be kept low; and one connected with the quality and complexity of the equipment –numerically-controlled equipment, machining centres, etc.– needed in order to tackle certain types of job characterized both by their complexity and by the high level of tolerance required.

In other words, in metalworking plants of this type the possibility of naturalizing the industry in the Latin American context depends decisively on the viability of creating and developing a good design and project engineering office and, at the same time, operating with plant at a high level of technical complexity. For both reasons the plants concerned are skilled labour-intensive, and it is precisely the supply of such manpower that is the main constraint as regards the installation of metalworking establishments of this kind.[49] Such countries as Argentina, Brazil, Mexico and Colombia must be regarded as those for which, in the Latin American context, it should be relatively easiest to naturalize satisfactorily a metalworking industry of this type.

Yet another additional remark seems to be justified in this field. The leading customer for the metalworking products manufactured by industrial plants of this type is undoubtedly the public sector, through basic infrastructure works; and it is this sector whose demand can provide a stable prop for the activity of a project engineering department of adequate size and level of specialization. This is a matter of official policy to which it will be appropriate to revert in the final pages of the present article.

Worthy of careful consideration is the desirability of maintaining in the Latin American context a third type of metalworking industry, i.e., that in which the region's production is organized on the basis of small batches and in workshop style, whereas developed countries increasingly tend to organize their corresponding production on a production-line basis. As in the preceding cases, what is of interest here is to evaluate how far it is admissible to resort to protection as a means of promoting the naturalization of the industry, even with the *a priori* knowledge that local production will labour under manifold disadvantages arising out of its different organizational arrangement.

Two facts play an important role in situations of this type, over and above the conventional differences in relative factor prices, which may in themselves wholly or partly offset the above-mentioned disadvantages.[50] We are referring, in the first place, to the degree of natural protection to which allusion has already been made, and which may often be found in given items of metalworking production, such as, for example, a harvester or other agricultural equipment entailing a more or less exacting task of technological adaptation to the specific environment in which it will be used. Secondly, in recent years substantial progress has been made in the application of techniques and methods of organizational engineering —such as studies of 'families of parts' or manufacturing organization by technological groups— allow of considerable gains in respect of scale economies in the framework of limited production on an essentially discontinuous basis.[51]

In some specific branches of the metalworking industry the sum of a measure of natural protection plus adequate exploitation —in terms of organization and methods engineering— of the economies of scale implicit in discontinuous technology may result in a successful naturalization of metalworking plants producing in small batches. Cases in point are some of the agricultural machinery plants studied under the present Programme. Of course, it is not a logical necessity that this should happen. We are speaking here of a relative difference in respect of the production function of a plant organized on a production-line basis —such as operates in markets in the developed world—; accordingly, where the disparity in scale economies between the two types of manufacturing organization permits, i.e., in that branch of metalworking in which the

[49] It must be noted that a contemporary trend in metalworking plants in the developed world which manufacture products of this kind is that of the introduction of Computer Aided Design Systems (CAD), which substantially changes the work of the design department, substituting micro-electronic technology for specialists in design. The subject gives rise to a series of interesting questions. Some of these relate to the desirability of substitution between capital and labour in environments where different relative factor prices prevail. Others, posed by the incorporation of CAD, concern the time required for the work of design and its incidence on the competitive capacity of a given firm. Lastly, it should be borne in mind that the introduction of CAD is now beginning to spread in Latin America, as we are told by R. Kaplinsky in a recent study. See R. Kaplinsky, "The Technological Gap betweeen DCs and LDCs: Computer Aided Design" (mimeographed text), Institute of Development Studies, University of Sussex, Brighton, Sussex, 1981; and "Trade in Technology, Who, What, Where and When? " (mimeographed text), Institute of Development Studies, University of Sussex, Brighton, Sussex, 1982.

[50] See H. Pack, *op. cit.*, 1979.

[51] E.A. Arn, *Group Technology, op. cit.*, 1975.

said disparity is not very wide,[52] the viability of naturalizing the industry in the Latin American context must not be dismissed *a priori.* And conversely, where the difference is really substantial, an attempt to force naturalization of the industry by means of protection may lead to a situation patently suboptimal from the social point of view.

To sum up: we have shown, in the first place, that the metalworking branch of industry is formed by at least three different segments –production lines, production in small batches and production of custom-made items or to meet individual orders. Secondly, that the feasibility of naturalizing a given branch of industry which can be installed or developed under the aegis of protection, depends upon: (i) the relative gap existing between the organization of the production process in the developed economies and in the relatively less developed countries; and (ii) the learning of technical know-how in each of these contexts.[53] Following on all this, we have offered empirical evidence to substantiate the idea that, setting aside specific cases in Brazil, where the domestic market has warranted the installation of branches of metalworking based on production lines, with operational scales similar to those internationally prevalent, in the rest of the region the same branches are lagging far behind equivalent plants in the developed world. Hence it can hardly be supposed that there has been successful naturalization of this type of organization of production. In contrast, the relative success of the naturalization effort seems to be greater in those metalworking branches which produce custom-made items or to meet individual orders, and in those others which operate on he basis of short series, offsetting by means of a strong local organization and methods engineering component the diseconomies of scale inherent in this mode of organizing the production process.

Perhaps what matters most is to have shown that no generalization seeking to evaluate the desirability or non-desirability of protecting the development of the metalworking industry and its naturalization in the Latin American scenario can be a blanket appraisal based on a simplistic specification of the production function, with the consequent disregard of the complexity of each individual situation.

The following section, the last in the present study, deals briefly with the question of economic and technological policy, and attempts to reflect, in relatively rough outline, some of the most important issues that the present exploration has brought to light.

IV
The metalworking industry and public policy

In the course of the foregoing pages we have reviewed various features of the techno-economic behaviour of about thirty metalworking establishments operating in six Latin American countries: Argentina, Brazil, Colombia, Mexico, Peru and Venezuela. These enterprises cover the various types of organization of production that can be found in the metalworking sector, i.e., mass production, based on production lines, of

[52] It must be borne in mind that here we are not speaking only of scale economies in the conventional physical sense. S. Jacobson's study shows that in the case of production of numerically-controlled lathes, operating on the basis of long series makes it possible to obtain very considerable reductions by placing the annual order for electronic control units –which represent practically one-third of the value of the machine– with the corresponding subcontractor. Producing in small batches implies a relative disadvantage so great as to call in question the very viability of naturalizing this type of metalworking industry. See S. Jacobson, *op. cit.*, 1982.

[53] Several years ago we had the opportunity to present a model of this type in J. Katz, *op. cit.*, 1974, chapter II.

highly standardized items, such as passenger cars and their parts and subassemblies; the manufacture of made-to-measure or custom-made individual products, such as, for example, the boiler equipment for a petrochemical plant or the turbine for a hydroelectric power station; and, lastly, production of small batches of such items as agricultural machinery or machine-tools. Briefly summing up some of the main findings obtained, we may say that the research has highlighted the enormous differences in physical structure and techno-economic behaviour between these various types of metalworking establishment. Again, the material gathered also reveals the wide disparities observable within Latin America in the evolution of metalworking production. While the evolutionary histories of enterprises in Argentina or Brazil extend over periods of thirty or forty years, the Peruvian or Venezuelan plants are much younger. Roughly speaking, there is an obvious establishment tendency towards correlation between the age of the firm and the size and complexity of the package of technology it handles.

Some of the various studies mentioned here have made it possible to describe the evolutionary process of a 'type' metalworking plant as being made up of successive phases or stages, which in their turn are linked to the gradual maturation and development of the firm's internal technological capacity. This latter involves the creation and consolidation of the various engineering or technical activities relating to the operation of any enterprise, i.e., product design, process and lastly production organization and methods engineering. It has been noted that as a general rule the development of domestic technological capacity follows a sequence which is influenced not only by the constraints and potentialities inherent in the product initially manufactured and in the equipment available for the purpose, but also by the nature of the climate of competition and of the macroeconomy in which the firm operates.

A complete maturative cycle —that is, a domestic technology learning process whereby adequate local engineering capacity is consolidated at each of the three technical levels mentioned above— may well last for several decades, and necessarily entails the recruitment of a wide range of professionals and technicians with different specialities and levels of skill.

Although in most of the enterprises studied we have found plenty of evidence of the appearance and development of different kinds of local technological capacity, there are few firms that can show they have successfully passed through the whole sequence of phases or stages relating to the maturation and consolidation of domestic technological capacity. And there are still fewer which, having done so, can, at the end of the maturative process, go on operating without having to resort to some form of protection or subsidy provided by the economic authorities. This last aspect of the problem is affected not only by the special form that local learning of technology has taken, but also, and essentially, by the rate and nature of the technological change occurring in the world frontier of technology.

In other words, only some of the cases considered seem to argue in favour of the infant industry dogma —i.e., that of protection for the growth of domestic technological capacity—, while others appear to have induced merely partial technological progress, or simply and solely to have given rise to the development of a package of technical and engineering skills not particularly well-fitted to enable the firm to continue operating on a competitive footing without requiring protection sustained through time.

So far we have briefly summarized the findings obtained. We shall next attempt to formulate, on the basis of the material presented, some observations on various subjects relating to official policy. The following pages are concerned not with putting forward a specific programme of action but with pointing to a number of topics which call for direct attention on the part of the authorities responsible for technological, education, and industrial policies, the last-named in a broad and general sense.

1. *Market size, production lines and exports*

Production lines in plants on scales far removed from those internationally prevalent breed disadvantages of several types which the present research has repeatedly brought to light; among them are not only the static effect of the higher unit cost of production, but also a dynamic effect associated with the character that this kind of plant imparts to the development of domestic technological capacity.

A caution against factories of this kind may reasonably be issued to those developing countries whose domestic market is relatively small, and which at the same time are embarking on integration programmes (for example the Andean Pact). The relative inefficiency of establishments of this type increases with the degree of diversification of the output mix, for which reason also wariness is advisable with regard to economic policies that tend to promote the broadening of the mix.

Generally speaking, in view of the size of Latin American domestic markets, production lines should imply high export coefficients –50% or more of the invoicing value– so that the installation of plants of this type must necessarily be accompanied by a comprehensive package of such industrial policy measures as promote –or at least do not discourage– the quest for international markets.

The lack of a relatively large domestic market to justify the installation of plants operating on the basis of production lines is of course no proof whatever that other forms of metalworking production –items that are custom-made or manufactured in small batches– are also inadvisable. The availability of good design engineering and the possibility of running workshop-type factories endowed with relatively sophisticated equipment, as well as the existence of a certain degree of natural protection resulting from the specificity of local demand, clear the way for the establishment of metalworking industries that can operate efficiently in special niches of the local and international market for products that are custom-made or manufactured in small batches. This would appear to be an option worthy of consideration by countries –such as several of the Latin American economies– with small domestic markets but with relative advantages in respect of the available supply of skilled human resources.

Obviously, a strategy of this type must be complemented with specific programmes relating to such questions as the following: (i) purchases by the public sector –unquestionably the leading buyer for custom-made or individually ordered metalworking products; (ii) training of skilled human resources; (iii) diffusion of technology –uses of numerical control, machining centres, etc.– and technical information (on normalization and standardization, minimum quality control criteria, etc.). The fact that Argentina's Atomic Energy Commission is at the same time engaged in designing, constructing and setting up an atomic reactor for Peru affords preliminary but suggestive evidence in support of the idea that countries like those mentioned can operate to some advantage in branches of the metalworking industry producing to meet individual orders.

2. *Duration of the period of learning technology, protection policy and the concept of the relative technological gap*

The empirical evidence brought to bear suggests that the development of domestic technological capacity –that is, the consolidation of the various plant engineering departments to the point of making viable the long-term maintenance of autonomous competitive capacity– may well necessitate a lengthy period of subsidization, certainly longer than is suggested in the recent literature of the subject.[54]

[54] Commenting on the normative position of B. Balassa, L. Westphal remarks that the author in question supports a standard programme of effective protection not exceeding ten or fifteen per cent for all those activities not classified as instances of 'infant industry'. Save in exceptional cases, it does not seem justifiable to grant the latter a rate of effective protection more than twice as high as those accorded to the mature sectors of industry. In addition, this protection for infant industry must be temporary, subject to a declining schedule which reaches the level of the other

It should likewise be borne in mind that almost as important as protection itself is the creation of an atmosphere of relative stability in the economic policy programme, which should avoid the erratic behaviour and the abrupt changes of direction which undoubtedly militate against slow-maturing projects such as many of those relating to investment in industrial plant and the development of domestic technological capacity.

A similar conclusion is reached by J. Bhagwati and T.N. Srinivasan in the NBER research programme referred to above. According to these authors, it would seem that the transition to a liberalization policy and its subsequent continuity are of crucial importance for the achievement and maintenance through time of successful export results. Otherwise, occasional spurts of liberalization –instead of the maintenance of a stable policy– would mean a continual going back to square one.[55]

Two other matters of importance in connection with protection policies are: (i) criteria for selection of the branches of industry to be protected; and (ii) the explicit formulation of a time schedule or time chart. At both levels a useful concept is that of the relative technological gap, which is simply an indicator that takes into account, on the one hand, the initial disparity between productivity (or costs) in the society opening its doors to a new industrial branch and, for example, in the latter's country of origin; and, on the other hand, the rate of learning of technology attained by the said industry in each of these locations.[56]

It seems evident at a glance that both a satisfactory choice of branches of industry to be given preferential treatment, and the made-to-measure design of an optimum time schedule or time chart for the relevant rates of protection, must necessarily be based on a more or less approximate idea of the 'relative technological gap' concept, as expounded in the preceding paragraph.

The work done by various researchers shows that this gap is determined by such factors as the plant size chosen in comparison with international sizes, the scale, composition and nature of local engineering efforts, the organization of the production process (degree of vertical integration, handling of subcontractors, etc.) among other.

In view of the peculiar features of each situation, and the specificity of each maturative sequence, it is impossible, in our view, to speak of protection programmes that are unvarying from one country to another or from one branch of industry to another, as has been the practice in recent literature on effective protection.

3. *Research and development efforts and diffusion of technological know-how*

The design and implementation of official programmes of action relating to the generation and diffusion of new technological know-how is justifiable on many and diverse grounds. At both levels –that of the creation of new technological know-how and that of the diffusion of technical information– plenty of reason exists to suspect *a priori* that the price mechanism does not send out appropriate or sufficient signals to induce a socially optimal resource allocation and that the intervention of the authorities is warranted for the sake of exploring alternative ways of approaching the optimum in question.

There come into play here not only the amount spent by a specific community on the above-mentioned activities and the relative participation of the public and private sectors in financing them, but also the degree of centralization and decentralization with which they are to be carried out, i.e., which and how many of the tasks of research, development and diffusion of technological knowledge will be undertaken by the private sector or, alternatively, by de-

---

subgroup in, say, five to eight years. See L. Westphal, "Empirical justification for infant industry protection", an article due to appear in *Trade, Technology, Equity and Stabilization in Latin America*, Moshe Syrquin and Simon Teitel (eds.), New York, Academic Press Inc.

The passage cited from B. Balassa comes from "Reforming the System of Incentives in Developing Countries", *World Development*, Vol. 3, 1975.

[55] See J. Bhagwati and T.N. Srinivasan, *op. cit.*, 1978, p. 16.

[56] Such a model is presented in J. Katz, *op. cit.*, 1974.

centralized public-sector entities, such as the universities, institutes of industrial technology, the Atomic Energy Commission, etc.

A first point seems clear: current spending on research and development in the field of metalworking technology, as well as on the diffusion of technical information in the various branches of that sector of activity, is on a relatively small scale in comparison with what is disbursed under these heads by enterprises and governments in the developed world[57] or even in some of the countries of Southeast Asia. We have noted that the R&D spending of the most successful firms in the sample examined here amounts to about 5.7% of their sales.[58] This is undoubtedly an atypical situation for the metalworking industry as a whole, the average for the sector being probably only one-fourth of that figure, perhaps less. Accordingly, it seems reasonable to assume that the margin of action available for boosting the domestic technology effort undertaken by the private sector is still wide, and that there is full justification for co-ordinated action in this respect. Although the information available on R&D spending and diffusion of technical information by the public sector is definitely unsatisfactory, such a conclusion does not seem to us unrealistic, for which reason we also think it valid to advocate a substantial increase in public expenditure on the work in question.

Let us next look at possible paths to follow, beginning with the task of disseminating technical information.

One of the studies prepared under the present Programme describes the operation of a sectoral centre whose function is to evaluate new production technologies and to disseminate technical information in the field of agricultural machinery. The organization and *modus operandi* of this centre are extremely attractive inasmuch as they could serve as a model for the experimental designing of similar channels for the diffusion of technical information in other branches of metalworking production.

The example alluded to is afforded by Argentina's Commission for the Development of Agricultural Machinery (Comisión para el Desarrollo de Maquinaria Agrícola - CODEMA), a body to whose work we are introduced in the study by J. Berlinski.[59] CODEMA is a sectoral centre for the evaluation and diffusion of technology in which the various entrepreneurial associations of manufacturers of agricultural machinery participate, together with the National Institute of Agricultural Technology (Instituto Nacional de Tecnología Agropecuaria - INTA) and the National Institute of Industrial Technology (Instituto Nacional de Tecnología Industrial - INTI). "*Inter alia*, the CODEMA experiments subcommittee dealing with machinery for the planting of crops has drawn up rules and guidelines for both laboratory and field trials of seeding-machines."[60] These norms, widely disseminated among users, INTA extension agents, entrepreneurs in the sector, etc., make the market picture clearer –and therefore improve the operation of the price and competition system– and encourage and guide technological innovation in the industry concerned.

Measures of this type –i.e., creation of sectoral centres for evaluation of technology, preparation of technical norms and diffusion of information–, which require not only applied research and experimental development on the part of the public sector but also the establishment of a system of co-ordination between that sector and entrepreneurs in a given branch of industry such as may ensure the viability of technological dialogue between them, should in our view be extended to other fields of metalworking activity.[61]

[57] By way of example, although the figures are not up-to-date, the reader may refer to the statistics on R&D published by the National Science Foundation. See, for example, *Research and Development in Industry, 1966*, Washington, National Science Foundation, US Government Printing Office, 1968.

[58] See, for example, H. Nogueira, *op. cit.*, 1982, table C.1., p. 100.

[59] J. Berlinski, "Algunas notas...", *op. cit.*, 1982.

[60] J. Berlinski, "Algunas notas...", *op. cit.*, 1982, p. 4.

[61] See, for example, the mode of operation, in the

In addition to the evaluation of technology and the diffusion of technical information, sectoral nuclei of this type may also be envisaged as a fitting framework for the implementation of group measures relating to other aspects of technology. These could include situations in which price signals are belated or incorrect, or where there is imperfect appropriability of benefits. Cases in point might arise in relation to the training of skilled human resources, or the generation of scientific knowledge of a more basic character, but useful in the event for the overall development of the technological atmosphere in which a given branch of production operates. (These questions will be taken up again a little later.)

Of course this is not the only way of promoting the diffusion of technical information in a specific branch of production. In some activities –for example, crop farming–, the role of the extension agent is typically that of a disseminator of information. With few exceptions, little attention has been paid to this role in the field of industrial production, probably because of the difference in degrees of private appropriability between scientific and technological knowledge relating to the primary sector and information of the same kind concerning industrial production. There is some suggestive empirical evidence to hand –for example, the repercussions on overall productivity that on different occasions we have seen to be produced when members of the technical sales service of large firms visit their customer firms in order to consolidate the business position of their respective enterprises.[62] What it suggests is that the industrial extension agent might become an important figure in relation to the perception of technical plant problems by the private entrepreneur and the consequent dissemination of technical information bearing on their solution. Little attention has hitherto been paid to the role that could be performed in this respect by public-sector technological institutes –such as INTI, mentioned above– or by the universities.

Other channels through which technical information can be disseminated are industrial fairs and exhibitions, sectoral conferences and meetings, programmed visits to industrial plants in developed countries, mass distribution of information on patents and other similar documents, preparation and diffusion of norms and standards for plant operation, maintenance, quality, industrial safety, etc. All these measures have a single common denominator: the social exceeds the private benefit, a basic justification for their implementation and financing by the public authorities.

Let us now go on to the subject of R&D spending. This may be conveniently divided here into expenditure on adaptation, optimization, etc., of known technologies, and major items, i.e., those involving technological exploration and development in frontier fields. As regards the former, we have found plenty of empirical evidence which shows that the private metalworking sector in the bigger Latin American countries has coped in the past –and is still coping today– with a vast spectrum of effort comprising: (i) the designing of new products; (ii) enhancement of quality in products already known; (iii) use of new materials; (iv) more efficient utilization of available equipment; (v) introduction of modern equipment, highly complex and automated; (vi) improvement and rationalization of plant lay out; (vii) application of up-to-date organizational engineering methods such as studies concerned with families of parts and with rationalization of the production process by technological groups, etc.

Obviously, not all the enterprises studied have covered every one of these technological areas, nor, when they have

---

United States context, of the Co-ordinating Committee for enterprises manufacturing motor vehicles, sponsored by the Office of Transportation Programs of the Energy Department. This Committee has published a long list of documents summing up what has happened at the successive meetings for exchange and diffusion of technological information in which all the major motor-vehicle manufacturers in the United States have participated, as well as the great majority of their suppliers and subcontractors.

[62] See J. Katz *et al.*, "Productividad, tecnología y esfuerzos locales de investigación y desarrollo", *Working Paper No. 13,* IDB/ECLA/UNDP Programme of Scientific and Technological Research in Latin America, Buenos Aires, March 1978.

attempted it, have all done so equally well. Implicit just in the very idea of maturative sequences which underlies the whole of the present paper is the concept of evolutionary differences and of wide inter-firm dissimilarities, even between close competitors, in respect of the technological paths they follow. A list of themes like that suggested before, and the above-mentioned notion of maturative differences, should, in our opinion, constitute the basis for the construction of an agenda of research and development projects of the adaptive type –i.e., of projects implying the adaptation and optimization of known technologies– to be tackled by the various engineering teams of the metalworking establishments in operation.

As stated earlier, many technological efforts of this type are being undertaken today even when the fiscal incentives provided are purely conventional or, in some cases, do not even serve as inducements. Generally they take the form of R&D projects with high rates of private profit[63] and short maturities, and therefore obviously attractive. This does not mean, however, that from the social standpoint it is not desirable to induce expansion of the resources which society as a whole earmarks for this purpose. This end might be served by seeking to ensure that more is spent on projects of this type by firms that are already tackling them today, or getting small and medium-scale entrepreneurs, currently playing little or no part on the technological scene, to take a gradually increasing interest in it. Fiscal incentives are conceivable –more localized and focalized than at present–, or programmes of direct action in which decentralized public-sector institutes, secific nuclei of the university system, etc., could assume the leadership. To judge by the empirical evidence collected, the increments in overall productivity that could be engendered by this means –especially where organization and methods engineering would permit a drastic elimination of dead time and other indicators of inefficiency– are of considerable magnitude. The sectoral centres for evaluation and dissemination of technological information might possibly be regarded as a suitable framework for the drawing-up of an R&D agenda concerted between the public and the private sectors and enlisting the approval and active participation of both.

While in the adaptive field the idea is to promote a significant increase in the type of technological effort which today is undertaken, although only in part, by the private sector, where the exploration of frontier areas is concerned it is the public sector that has to play the more outstanding role as leader and in many cases even as direct executor. Obviously, the greater the elements of uncertainty and risk, the longer the periods of maturation, and the more sophisticated and complex the type of human resources and equipment required for exploratory work, the lesser is the likelihood of the private sector's allocating sufficient resources to allow local development of a scientific and technological base adequate for closely following or even taking the lead in the extension of the world scientific and technical frontier. The rapid penetration of microelectronics and the difficulties that some of the biggest manufacturers of capital equipment in Latin America have encountered in recent years on this account bear eloquent witness to the problem posed here.

In contrast to the case of adaptive R&D, where the objective of technological policy ought to be that of getting many different firms to join in a generalized programme of domestic technological development, with regard to frontier R&D projects careful selection would be necessary, respecting not only their object *per se* but also the entrepreneurial group and the technical and professional team with which it is decided to implement the programme. Again in contrast with the preceding case, this is a field in which technological dialogue between the production sector and the universities will necessarily have to be intensified, since human resources with a high level of skills

[63] See P. Maxwell, "Implicit R&D Strategy and Investment-Linked R&D. A study of the R&D Programme of the Argentine Steel Firm, Acindar S.A.", *Working Paper No. 23*, IDB/ECLA/UNDP Programme of Scientific and Technological Research in Latin America, Buenos Aires, March 1979.

and a proper grasp of the main lines of exploration pursued at the international level are a *sine qua non* for progress along this path. Different experiences connected with the development of spearhead technologies in industrialized countries reveal that there are few firms in the private sector which are capable of promoting this technological dialogue with the universities and with the public-sector offices responsible for scientific and technological policy and for industrial planning. Furthermore, the available evidence suggests that these are slow-maturing programmes whose incidence on the production sector barely becomes apparent in periods of less than a decade, or even longer. Financing and direct action by the public sector in this context are not only considered admissible but are openly practised by all the countries of the developed world.

4. *Subcontractors and supply of basic inputs*

Over and over again our studies bring to light the existence of many difficulties in connection with the employment of subcontractors as well as in obtaining supplies of basic inputs such as iron and steel and other similar raw materials.

We shall first consider the matter of subcontractors. Their absence must be interpreted as a general problem of maturity of the industrial structure and as a manifest failure of the price mechanism; here we are faced with a breakdown of the market that should be corrected by direct public action.

In our opinion, an organized effort in this direction would have to begin with a broad programme of standardization and normalization of parts, subassemblies, materials, etc., and also with a concerted agreement to reduce the output mix manufactured by each firm, or per production line. This would make it possible, in the first place, to take advantage of economies of scale deriving from specialization and from elimination of dead time —delay, machine preparation, etc.— and, secondly, to select a list of specific fields in which it would be advisable to induce the emergence and development of independent subcontractors.

The aforesaid work of standardization and normalization involves difficulties which must by no means be minimized. The existence of profits deriving from differentiation of products, of miscellaneous problems inherent in the private appropriability of technical know-how, etc., means that awkward obstacles have to be surmounted in the implementation of a programme of public action in this domain. Inter-firm coordination and a time schedule of close collaboration with public-sector technological institutes seem to be indispensable requisites for any real progress. In this connection, the sectoral centres for evaluation of new technologies and dissemination of technical information, whose significance was previously discussed, might be envisaged as valid nuclei through which to promote measures such as those suggested here.

The standardization and normalization effort will undoubtedly assist in the identification of a schedule of activities and lines of production in which the economies of scale potentially obtainable through the development of specialized subcontracting are sufficiently attractive to convert these branches of industry into priority items on the industrial policy agenda. Castings, gear-boxes, electric motors, etc., are obvious targets for incorporation into such a list.

The next step relates to the area of industrial policy and consists in the preparation and launching of specific investment projects in the fields thus selected. Conventional fiscal incentives, or direct agreements with entrepreneurial sectors whose day-to-day operations would be affected, may, at this level of generality, be thought of as possible channels for the installation of an infrastructure of specialized subcontractors. These measures would have to be complemented by others relating to diffusion of information, strengthening of the channels of financing for small and medium-sized firms, and other similar activities favourable to the consolidation of a productive sector of society which today is on a definitely shaky footing, or, in many cases, simply non-existent.

Moving on now to the subject of basic inputs, it seems important to note that almost invariably the metalworking firms studied declared that they encountered difficulties in respect of the costs, quality and delivery times of basic raw materials such as iron and steel or others of a similar kind, often supplied by decentralized public sector enterprises. In various branches of the metalworking sector, the relative incidence of inputs of this type on the overall costs structure is significant, for which reason the trickle-down of the operational inefficiency of basic sectors to the terminal establishments raises the latters' production costs and impairs their capacity to compete with international substitute products. Measures of various kinds are conceivable as means of counteracting this situation, from temporary import permits to the management of an effective rate of protection which could take care of the high level of inefficiency often present in the production of basic inputs. Ultimately it is the overall problem of protection of the basic production sectors that will have to be tackled through suitable instruments, but during the transitional phase it seems wise to adopt specific measures to prevent transfers of operational inefficiency originating outside the metalworking industry.

5. *Equipment and skilled human resources*

A number of points call for attention in connection with manufacturing equipment and the training and incorporation of skilled human resources.

As regards the first matter –manufacturing equipment–, it seems clear that the diffusion of numerical control, of Computer Aided Design systems (CAD), of flexible machining centres and lines, and of robotics in general, has barely begun to take place in the Latin American metalworking industry. This sluggishness in the dissemination process is partly attributable to the problem of relative prices, but due account must also be taken of major shortcomings in respect of access to the relevant technical information, as well as in the methods of evaluation available to the entrepreneurial community.

Clearly, in the medium run the region's metalworking industry cannot stand aside from the technological revolution in this field which is now brewing in the international scenario: a revolution whose epicentre is in the Japanese economy.[64]

The questions inherent in the dissemination of technical information on these new kinds of equipment could be dealt with both through industrial extension agents and by means of the sectoral centres for evaluation of technologies proposed above.

It seems important to note here that a considerable proportion of the new numerical control technology is especially suitable to production in small batches and must therefore be viewed as particularly useful for the type of production programmes predominant in Latin America. This leads us to assume that an adequate programme of technical assistance for users, capable of providing information on the optimum type of systems and equipment for each individual situation, will undoubtedly have a highly positive effect on the rate of dissemination of numerical control technology throughout the region's metalworking sector.

Obviously, over and above informational shortcomings, there is also a problem of relative prices and of available supplies of skilled manpower, as regards the rate of dissemination of numerical control, machining centres and other forms of automation. While the question of relative prices could be tackled through specific legislation to encourage investment in equipment through tax and credit advantages, etc., the problem of the skilled human resources required to operate this modern equipment involves not

[64] During the 1980s we are witnessing a revolution in production systems in so far as a larger number of metalworking establishments is incorporating entirely automated machining centres to take the night shift ... Furthermore, special attention is apparently being paid to flexible manufacturing systems (FMS) which are concerned with the work of handling, positioning, etc., of materials and parts and in which numerically-controlled lathes and other miscellaneous equipment operate at the orders of a single intelligent and reprogrammable robot. Such is the approximate wording of a comment in ***Metalworking Engineering and Marketing***, a two-monthly Japanese magazine responsible for disseminating information on the state of the international production frontier in the metalworking field.

only their training at the level of society as a whole, but also the informal training often given by the individual manufacturing establishment. Where in-service training is concerned, as we suggested in connection with incentives to physical capital formation, use may be made of fiscal and credit subsidies for private expenditure on the training of technicians and professionals, fellowship programmes, periodical refresher courses, and other similar outlays undertaken by the individual firm.

If we now go on to the second of the topics discussed here, i.e., training of skilled human resources at the level of society as a whole, it becomes immediately evident that the spectrum of problems involved is extensive and will have to be the object of a special programme of action whose coverage ranges from society's expenditure *per se* on education and training in the various professions and specialities linked to metalworking production, to the curricula of the various educational programmes. It is a matter not only of stepping up the effort made by society as a whole in the educational field but also of improving the dialogue and interrelationship between the educational system and the productive sector. Special care should be devoted to such questions as the mobility of professionals and technicians between the various places of study and the main enterprises in the sector, the creation of new technical careers and specialities not offered in the curriculum today, the launching of programmes of collaboration in basic and applied research between university professionals and personnel of public and private enterprises in the metalworking sector, etc.

APPENDIX

Details are given below of the working papers published by the IDB/ECLA/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America. Up to No. 36, the papers correspond to the first phase of this programme, and as they do not deal with the metalworking sector they have not been included on the following list.

37 – Staffan Jacobsson, *The Use and Production of Numerically Controlled Machine-Tools in Argentina* (December 1980).

38 – A. Castaño, J. Katz, F. Navajas, *Etapas históricas y conductas tecnológicas en una planta argentina de máquinas-herramienta* (January 1981).

39 – Hélio Nogueira da Cruz, *Evoluçao Tecnològica no Setor de Máquinas de Processar Cereais. Um Estudo de Caso* (July 1981).

40 – Julio Berlinski, *Productividad, escala y aprendizaje en una planta argentina de motores* (August 1981).

41 – M. Ramírez Gómez and José Leibovich G., *Cambio tecnológico en la firma Distral S.A. fabricante de calderas y equipos de presión* (August 1981).

42 – D. Sandoval, M. Mick, L. Guterman, *Análisis de la trayectoria de una planta automotriz en Colombia: El caso de Sofasa.* (November 1981).

43 – Julio Berlinski, *Innovaciones en productos y aprendizaje (El caso de una planta argentina de implementos agrícolas)* (January 1982).

44 – Staffan Jacobsson, *Technical Change and Technology Policy. The Case of Numerically Controlled Lathes in Argentina* (March 1982).

45 – Julio Berlinski, *Innovaciones en el proceso y aprendizaje en una planta argentina de fundición* (April 1982).

46 – Marcos Eugenio da Silva, *Inovaçao Tecnològica no Setor de Máquinas Ferramentas Brasileiro - Um Estudo de Caso*, (May 1982).

47 – H. Nogueira da Cruz, M.E. da Silva, L.A. Gunnar Hugerth, *Observaçoes sobre a Mudança Tecnològica no Setor de Máquinas Ferramentas do Brasil* (May 1982).

48 – Julio Berlinski, *Cambio en la información técnica y aprendizaje en una planta argentina de motores* (June 1982).

49 – D. Sandoval, L. Jaramillo, *La industria de máquinas-herramienta en Colombia. Estudio de una firma productora de tornos y otras máquinas para trabajar metales* (June 1982).

50 – D. Sandoval, M. Mick, L. Guterman, L. Jaramillo, *Análisis del desarrollo industrial de Forjas de Colombia, 1961-1981* (June 1982).