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FIRST-BEST TECHNOLOGICAL STRATEGY IN AN "Nth-BEST" ECONOMIC CONTEXT

A Case-Study of the Evolution of the Acindar Steelplant in Rosario, Argentina

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PART I. INTRODUCTION

The purpose of this paper is to present a case-study of how an Argentine steelplant built in 1943 has evolved in the 34 years since then - and to offer an interpretation of this evolution as an example of a "first-best" technological strategy being applied in an "nth-best" economic context.

The interest of such a case study is that it can exemplify a theme which is of common interest and relevance in many Latin American countries - namely how firms owning industrial plants can manage to adapt and evolve their plants in the face of a "macroeconomic" context which is full of economic distortions and irrationalities.

Of course, the existence of serious macroeconomic distortions and irrationalities in Latin American economies is perfectly well known and nothing new, yet there still remains very much that is unknown about the way microeconomic agents such as firms respond to such distortions. Patently, there must be some ways of responding more successfully than others, and one can therefore ask - what might "first-best" technological strategy for firms consist of when the macro-economic context does not conform to what the text books say it should be? Or to put it more succinctly, in the words of an Argentine nuclear engineer - how does one succeed in "innovating in the midst of organised chaos"? 1/

This problem, of trying to work out a first best technological strategy for the firm in response to imperfectly predictable outside circumstances extends not just to the classic "choice of technique" decisions faced by firms when installing brand new capacity, but also to the much less studied topic of how firms should best evolve their installed technology over time. What happens, then, to the economics of choice of techniques, of replacement and obsolescence decisions and of "evolutionary operation" of plants when factor markets are subject to rationing, when capital markets don't always function properly, and when sharp fluctuations of the political and institutional horizon are likely to occur yet difficult to predict?

Even to put the question is to see that the answer will not come out of a neat model or even a score of neat models - as we are plainly up to our necks here in "institutional" factors which will continually mess up the picture with problems such as - "but how were they to know that scrap supplies would be rationed in 1967 or that steel prices would be liberated by the new government?"

Nevertheless, although neat models are not in sight, there should still be some interesting economic conclusions to be drawn by observing how firms have actually responded to difficult macroeconomic contexts over longish periods of time.

It is in this spirit that we now put forward - in Part II of the paper - the following case study of the evolution of the Rosario steelplant of Acindar during 34 years. Although case-studies can never by themselves be conclusive, the study does point to a number of specific issues on which the traditional economic

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1/ This aphorism was coined by Jorge A. Sabato, who is well known for his participation in the Argentine nuclear energy programme and for his contributions to the field of science and technology policy.

analysis of decisions on steelmaking technology might be improved. These issues are discussed in Part III of the paper, which follows after the case-study.

PART II. THE CASE STUDY

The case-study that follows is concerned to describe and then explain the "paradox" that Acindar - which is a well managed and technologically progressive steelmaking enterprise - continues to operate one of its plants - the Rosario plant - with long outdated technology.

In Section 1 of the case study Acindar's record as a technologically and managerially progressive enterprise is traced out. Then in Section 2, the role of the Rosario plant within Acindar's overall steelmaking activities is explained. This then equips us to present, in Section 3, the nature of the "paradox" of the Rosario plant. Section 4 is then concerned with the "imperfections" in the postwar Argentine economic context which can help account for the Rosario paradox and thus enable Acindar's technological "strategy" for the Rosario plant to be seen as rational in profit-maximising terms. Finally, in Section 5, some interesting detailed features of the unconventional technological strategy adopted by Acindar in the Rosario plant are explored and discussed. Section 6 then sums up the key points of the case-study, thus paving the way for the last part of the paper, which offers a series of reflections concerning some of the interesting economic issues which emerge from the Rosario plant's experience.

We now turn to the case-study itself.

Section 1. Acindar as a progressive enterprise

Acindar S.A. was started in 1942 and is today Argentina's largest private nationally-owned enterprise. 2/ Its record shows that the enterprise has displayed a consistently dynamic technological and managerial "thrust" right from its start in 1942 up until the present day.

Thus, in 1943 Acindar pioneered by designing, constructing and starting up the Rosario steel plant - which is the subject of this study - at a time when all the usual technology channels from abroad were cut-off by the war. Then in the period 1947-51 Acindar reached right out to the "technological frontier" and imported and started up a huge 250,000 tons modern continuous rolling mill in a brand new plant, which it built in Villa Constitución, some 50 km from Rosario. Since then, Acindar has also pioneered, within Argentina, in forged products for the automobile industry during the 1950's; in iron-ore exploration, in special steels and in PVC tubes during the 1960's; and in pre-stressed steel bars, in high quality forging products, in electrodes, and now in direct reduction steelmaking technology during the 1970's.

2/ As measured by sales volume. Only the two state enterprises Yacimientos Petrolíferos Argentinos and SOMISA, and the multinational firm Fiat appear ahead of Acindar in La Prensa Economica's list of "las mas grandes empresas de la Argentina", Editorial Lourdes, Buenos Aires, 1977.

Furthermore all three of the steelplants with which Acindar currently operates - and the fourth plant now going up - embody highly significant inputs of Acindar's own engineering designs and adaptations.

There can therefore be no doubt about the consistent technological capability of the enterprise throughout its entire evolution from 1942 to the present day.

Turning next to the entrepreneurial and managerial side, Acindar has also revealed itself to be consistently dynamic and well run. Both under its first president (and founder) Arturo Acevedo, who ran the enterprise from 1942 to 1967, and under its second President, José Martinez de Hoz (now Argentina's Economy Minister), 3/ Acindar was widely acknowledged for its efficiency and progressiveness - and in support of this one can note that Acindar was able to command a long succession of important loans from international banking institutions.

In short, there is every reason to consider that Acindar conforms very well to the economist's model of a "profit-maximising" firm. Furthermore, it is clear from both published material and inside knowledge of Acindar that the enterprise's strong technical and engineering capability provided its management with a full range of "technological strategies" amongst which to choose the most profitable.

Therefore, in seeing how Acindar has reacted to the difficult macroeconomic context of three decades in post war Argentina, we are examining the reactions of a well-run, technologically dynamic, and profit-maximising enterprise.

Section 2. The role of the Rosario plant within Acindar's steelmaking activities

The next indispensable element of "background" needed to understand the nature of the "paradox" presented by the Rosario plant is to appreciate how the Rosario plant fits into the overall set of Acindar's steelmaking operations. These operations are summarised in the flow diagram next page which refers to the year 1975-76. (NB See footnote below) 4/

As can be seen in this diagram, Acindar currently has three working steel plants, and one more is under construction. To start with we have the Rosario plant, which is the object of this study. This was the enterprise's first plant, which started up production in 1943. It is located on one of the principal avenues

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3/ Martinez de Hoz left the Presidency of Acindar in April 1976 to become Argentina's economy Minister under the new military government.

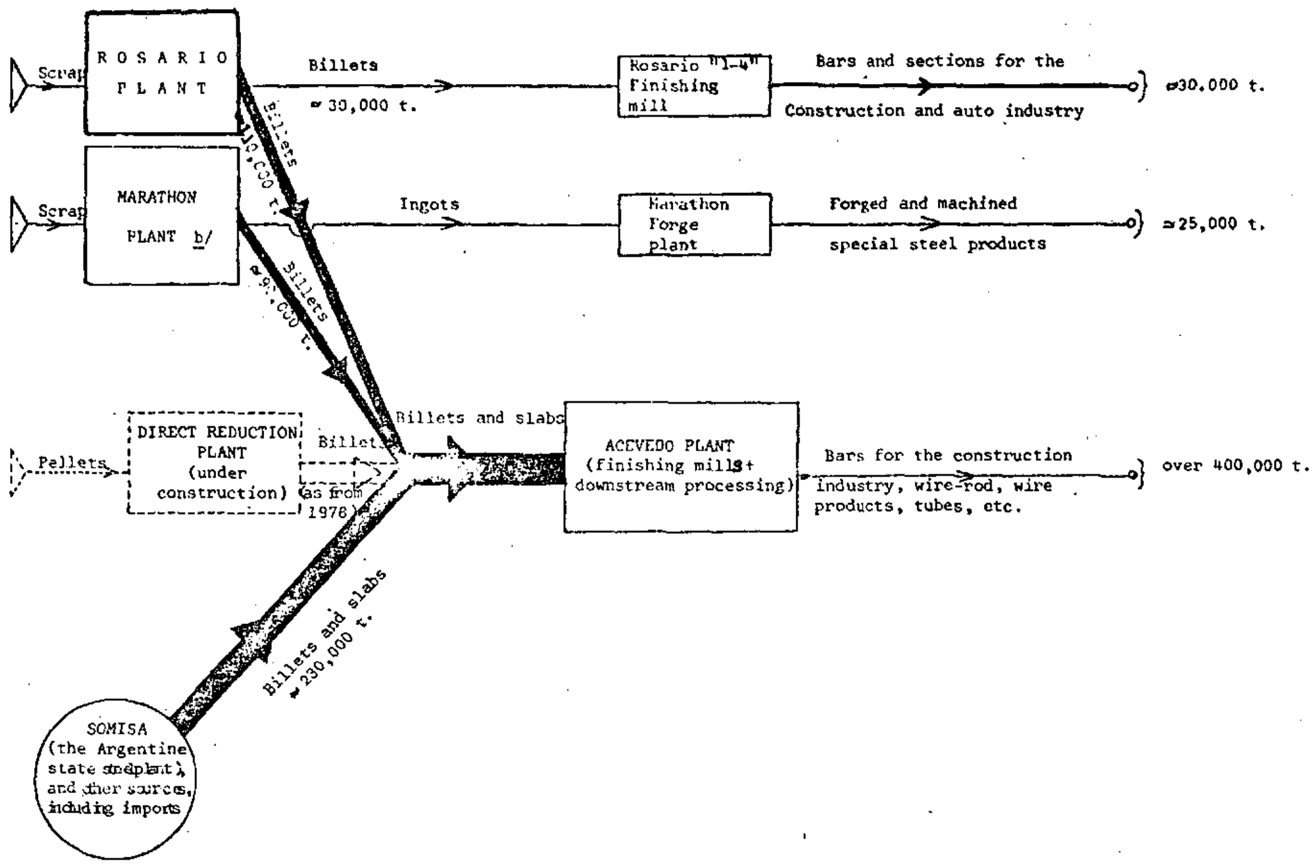
4/ The manuscript of this paper was completed in September 1977, when the Rosario plant was still in full production. However, prior to the submission of the manuscript we heard that Acindar in November 1977 had finally closed down the Rosario plant's Siemens Martin steelmaking units.

This is a significant event in the context of this case study and we comment on it in a special postscript appended to the end of the case-study.

The reader should therefore understand that the author's use of the present tense in this paper refers to the period up until September 1977 when all the Rosario plant's units were still functioning.

leading into the city of Rosario in the Province of Santa Fe, Argentina, on a site which is a few miles inland from the river Paraná.

Diagram 1 - Acindar's Steelmaking Activities 1975-76 (Simplified a/)



a/ The readers will appreciate that this is a highly simplified representation. For instance, no recycling flows are shown and both inputs and outputs have been treated in broad categories. A further significant point is that the production capacities of the various installations are in most cases considerably greater than is suggested by the production figures shown in the diagram. In approximate terms Acindar's installed capacity in 1975-76 consisted of 1) Rosario: Siemens Martin steelmaking 145,000 t.p.a., Billet mill 160,000 t.p.a., Finishing mill 120,000 t.p.a.; 2) Marathon: Electric arc steelmaking 160,000 t.p.a, Continuous casting 200,000 t.p.a.; 3) Acevedo: Morgan 1 360,000 t.p.a., Morgan 2 380,000 t.p.a., Wire plant 180,000 t.p.a., Tube plant 80,000 t.p.a..

b/ This plant is now named the "Fine and Special Steels Plant", following the acquisition of 100% ownership in Marathon by Acindar from 1972 onwards.

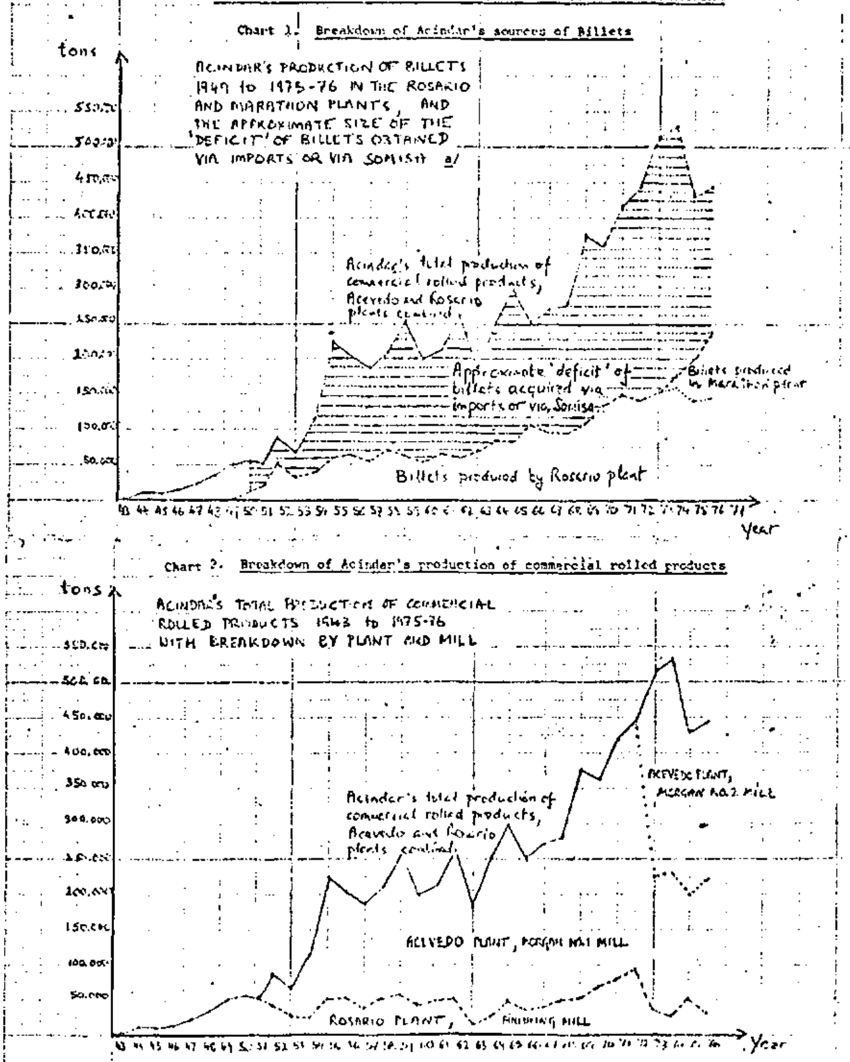
Then we have Acindar's other steel plants which have all been constructed in Villa Constitución, on a single large site actually on the banks of the Paraná some 50 kilometers downstream from Rosario. Here on this second site are located the "Acevedo" rolling plant (which started up in 1951), and which is named after the enterprise's founder, and the "Marathon" steelmaking plus forge plant which was begun as a small joint venture in 1961 between Acindar and the German Thyssen group - but was then completely taken over by Acindar as from 1972 and greatly expanded since then.

Finally, we have the large new "Direct Reduction" plant which is currently being built by Acindar right next to these two existing plants. This is due to come "on stream" at the end or 1978, with the objective of largely replacing the billets which Acindar has at present to acquire from or via SOMISA, the Argentine State steelworks whose plant is only a few kilometers from Villa Constitución further down the river Paraná, in San Nicolás.

It can be appreciated from the diagram that the basic role of the Rosario plant within Acindar is to produce a significant fraction of Acindar's overall billet requirements. 5/ The secondary role of the plant is to produce a quite small proportion of the range of finished rolled products produced by the enterprise.

To see the precise historical contribution of the Rosario plant in these two roles - i.e. first as billet producer, and second as producer of finished (commercial) rolled output, the reader is referred to the two historical charts shown below.

CHARTS WHICH EXPLAIN THE ROLE OF THE ROSARIO PLANT WITHIN ACINDAR



a/ To calculate the 'deficit' we have made the simplifying approximation that one ton of billets is converted into one ton of commercial rolled products.

Source: Production figures compiled from Acindar's annual "Plant Technical Reports".

5/ The reader is reminded that these lines were written prior to the Nov. 1977 closure of the Rosario plant's steelmaking units.

These charts show how the Rosario plant's production contribution within Acindar as a whole has evolved since 1943. The first chart shows how the Rosario plant has, ever since 1954, been producing a fraction ranging from 25% to 35% of the billets used as raw material in Acindar's finishing mills. Then, with regard to the Rosario plant's finishing mill, the second chart shows that since 1956 it has rolled less than 25% of Acindar's finished output, and in recent years is rolling less than 10% of finished output.

In recent years, in fact, only a small fraction (some 20%) of the billets produced in the Rosario plant have gone on to be processed on the plant's own finishing mill. The other 80% of the billets have been sent for processing in the Acevedo plant 6/ - so that one can for most purposes analyse the billet making role of the Rosario plant separately from the finishing mill role. Our principal concern in what follows will be with the Rosario plant in its role as billet producer.

This now completes the basic information about how the Rosario plant fits into Acindar's overall steelmaking operations. The next task, which we now take up, is to describe why the long continuation of billet production in the Rosario plant can be considered as a "paradox".

Section 3. The paradox of the Rosario plant

Even the most casual acquaintance with the production technology of the Rosario plant reveals that - by modern technological standards - the plant's basic process technology is almost a "museum piece". For example, the plant itself is 34 years old. It uses Siemens Martin furnaces for steelmaking, a 27 year-old old primary mill for billet rolling, and its semi-continuous finishing mill is of equally antique origins. It can be stated unequivocally that two of the plant's three basic technologies (its steelmaking and billet making technologies) are clearly "outmoded" in the sense that no entrepreneur putting up a new plant would now install them. As for the third basic technology - the plant's finishing mill - although this is not "outmoded" at its particular scale of production, it is nevertheless not competitive with high speed continuous mills producing at larger scales of production. The chart next page compares the Rosario plant's three basic technologies with what is generally acknowledged to be today's "best-practice" basic process technology.

6/ The point is that for most of the sizes and production-runs of the various products rolled on Acindar's finishing mills - e.g. reinforcing bars, sections, wire rod, etc. - it is considerably cheaper to roll these on high speed continuous mills, like the two Morgan mills in the Acevedo plant, rather than rolling them on low speed "discontinuous" or "open-layout" mills such as the one in the Rosario plant. However, the Rosario mill has the "comparative advantage" over the modern Morgan mills in (a) the low speed precision rolling of forging bars for the auto-industry, and in (b) the rolling of "filler" items in the production programme, which involve very small production runs or which involve the use of off grade raw material which may cause expensive production halts on the high speed mills.

Chart 3. Comparison of the Rosario plant's technology with best-practice technology.

Process technology used in the Rosario plant	Year of initial 1/ installation	"Best-practice" process technology	Period when best-practice technology began to be adopted commercially in 2/ many different countries and clearly established its economic superiority.
Siemens-Martin Steelmaking (from a cold scrap charge)	1943	Electric arc-steelmaking	1955-60
Ingot casting followed by rolling to billets	1950	Continuous casting	1965-70
Slow speed, open layout bar and section mill	1950	High-speed continuous mill(s)	pre 1950

Sources: 1/ Author's research in Acindar. 2/ On Electric arc steelmaking, see Alan Leckie and Philip Maxwell, Transfers of Electric Arc Steelmaking Technology to Latin America, Science Policy Research Unit, University of Sussex, 1975. On continuous casting, see L. Nabseth and G.F. Ray Eds, The diffusion of new industrial processes, Ch.9, Cambridge University Press 1974. On high speed continuous mills, no specific dates could be traced by the author, but these mills were developed and widely adopted long before Acindar's first purchase of a continuous mill in 1950.

This chart gives a good idea of just how "old fashioned" the basic process technology of the Rosario plant is.

Given then that its technology is so outmoded, the thing that economists find surprising about the Rosario plant today is - why is this 34 year-old plant still running?

The surprise lies in the fact that as a result of its being based on veteran technology the Rosario plant today produces steel billets - its main product - at costs estimated recently at 13% above the cost of similar billets produced in Acindar's new billet making plant, the "Marathon" plant, in Villa Constitución 7/. So the question that immediately springs up is - why has Acindar continued billet production at the Rosario plant for so many years on the basis of out of date, high cost production technology? Even more specifically one can ask, - why did Acindar not adopt any of the following four alternative courses of action which would strike almost any steel technologist or economist as having been clearly superior to prolonging billet production in Rosario? The four options involved were (1) to substitute Rosario billet production, and also the purchases of billets from outside suppliers, by integrating the Acevedo plant with modern ore-reduction, steelmaking and billet making facilities (i.e. blast furnaces, oxygen converters and blooming-slabbing mills, or a direct reduction plant, electric furnaces and continuous casting); (2) to substitute expensive Rosario billets by purchases of lower cost billets on the open market; (3) to replace the Rosario plant's Siemens Martin furnaces by a single electric arc furnace, and to replace the plant's ingot casting system by continuous casting; or (4) to expand investment and billet production at a faster rate in its new Marathon plant, so as to replace the billet output from the Rosario plant. Any of these four options, on the face of it, seem as if they would have been superior to the option actually followed by Acindar of keeping its old 'grandad' plant in business.

7/ This was the differential that applied on 1.2.77 according to internal company figures for billets of a common steel grade (1017) produced in both the Rosario and Marathon plants.

Now this reasoning would probably have been correct in a "first-best" economic context, - and Acindar's directors have in fact been considering closing down the Rosario plant for more than twenty three years! Yet the sentence of execution under which this plant has been operating has never been carried out because - as we shall seek to show - in the "nth-best" economic context of the Argentine steel industry it has never yet proved simultaneously both possible and profitable for Acindar to do so.

Section 4. "Imperfections" in the economic context of the Argentine steel industry

We have now introduced the 'paradox' of the Rosario plant, and it is the purpose of this present section to offer an explanation of it. Obviously a simple explanation would have been that Acindar possessed an unenterprising or technologically laggard management - but as the information presented in Section 1 shows, this explanation cannot be sustained.

Another immediate candidate for explaining the surprising Rosario lifespan is labour relations - i.e. the pressure on, or the desires of Acindar management to avoid putting their Rosario plant staff out of work. However this explanation does not square with the facts either, as Acindar was always able to offer alternative employment in its Villa Constitución plants to virtually all those who would have been put out of work by closing down the Rosario plant. The labour factor did not therefore limit Acindar's range of options at all. 8/

A satisfactory explanation that does fit the facts is that Acindar did not adopt any of these four alternative options because the existence of various pronounced "imperfections" in the economic context of the postwar Argentine steel industry made each one of the alternative "superior" options either (i) impossible to take up, or (ii) less profitable in prospect, on the information then available, than the option of continuing billet production in the old-fashioned Rosario plant 9/

8/ Some further considerations help explain the lack of labour pressure on Acindar's directors so far as resistance to possible closure was concerned. Firstly, company plans involved not the close-down of the whole plant but only of the steel shop involving 400 to 500 of the workers. Secondly the plant's siting in Rosario, a major city of 800,000 people, offered alternative job opportunities -specially to the sizeable proportion of men performing such jobs as mechanical or electrical maintenance, refractory brick laying etc - i.e. skills readily transferable to other jobs. Thirdly the long-service status of many of the potentially affected workers meant that they could excercise an early retirement option involving the company in only s mall extra costs by way of compensation payments. All these factors, plus the ability to offer work at Villa Constitución meant that Acindar's option to close the Rosario steel units was never blocked by the labour force.

9/ The economic comparison was between each alternative option that would involve radically new technology and the option of continuing production in the old-fashioned but nevertheless improvable Rosario plant. As we show further on, Acindar was in fact able to greatly upgrade its Rosario plant and thus to reduce, although not reverse, the economic inferiority of the plant's old-fashioned technology as compared to best-practice technology. This success raises the economically interesting theme of just how "upgradeable" old-vintage technologies are, and we make some remarks on this in Part III of the paper.

The chart below, which is based on detailed research on Acindar's evolution, outlines why each one of these four apparently superior technological options were not taken up by Acindar and the chart also identifies the type of "imperfection" responsible for ruling out the superior strategy in each case.

What this chart shows is how three factors, namely (1) prolonged official

Chart 4. Summary of why apparently superior technological strategies which would have involved the closure or radical modernization of the Rosario plant were not adopted by Acindar

Period	Superior technological strategy	Reason why Acindar did not adopt it	Type of "imperfection" involved
1953-75	Substitute Rosario billet production and also the billets purchased from outside sources by integrating the Villa Constitución plant with ore-reduction, steelmaking and billet making facilities based on modern technology.	Acindar's successive integration projects between 1953 and 1971 were all rejected by the Argentine authorities. 10/	Government constraints on investment.
1963-76	Purchase billets from the "open market" at lower prices than the costs of Rosario billets.	(1) Billet sales made available only from or through SOMISA were frequently rationed - causing Acindar to go without the full quantities of billets it wanted in 7 of the 13 years under consideration. Keeping Rosario billet production going thus increased Acindar's security of supply.	Rationing in factor markets (billets).
		(2) Also SOMISA's billet prices and Rosario's billet costs were closely similar in the period from 1969 to 1976 (except from January 1973 to January 1975 when SOMISA's billets were much cheaper). Cost comparisons did not therefore usually suggest any marked advantage in substituting SOMISA billets for Rosario billets, even if it could be safely assumed that the former would be available in the quantities needed.	Monopoly price setting by government controled steel works.
1961-68	Replace the Rosario plant's Siemens Martin furnaces by electric arc furnaces, - and (in some projects) also replace the plant's ingot casting system by continuous casting.	Projects embodying the first or both of these measures could, with hindsight have been rationally adopted, and were in fact actively considered during this period. However they were rationally rejected at the time given the legitimate expectations by Acindar's directors that they would soon be able to go ahead with their integration project for the Acevedo plant (which then enjoyed active government approval).	Uncertain and shifting planning perspectives caused by the alternations of government policy towards the private steel sector. 10/
1969-71	Replace the Rosario plant's Siemens Martin furnaces by electric arc furnaces, - and (in some projects) also replace the plant's ingot casting system by continuous casting.	In this period such measures were ruled out owing to shortage of investment funds, because Acindar's directors were pursuing the sound policy of increasing the enterprise's liquidity so as to recover from (a) some trading losses, and (b) from having been forced by the government to write off its investment in the previously rejected blast-furnace integration project, and to pay back to the government the previous tax deductions which the enterprise had enjoyed by virtue of the regime promoting integration projects.	Uncertain and shifting planning perspectives caused by the alternations of government policy towards the private steel sector. 10/
1972-76	Expand investment and billet production in the modern Marathon plant faster than was actually done, so as to replace Rosario's billet output.	Not possible mainly due to the lack of security of supply with respect to getting adequate qualities of high-grade scrap - since this raw material was in short supply in Argentina as well as being subject to import rationing.	Rationing in factor markets (high quality scrap).

Source: Author's compilation based on information gathered during case-study.

constraints on investment and changing official plans for the steel industry 10/ (ii) billet rationing and high billet prices on the "open market", and (iii) inelasticities in the supply of high quality scrap, have all combined to make Acindar's continuance of the Rosario plant a rational decision on the part of the enterprise. This will now be explained in a little more detail.

In the first place the prolonged "no through road" placed by successive Argentine authorities on Acindar's various integration projects 10/coupled with the insecurity of supply of billets bought from or via SOMISA and the usual non-existence of any marked cost advantages in the price of SOMISA billets compared to the cost of Rosario billets, meant that the continuation of the Rosario plant was needed so that Acindar could be sure of having at least a fraction of the billets it needed. The point was that any lack of sufficient billet supplies inevitably meant expensive idle capacity on the finishing mill(s) and all the ancillary machinery in the Acevedo plant. Therefore, as one of Acindar's directors put it "each kilo of additional steel justifies itself to the extent that it makes it possible to get all these sections working". Hence, it was certainly better for Acindar to continue steel production in the Rosario plant rather than just shut it down.

Secondly, if one considers the radical modernization options which Acindar rejected for the Rosario plant, these rejections should be understood as correct strategy at the time, given the legitimate expectations of Acindar's directors that their integration project for the Acevedo plant would be approved.

10/ Steel industry investments in Argentina, since 1941, have depended on receiving the green light both from the government of the day and from the Dirección General de Fabricaciones Militares (i.e. General Directorate of Military Production, DGFM) - and it never proved possible until 1975 for Acindar to obtain the final approval from both sets of authorities for it to proceed with its successive plant integration projects. In this respect Acindar suffered a similar fate to all the other major Argentine private steel enterprises whose integration projects were also all rejected or interrupted with the result that from 1947 to 1976 - i.e. almost three decades, the DGFM has had a "de-facto" monopoly of the Argentine production of steel starting out from iron ore.

The principal cause of the long chain of frustrations for Acindar and other private steelmakers was the frequent and unpredictable alternation of Argentine government policies which (a) from time to time promoted the integration of private steel plants, and then (b) sometimes provided conditional approval to specific integration projects put forward by one or other private steel enterprise, only to end up in (c) the final interruption or rejection of each and every specific integration project often after prolonged investment of time and money by the enterprise concerned.

Inevitably this chain of events interfered with orderly planning by the private enterprises concerned and led to inferior investment options having to be taken up, suspension of projects for which previous stages had been completed, etc.

Acindar, for instance, had at least six different integration projects between 1953 and 1971 rejected by the authorities - and it was only in 1975 that they received the final go-ahead needed from the authorities to proceed with the construction of their direct reduction plant, which, when it starts up in 1978, will be realizing the integration plan already firmly announced by Acindar's founder Arturo Acevedo in the company's Annual Report and Accounts of 1949!

Finally, Acindar's rejection of expanding the Marathon plant's billet production faster was due to a rational assessment that the risks that high-grade scrap supplies would be rationed were too big to justify abandoning the security of the Rosario plant's billet production which was based on the use of lower average grades of scrap that were in much easier supply.

Thus, Acindar's strategy of keeping the Rosario plant in business so long was perfectly defensible in profit maximisation terms, but only because of the strongly imperfect economic context in which Acindar had to function. 11/

The interesting economic point here is that the conventional assumption that is usually made about "well functioning factor markets" does not correspond to the real situation that existed during significant periods in Acindar's evolution - particularly so far as billets are concerned, and to a lesser extent for scrap supplies.

Also, so far as the supply of the factor "capital" was concerned, the deviation of Acindar's real situation from conventional assumptions lies in the fact that the presence of government constraints on investment makes it impossible to refer to the existence of a "proper" market for capital in the usual sense. The point is that Acindar could not, as firms normally can do in "theory of the firm" models, freely hire the amounts of the capital factor it wanted in the certainty of being able to embody that capital swiftly in a functioning plant. The existence and use of official powers to veto investment projects meant that the mere ability and desire to "hire" capital and other factors was not enough to ensure that the associated projects would be permitted to go ahead.

Obviously, then, once inelastic factor supplies and/or substantial bureaucratic constraints on investment come to form part of the real economic context in which

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11/ As the reader will be aware, we have taken the liberty of suggesting in this paper that the technological strategy followed by Acindar in the Rosario plant was "first-best. However, this needs some qualification. First of all, as we showed earlier, the decision not to modernise the Rosario plant early in the sixties turned out, retrospectively, to have been an error, since the firm's integration project got delayed far longer than could have been reasonably expected and in turn greatly prolonged the useful economic life of the Rosario plant. Had this been foreseen, then the radical modernization of the plant - which was carefully considered by Acindar at the time- would definitely have been undertaken. However, anybody can be an investment genius with the benefit of hindsight!

Secondly, even leaving out the hindsight aspect, we are not trying to claim that Acindar's directors never made any mistakes or errors of judgement, and nor are we claiming that they always invested the exact "optimum optimorum" in technical change in the Rosario plant. Instead, what we have tried to show is that several apparently "superior" technological strategies discussed in the text were either impossible for Acindar to implement (due to government restrictions) or else were rejected by Acindar's directors on rational and defensible grounds given the company's profit maximisation objectives. It is in this sense that the strategy of keeping the Rosario plant going, and (as we show in Section 5) upgrading it by low cost technical changes, can be seen as an election by Acindar's directors of the "first-best technological option that was open to them.

a steelplant functions, it follows that the investment, output and technical change strategies which such a plant will rationally follow will no longer conform to what would be "first-best" strategy for a maximising firm which is completely free to invest as it deems best, and which is faced by elastic factor markets.

So when the economic context is "imperfect", strategies which one conventionally regards as inferior may in fact prove to have been correct profit-maximising strategies given the constraints that actually prevailed in that context at the times when decisions had to be made. This is the interpretation which in our opinion fits with, and satisfactorily explains, the 'paradox' that the old fashioned Rosario plant is still producing today.

Section 5. The technological strategy pursued in the Rosario plant

Interestingly for our purposes, there is a second surprise for economists in the record of the Rosario plant in addition to the challenge of tracing the peculiar economics which has enabled this old plant to survive. For, what turns out to be equally interesting and 'peculiar' is the evolution over time of the plant's technology. Not only has the plant's antiquated technology been maintained in action over such a long period but, still more significant, it has been greatly improved over time by a long series of piecemeal technical adaptations and improvements. What one sees in Rosario, therefore, is not the text book chronicle of major modernizations involving switchovers from earlier to later generations of technology, but rather the story of a prolonged series of evolutionary improvements in the original installed technology. In fact it is possible to observe over thirty years of evolutionary improvements in the technology of the Rosario plant - a longer period that could have been observed had the functioning and planning of the postwar Argentine economy and its steel industry been more rational than was actually the case. In a more rational economic environment, Acindar could have scrapped the Rosario plant some fifteen to twenty years ago, in favour of more up to date steelmaking technology. The fact that it didn't (and still hasn't) is what makes the evolution of the Rosario plant's technology a worthwhile subject to explore.

Therefore, the nature of the changes introduced by Acindar into the technology of the Rosario plant forms the theme which we shall now take up in this final section of the case study:

To explore this technological theme the starting point is to recall from the above discussion of "imperfections" how Acindar found itself repeatedly "saddled" with having to make the best out of its outmoded Rosario technology because superior technological strategies were continually ruled out. In consequence, the dynamic problem for Acindar became that of seeking to introduce improvements, replacements, additions, etc. into the outmoded Rosario technology so as to improve the plant's efficiency and adjust the plant to the changing requirements on it.

However, the solution to this dynamic problem was not so easy, as on the one hand, Acindar's directors could not invest much money in the outmoded plant because its future economic lifetime was always feared to be short; yet on the other hand they could not rationally avoid seeking to introduce such changes as were necessary to (a) maintain the plant's economic viability in the face of changing economic circumstances, and (b) to match the changing urgency of the needs of Acindar as a whole for the billets and finished rolled output of the plant.

The premium was therefore always on finding ingenious low cost ways of upgrading and adapting the Rosario plant rapidly to fit in with the changing circumstances and needs. 12 / In the event these ingenious ways were, to an impressive extent, found.

To illustrate this, space permits us only to refer to three of the most outstanding features of the technical changes introduced. These are, first, the extent to which the production capacity of all the plant's main process units has been increased by technical changes; second, the long record of technical changes introduced into the plant's finishing mill to diversify its product mix; and third the critical importance of the endogenous creative efforts of the Rosario plant's staff in making this impressive record of low-cost technical change possible.

To demonstrate the first outstanding feature - i.e. increases achieved in production capacity - we can begin by referring to the Rosario plant's Siemens Martin furnaces. These have been subjected to a long series of modifications throughout their history, in which the most consistently important design objective pursued - though not the only one - was to increase the production capacity of these furnaces. As a result, the annual production capacity per Siemens Martin furnace has been raised from approximately 20,000 tons per annum in the early 1940's to around 50,000 tons per annum today with the interesting consequence that these Rosario plant furnaces are today clearly superior in terms of annual output capacity to all the comparable furnaces in other Argentine steelplants 13/.

A similar success story applies to the Rosario plant's billet mill. This was originally installed in 1950 with a production capacity of around 50,000 tons per year, however this capacity has been raised by a whole series of minor technical changes so that the Billet mill's capacity today is over 160,000 tons per year. This was achieved with a remarkably low investment, and with no change in the originally installed horsepower of the mill. Indeed this mill is widely acknowledged in the Argentine steel industry as a "peach of a mill" and is more

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12 / The low level of investment in the Rosario plant emerges clearly from inspection of data in the company's file of investment projects approved. For example between 1967-68 and 1976-77 Acindar's directors approved investments totalling approximately U$S 7 million in the Rosario plant compared to U$S 22 million in the Acevedo plant and U$S 27 million in the Marathon plant.

13/ This emerges clearly if the three Rosario Siemens Martin furnaces of approximately 30 tons static furnace capacity are compared to all the similar Siemens Martin furnaces ranging from 21 to 45 tons static capacity that are found in other Argentine firms. In terms of total annual production capacity per ton of static furnace capacity, the figures for each firm in 1973 were Ohler S.A. 704 tons; La Cantábrica 850 tons; Santa Rosa 897 tons; Tamet 1,000 tons; Acindar Rosario 1,667 tons. These figures were calculated by the author based on capacity data found in Julio J. Montu "Tendencias tecnológicas en los programas de expansión de las miniplantas siderúrgicas en Argentina", ILAFA Congress, Buenos Aires, 1973.

productive than other more modern primary rolling mills in Argentina which have twice the installed horsepower and involved more than twice as much investment.

As for the plant's finishing mill the annual capacity of this unit has also been greatly improved - from around 50,000 to around 120,000 tons - mainly by means of substantial mechanisation and layout improvements.

The exact extent of all these capacity increases is summarised in the table shown below

Table 1. Increase in the production capacity of Rosario plant units due to technical change.

Installation	Time Period	Working capacity of the unit at the beginning of the period (tons/operating hour)	Working capacity of the unit at the end of the period (tons/operating hour)	% Increase achieved
Siemens Martin Nº1 Furnace	1944 to 1972-73	2.75	6.32	130
Siemens Martin Nº2 Furnace	1949 to 1972-73	3.68	6.32	72
Siemens Martin Nº3 Furnace	1963-64 to 1972-73	3.80	6.32	66
Billet mill	1954-55 to 1973-74	8.30 *	19.00*	129
Bar and Section mill	1954-55 to 1970-71	9.90	17.20	74

* In the case of the billet mill, the available capacity figures refer to tons per shift hour, rather than tons per operating hour.

Sources: 1/ Calculated by the author from historical production data in the Rosario plant technical reports supplemented by additional data provided by Acindar staff.

This table shows that increases ranging from 66% to 130% over initial design capacity were brought about as a result of technical changes - an impressive degree of "capacity-stretching" by any standards. 14/

14/ The great economic importance to Acindar of this "capacity stretching" achieved in the Rosario plant can be appreciated by reference to the major change in the plant's billet production "mission" in the period from 1962-63 onwards. Before then, the role of billet production in Rosario was basically to keep on going, with a minimum of maintenance investment, until its expected forthcoming shutdown, and to supply the Rosario plant's own finishing mill with approximately 50,000 tons of billets for rolling into bars and sections. But in 1962, with the coming on stream of a massive increment to the Acevedo plant's finishing mill capacity, and with the firm's integration project bogged down in official uncertainties - the billet mill's "mission" was radically changed to one of providing feedstock to the Acevedo plant's expanded finishing mill - so the Rosario plant had to expand its output of billets rapidly. Then, throughout the rest of the sixties and early seventies, the ups and downs of Acindar's integration project, plus frequent billet rationing in the market, led to repeated demands on the Rosario plant to increase its billet production still further. So from 1962 onwards, historical circumstances exogenous to the plant (and mainly exogenous to Acindar as a whole) led to a virtually permanent "output-expanding" mission for billet production in the Rosario plant.

The point is that this mission was fulfilled in the Rosario plant mainly by means of "capacity-stretching" technical change in the steelmaking section and billet mill of the Rosario plant. The only "duplication" type investment made by Acindar in this period to increase output was the addition of a third Siemens Martin furnace in the Rosario plant to join the two already installed.

The second very notable feature of the Rosario plant's technical change record concerns the many changes introduced over time into the plant's finishing mill with the aim of diversifying the range of products that could be produced on this mill. Indeed, no less than 14 different classes of products have been produced on this finishing mill since 1943, and the average rate of launch of classes of new products by the mill has been approximately one class of new product every two years. (Furthermore one must remember that within each class of product the mill has produced a whole range of sizes and grades).

This ability of Acindar to adapt the Rosario finishing mill to different products has been vital not only to keep up with the evolving sophistication of market demand - for example new qualities and shapes of reinforcing bars have taken over much of the market which was previously served by plain reinforcing bars - but also to maintain the viability of the Rosario finishing mill in the face of expansions in the rolling capacity of the modern Morgan rolling mills of the Acevedo plant. In other words, product diversifying technical change on this mill was an extremely important and successfully used tactic for ensuring that the unit, when threatened by changing markets and rival technology, could broaden its product mix to avoid becoming obsolete. 15/

In summary, then, the record of the Rosario plant both in "stretching" the capacity of its "old-vintage" units - and in adapting its finishing mill to a long series of product diversifications, all on a low budget, seems to have been a definite success.

This now brings us to the third outstanding aspect of the technical change record of the plant - which concerns the sources of the technical changes introduced. The striking feature of the plant's record in this respect is the notable degree to which the technical changes introduced have involved a creative endogenous (i.e. "in-house") contribution, made by the plant's own staff.

Indeed if one analyses the most important technical change projects which were carried out throughout the life of the plant, and which involved sizeable investments in new and modified equipment, it turns out that the endogenous

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15/ A superb example of this tactic in the history of the mill refers to the diversification carried out in 1972-73 into producing special steel forging bars for the automobile industry. The need to diversify had been caused by the start-up of the second Morgan rolling mill in the Acevedo plant, which caused the Rosario finishing mill's output to drop in one year from around 90,000 tons to around 15,000 tons. The challenge then involved for the Rosario plant was to modify its finishing mill so as to give it a "different focus". When the mill was built it was designed to produce "tonnage" in common steel products, but "we then had to modify it to produce dimensional precision in special steel products". This required - amongst other important changes - the designing and building of two new mill stands with specially designed housing and bearings, and equipped with variables speed motors, to replace the existing units, so that the rolling operation could be carried out with the necessary precision. It offers an excellent example of technical changes being carried out on "fixed" capital so as to "mobilize" it to fulfil a radically changed product mission.

contribution to these projects has been the dominant factor in at least 75% of the major projects. This contribution went far beyond the mere installation of equipment provided by machinery supplying firms, or the simple following of outside designs and layouts. The really notable point is that many of the projects were designed "in-house", and incorporated creative and original ideas, layouts and equipment specifications.

The following examples all illustrate the great importance of the "endogenous" contribution.

First of all the billet mill: - this mill has been extensively modified and its performance upgraded entirely as a result of small design and engineering changes generated "in-plant". For instance, in a major overhaul of the mill in 1969-70, the Rosario plant's rolling mill division and its engineering division designed, planned and executed nineteen separate modifications to the mill, affecting virtually all its component units. 16/

Secondly, the finishing mill: - this mill, too, has been extensively improved by "in-plant" design and engineering. Indeed, the major two-stage reform of this mill which was carried out in 1970-71, and in 1972-73, offers an outstanding "text-book" example of what can be achieved by internally generated learning, design and engineering - so much so, that this project was the subject of a lecture given to an international Latin American conference on Rolling technology in Buenos Aires in May 1976. 17/

Thirdly, the plant's steelmaking units: - all three Siemens Martin furnaces were designed and constructed by Rosario engineers. Also the incorporation of major improvements to the furnaces, such as the switchover from acid to basic

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16/ For instance, they redesigned and enlarged the mill's reheat furnace, modified the ingot charging and discharging zones, modified the layout and action of many of the mill's inter stage transport units, redesigned the mill's lifting table and hydraulic system, improved instrumentation and process control, etc.

17/ This project was developed, designed and implemented under the leadership of the Director of the Rosario plant's rolling division, with assistance from his Deputy, and from the plant's engineering division. It had three major objectives: 1) to increase the capacity of the mill by a factor of 70% on the basis of its existing product mix, from 70,000 tons per year to 120,000 tons per year to meet immediately pressing demand; 2) to modify the mill so as to equip it for a major product diversification into the production of special steel forging bars for the automobile industry, in view of the impending planned transfer to Acindar's Acevedo plant of the majority of the existing product mix produced on the mill; 3) to take into account in the design the possibility of a still further diversification in the future into the production of small-diameter alloy steel round bars. The first two stages of this project were successfully completed and have been a great economic success, while the third stage is currently being held in reserve pending the evolution of market demand. See Oscar R. Amorini, "Remodelación del tren de laminación de perfiles pequeños y livianos" in Laminación, tecnología, equipos, productos, published by ILAFA, Santiago de Chile, 1976.

lining and the injection of oxygen into the metallic bath, involved strong participation by Rosario personnel. Furthermore, the major improvements to the plant's cupola melting furnaces - including the use of a more durable refractory lining and the introduction of hot-air injection were the result of considerable experimentation and engineering by Rosario plant personnel.

These above examples demonstrate the highly significant contribution made by "in-house" technical effort in important investment projects carried out in the Rosario plant.

In addition to its important input in these major projects, the "in-house" contribution has also been extremely important in the innumerable minor technical improvement projects carried out in the Rosario plant.

It is therefore clear that technical progress in the plant has been achieved with a large contribution of "endogenous" original inventive and engineering efforts. Indeed, one clearly visible result of this is that much of the Rosario plant's present equipment is now remarkably "idiosyncratic" in the sense that it incorporates a large number of "home made" designs, equipment features and improvements which will not be found in any machinery manufacturer's catalogs. 18/

Of course, there has been an important "exogenous" contribution too, which we have not analysed here, which has come from Acindar's central production, engineering and technical departments in Villa Constitución and Buenos Aires, and to a lesser extent, from machinery suppliers and - in two important projects -

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18/ It is nevertheless interesting to see that some of the experience gained in the Rosario plant by its engineers has been transferable beyond the confines of the plant. For example, the present Director of the plant-who developed his whole career there- has also contributed to several major technical changes in the Morgan mills of the Acevedo plant. Furthermore this man gives lectures on Rolling Technology sponsored by the Instituto Argentino de Siderurgia to audiences of engineers and technical personnel drawn from a wide range of steel and other metallurgical firms.

A further interesting point in this regard is that, according to the Rosario plant's current Supervisor of Rolling mills, the plant affords superior learning opportunities to its technical personnel than does the Acevedo plant. This is because the relative lack of specialization of personnel that is possible in slow-speed mills like Rosario's permits the technical personnel to grapple with virtually the whole range of problems and variables involved in the rolling operations in contrast to the situation on hich speed mills where personnel are usually required to specialize in one or two aspects of the overall operation, thus limiting their range of experience.

from outside consultants 19/; and there have been some significant replacements of equipment carried out - e.g. the Bar and Section mill's reheat furnace, which was replaced in 1970-71 - however the "leitmotif" of the technical change record of the Rosario plant has clearly been endogenously generated modifications to the existing equipment 20/ Furthermore, it was precisely this creative endogenous contribution which provided the low cost solutions which permitted Acindar to "make the best" out of the situation of having to keep the Rosario plant going.

In other words, given that "imperfections" in the economic context continually made the extension of the Rosario plant's life necessary, it was a blessing for Acindar that it could draw on the strong endogenous creativity of the Rosario plant's engineers in finding ingenious ways of upgrading and adapting the old plant. This unquestionably had the effect of greatly softening the negative economic impact on Acindar of not being able to proceed with its more optimal technological solutions.

Section 6. Review and summary

We are now in a position to review and summarise the case study just presented so as to refresh the reader's memory on the main points that were covered.

19/ In the Rosario plant the two major projects involving leadership by outside consultants were (i) the installation of the plant's billet mill in 1949-50, and (ii) the modification of ingot casting practice and the accompanying intensification of quality control and inspection procedures in plant in 1960-61. The first of these projects corresponds to a straightforward move to greater capital intensity. The second project, however, offers a mixed picture: - i.e. on the one hand there was a move to slightly greater capital intensity in ingot casting due to the modifications introduced, but on the other hand this shift was almost certainly outweighed by the considerable increase in the labour force employed in the new procedures of quality control inspection that were also introduced by the consultant.

20/ This type of technical change seems to be exactly what Atkinson and Stiglitz had in mind when they developed their alternative view of technical changes as being "localized": - see J.B. Atkinson and J.E. Stiglitz, "A New View of Technical Change", Economic Journal, Vol. LXXIX, 315, September 1969. Paul David has also made use of the concept of "localized" technical change, and he adds the hypothesis that sequences of localized technical change tend to be neutral in their effect on the capital-labour ratio. This is an extremely interesting - and in my view implausible - hypothesis which needs to be tested empirically. See P.A. David, Technical Choice, Innovation and Growth, Cambridge University Press, 1975, p. 58 onwards.

Right at the start, when reviewing the current technology of the Rosario plant, it appeared that something was "wrong" - namely that in a world which had long witnessed the breakthrough of the electric arc furnace and continuous casting all over the globe as best-practice billet making technology for small scale steelplants, that there should still exist a plant based on Siemens Martin furnaces and ingot casting producing merrily away.

Of course, if capital, labour and raw materials has been "hirable" by Acindar in "properly" functioning factor markets - i.e. those in which factor rationing leading to more than just short-run supply inelasticities did not occur, and in which bureaucratic investment constraints blocking investments were not an important feature - then Acindar would have integrated its Acevedo plant or else bought electric arc furnaces and continuous casting to replace the outmoded Rosario technology long ago. Indeed, they consistently wanted to do so.

But the reality of "factor rationing" and "bureaucratic investment constraints", coupled with the uncertainties as to the future of both the rationing and the constraints, and also the opportunity costs of investing heavily in modernizing the Rosario plant, all combined to rationally rule out the "normal well behaved" path of technical change in the Rosario plant, which would have involved either (i) its radical modernization to electric arc and continuous casting, or (ii) its scrapping many years ago in favour of acquiring billet supplies from the open market or from the integration of the Acevedo plant with up-to-date steelmaking technology.

The decision was therefore to keep the Rosario plant going, with relatively low levels of investment in modernizing it - which at the same time also subjected engineering efforts to a technological constraint. Then, given this set of conditions (produced by the described situation), the path of technical change in the Rosario plant became inevitably one of piecemeal upgrading and adaptation of the plant in accordance with both the changing requirements on it, and with whatever the endogenous creativity of the plant's staff could generate in the way of low cost improvements. 21/

Essentially therefore, the constraints operating in the economic context of the Rosario plant imposed a virtually permanent delay in the adoption of best practice techniques, a far longer delay than the one visualised by Salter in a "well-behaved" path of technical change. In Salter's model, technical change to best practice techniques becomes obligatory on the firm as soon as the unit variable operating plus capital costs of producing a product with the "best-practice" technique; falls below the variable operating costs of the "outmoded" technique. Indeed, at that moment, the "outmoded" technique becomes no longer

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21/ For many of the improvements made in the Rosario plant the stimulus came from very specific equipment malfunctions and processing problems. The Superintendent of the plant's rolling mills has described the "design philosophy" which he and his colleagues applied, as follows: "To go along, eliminating passes, redesigning mill rolls so as to minimize problems, to roll with greater crosssection wherever possible, to try to minimize production halts and nuisances, and if possible to withdraw men because it's a pretty unpleasant type of work involving risks of getting burnt. To go along making adjustments in the elements or ancillary machinery of the mill which bring you problems".

profitable to operate. It is therefore, by definition, then obsolete and must be replaced or scrapped. 22/

But a technique which is obsolete assuming properly functioning factor markets and freedom of entrepreneurs to invest, is by no means necessarily obsolete when these assumptions do not apply. With unsatisfied market demand for an outmoded plant's products (in this case billets), and with raw material supplies for a potentially competing best practice technology rationed (which happened for the high quality scrap for the Marathon plant), it is not difficult to see how an outmoded technique like the Rosario plant's can go on for a long time being outmoded without actually becoming obsolete (i.e. profitable to replace). Equally, if the investment funds which are needed to actually install competing best-practice plants are not available or are bureaucratically frozen or vetoed, then the market in which the outmoded technique is operating is in a sense "shut off" from advances in technology in such a way as to prevent outmoded techniques from ever becoming obsolete.

In short, in a well functioning economic context, advances in technology progressively forced outmoded techniques into becoming obsolete, at a rhythm which depends basically on factor prices and on the extent of the technological superiority of the new techniques. But malfunctions or imperfections in the economic context, can slow this rhythm down temporarily, or in the extreme case permanently, thus forcing entrepreneurs to continue production in more and more outmoded plants. This is the kind of situation into which the experience of the Rosario plant fits. Let us now turn to look at the dynamic consequences.

Once "saddled" with having to make the best of outmoded technology because superior technological strategies are ruled out, the dynamic problem becomes to introduce profitable improvements, replacements, additions, etc. into the outmoded technology. Ideally, the entrepreneur would wish that the context would permit him to switch from his outmoded vintage to best practice technology, but the context does not allow him to do that. So, as his "first-best" option given the context he is in, the entrepreneur seeks to improve his outmoded technology within the existing constraints. Nevertheless, there is still an important dilemma: for if the entrepreneur has reasonable expectations that the context may shortly be about to improve, he may be loath to invest much in improving the outmoded technology that he still hopes he will soon be able to scrap. If however he does not take the opportunity to make improvements in his outmoded technology and the obstacles preventing superior technological strategies remain in force, then the entrepreneur will find himself with technology which is becoming more and more outmoded and ill-adapted every day - and will therefore find himself under greater and greater pressure to modernize it.

Repeatedly faced with exactly this dilemma, the solution which Acindar applied in its Rosario plant was to make repeated demands on the ingenuity of the plant's own engineers to squeeze maximum production out of the plant's old-fashioned steelmaking and billet units and to inject maximum flexibility into the plant's finishing mill unit, on the basis of a bare minimum of investment - and

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22/ See W.E.G. Salter's outstanding account of the economics of obsolescence, replacement and scrapping decisions in his well known book Productivity and Technical Change, Cambridge University Press 1960, esp. Chs. IV and V.

as the study showed, these demands were met with great success. Indeed it was precisely the creative ingenuity of its engineers that was able to compensate Acindar to a significant extent for the imperfections of its surrounding economic context. *

PART III. REFLECTIONS ON THE CASE-STUDY

In this final part of the paper, our aim is to step back from the micro-details of the case study itself so as to reflect on some interesting economic issues that emerge from the Rosario plant's experience.

To start with, it is worthy of note that if one surveys the panorama of Latin American steelmaking today, one comes across a quite appreciable number of plants which are based, like the Rosario plant, on long outmoded technologies 23/ - and one also find that "imperfections" in the form of government constraints on private investments, capital rationing, price-fixing on steel products, rationing of key raw material or energy supplies,etc. exist to a considerable

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* Postscript on the closure of Rosario's Siemens Martin furnaces. As mentioned at the beginning of the case-study, it came to the author's attention after completion of the manuscript that Acindar had taken the decision, in November 1977, to finally close down the Rosario plant's Siemens Martin units. This was 34 years after the first heat from the Nº 1 furnace was tapped.

The circumstances that made this decision finally possible were (i) that as from the end of 1978 or early 1979, Acindar will be able to count on an assured supply of cheaper billets produced by its new direct reduction cum arc-steelmaking and continuous casting plant in Villa Constitución, so that the end of steelmaking in Rosario was already very near, coupled with (ii) the fact that for an interim period of 18 months between the closure of the Rosario plant and the time when Acindar can be sure of its own alternative supplies from the new plant, SOMISA has agreed to sell billets to Acindar at a 10% discount off normal prices in return for a firm commitment by Acindar to purchase not less than 13,000 tons of billets per month for 18 months.

This combination of (a) security of supply from SOMISA (given that this enterprise now has surplus steelmaking capacity due to the bringing back into production of its second blast furnace), and (b) favourable prices from SOMISA (due to the 10% discount), and (c) predictable planning horizons during the eighteen months to follow (since Acindar's new plant is now being constructed with full and continued government approval) represents a combination of favourable circumstances that have not existed at any point up until now in Acindar's history. However, once this combination of circumstances came to exist, then the "straightforward" solution, so long postponed, of closing down the old Rosario Siemens Martin furnaces was one which Acindar's directors could quickly adopt.

Apparently many of those present cried when the last heat of Rosario steel was tapped - yet it surely is an appropriate end to the Rosario saga that it should have required a hefty price discount from the giant state steel company to finally make these resistant old furnaces obsolete!

23/ For example production of steel in Siemens Martin furnaces accounted for 42% of Latin American steel production as recently as 1975. Source "La Siderurgia latinoamericana en 1974-75 y Metas a 1980", ILAFA, Santiago, 1976.

extent in virtually all Latin American countries. Furthermore one does not have to delve very far into the history of the steel sector in each country to come across various examples of what appear to be gross errors of initial choices of technique 24/, and examples of quite a number of plants that have been pursuing frankly "nth-best" technological strategies. This is not meant to suggest that such examples represent the general rule in the Latin American steel industry; nor is it meant to suggest that Latin American national experiences with regard to the steel industry have - when viewed as a whole - been any more irrational or trouble-filled than have the experiences of many other continents or countries, including the most developed ones of all 25/, but, equally, such examples cannot be considered as rare. In fact they are common enough to make one wonder whether (i) there is something inherently difficult about making correct technological choices in the steel industry, which would account for the existence of a fair proportion of disasters or monstrosities, or (ii) whether the examples of when things have obviously gone wrong can be attributed to "imperfections" of the kind found to be at work in the Argentine steel industry; or (iii) whether some of the fault may lie in the insufficient "fit" between steel industry realities and the economic concepts and tools which steel industry planners and executives use to help guide their technological choices and strategy. Of course these three explanations may be complementary rather than exclusive, and other explanations - perhaps more powerful - may well be put forward. But the problem itself - of the not uncommon and socially costly recurrence of "sub-optimal" technological choices and strategies in the steel industry 26/ - remains, and the problem is of sufficient practical importance and impact in Latin American economies to merit some efforts to clarify possible causes.

With this perspective in mind, we can now ask - what light, if any, does the present case-study throw on the problem of correct technological strategy in the Latin American steel industry, both with regard to "official" government policy for the industry, and with regard to best strategy for enterprises confronted with whatever is the official policy? In our view, the case-study does suggest some interesting insights in this respect.

A first point suggested by the case-study is that one might, in making choices of technique and replacement decisions in steel technology, tend to

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24/ For instance, such errors have been alleged with regard to the choices of Siemens Martin steelmaking technology by several Latin American state steel firms at a time when oxygen converters had already been adopted almost universally elsewhere. See G.S. Maddala ad P.T. Knight "International Diffusion of Technical Change - A Case-Study of the Oxygen Steelmaking Process", the Economic Journal Nº 307, September 1967.

25/ The recent battering being received by the U.S. steel industry at the hand of the Japanese, the chronic postwar oscillations of policy for the British steel industry and the conflicts between private and public sectors in the Indian steel industry are examples of this.

26/ Obviously, the presence of defects in the competitive environment, or balance of payments crises or governmental or entrepreneurial planning errors can have consequences which go far beyond influencing just the technological variables in the steel industry - but in this paper the focus is precisely on the effect of such economic imperfections or errors on the technological variables.

underestimate the degree of improvement which can be got out of old-vintage facilities by adaptive engineering. Thus we saw that very notable upgrading results were achieved in the Rosario plants in response to historical necessity, and were achieved at very low investment cost. This then raises the question as to whether other steelplants are taking full advantage of the upgrading possibilities which their history has not forced them to explore?

Correlatively, we can take note of an exactly opposite potential error in choice of technique or replacement decisions, which consists in overestimating the degree of ease with which new best-practice technology (particularly if it also large-scale technology) can be brought into full operation. This error often arises because of leaving out of the economic calculations the time that will be taken by the firm's engineers and production staff to become familiar with the new equipment, to iron out the 'bugs' in getting it working properly, and to generate and analyse sufficient working experience to enable process-control to be progressively refined and improved until the plant is working at its designed performance levels. 27/

Obviously, both these two potential errors tend to pull in the same direction - which is to exaggerate the short-run profitability of those decisions which involve scrapping old vintage technology in favour of best-practice technology, and may thus lead to economically premature scrapping of serviceable and improvable old plant in favour of sophisticated new plant which brings all kinds of unforeseeen headaches with it.

On the other hand, common though these two potential errors may be, they are hardly the errors which were most noticeable in the record of Acindar and its Rosario plant! Here, as we saw, the problem was not that a premature scrapping decision was made, but that the imperfections of the Argentine economic context have inordinately prolonged the existence of this old-fashioned plant, far beyond the point when, even taking into account its great potential for improvement, this technology should have been scrapped.

Thus the Rosario case clearly illustrates one of the important reasons why plants may have their economic life prolonged beyond the economic optimum, - i.e. the existence of imperfections of various kinds in the surrounding context. It is, however, also relevant here to mention one other important reason why plants may go on being run too long. This concerns the entrepreneurial error of overestimating the degree of improvement and/or longevity that can be obtained by the ingenious patching up and modification of older plant (i.e. the exact opposite of the underestimation error in this regard that we mentioned earlier). This kind of error has been aptly described in the following way by a senior economic consultant to the British steel industry:

> "Everyone knows that the way to increase output at lowest investment cost is to improve existing plant. It is doing just this which landed

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27/ On this, apart from much empirical evidence, there is also an excellent theoretical paper worth seeing - R.S. Eckhaus "Absorptive Capacity as a Constraint due to Maturation Processes", in J.N. Bhagwati and R.S. Eckhaus, Development and Planning Essays in Honour of Paul Rosenstein Rodan, M.I.T. Press, Cambridge, 1973 the UK steel industry with much obsolescent plant when the British Steel Corporation took over in 1968. This may be an illustration of what is best from the financial return point of view is worst from the aspect of future efficiency. The homely analogy is that it is usually cheaper to patch up your old car and keep it going until the whole thing collapses, then you wish you had bought a better car earlier". 28/

This suggests that the pitfall involved in a deliberately prolonged strategy of actively "upgrading" old plant is that this strategy may discount the longer term future too heavily. Expressed more precisely, we can say that whilst there are likely to be very real and tangible short-term benefits in upgrading old plant - these benefits are definitely subject to a diminishing returns or "saturation" effect for technological reasons (e.g. due to the wearing out of plant or the inherent limits implied by the "technological regime" defined by the old vintage technology). And correlatively, although the short term benefits expected from adopting new technology may often be overestimated by entrepreneurs due to their false notions of the ease with which the many "headaches" accompanying new technology can be overcome, it is also true, as Bela Gold has pointed out, that "the long term benefits of technological innovations tend to be enhanced beyond the expectations leading to their adoption, partly because of the continuity of technological development efforts and the increasingly effective integration of innovational operations with those surrounding them" 29/ - i.e. it is not only "old-vintage" and outmoded technologies that can be upgraded, new technologies can be upgraded too! And as Gold points out, there is usually a great deal of room for such upgrading to take place.

What this whole discussion shows very clearly is that dynamic considerations, related to the upgrading of technologies over time as a result of the application of engineering efforts and investment, ought in theory to play a fundamental role in the determination of what constitutes optimal strategy with regard to choice of techniques, investment and scrapping decisions, and modification investments in existing steelplants. The trouble, however, is that many of the relevant factors are by no means easy to estimate. Indeed, the three tasks of assessing the upgrading possibilities for old technology, estimating the probable start-up and de-bugging time of prospective new technology, and estimating the longer term upgrading possibilities for prospective new technology are inherently difficult and error-prone. As a result they tend to be left out of the calculations or else estimated "intuitively" by the seat of the pants.

Yet the fact remains that, implicitly at least, Latin American (and other)

28/ Private communication to the author.

29/ This quotation, from Gold, continues as follows "Beyond these, experience demonstrates that additional gains in capacity, efficiency and control can usually be obtained merely by easing localized bottlenecks or constraints rather than adding to the system as a whole. And at least comparable gains may also accrue as interactions with marketing, procurement and transport come to be analysed and improved along with other organizational arrangements". See Bela Gold, "A Framework for Productivity Analysis", Ch. 2 of S. Eilon, B. Gold and J. Soesan, Applied Productivity Analysis for Industry, Pergamon, Oxford, 1976.

steel firms make such estimates, and subsequently then commit their scarce engineering resources to either upgrading the old, or else de-bugging and then upgrading the new. Equally, by their positive policies, or by the existence of the contextual "imperfections" which they permit, governments, too,tend to foreclose the options both of their own state steel firms, and of the private sector firms, thus in effect channelling both investment resources and engineering resources "blindly" into one or other of the alternative technological strategies of sticking with old technology or jumping to new.

The problem with this "implicit estimating" is that - at least in quite a few cases in the Latin American steel industry - the "implicitly" chosen strategy has clearly not been the economically correct one. In Argentina, for example, we have come across not just the Acindar, Rosario case where the "implicit" choice has clearly been far from optimal, but also the very notable case of SOMISA, the Argentine state steel company where there is evidence that the exactly opposite error was made, of continually "jumping to new technology" in advance of the enterprise's true capabilities for absorbing and getting the technology to work properly.

There would therefore seem to be a strong argument for researching into more case-histories of the evolution of Latin American steel firms to see (a) whether firms have tended to systematically underestimate or overestimate the three parameters related to old versus new technology mentioned above, and (b) to see how plants have been evolved in response to official steel policies and the various significant "imperfections" embodied in either these policies or in the surrounding economic context. 30 /

Independently of further research, however, the Rosario case-study does by itself suggest two simple conclusions: first of all, the private firm faced by the problem of "trying to innovate in the midst of organized chaos" can profit considerably from the example shown by Acindar in its Rosario plant - which suggests that whatever the degree of "imperfection" or "perfection" of the surrounding context, it will help the firm very much to have creative engineers on its staff ready at short notice to either compensate the firm for the former or take full advantage of the latter.

Secondly, from the social point of view, given that a society has limited supplies of skilled engineers, it make obvious sense to try to avoid that they waste their talents on minor problems. Acindar's Rosario engineers could have been working on blast furnace or direct reduction or oxygen-converter technology since more than a decade ago - but found themselves having to make minor ingenious improvements in a technology that should by then have been obsolete. This was economically much better for Acindar and for Argentina's balance of payments than it would have been if they had not made these improvements. But why, as our Argentine nuclear engineer has remarked, "make use of a catapult to kill mosquitoes", when much bigger targets are in view?

30/ 10 to 12 further case studies of the evolution of different Latin American steelplants are now beginning under the auspices of the IDB-ECLA Regional Programme on Science and Technology, covering plants in Brasil, Mexico, Peru, Colombia, Venezuela and Argentina.