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IMPLICIT R & D STRATEGY AND INVESTMENT-LINKED R & D

A Study of the R & D Programme of the Argentine Steel Firm. Acindar S.A.

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I. INTRODUCTION

Until now, not much detailed empirical research has been done into the characteristics of the local R & D programmes and R & D projects 1/carried out by Latin American firms.

This seems dues to the fact that (a) the whole subject of local technology creation by Latin American firms has only recently become the focus of intensive research, and (b) most of the local technology creation efforts identified so far have been of the "implicit" kind i.e. associated with direct production activities, or organized on an ad-hoc basis, rather than being organized explicitly as "R & D". or carried out in a separate "R & D" department.

It nevertheless seems useful to enquire empirically into the nature and economic characteristics of the "portfolios" of R & D projects which Latin American firms operate with -even if most of these projects are of the "implicit" rather than "explicit" kinds, and even if the R & D programme or strategy of the firms concerned was mostly an unconscious programme whose characteristics are recognisable "ex-post-facto" by the investigator, but were not actually deliberately planned in this way by the firm.

In our view such empirical enquiries into R & D project portfolios promise two kinds of useful results: first of all they should lead towards an exact specification of the kinds of R & D projects that get performed, an indispensable first step prior to theorising: second, they should lead to some kind of characterization of R & D Programmes on the basis of their degree of "explicitness". As a result, it should be possible to begin to see how explicit, articulate R & D programmes actually emerge from, or succeed, their more primitive predecessors.

Such considerations suggest that empirical studies of Latin American firms' R & D project portfolios would be worthwhile to perform. Yet, published empirical analysis or even description of such portfolios is only now beginning to become available. 2/

1/ The accepted short form "R&D" will be used throughout the paper to specify Research and Development.

2/ Within the IDB/ECLA Programme studies see especially J. Katz et al's study of Ducilo S.A., Argentina, which contains a detailed description and interpretation of the main research lines and evolution of Ducilo Rayon's R & D programme. J. Katz et al, Productividad, Tecnología y Esfuerzos Locales de Investigación y Desarrollo, Programa BID/CEPAL Monografía de Trabajo N° 13, Buenos Aires, Marzo 1978, in particular, pp. 35-51. See also C. Dahlman and F. Valadares, From Technological Dependence to Technological Development: The Case of the Usiminas Steel Plant in Brazil, Working paper N° 21, IDB/ECLA Programme, Buenos Aires, November 1978, in particular pp. 218-227 on the plant's research centre and Appendix IV on examples of specific R & D and operational research projects.

To help fill this gap in our knowledge, the present paper presents the results of a detailed empirical examination of the R & D project "portfolio" of an Argentine steel firm, Acindar S.A.. Its aim is to describe and discuss the characteristics of a representative sample of the R & D projects carried out by this firm.

The paper is thus of the "case-study" kind, based on a particular firm's experience. So it is essential to have in mind the kind of firm involved. Acindar S.A. is Argentina's leading private sector steel firm and currently produces some 500,000 tons of rolled non-flat products per year. It is also the country's largest private-ownership national firm as measured by its sales volume 3/ -which in recent years has been around 150 to 200 million U.S.$ per year. It employs over 5,000 people in steel production, sales and administration, and has a sophisticated technical organization at its plants which includes specialized departments handling quality-control, project engineering, industrial engineering (operations research), maintenance engineering, information systems, etc.. Technologically speaking, Acindar has always been regarded as one of Argentina's most progressive firms. All its steel plants embody significant inputs of the firm's own engineering designs and adaptations, and the firm regularly publishes technical articles in national and Latin American trade journals and congresses.

So this is a case-study of the R & D performed by one of the largest and most technically sophisticated firms in Argentina in the field of steel production. Therefore its findings are likely to represent a kind of "leading edge" of what one might expect to find in smaller and less sophisticated steel firms.

Concretely, the paper explores 54 specific R & D projects undertaken by Acindar between 1970 and 1974.

The principal source of our information on these 54 projects was the set of three annual applications submitted by Acindar in 1972, 1973 and 1974 to the Subsecretariat for Science and Technology of the Argentine Government, aimed at securing certain tax deductions that had been recently legislated as applying to firm's bona fide expenditures on "scientific and technological investigations in the national interest".

To prepare these applications, Acindar had to engage in much time-consuming work so as to (a) collect all the detailed information required by the tax legislation for all the 54 R & D projects, and then (b) present this information in systematic standardized form for each project. Unfortunately for Acindar (and many hundreds of other Argentine firms) no tax deductions on the submitted research projects were ever granted by the Argentine authorities, and the relevant legislation was repealed. What remains is the compilation of information which for obvious reasons, is a potential "external benefit" to research on R & D project portfolios.

3/ Only the two largest state-owned enterprises, Yacimientos Petrolíferos Argentinos (petroleum) and SOMISA (steel), and the multinational car firm, Fiat, appeared ahead of Acindar in the list of the largest Argentine firms in 1977 published by La Prensa Económica, Editorial Lourdes, Buenos Aires, 1977.

Thanks to the generosity of Acindar's Directors, access to the firm's tax applications was granted and several weeks were then spent in reworking, analysing and interpreting the data contained in them. The main results emerging from this investigation are presented in the present paper. These results consist of:

1) A body of descriptive findings concerning the characteristics of Acindar's R & D portfolio, including the type of projects, stimuli to projects, project objectives, labour input, cost, degree of implementation, etc. This body of findings is presented in Section II of the paper.

2) The finding that the majority of the R & D projects were of the "investment linked" kind -i.e. bound up with the acquisition and implementation of capital equipment additions to the existing technological stock, so that the assignation of resources to this kind of R & D has to be considered as a joint assignation along with investment in capital equipment. This finding is explored in Section III of the paper.

3) The finding that the "strategy" for R & D displayed by Acindar in these projects was an "implicit" strategy, mainly involving ad-hoc reactions by Acindar to particular inducement signals of the need-pull kind, but also involving some "spontaneous" and "active" elements. This finding is explored in Section IV of the paper.

In addition to transmitting these three results, the paper also engages in a modest, exploratory effort to draw out some of the economic implications of the second and third ones -i.e. that most of Acindar's R & D was investment-linked and that its R & D strategy was an implicit, mainly reactive one. In particular, the paper offers, in Section III a simple theoretical model of how localized "investment-linked" R & D can either complement or substitute for capital equipment investment, and in Section IV some speculative arguments in favour of a more explicit R & D strategy.

It must be emphasized, however, that although both this model and the speculations on explicit R & D strategy arose as a result of reflecting on features of Acindar's R & D that emerged in the empirical analysis, we cannot claim that either the model or the speculations are validated by the empirical results that led to their conception. Such validation (or refutation) would depend on further empirical work beyond the scope of this paper.

The main hope of the paper is that it will demonstrate the value of detailed research into the R & D portfolios of Latin American firms, and thus contribute to strengthening the empirical coverage of this at present neglected area.

II. CHARACTERISTICS OF ACINDAR'S R & D PROJECT PORTFOLIO.

This section is concerned to describe the main characteristics of Acindar's R & D project portfolio, as derived from the analysis of the data in the tax applications.

However, before reporting on these characteristics, two important methodological questions need to be clarified. These are (1) What definition of R & D was Acindar using when supplying data on its R & D spending and projects in the tax deduction applications? (2) How representative are these 54 R & D projects of the complete set of R & D projects carried out by Acindar in the period concerned?

We shall now discuss these two questions, starting with the one on the definition of R & D.

The R & D projects on which tax deductions could be granted were specified in the rules governing the applications as including

> "the design of prototypes, development of new processes, use of non-routine raw materials, product engineering, pilot plant operations and non-routine tests"

but as excluding

> "tasks related to methods engineering, production programming and control, operations research, routine quality controls, product style changes, market research, sales promotion, feasibility studies, or services to clients". 4/

This definition of what could and could not be counted as R & D projects for the purpose of tax deduction corresponds rather well with the distinction between "R & D" activities and "technical services" activities as defined by the OECD Frascati Manual. 5/

4/ Information based on the circular Beneficios impositivos previstos en la Legislación vigente en la República Argentina: Promoción de las Actividades Científicas y Técnicas en el sector privado (Tax benefits contained in the current legislation of the Argentine Republic: Promotion of Scientific and Technological Activities in the Private Sector), Secretaría de Planeamiento y Acción del Gobierno, Subsecretaría de Ciencia y Técnica, agosto de 1972.

5/ See the "Measurement of Scientific and Technical Activities", OECD DAS/SPR/70.40 (mimeo), 1970, Chapter 2, pp. 8-21 (otherwise known as the "Frascati Manual") for the OECD definitions. These are fully reproduced as an Appendix to Christopher Freeman, The Economics of Industrial Innovation, Penguin, Harmondsworth, 1974.

In practice it meant that quite a large number of minor projects with a "research component" carried out by Acindar's Industrial Engineering Department, Quality Control Department, Engineering and Maintenance Department, etc. were not submitted for tax deduction nor included in the figures for Acindar's total R & D spending, because they could not be counted as R & D.

So far so good. We now come, however, to a significant difference in the "tax application" definitions of R & D and the OECD definition of R & D, which relates to the precise interpretation as to which kinds of activities and expenditures connected with the "development of new processes" and "product engineering" should be included as "R & D" and which should be excluded. So far as the OECD Frascati Manual is concerned, the term R & D is closely associated to the concept of "off-line" experimental work, pilot plant work and prototype development. As a result, such activities as design and drawing work which modifies on-line equipment, or trial production and tooling up for new or modified equipment being installed in the production line, do not count as "R & D". Although such activities do transparently involve process modification and/or new product diversification, the fact that they take place "on line", rather than in a pilot plant, excludes them from being termed R & D according to the conventions outlined in the Manual.

In contrast, it is clear that Acindar interpreted the tax-application definition of R & D as including the engineering design work and start-up work associated with the direct introduction into the production line of new processes and products. Indeed virtually the entire class of the projects which we shall be terming "investment-linked" R & D projects fall into this category.

It will therefore be essential for the reader to remember (a) that only those projects which we term "experimental" R & D projects can be regarded as directly corresponding to the OECD definition of "R & D", and (b) that the term " R & D" as used from now on in this paper refers to <u>both</u> "investment-linked" R & D <u>and</u> "experimental" R & D.

With these points clear, we now proceed to the question as to how representative is our sample of 54 R & D projects.

The answer is that it can be taken as a highly representative sample. This is because Acindar's objective in filling out the application forms was to include all those projects that could be considered as falling within the scope of the legislation and for which adequate information could be gathered from the firm's records so as to document and substantiate the information to be provided in the applications. As it was plainly in the firm's interest to secure tax deductions on the maximum number of projects, a considerable effort was made to assemble the necessary information on all the ones that could possibly be included. Although some projects got left out, it is clear that the 54 projects represent the great majority of the projects actually undertaken in the period concerned and include all the important ones.

Two "caveats" do, however, need to be stated.

Firstly, no reference is made in the list of R & D projects to any project related to a major technology acquisition which Acindar was making in the 1973-74 period, namely a second electric arc furnace and continuous casting lines for one of its plants. In fact all the R & D projects refer exclusively to "improvement efforts" based on the already installed technology in Acindar's three plants. The projects are therefore, representative of the firm's "improvement-effort" R & D and not of its R & D in connection with major acquisitions of new plant.

Secondly, -as we pointed out earlier- the fact that the tax legislation deliberately excluded projects of the "Technical Services" type from being presented meant that a large number of minor projects with a "research component" carried out by Acindar's Industrial Engineering Department, Quality Control Department, Engineering and Maintenance Department, etc. were not submitted for tax deduction because they could not be counted as R & D.

The sample is thus highly representative of all the improvement-type R & D projects carried out by Acindar (including both "experimental" and "investment-linked" R & D) in the period concerned, but it excludes the range of minor projects with a research component stemming from the firm's technical departments i.e. projects which can be grouped under the "technical services" heading.

Having dealt with the two methodological questions, we can now proceed to report the findings which we obtained on the characteristics of Acindar's R & D spending and of the 54 R & D projects. These findings are summarized below:

1. Acindar in 1972-74 spent on average 0.5% of sales on its own direct labour input to the R & D projects which it undertook, and some 2.5 to 5 times this amount on other technical services and tasks. By way of comparison, it spent 9 to 14 times this amount on imported capital equipment.

2. There were no Acindar staff assigned full-time to R & D in the years analysed. Nor was there any separate R & D department. The 117 staff said to participate in R & D devoted an average of 18.4% of their time to it in the year 1972-73.

3. This expenditure of endogenous resources and time, and the projects that were analysed, all refer to modest, incremental, R & D efforts, aimed at securing improvements in, or product diversifications from, the plant's existing technology. In addition these projects can all be considered to fall into the theoretical category of "localized R & D efforts and technical changes. 6/

6/ The key idea in "localized technical change is that it involves technical changes in one particular production technique, and not others. For example, when in the course of operating a plant, some new know-how is generated which helps to improve that plant's performance via technical changes introduced using this new know-how, the technical change is regarded as being "localized" at that plant if the new know-how has little relevance or "spillover" from the point of view of improving performance via technical change at other plants. Or -to put it another way- if new "know-how" is parochial in the sense of being largely applicable to the idiosyncratic circumstances and machinery of a particular plant, but largely inapplicable outside that plant, then the new know-how and the technical changes it helps generate for that particular plant can both be regarded as "localized". If, on the contrary, such "know-how" is readily applicable to different plants (or, in economists language across a range of techniques,) then one might term that know-how as being of "generalized" rather than "localized" value. In practice the know-how going into technical changes nearly always contains a mixture of "localized" and "generalized" elements. However a great number of the minor changes and improvements introduced in particular plants - such as in the present case - have a strongly "localized" character because they are designed as small additions which must fit in with the particular unique combination of machines,

4. 75 to 85% of R & D expenditure was on "investment-linked" projects compared to only 15-25% on "experimental" projects. The special feature of the "investment-linked" projects was that the implementation of these projects via investment in capital equipment was already built into these projects' objectives at the start. In other words, the particular R & D to be performed was the R & D necessary to successfully specify and/or implement an investment in capital equipment that was already decided on prior to the initiation of the project. In contrast, the "experimental projects" were ones in which any future implementation depended on the results of the R & D project. In other words implementation was not already built in at the start, and the mission of the experimental projects was only to generate new information upon which a subsequent decision to implement, via a new project, might later be taken. Of the 54 projects, 37 were investment-linked and 17 were experimental.

5. 50-55% of the R & D expenditure was on "exclusively-process-change" projects compared with 45-50% on "new-product-linked" projects.

6. Fully 60-70% of R & D expenditure was devoted to just seven large investment-linked projects, costing from $ 100,000 to $ 500,000 in terms of Acindar's labour input. The other 30-40% of expenditure was shared out amongst the other 47 projects, most of which cost less than $ 20,000 each in terms of Acindar's labour input.

7. The modest technical complexity of the projects is illustrated by the fact that the average level of Acindar university and technically trained manpower input to projects, both of the investment-linked and experimental types, was only about 2 man-years. Also, only 5 of the total of 54 projects were expected to take more than two years to complete.

8. Virtually, all the investment-linked projects were completed, and by their nature, already had implementation built into their objectives. Most of the experimental projects were also completed but only about one in three went on to a successful commercial implementation. Failure to implement or failure in implementation of the experimental projects was three or four times as often due to commercial reasons as due to technical ones. Conclusion: investment-linked projects were characterized by low technical uncertainty and low commercial uncertainty. Experimental ones seemed to be characterized by mostly low technical uncertainty but considerable commercial uncertainty.

9. Most of the projects were clearly stimulated by specific market demands, specific production problems or specific raw materials constraints. But a minority seemed to originate in the spontaneous suggestions of the firm's technical staff, or in the firm's desire to maintain its "technological leadership" position by launching advanced products in certain product lines (For more details, see Section IV).

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methods and men that each plant uses. They are -as it were- "plant-specific" changes. For the original theoretical reference to "localized" technical change, see A.B. Atkinson and J.E. Stiglitz, "A New View of Technological Change". Economic Journal, Vol. LXXXIX 315, September 1969. An interesting empirical paper touching on this subject (and mentioning specifically the idea of "system-specific" and "firm-specific" know-how) is G.R. Hall and R.E. Johnson, "Transfers of United States Aerospace Technology to Japan", in R. Vernon Ed., The Technology Factor in International Trade, Columbia University Press, New York, 1970, pp.305-358.

10. The objectives of the R & D projects were varied. The leading primary objectives for the projects were (1) to launch, or support the launch of new products (37% of the sample) (2) to stretch production capacity for existing products (24%); and (3) to reduce existing product cost (17%). Less important, but still significantly frequent primary objectives were (4) to ease raw material supply restrictions (11%); and (5) to improve product quality (9%). Half the sample also had secondary, or additional objectives in addition to their primary ones.

This completes our summary of the project portfolio characteristics emerging from our exploration of the tax application data. However we do not intend to analyse all these characteristics. Rather, our idea in presenting these findings was to first familiarise the reader with the overall character of the portfolio of projects we are dealing with, prior to proceeding to a more detailed discussion of two particular characteristics in Sections III and IV below. These two particular characteristics are, as mentioned in the introduction, the "investment-linked" character of most of the projects, and the type of R & D "strategy" which underlies the projects in the portfolio. We now turn to this more detailed discussion, starting in the next section with the "investment-linked" nature of most of the projects.

III. AN EXPLORATION OF LOCALIZED "INVESTMENT-LINKED" R & D

A striking fact that emerged from the empirical analusis of the portfolio of projects is that the majority of them were "investment-linked". In other words they were research projects which inherently involved investments (nearly always in equipment) and in which the specific target of research was to generate the necessary information, designs, specifications, components and adaptations etc.- i.e. the necessary "localized know how" 7/ needed to support the purchases of equipment accompanying each project and to ensure the project's subsequent successful implementation. Moreover, the preponderance of "inv-stment-linked" projects over the "experimental" ones was not merely reflected in their numerical superiority (37 vs. 17 projects) but also in the relative expenditures involved. Thus, the investment-linked projects accounted for 75 to 80% of Acindar's direct expenditure on the labour input to the overall sample of projects, compared to only 20 to 25% for the experimental projects.

Hence to a first approximation, one is justified in ignoring the experimental projects completely, and considering Acindar's R & D effort as consisting exclusively of localized R & D carried out as part of investment-linked projects.

Yet, if this is so, then it suggests that the economics of assigning resources to this localized R & D 7/ are closely linked to the economics of the investments of which these localized R & D efforts form a part. In other words, there seems to be a strong prima facie case for examining both assignations of resources jointly, i.e. investment in the exogenously acquired "hardware" added to fixed assets and the expenditure on the endogenously generated "software" (the localized R & D) that accompanies it. This perspective allows one to formulate questions, such as - to what extent can these two assignations of resources be considered as complements, and to what extent can they be considered as substitutes? In either case, what would an optimum "mix" of expenditure on hardware and software consist of? At the back of one's mind lies the idea that here is some kind of joint maximisation problem.

If this view of the problem is accepted, then although the average 0.5% of its sales spent by Acindar on R & D may seem like "peanuts", its economic impact on the firm may nevertheless be great -given that these small localized R & D expenditures may strongly influence the degree of "efficiency" with which the 9 to 15 times larger capital equipment investments can be implemented by the firm.

In fact, consideration of some examples of the investment-linked R & D projects in the portfolio definitely supports this "interactive" view of the relationship between investment in capital equipment and investment in the localized R & D associated with it. In particular our attention was drawn to three basic economic

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7/ The reader is referred to the earlier discussion of the meaning of "localized" know-how and R & D in the footnote to page 7.

features of localized investment-linked R & D that seemed to apply to these projects.

1) In many projects localized R & D seems to act as a complement to the investment in exogenous, embodied technology, in the sense that the performance of this embodied technology, when fitted into the complex of the firm's existing machinery, is better than it would otherwise have been if this localized R & D had not been performed at all, or if not as much of it had been performed.
A good example relates to the installation and implementation of on-line quality control equipment. Here the precise location of the equipment in the production line and the formulation of the procedures and the precise timing of the quality control operations to be performed are clearly critical in making the investment succesful -yet the determining of the location, procedures and timing is obviously a problem requiring localized R & D.
In such cases localized R & D "works with" or "complements" an already defined exogenous design or piece of equipment. We can therefore term it "capital-complementing" localized R & D.

2) In a lesser number of projects the localized R & D and its accompanying capital equipment investment are concerned with, and embody, an alternative "localized" design-concept that acts as a substitute for a much larger investment in capital equipment that would have been needed had it been desired to accomplish the same performance increases using a more standard design concept based on "out of the catalog" exogenous technology. Good examples of this are provided by the projects involving reforms made to the rolling mills in the Rosario and Acevedo plants. In these cases, ingenious adaptations, layout changes,and relatively minor equipment additions designed locally were able to accomplish very substantial increases in mill production capacity that would have required far more capital investment to accomplish by more traditional methods based exclusively on exogenous embodied technology. In such cases we can talk of localized R & D being of the "capital-substituting" kind.

3) Previously acquired "learning" (learning-by-doing) often seems to have contributed a great fraction of the "localized know-how" that, in effect, "complemented" or "substituted" for new capital investment. In other words localized R & D expenditures taking place simultaneous with investments can in some sense be regarded as "building" on the already available stock of relevant "localized know-how " accumulated previously through learning-by-doing. Such localized R & D expenditures apparently both add some needed new "units" of localized know-how, and at the same time systematize the previously accumulated "units" available from past learning-by-doing. This suggests that the "effectiveness" of a dollar spent on localized R & D in connection with an investment project is partly a function of the extent of the previous learning that occured with regard to the functioning of that part of the plant into which the investment is to be inserted.

Accepting the existence of these three economic features of "localized investment-linked" R & D, we shall now attempt to see if some kind of simple model can be devised to exhibit their workings.

Towards a simple model

A way in which the problem might be modelled is as follows: suppose that a firm has a stock of capital K_o with which it is operating normally and producing output Q_o. This is its status in the initial time period t_o. Then, in the next period, we shall suppose that it has allocated a fixed amount, say iK_o, to invest where i is a constant. 8/

Our firm's problem is to invest this sum in the most efficient possible manner through introducing improvements, additions and adaptations to its existing stock of capital K_o What we visualise is that to achieve these improvements there are essentially two related uses which the firm can make of these investment funds iK_o These are (1) to apply these funds to purchasing new exogenous embodied capital (machines) for uniting with the existing capital stock; and (2) to apply these funds to localized disembodied R & D of the "investment-linked" kind so as to produce information helpful in the better specification, adaptation and implementation of the particular machinery additions that are contemplated, including any adaptations that may be needed to the existing capital stock as a result of these additions. Funds spent on the first use will be symbolised by the letter K. Funds spent on the second use will be symbolised by the letter R. Obviously $K + R = iK_o$, the budget constraint on investment.

The firm's maximisation problem is to choose that combination or "balance" of expenditures on K and R which will maximise the benefits which it will secure from investing in improvements to its existing plant. If the firm invests nothing in localised R & D, the chances are that it will commit significant errors in specifying the equipment to be bought with K and that it will also encounter unexpected difficulties and "bugs" which will slow down or make more costly the production obtained from the "improved" block of capital consisting of $K_o + K$. If, on the other hand, the firm invests its entire investment budget in localized R & D and does not buy a single new piece of equipment then it might in the extreme case expect no productivity or performance improvement whatever, (or, more plausibly, it could expect sharply diminishing returns on this localized R & D expenditure, as the opportunities for squeezing performance improvements out of the existing machinery through applying purely disembodied localized know-how would be quickly saturated 9/.) The conclusion is that some positive level of "localized" R & D expenditure by the firm in relation to its hardware investment, K, can be hypothesised as being "optimal".

But how can this possible "optimum" be located? What are the factors that might determine it?

8/ If we wish to require that the application of this investment to the existing block of capital should fall within the category of "incremental" or "improvement" investments then we could require that say $0 \leqslant i \leqslant 0.2$.

9/ In Hollander's study of the Du Pont plants, he found that "90% of cost reductions owing to technical change were dependent on (capital) investment at textile-yarn plants, and 80-90% at tyre-cord plants", S. Hollander, The Sources of Increased Efficiency, M.I.T. Press, 1965.

To begin to answer these questions, we obviously must try to say something more about how the "efficiency" of an incremental capital equipment investment is supposed to depend on the firm's expenditure on localized R & D in connection with this investment.

To start off with, we shall consider only "capital-complementing" localized R & D (i.e. when localized R & D acts as a complement to a standard "out of the catalog" investment in exogenous, embodied technology in the sense of improving its precise specification and detailed implementation). Some initial ideas about the form of the relation between K, the machinery investment, and R the expenditure on localized R & D in relation to it, are expressed in Diagram 1 overleaf. This shows an isoquant formed from what we shall call the "incremental production function". This is a function which describes the percentage increase in output capacity which is obtainable from our initial plant when K more equipment of a particular "standard" design-concept is installed in it and R of localized R & D gets spent on specifying and implementing this particular equipment. We suppose that $q = f(K_o, K, R)$.

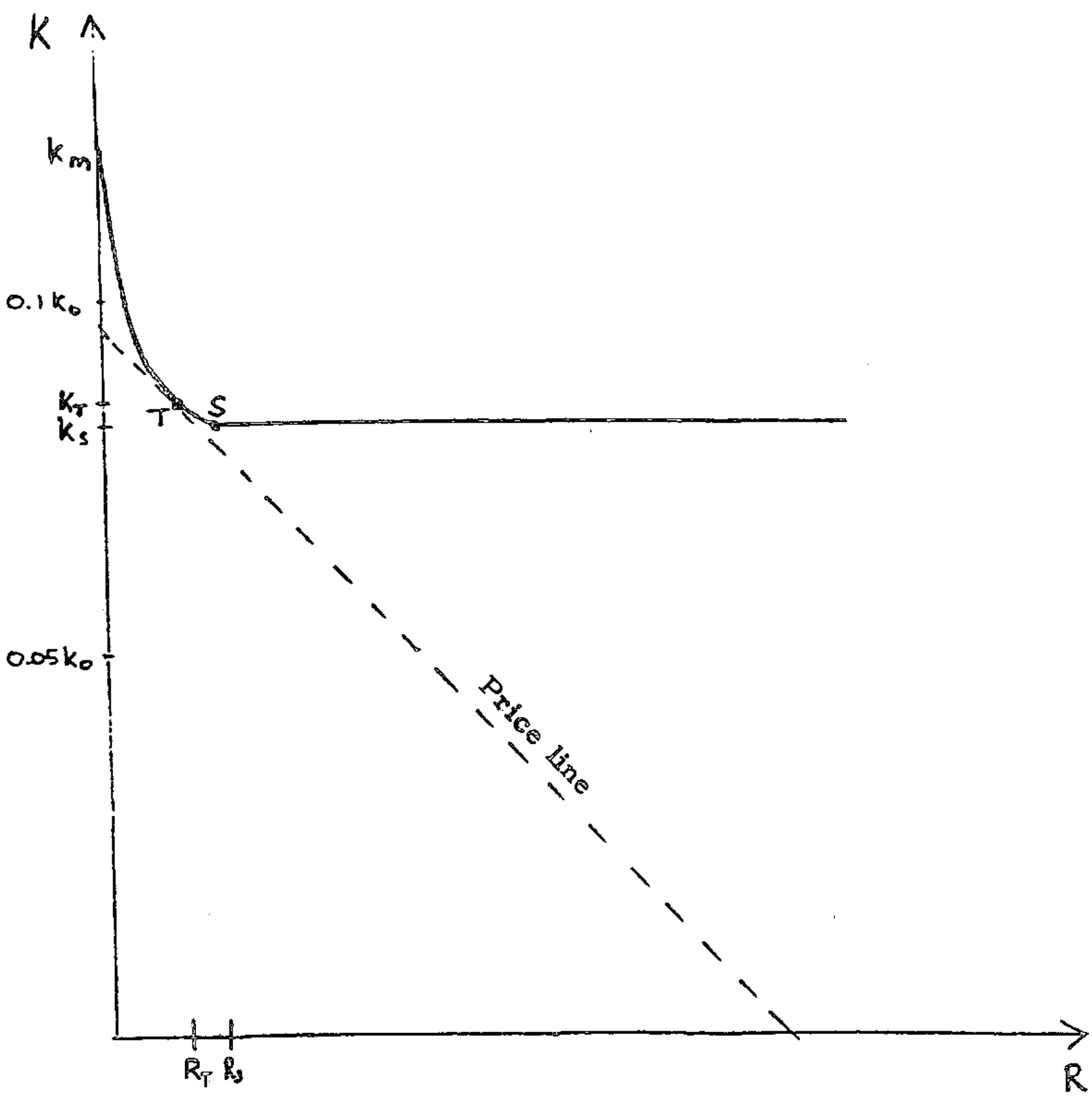
The isoquant in Diagram 1 represents all the input combinations of K and R required to produce, say, a 20% increase in the plant's production capacity by means of an investment in this particular kind of equipment of the order of 10% of the initially installed capital stock. The two scales to which the diagram is drawn are deliberately chosen so as to illustrate the relative orders of magnitude of the equipment expenditures vs. the localized R & D expenditures (which experience suggests are often of the order of 5:1 to 20:1). The units of the two scales are, on the K scale, "units" of capital, and on the R scale "units" of localized know-how, and the prices at which units of these two factors can be "bought" by the firm are set at $ 1 per unit in each case, which makes the firm's price line slope at 45º. Obviously there are some acute definitional problems with the concept of a "unit" of localized know-how, but we shall ignore these for the moment. We can think of the price per unit of localized know-how as being closely related to the salary levels of those of the firm's personnel who carry out the localized investment-linked R & D projects. A crucial point, which does, however, form part of our model later on is that units of R cannot be "purchased" from the firm's own staff in unlimited quantities. This is because the firm has only a limited number of staff capable of carrying out these activities.

Let us now turn to see what this Diagram 1 suggests. Its essential points are as follows :

1) If no expenditure on localized R & D relevant to the investment is made (i.e. no extra units of localized know-how beyond those already available from past "learning-by-doing" are deliberately generated), then K_m has to be invested in capital equipment to produce a 20% output capacity increase. Essentially what this means is that the investment in this particular kind of equipment gets "overloaded" or "over-engineered" due to ignorance. A very simple example of over-engineering would be when, say, a 3500 Horse Power engine is specified when more localized know-how would have shown that 3000 H.P. was sufficient. In other words the design includes surplus equipment items or superflous safety factors or operating features that increase capital equipment cost and could perfectly well be left out. 10/

10/ A pioneering empirical and theoretical microeconomic treatment of the problems of "overdesign" (and "under-design") in process plants can be seen in

Diagram 1: Isoquant of K and R input Combinations required to produce a 20% increase in a plant's production capacity.



2) If, however, the firm devotes resources to localized R & D, in connection with this particular kind of equipment, it can specify and implement this capital equipment more effectively, so that somewhat less capital is needed to get the desired capacity increase. In other words, localized R & D is traded off against capital equipment cost reductions in the travel down the isoquant slope. The optimum point is given by the tangent of the price line to the isoquant at point T, corresponding to capital investment of K_T and research expenditure R_T. This is the resource allocation that achieves the desired capacity increase at the lowest outlay. Capital costs can however be slightly further reduced if research is increased to R_s. At this point, "saturation" is reached in the sense that any further expenditure on localized R & D would be redundant -i.e. unable to reduce capital requirements any further.

3) We can also extract from the diagram a fairly precise meaning for the term "capital complementation", for the diagram shows that when a block of additional capital K_T is "complemented" by localized research R_T, the increased output achievable from this additional capital is equal to what could have been achieved by the addition of a larger block of capital K_m, uncomplemented by any localized R & D. K_m / K_t gives the capital complementation ratio achieved in this case.

4) There are, moreover, some other points that can be derived from this diagram by introducing different assumptions about the price and availability to the firm of each of the two factors, K and R, involved in the incremental production function. One such point concerns the fact that units of R can also be bought from outside firms (consultants or machinery suppliers). To model this we might imagine that such units acquired "out-house" cost three to five times what they can be bought for "in-house" (because of the high travel costs, salaries, and "learning-time" inherent in outside consultancy). This has the effect of sliding the price line up to the angle of a "ladder" leaning against the capital axis. The result is that it becomes optimal for the firm to tolerate a greater extent of "over-engineering" of its capital investments than would have been optimal if it had been able to count on a lower cost of creation of localized know-how through the efforts of its own personnel. Interestingly this situation can also come to pass when a firm has such a high rate of investment in relation to its available qualified personnel that these latter only have time to do the localized R & D needed for a fraction of the investment being carried out. 11/ Since such qualified personnel are, in the short run, an inelastic factor, the firm in such cases cannot buy any more units of R at "internal" prices and can only acquire additional units from the consultancy market at higher prices.

Francisco C. Sercovich, Ingeniería de Diseño y Cambio Técnico Endógeno, (Design Engineering and Endogenous Technical Change, Monografía de Trabajo N°19, IDB-ECLA Programme, Buenos Aires, agosto, 1978.

11/ This kind of situation also has a macroeconomic parallel, when whole countries (eg. Brazil) or highly dynamic sectors within countries (eg. steel in Venezuela at the present time) experience such rapid growth rates of investment that the growth in the supply of qualified local personnel from the local educational system and from learning-by-doing in industry cannot keep up. The inefficiencies this generates have been theoretically explored in an exciting paper by Richard Eckhaus "Absor-

We now come on to the "capital-substituting" case. This refers to situations when localized R & D does not merely "complement" an existing "standard" exogenous design by more precise specification and implementation, but introduces an essentially new "design-concept" for the investment. This design-concept is one that relies much more on ingenious adaptations of the firm's existing equipment than does the former investment. The idea is that this new design-concept, the fruit of localized R & D, enables an equivalent increase in performance to be gained at much lower investment cost than with the former idea -hence the term "capital-substituting". 12/

In Diagram 2 overleaf we have tried to display several features of "capital-substituting" localized R & D. We shall now explain this diagram, and then go on to discuss some of the results that can be derived from it.

The diagram shows two isoquants. These are AB and CD. AB is the isoquant of K and R input combinations needed to produce an X% increase in the plant's existing production capacity using a "capital intensive" technique of an essentially "standard" design i.e. one which is normally obtainable from a machinery supplier's existing range. The isoquant has the same features as the one portrayed in Diagram 1, in the sense that localized R & D is needed to "complement" the investment in this standard design. CD, on the other hand, depicts an alternative isoquant which shows the K and R input combinations needed to produce the same X% increase in the plant's capacity using a "capital-substituting" design-concept based on the application of a considerable input of localized know-how.

Also shown on the diagram are three different price lines representing different ratios of the cost to the firm of units of capital equipment versus "units" of localized R & D. 13/

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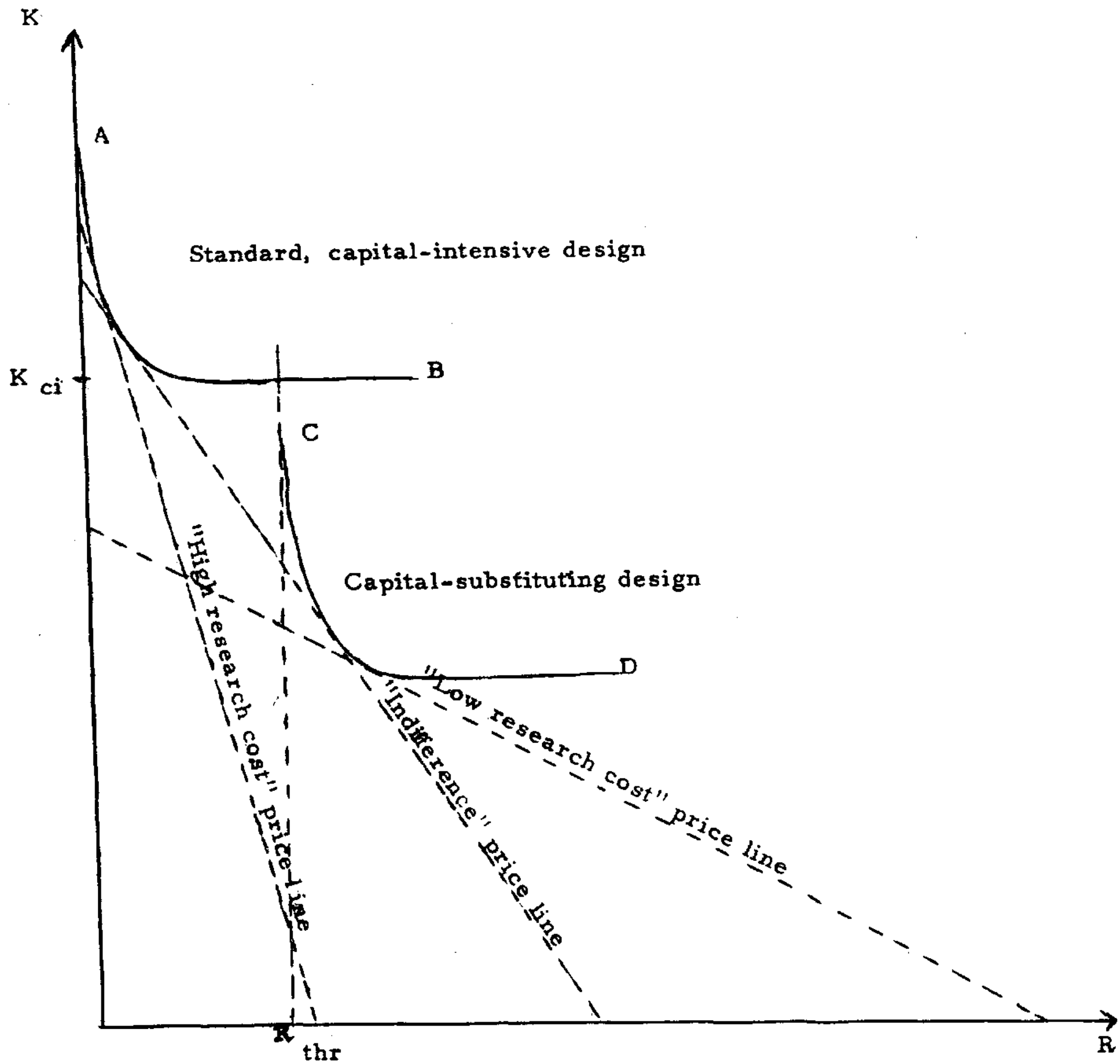
ptive capacity as a Constraint due to Maturation Processes", in J.N. Bhagwati and R.S. Eckhaus, Development and Planning Essays in Honour of Paul Rosentein Rodan, M.I.T. Press, Cambridge 1973.

12/ Excellent "real-life" examples of capital-substituting localized R & D were provided by the various projects in the portfolio concerned with reforms to the billet mill and bar & section mill in Acindar's"Rosario"plant, and with the adaptations of the Morgan N° 1 mill in the firms "Acevedo" plant.

13/ Strictly speaking, it could be claimed that we should not have put both isoquants on the same diagram, given that the type of localized know-how (units of R) needed for the capital-intensive technique is different from the type of localized know-how needed for the capital-substituting technique. (Indeed in our model we have assumed that the relevant know-how is specific to each technique and that there is no spillover). However we can conceptually imagine that the relevant know-how in each case can be divided up into "packages" or "units" which are approximately equivalent in terms of their degree of "complexity", "difficulty to obtain", etc. -and thus compare the number of such "units" of localized know-how that are needed in either case.

Diagram 2: Isoquants of K and R input combinations required to produce an X% production capacity increase by means of (i) a capital-intensive design, and (ii) a capital-substituting design.



If accurate knowledge of the two isoquant forms can be assumed, then optimum choice for the firm, as between the capital-intensive and capital-substituting designs, simply depends on the slope of this price line. At "low research cost", the capital-substituting design is the optimum one. And at "high research cost", the capital-intensive design is optimal. There is also a research cost to capital cost ratio at which the firm would be indifferent as between the two designs.

But what determines the slope of the price line, and along with it, the desirability to the firm of engaging in a localized "capital-substituting" R & D project? The answer of course, is that several different factors can help to determine its slope. We shall briefly mention three of them, so as to see how each affects the localized R & D decision as visualised through our model.

Firstly, consider the stock of past "learning-by-doing" which our firm may have accumulated concerning its existing capital equipment. It seems reasonable to assume that if this stock is large, then the cost to the firm of producing the relevant localized know-how for the capital-substituting design will be much lower than it would be for a firm operating with similar equipment but without this stock of experience. (For example, the latter firm might have been producing for only a short time or else lost key engineers who departed to other firms taking their "learning-by-doing" with them). The cost of capital equipment to both firms may, however, be supposed to be the same. The result is that the "experienced" firm will have a relatively "low research cost" price line, and the "inexperienced" firm will have a relatively "high research cost" price line. This is one reason why localized "capital-substituting" R & D projects are more likely to be undertaken by experienced than by inexperienced firms. 14/

Secondly, it is obvious that the cost of capital also determines the slope of the price line. If foreign exchange is very short, or import duties on imported capital equipment high, this will bias the choice towards the research-intensive -i.e. capital-substituting design.

Thirdly, if we suppose that the firm does not have, ex-ante, a completely clear idea of the likely cost of the localized research needed for the capital-substituting design, then it might overestimate (or underestimate) these research costs, thus taking its decision on the basis of a "ficticious" price line. We would expect that the most common case, in practice, would be the overestimation by inexperienced firms of the research costs for capital-substituting designs. If this is right, it will lead to underinvestment by inexperienced firms in capital-substituting localized R & D and overinvestment in exogenous capital equipment of "standard" design.

14/ Notice, however, that at very high values of the research-costs to capital rental ratio even the firm which has a valuable past stock of learning-by-doing will still find it optimal to select the capital-intensive technique. Conversely, at very low values of this ratio, it will pay even the firm which does not have a valuable stock of past learning to invest heavily in localized R & D so as to devise the capital-substituting technique.

Our model can also be used to illustrate how the choice of techniques (and associated choice of localized research project) may be affected by factor restrictions. If the firm's investment budget does not permit as much as K_{ci} units of capital equipment to be bought, then expenditure on localized R & D relevant to the capital-substituting technique is the only course open if the capacity increase is to be obtained. If, on the other hand, resources for research are restricted (e.g. because of the lack of internal personnel to perform it) such that less than R_{thr} units localized know-how can be bought (the threshold requirement for even the "experienced" firm to actually develop the capital-substituting design) then the only option open is to select the more capital-intensive technique, which requires less localized R & D input.

This completes our presentation of the model. We believe it throws light on certain aspects of the economics of "investment-linked" R & D projects of the kind found to make up the bulk of Acindar's R & D project portfolio. It should be emphasized, however, that we are not claiming to have presented an actual behavioural model of how decisions on investment-linked R & D projects get taken in Acindar. Rather, we have presented a speculative model as an aid to exploring some of the factors that underly such decisions.

IV. SOME ASPECTS OF ACINDAR'S R & D "STRATEGY"

This section is concerned with clarifying the nature of the specific "strategy" displayed by Acindar in its R & D portfolio, and with speculating on arguments in favour of a more explicit strategy.

To start with, there is no doubt whatever that- at least in the period under consideration (1970-74)- Acindar did not have an explicit "R & D" policy. This was demonstrated not only by the absence of any separate R & D department, but also by the fact that when the tax deduction legislation for R & D projects was published, Acindar did not have readily available any systematically organized information on the different R & D projects which it was carrying out in its different plants and departments, but had to appoint one of its staff as temporary "R & D Director" and assign him to collecting and coordinating all the data on R & D projects so that the firm would be able to submit the necessary data in the tax deduction applications.

Also consistent with this lack of explicit R & D policy was the fact that in the two years 1971-72 and 1972-73, direct labour expenditure by Acindar on R & D varied from roughly 0.8% to 0.2% of annual sales showing visibly that R & D expenditure was not targeted at some roughly fixed level, but varied according to the number and type of projects being performed rather than vice versa. 15/

In order to identify the "implicit" strategy guiding the choice of R & D projects, we consulted the tax applications so as to explore the kinds of stimuli that had given rise to individual R & D projects. Information on these stimuli were contained in the project descriptions in the applications. These descriptions provided reasonably detailed and unambiguous data on the stimuli to the majority of the projects, though only vague data on a minority. In fact we had to be content with vague data for about one-third of the projects in the sample- especially amongst those projects involving the actual or potential launch of new products for which often the only reason given as justifying the project was "market demand" without any further details. In these cases we had no choice but to record the stimulus as "market demand for new product", which is of course a somewhat nebulousconcept. (The point is that one would like to know how this demand came to the attention of the firm and whether the firm in some cases led the market rather than following it. In a few cases we do have this information and it is recorded in the analysis that follows).

Accepting then, that there are some significant data limitations, we were able to assemble Table 1 that follows showing the detailed classification of the main single stimulus to each of the 54 projects, on the basis of the project descriptions provided.

15/ In an explicit R & D programme, it is the number and type of projects that adjust themselves according to the previously earmarked budget set, for example, as a fixed percentage of the previous year's sales.

Table 1: Classification of the Stimuli to the 54 R & D Projects

Origin of the stimulus	Type of Stimulus	Classification of the Stimulus	Number of Projects
From the market	Need-pull	Increased market demand for existing product	11
	"	Market demand for better quality product	3
	"	Market demand for new product	13
From within Production	Need-pull	Production problems with existing process	3
	"	Production problems with existing raw materials	1
	"	Quality defect noted with output of existing process	3
	Capability-push	Opportunity spotted to reduce labour costs	2
	"	Opportunity spotted to eliminate process stage	1
	"	Opportunity spotted to improve product yield	1
	"	Opportunity spotted to speed process up	1
	"	Opportunity visualized to utilize a radically different process to produce an existing line of products	1
From the Advance of Technology outside the firm	Capability-push	Advance of the state of the art in analytical techniques related to quality control	2
	"	Offers of technical assistance in metallurgy from National Commission of Atomic Energy	1
	"	Desire to "lead" technologically in Argentina in a major new product line for which foreign technology had been licensed	2
	"	Demonstration effect of the success of a new product in overseas markets	1
From Factor Markets	Need-pull	Supply restrictions and/or price increases in raw material inputs	6
	"	Quality decline in raw materials inputs	1
		TOTAL	54

Source: Author's Compilation based on Project Descriptions contained in Acindar's presentations to the Subsecretariat for Science and Technology.

The main point which emerges from this table is that the majority of the R & D projects fit rather well into a model whereby innovations get "induced" by quite definite "signals" of the need-pull kind. Thus even if we leave out all 13 projects shown in the table for which the need-pull is specified only vaguely as "market demand for new product", we are still left with 29 projects -i.e. 54% of the sample, where some tangible and definite "need-pull" signal indicated the need for a technical change.

This suggests that the role of the majority R & D projects was to respond to clearly identified emerging needs, whether coming frommarketplace, from production, or from restrictions in factor markets. Such R & D projects might therefore be described as fulfilling a "reactive" role -i.e. they enable the firm to react to definite signals by improving its technology to match the specific needs involved.

What about the other 25 projects, however, when the impulse was either of the "capability-push" kind, or involved the rather vaguely defined "market need pull" leading to new-product-linked projects? First, so far as the "capability-push" kinds of projects are concerned it appears that what led to them was the ability of individual Acindar staff to suggest improvements without the incidence of any special, immediate or urgent need to catalyse the suggestions. In fact we could say these projects resulted from the spontaneous application of "engineering provement criteria" by the firm's engineers to the machinery and processes under their control.

Second, with regard to the 13 new product linked projects said to have been stimulated by "market demand", it seems likely that whilst most of these projects responded to specific market demand, some may well have responded to a strategy of "technological leadership" whereby Acindar was trying to "lead" the market rather than following it. 16/ This latter kind of situation of course lies in the realm of "active" or "offensive" new product strategy (with its accompanying need for localized R & D) and not in the realm of "reactive" strategy.

With due allowance for the gaps in our data, we can now make the following rough estimate regarding how the sample of 54 projects was divided up in terms of the nature of the stimuli involved: that some 60-70% of the R & D projects were of the "reactive" kind, responding to the emergence of quite precisely defined market needs, production problems or raw materials supply problems; some 15-20% may be considered to have emerged from the "spontaneous" application of engineering improvement criteria by individual technical staff; and a further 10-20% seem to have responded to some kind of "technological leadership" strategy, whereby the firm was attempting to experiment with or introduce new products or quality improvements not yet put on the market by its rivals.

16/ This hypothesis is supported by the fact that Table 1 shows four definite cases of new product launches responding to such a strategy, classified as stimulated by the advance of technology outside the firm.

It should, however be recognised that this is our "ex-post-facto" reconstruction of the characteristics of the 54 R & D projects. It definitely does not reflect any explicit, ex-ante, policy on the part of Acindar, that its R & D programme should incorporate this particular balance of "reactive" "spontaneous", and "technological leadership" projects.

Hence one cannot regard these 54 projects as constituting a planned "portfolio" of R & D projects in the sense that this term is used by the directors of reseacrh laboratories. Rather, one has to regard this collection of projects as the implicit result of a set of projects decisions taken individually.

Towards a more "explicit" R & D strategy

The question obviously arises -would it not be more rational for a firm like Acindar to plan its R & D programme more explicitly?

Related to this, one can ask -is the "implicitly determined" level or R & D expenditure the optimum one from the viewpoint of the firm ? Should it, perhaps be higher? What is the optimum "balance" of a portfolio between "reactive" and "active" projects, and between investment-linked and experimental ones? Should there be a separate R & D department? etc.

Obviously, our empirical analysis of Acindar's R & D portfolio characteristics in this paper does not equip us to provide definite answers to these questions. Nevertheless a number of observations and speculations can be advanced.

First of all, regarding to the de-facto "implicit" R & D strategy actually followed by the firm, it should not be assumed lightly that this strategy is easily copiable by any steel firm whatsoever. This is because the capacity to (i) generate R & D in reaction to specific need pulls (ii) generate some R & D "spontaneously" and (iii) generate the R & D needed to match some technological leadership projects is certainly not automatic, but reflects an already sophisticated technical organization. In Acindar's case this includes the quality control department and all its analytical and metallurgical back-up, the industrial engineering department which carries out methods and operations research studies, the project engineering department, the maintenance engineering department, and many other technical offices, some of them closely connected to production operations, as well as all the brain-power of the engineers and technicians directly in charge of production. This complex of "technical capabilities", although not containing separate R & D laboratory, is perfectly capable of generating the small project teams and combinations of resources needed for individual R & D projects. Therefore it is not "obvious", prima facie, that specialisation of the R & D function would automatically provide better R & D performance. One would need to show that the existing set-up suffers from problems of coordination, or fails to take advantage of potentially synergistic overlaps between different projects. or is unable to sustain some needed threshold of effort, or that it does not effectively select the more profitable projects, for the case for R & D specialisation to start becoming persuasive.

On the question of possible "underinvestment" in R & D. It seems necessary to split the issue up into parts. First of all, regarding investment-linked R & D it follows directly from our model presented in the previous section that there always exists the potential for underinvestment (or overinvestment) in localized R & D on any particular investment project. Such underinvestment necessarily leads either to "over-engineering" or "misspecification" (in the capital-complementing case), or else to failure to opt for attainable "capital-substituting" designs (a mistake more likely to be made by inexperienced firms).

Secondly, regarding experimental R & D projects, the relatively low commitment of R & D expenditure to projects of this kind might conceivably reflect a relative lack of profitable opportunities to carry out experimental projects (i.e. some kind of "saturation" of inventive opportunities), however a more likely explanation is that it reflects that Acindar, whilst open to individual experimental projects suggested at the initiative of individuals or department heads, is not yet fully committed to experimental R&D as a "way of life", which would imply allocating a regular budget to it. 17/

There is however, evidence that an increasing interest in experimentation seems to be gradually emerging as a result of experience. Thus, even though Acindar does not have a separate R & D department, it has for more than ten years had an Industrial Engineering Department which regularly carries out operations research studies aimed at such matters as improving yields, reducing production-cycle times, etc. Furthermore, the firm's quality control department, which was greatly strengthened in the past few years following Acindar's entry into the special steels field, now regularly experiments with new grades of special steels. The firm also now has a formalised R & D department for "metallic structures" which has grown out of the function of providing technical assistance to clients.

On the face of it, the next logical step would appear to be for Acindar to provide a more sustained and explicit resource allocation to experimental projects coordinated through a specialist R & D department which would supervise or at least monitor the whole portfolio of experimental projects that are underway or planned. In any event, such a step would appear to be quite easy for Acindar to take if it wished to do so.

Thirdly, regarding investment in "reactive" versus "active" R & D projects, a case can be argued that the balance of Acindar's programme leans too heavily on "reactive" R & D, and neglects "active" R & D (i.e. the R & D which we identified as arising spontaneously from engineer's suggestions or as a result of technological leadership strategy rather than as a reaction to specific need pull stimuli). This case gains support from the idea due to Nelson and Winter that there may exist "natural trajectories" of technical change, appropriate to the particular "technological regime" with which a firm is working, that "focus the attention of engineers on certain directions in which progress is possible, and provide strong guidance as to the tactics likely to be fruitful in probing in that direction", and for which the "payoffs from advancing in that direction exist under a wide range

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17/ In this context, it should be born in mind that even if no experimental projects at all were conducted, there would still be a very substatial and challenging set of "investment-linked" R & D tasks to perform, of the "reactive", "spontaneous" and "technological leadership" kinds -so that conducting no experimental projects would not imply technological stagnation.

of demand considions". 18/ This idea is strongly corroborated by the studies on steel plants in Mexico, Brazil and Argentina carried out in the IDB-ECLA Programme in which a good number of "natural trajectories" appropriate to steel plants were independently discovered. 19/ Sixteen of these natural trajectories are listed below.

1) Resolving bottlenecks
2) Stretching the capacity of existing units through mechanization layout changes, faster loading, simplified product mix, lowered rejection rates etc.
3) Reducing process cycle times
4) Minimization of non-recuperable metallic losses and recycling of recuperable losses
5) More intensive utilization of bye-products
6) Improved in-plant materials handling
7) Establishment of operating routines for the principal equipment units and process optimization
8) Minimization of maintenance and repair down-times
9) Standardization and beneficiation of raw materials leading to more successful operating routines and more consistent product quality
10) Cost reduction through altered input mix
11) Saving on energy consumption through greater thermic efficiency
12) Extending the useful life of equipment units
13) Extending the useful life of refractories, mill rolls and ingot moulds
14) More exact and intensive quality control
15) Product diversifiaction and new product development on the basis of existing equipment
16) Organizational innovations to meet the challenges inherent in the inmense scale and multi-departamental complexities of modern steelmaking.

The argument is that there is no inherent reason why all these natural trajectories should only be followed "reactively" i.e. when necessity arises. They can also be pursued "actively" by a combination of capital investment, localized R & D linked to this investment, and experimental R & D. In this perspective, an explicit R & D policy, coordinated with investment, and aiming at rapid advance along these natural trajectories, could make a lot of sense.

18/ For the concept of "natural trajectories", see R. Nelson and S. Winter, "In Search of a Useful Theory of Innovation", Research Policy (6) 1977.

19/ The researchers involved were Luis Alberto Perez and Jesus Perez y Peniche (Mexico), Carl Dahlman and Fernando Valadares Fonseca (Brazil), and the author (Argentina).

V. CONCLUSIONS

The empirical analysis of Acindar's R & D project portfolio on which this paper is based has enabled us to take quite a "microscopic" look at the kind of R & D performed by this enterprise.

Whilst we cannot claim that this analysis has produced any major surprises -as looking at familiar objects through an optical microscope sometimes does- it has served to provide confirmation of (i) the essentially modest, localized, improvement character of Acindar's innovations, (ii) the implicit nature of Acindar's R & D strategy, and (iii) the need-pull induced character of most of the projects in the portfolio.

If there was one finding that could be regarded as possibly "surprising", it was to discover how closely related the localized R & D in Acindar was to investment in capital equipment- so much so that it seemed correct to us to treat this problem economically as one of joint assignation of resources.

Our model of this joint assignation problem emphasized the alternative roles of localized R & D as either "capital-complementing" or "capital-substituting". It underlined the relevance of the assignation of resources to localized R & D in influencing the efficiency of a firm's capital investment programme.

Therefore, one direction in which the results of this paper point is towards the need for a more refined theory of investment -in which localized investment-linked R & D would be explicitly taken into account. In this connection, an empirically significant problem would be to find out more about the location and shape of the trade-off curve between capital investment and localized R & D in the capital-complementing case. Another empirical problem would be to explore how enterprises actually reach investment decisions as between capital-intensive techniques and possible capital-substituting alternatives.

The other direction of research which our results indicate could be fruitful is to probe deeper into (a) the specification of natural trajectories in steel-plants and (b) the evidence that an explicit, more "active" or "offensive" R & D strategy aimed at proceeding swiftly along these trajectories could be demonstrably superior to the kind of implicit, mostly "reactive" R & D strategy observed in the present case.

APPENDIX

Appendix. Table 2. Classification of the 54 R & D Projects in Terms of the Nature of the work involved

54 Projects in all	"Exclusively process change" projects (31 projects)	New-product-linked" projects (23 projects)
"INVESTMENT-LINKED" PROJECTS (37 PROJECTS)	Process changes involving the design and execution of alterations to a whole line of machinery or to a major stage in the production process .... 4 projects.	Alterations to produce new product lines which involved adapting a whole line of machinery or a major stage in the production process, or the adding of a new supplementary stage and which implied something more than just the exercise of mechanical engineering design skills 1/...... 8 projects.
	Process changes involving essentially mechanical engineering type changes to individual machines or substages in the production process ..... 15 projects.	Adaptations via purely mechanical engineering type design projects for new individual machines or substages in the production process required for new product lines .... 3 projects.
	Changes involving the introduction of speedier and cheaper methods of chemical analysis required in the process cycle .... 3 projects.	Installation followed by familiarization and calibration of sophisticated new quality control equipment needed for new product lines with more stringent quality requirements ..... 4 projects.
"EXPERIMENTAL" PROJECTS (17 PROJECTS)	Experimental process changes involving trials with a significant modification of process variables ... 4 projects	Experimental new product-and-process development projects involving (a) studies, tests, etc. to determine new product specifications and related process variables and conditions, and often (b) the operation of pilot manufacture or a pilot line ... 8 projects
	"Studies" to improve existing product quality via process changes which involved investigation, tests and experimentation with alternative processing methods ... 5 projects	

Source: Author's classification based on the Project Descriptions contained in Acindar's presentations to the Subsecretariat for Science & Technology.

1/ For example, involving changes to a rolling-mill line or changes which involve metallurgical factors.

Appendix. Table 3. Ranking of the 54 R & D Projects in Decreasing Order of the Estimated Input by Acindar of man-months of university-trained and technically-trained Manpower to the Projects.

See Key to the Table and Notes to the Table on p. 35.

Project N°	Project Title	Type 1/	Type 2/	Acindar U + T	Acindar Total Labour	Other firm's U + T	Other firm's total labour	Overall total labour (Acindar+other firms)	Approximate Estimated expenditure by Acindar on its total labour input (expressed in US$).	
				Expressed in man-months						
22	Modification of reheat furnace and section mill	I-L	EPC	147	565	353	588	1272	$ 483,000	1/
25	Rolling mill for special steels	I-L	NPL	98	348	-	1350	1698	$ 438,000	
34	Improvements in the section mill	I-L	EPC	68	73	-	395	468	$ 128,000	
01	Wire galvanization by hot immersion	EXP	NPL	66	73	-	-	73	$ 47,000	1/
54	Conditioning of special steels	I-L	NPL	63	63	-	1333	1396	$ n.a.	
05	Automatic packing of nails	I-L	EPC	61	210	9	124	334	$ 100,000	
21	Modification of reheat furnace and billet mill	I-L	EPC	56	145	10	15	160	$ 248,000	2/
12	Reform of the patenting line	I-L	NPL	50.2	88.2	7	27	115.2	$ 35,000	
02	Separators" for suspended wire	EXP	NPL	45	159	6	6	165	$ 103,000	1/
20	Optimisation study for heat-treated spheroid steel	EXP	EPC	33	33	-	-	33	$ 19,000	2/
17	Investigation to use steel of high carbon and magnesium content	EXP	EPC	28	28	-	-	28	$ 11,000	

Table 3. (cont.)

28	Automation of the air-blasting of galvanized pipes	I-L	EPC	27	27	13	68	95	$ 39,000	
37	Reduction of steel production time using new analytical systems	I-L	EPC	27	27	-	-	27	$ 15,000	
11	Fabrication of torniquets	EXP	NPL	27	28	-	-	28	$ 19,000	1/
26	Gas injection in hot air cupola furnace	EXP	EPC	25	102	-	18	120	$ 51,000	1/
10	Double rewinding unit	I-L	NPL	23	40	10	16	56	$ 19.000	
09	Torsioning machine with three stations	I-L	NPL	22	204	-	-	204	$ 109,000	2/
43	Improving distribution of carburos in MO 20 steel	EXP	EPC	20	30	-	-	30	$ 16,000	
15	Machines for relaxation tests	I-L	NPL	20	21	-	-	21	$ 90,000	1/
16	Saline fog room	I-L	NPL	18	18	-	-	18	$ 8,000	
04	Differential bobbins	I-L	EPC	18	220	-	-	220	$ 36,000	1/
44	Mechanical engineering drawings of Schumag cropping machine	I-L	EPC	18	18	-	-	18	$ 10,000	
13	Design of prototype metallic posts	EXP	NPL	17	17	-	-	17	$ 5,000	
33	Oxygen cutting of Somisa Blooms	I-L	EPC	16	117	-	41	158	$ 33,000	
40	Investigation of the rolling of high alloy special steels	EXP	NPL	14.5	70.5	-	-	70.5	$ 25,000	
41	Proving out of new ultrasonic tests	I-L	NPL	14.5	17.5	-	-	17.5	$ 42,000	
18	Studies of the utilization of 1008 R ingots in electrode fabrication	EXP	EPC	14	16	-	-	16	$ 16,000	2/

Table 3. (cont.)

29	Rolling of American type 3" and 4" U-shapes	I-L	NPL	13	27	-	12	39	$	22,000	
38	Adaptation of Sybetra oven into mobile hearth oven	I-L	EPC	13	19	-	-	19	$	7,000	
39	New methods of chemical analysis	I-L	EPC	13	13	-	-	13	$	6,000	
50	Rolling of 17.5 to 30mm round bars from 100mm billets	I-L	EPC	11	15	-	6	21	$	13,000	
30	Rolling of angle steel	I-L	NPL	11	34	-	3	37	$	16,000	
52	Diminution of flakes in steel	EXP	EPC	9	16	-	-	16	$	n.a.	
35	Injection of oxygen in the Siemens Martin furnaces	EXP	EPC	9	55	-	-	55	$	20,000	
42	New Processes for improving the quality of tool steel	EXP	EPC	9	21	-	-	21	$	8,000	
51	Rolling of 32 to 50.8 mm round bars from 50mm billets	I-L	EPC	8	12	-	7	19	$	10,000	
03	Increase in the productivity of barbed-wire making machines	I-L	EPC	8	8	-	-	8	$	2,000	
47	Coppering in the Aetna standard wire drawing machine	I-L	NPL	8	22	-	-	22	$	10,000	
48	Rolling of T&I shapes	I-L	NPL	8	10	-	3	13	$	7,000	
53	To reduce fusion time of low-alloy steels	EXP	EPC	7.5	9.5	-	-	95	$	n.a.	
49	Rolling of L-shapes	I-L	NPL	7	11	-	6	17	$	10,000	
23	Productivity increase in section-straightening machines	I-L	EPC	6.4	27.4	13	27	54.4	$	29,000	2/

Table 3 (cont.)

24	Fabrication of metallic post for wire-fencing	EXP	NPL	6	12	9	18	20	$	8,000	
46	Compacting machine for wire rolls	I-L	EPC	6	6	-	65	71	$	26,000	
08	Bar aligner	I-L	EPC	6	18	-	-	18	$	5,000	1/
13	Feed system N°1	I-L	EPC	6	6	-	-	6	$	2,000	1/
27	Niobium steels	EXP	NPL	5	7	-	-	7	$	2,000	2/
45	Machine for enrolling steel	I-L	EPC	5	24	5	5	29	$	11,000	
14	Reform of galvanising line N°4	I-L	EPC	4	15	-	-	15	$	5,000	1/
07	Salomonic nails	I-L	NPL	4	4	-	-	4	$	2,000	2/
06	Phosphating-coppering line for fine wire immersion	I-L	NPL	4	5	-	-	5	$	3,000	
32	Transfer of sections from straightening to dispatch	I-L	EPC	3	5	-	6	11	$	3,000	
31	Reduction in the refining time of liquid steel	I-L	EPC	3	3	-	22	25	$	5,000	
36	Tests on quality improvements and new types of electrodes	EXP	NPL	1.5	1.5	-	1.5	3	$	1,000	

Key to the Table :

a/ I-L = Investment-linked project; EXP = Experimental project.

b/ EPC = Exclusively-process-change project; NPL = New-product-linked project

c/ U + T = University plus technically trained manpower.

Notes to the Table

1/ implies estimated at $ 1 = 6.14 pesos
2/ implies estimated at $ 1 = 3.86 pesos

The US$ dollar figures in the extreme right hand column refer to current dollars in the 1970-73 period -and these figures would need to be multiplied by approximately 1.5 to bring them up to their 1977 purchasing power.

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