

Technology strategy

Management of technology in the Brazilian power sector

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The generation and diffusion of innovations in the Brazilian power sector are discussed, emphasizing the role played by some of the most important actors: suppliers of materials and equipment, power utilities and the Eletrobrás Research Center (CEPEL), which is the largest R&D institution for the development of electricity-related innovations in Brazil. Lack of coordination between the actors induces inefficiencies such as duplication of R&D efforts, sub-optimal levels of R&D expenditure, low quality-standards for operating plant and equipment, and inefficient electricity end-use. A revision of the mechanisms of interaction between CEPEL, utilities and suppliers is therefore required. Although significant innovations have been developed, in particular by CEPEL, an efficient technology strategy remains to be formulated and implemented.

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We dedicate this paper to our friend Roberto Iazlovitch Besnosik who tragically died trying to save his son while this paper was being finalised. His sweetness and friendship remain in our hearts.

THE PROCESS OF technical change in the Brazilian power sector has had far-reaching effects. This paper assesses this process and analyzes the innovative behavior of the important actors, including suppliers of materials and equipment, power utilities and the Eletrobrás Research Center (CEPEL), which is the most important electricity R&D institution in Brazil. An effort is made to identify the technology strategies adopted by these actors, and to assess their appropriateness on the basis of the potential of technical change to improve power system performance. Besides the analysis of the innovative behavior of each actor, emphasis is also placed on their relationship and on mechanisms that may overcome market imperfections in sector R&D resource allocation.

The evidence that supports the analysis is derived from a survey based on formal questionnaires that were applied to nine important suppliers, five officers from utilities and eight officers from CEPEL. The paper is organized as follows. An introductory section comments on the changing role of public R&D at the international level, technological trends in the international electricity supply industry (ESI) and performance problems facing the Brazilian power sector.

The strategy and technological problems facing suppliers are then discussed, as well as their relationship with CEPEL. The perspective of the utilities is presented, followed by an exploration of the dominant perceptions inside CEPEL relating to its objectives, strategy, performance and relationship with the other actors. A conclusion sums up the main results of the analysis.

Breaking down the traditional cultural and institutional barriers between basic and applied research is an important challenge for public laboratories, which must establish stronger links between scientific findings and the commercialization of innovation

Power sector performance

At the international level, science and technology have been increasingly recognized as key elements in the dynamics of markets. Government policies have emphasized the need to strengthen national technological capabilities to improve economic competitiveness within a process of globalization of markets. In this context, government research policy, in particular the role of public laboratories, has also changed.

An important dimension of this process refers to traditional cultural and institutional barriers between basic and applied research (Perrin, 1983). While research institutes are usually concerned with the advancement of knowledge, engineers are typically concerned with practical applications of research results, the solution of specific problems and financial implications of R&D to the firm (Nelson, 1982). Breaking down such traditional barriers is an important challenge for public laboratories, which must establish stronger links between scientific findings and the commercialization of innovations.

Public laboratories are being required to provide relevant social and economic results, which often depend on higher priority being given to applied research in cooperation with industry. Indeed, central aspects of public policies in developed countries have been

- emphasis on transfer and commercialization of research results and
- incentives for cooperative R&D.

Collaborative work between laboratory and industry is encouraged to improve economic competitiveness (Warrant, 1991).

As research activities become more oriented towards user needs, the innovative process tends to become more dependent on such factors as (Rothwell, 1992):

- commitment and support to innovation by top management;
- existence of long-run corporate strategy in which innovation plays a key role;
- selection of investment alternatives based not only

- on short-term returns, but also on future prospects of growth and entry into new markets;
- organizational flexibility to respond to changes in environmental conditions;
- existence of a culture of innovation within the firm with the design of incentives to foster creativity.

The international power equipment industry has itself undergone a process of re-structuring. A trend towards the merging of large groups appeared (for example ASEA/Brown Boveri in 1982 and Alstom/GEC in 1988), associated with a range of agreements between firms. In this re-definition of the industrial landscape, technology has come to play an important role in corporate strategies and competition in the market place (Chesnai, 1990). Strategic moves have tended to favor local cooperative agreements in order to improve competitiveness and positions in markets, thus increasing the technological autonomy of subsidiaries. The latter often need to develop activities based on the design of new products and additional innovative capabilities, which may require renewed R&D efforts in host countries.

It is important to notice that in many other countries the ESI is also passing through processes of re-structuring, a key element being the move towards competition. Indeed, natural monopoly characteristics of some segments of the ESI are being challenged by changes in technologies and regulation (de Oliveira, 1991). Research management in the power sector needs to adapt itself to such changes. For instance, in the case of the transfer of assets from public utilities to private investors, the usefulness of R&D programs may need to be proved to bosses operating under different criteria, which reinforces the importance of bridging the gap between R&D and the commercialization of innovations.

Thus, both suppliers of equipment and incumbent firms in the ESI need to seek new strategies of survival and growth in rapidly changing environments. At the same time, technological activities have been significantly affected by concerns over quality and efficiency in supply as well as environmental impacts from power production and use.

While these are general international trends, the trajectory of each country or firm is related to specific conditions that are important in the shaping of learning patterns and the rate and direction of technical change (Dosi *et al.*, 1992). In any case, R&D policies must explore various forms of cooperation between economic agents in the industry in order to enable the strengthening of local productive and technological capabilities and the appropriation of benefits from significant technological opportunities which exist at present in the ESI.

Around a century old, the ESI is a mature industry. Nevertheless, technologies have been changing markedly in its various segments — generation, transmission, distribution and, specially, final use. At the level of generation, a notable change has been the development of combined-cycle gas plants, increas-

ing the attractiveness of thermoelectricity, altering economies of scale and reducing costs and environmental impacts (Williams and Larson, 1989). At the level of transmission and distribution, efficiency gains have been obtained by introducing innovations in areas such as new materials, high tension in distribution and applications of power electronics. Breakthroughs may occur in future in promising fields such as superconductivity (Yamaji, 1991).

Substantial opportunities exist also on the demand side (Schipper, 1994) for efficiency gains that will lead to the optimization of the operation of existing networks. The scope for the diffusion of innovations is particularly significant in developing countries which, by and large, have not yet followed the example of developed countries in areas such as household appliances, more efficient lamps and engines, and electronic metering processes (Walker, 1985; Bell, 1990).

Thus, an important point to be stressed is the dynamism of the technological frontier in the power sector. Related gains in quality and productivity are important sources of competitive advantage for those who are able to capture them. However, as is typical of the innovative process, the allocation of resources for technological development in the power sector is affected by important market imperfections, so that the voluntary allocation by individual agents is normally at sub-optimal levels (Vickers and Stoneman, 1988). Some specific imperfections may be singled out in the case of the Brazilian power sector:¹

- a protected domestic market for plant and equipment, without related performance requirements and monitoring, diminished the innovative impetus created by international competition and by the technological trajectory of the industry;
- macro-economic instability during the 1970s and 1980s increased the importance of the perception of technological risks;
- R&D allocation by transnational companies depends on their global strategies;
- at the level of utilities, the appropriability of innovation-related benefits is marked by problems associated with tariff regulation and system coordination.

Bearing in mind the technological dynamism of the ESI and these R&D market imperfections, it is also important to understand how technology issues fit into the general picture of power sector performance in Brazil. In this respect, a central point is that power system performance has deteriorated steadily since the mid-1970s, in a similar process to that which took place in the majority of developing countries (de Oliveira and Besnosik, 1992; Araújo *et al.*, 1991; DNAEE, 1991). At present, there is an important debate in Brazil concerning the reforms that need to take place to ensure that electricity supply does not become a bottleneck to economic growth.

In this context, the introduction of changes to over-

come the financial and institutional crisis of the Brazilian power sector should focus on at least three sets of issues. The first is regulation. The second involves an institutional reform that can stimulate competition and private sector involvement in the expansion of the ESI. A third promising area is the potential for improvements in the technological performance of operating utilities. This paper focuses on the latter by investigating technological strategies and relationships among suppliers, utilities and the Eletrobrás Research Center (CEPEL).

Materials and equipment suppliers

Evidence to support the analysis in this section was collected in interviews with officers from nine companies with an important presence in the Brazilian market, including Siemens, ASEA Brown-Boveri (ABB), Tusa, Toshiba, Furukawa, Alcan, Electrovidro, Acesita and Mecanica Pesada. Most of these companies are subsidiaries of foreign firms. This is reflected in R&D expenditures that are heavily concentrated on the countries of origin. While this is an important constraint for indigenous technological development, the power sector might still organize itself to benefit from technologies developed abroad.

There is a contrast in this respect between the behavior of the power sector and the Brazilian State oil company, Petrobrás. Unlike the power sector, Petrobrás has had considerable success in promoting partnerships that allow for the acquisition of technological capabilities both by research centers and by Brazilian companies. This difference may be explained, at least in part, in terms of existing market structures. While Petrobrás operates as a centralized and integrated monopoly, the Brazilian ESI is somewhat fragmented between state-level and federal utilities. Eletrobrás is a holding company with major interests in federal utilities and minor interests in most of the others. While being at the top of the structure of the industry, it has actually been unable to avoid the development of serious institutional conflicts between utilities.

All companies in the sample perform some R&D activities in Brazil, basically adaptations, applied research and product tests or quality control. Four of the

R&D expenditures of the main companies in the Brazilian ESI are heavily concentrated on their countries of origin: this is a constraint for indigenous technological development yet the power sector might still be able to benefit from these technologies

nine companies in the study made use of CEPEL laboratories for tests and product development, while three prefer to contract university services.

Three major factors were pointed out by interviewees to guide the innovative process: accumulated technological experience, demand, and introduction of innovations by competitors.

The relationship between suppliers of materials and equipment and CEPEL is marked by some significant problems from the point of view of the suppliers:

- CEPEL does not show its potential to those who could benefit from its services;
- the integration between suppliers and CEPEL depends on some form of coordination which does not exist at present;
- because services from CEPEL have high costs, they tend to be contracted when there is no possibility of using other research centers.

Despite these criticisms, the good technical performance of CEPEL has been generally recognized. Accordingly, some suggestions were made to improve the relationship between suppliers and CEPEL, including: coordination of activities performed inside and outside CEPEL, to avoid duplication of effort on specific problems; cost and time control in research projects; and marketing by CEPEL to increase its recognition in Brazil and Latin American countries.

All companies in the sample have programs directed towards total quality, with emphasis being generally laid on workforce involvement. This trend may be linked to the suggestion that competition with other countries was a significant driving force in the innovative processes in hand, for various reasons. First, a long recession in the Brazilian economy increased the short-term importance of external markets for the performance of individual firms. Second, Brazilian trade and industrial policies have significantly moved away in recent years from import controls and domestic market protection, creating a more competitive environment. Third, the prospective formation of Mercosul, a free-trade zone including Brazil, Argentina, Uruguay and Paraguay, is generally perceived by suppliers as a relevant determinant of their performance in the coming decade.

Utilities

Officers from four utilities (Eletrobrás, Furnas, CESP and CEMIG) were interviewed. Despite the limitation of their number, they are of strategic importance in the Brazilian ESI. While Furnas, CESP and CEMIG account for around 40% of supply, Eletrobrás is a holding company that controls several large federal utilities and has interests in most state utilities, besides having a central role in planning, coordinating and financing the operations and the expansion of the industry.

Among these, only Eletrobrás and CESP have an explicit R&D function in their organizational structures. CEPEL, the R&D Center financially controlled by Eletrobrás, is managed with relative autonomy without much interference from the parent company. In the case of CESP, a Technology and Development Sector operates under the control of a Materials Bidding and Technology Division, the latter being itself part of a Department of Supplies. Indeed, the R&D function is at the lowest hierarchical level.

Despite long-run planning being required to ensure success in electricity supply, R&D activities have not been a priority for any of the utilities studied. As they are among the largest utilities and operate among the richest states, there is no reason to expect that this should be different in other utilities.

It is not surprising that, in this context, there are no estimates of R&D costs as a percentage of sales. Similarly, the criteria used for R&D resource allocation are either obscure or non-existent. In the absence of explicit R&D strategies, scarce resources tend to be wastefully used, while national initiatives that should have a notable impact on sector R&D have had a negligible impact on the innovative behavior of utilities, with the exception of individual initiatives by technologists or utilities.

This was suggested by interviewees to be the case with the *Electricity Conservation Program* (PROCEL), a power sector program designed to promote electricity end-use efficiency, the *Brazilian Quality and Productivity Program* (PBQP) — a nationwide program to improve the competitiveness of Brazilian firms — and the *Commission for the Planning of Transmission from the Amazon Region* (CPTA) — an initiative by the power sector to deal with an important technological and economic challenge it will face in the expansion of electricity supply. A notable contrast appears between this situation among the utilities and the behavior of equipment suppliers, for whom the efforts to raise quality and productivity tend to be an explicit and important component of competitive strategies.

Another potential area of interest for innovative behavior by utilities lies in their interaction with electricity consumers. However, consumers were said to have no active participation in R&D resource allocation by utilities. Therefore, efficiency gains in the final use of electricity have not been adequately explored. An inappropriate culture still seems to prevail in the power sector, according to which the behavior of consumers should depend basically on price signals in the marketplace.

Similarly, a significant potential for productivity gains is not being tapped in the relationship between utilities and suppliers of materials and equipment. The selection of suppliers by utilities has historically depended more on price than on quality considerations, a trend that gained impetus because of the financial difficulties faced by most utilities in the last two decades. What is clear is the inability of the utilities to derive competitive advantage in

The utilities considered the CEPEL's R&D services an important contribution to technological development, even though the sector's problems are not well known in CEPEL and the results of R&D are not efficiently transmitted to potential clients

terms of technological gains from their strong purchasing power, in a concentrated industry that accounts for around a tenth of gross fixed capital formation in Brazil.

We turn now to the relationship between utilities and CEPEL. The utilities in the study have contracted in the past or still contract R&D services from CEPEL. With one exception (CESP) they considered the quality of such services an important contribution to technological development in the power sector. This perception was clearer in the federal utilities that have a closer commercial link with CEPEL as financial sponsors.

Nevertheless, CEPEL strategic behavior was questioned by utility officers on several grounds. First, it was argued that sector problems are not well known inside CEPEL. One result is that projects demanded by utilities often meet with resistance from CEPEL R&D management and staff. When the interests of CEPEL and utilities eventually coincide, results tend to be very good.

Another complaint is that the results of technology developed by CEPEL are not transmitted efficiently to potential clients, which leads to unnecessary repetition of effort. The potential role of CEPEL as a pole for the diffusion of innovations has not been explored, with the resulting loss of significant technological opportunities for the power system as a whole. It was also argued that a more effective relationship between CEPEL and the utilities is limited by the inability of CEPEL to control project costs and lead-times.

From the perspective of the utilities it was suggested that, as well as tackling these problems, CEPEL might facilitate the formation of closer ties between utilities and their suppliers, to induce the development of products and processes more responsive to the needs of the power sector.

CEPEL

Thus far, it has been suggested that there are significant weaknesses in the innovative efforts of suppliers and utilities, and that the nature of their links with CEPEL has played an important role in this respect. It is also clear that CEPEL is an essential actor in the innovative process in the Brazilian ESI. We analyze

next the evidence collected in eight interviews with CEPEL managers.

CEPEL was created in 1974 in the context of an effort by the Government to develop indigenous technological capabilities in areas of strategic interest to the process of industrialization. It operates in Rio de Janeiro and is the largest center for research on electric energy issues in Latin America.

Initially our survey addressed the identity of CEPEL as a research center. It was widely agreed that, from its creation until the beginning of this decade, there has been a lack of clear and explicit procedures in the definition of R&D activities. Only in the last few years have managerial and technical staff been engaged in an effort to define common objectives and operational policies to achieve them. It is not surprising that different perceptions emerged in the interviews in relation to the 'mission' of the institution.

First, there are conflicting views in relation to the importance of creative work *vis-à-vis* laboratory support for suppliers and utilities. A trend emerged suggesting that the generation of innovations became progressively more important, due to a combination of the professional interests of scientists and technologists in a staff of rising academic standards, and the demand by external clients, mainly utilities.

Second, there are three different perceptions as to whose needs CEPEL should be responsive to: Eletrobrás and the federal utilities who financially support CEPEL; all utilities in the system; or the power sector as a whole, including utilities and equipment suppliers. Strategic decisions in this respect will depend on related questions such as: should CEPEL seek to maximize benefits to its direct sponsors or to society as a whole?; and which attitude is more likely to ease the mounting financial restrictions facing the survival and growth of CEPEL?

The absence of clear-cut identity and strategies was reflected in inappropriate forms of definition and monitoring of the research agenda, according to a common view expressed in the survey. In the light of weak communication channels with utilities and suppliers, a trend was identified towards strengthening scientific interests at the expense of the economic implications of R&D results. As mentioned in the introductory section, however, public policies in developed countries have increasingly emphasized the importance of applied research and the commercialization of innovations in order to enhance industrial competitiveness.

As the sector's financial and institutional crisis gained momentum, CEPEL faced mounting financial problems. In 1991, it initiated a voluntary system of debate and change in order to adapt itself to the unfavorable environment in which it had to operate. In this process, some of the problems referred to above became evident and some initiatives were launched to deal with them. First, a commercialization office will handle the dissemination of the Center's potential services and R&D outputs. Second, a permanent process of project evaluation and monitor-

ing is being established. Third, strategic plans will be responsible for the definition of criteria for resource allocation.

The results so far are uncertain in view of the short period elapsed. These initiatives are in line with the expectations of potential users of CEPEL services, but it remains to be seen how successful they will be in practice. However, the dominant perception that emerged was the need to re-think the trajectory of the institution; this is a favorable sign of willingness to change which should be recognized.

The survey also provided evidence on selected strategic issues faced by CEPEL. The strategic position of firms or institutions depends, on the one hand, on the threats and opportunities in the environment in which they operate, and, on the other hand, on the combination of strengths and weaknesses they exhibit in facing up to these threats and exploring the opportunities to their advantage (Porter, 1986).

Some key environmental variables were identified, including: R&D resource allocation in power-sector policies; foreign trade liberalization policies; and recession, inflation and the financial and institutional crisis in the sector. Some comments are in order for each of these variables.

There is a consensus that R&D resource allocation is inappropriate, investment in technical change being sub-optimal. This perception is not surprising since institutions can be expected to think that they ought to receive more than they do and there are grounds for this assertion. Indeed, R&D expenditure in the Brazilian power sector reached only 0.4% of sector investment in the late 1980s. Long-run planning documents by Eletrobrás recommend an increase to 3% in the early 1990s.

Amaral (1989) related R&D expenditure by utilities to electricity generated as an index of innovative effort. In Brazil in 1987 this index was three times lower than in the USA in 1977, four times lower than in Canada in 1988 and nearly ten times lower than in Japan in 1981.

There is also evidence that R&D spending has not been generally internalized by Brazilian firms as a priority investment in their quest for competitiveness (Dahlman and Frischtak, 1990). Besides insufficient amounts having been allocated, there is concern about the management of R&D efforts, as reflected in the absence of common institutional objectives and insufficient emphasis on the commercial impacts of R&D.

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A second relevant strategic variable is the prospect for foreign trade liberalization and the formation of a South Cone free-trade bloc (Mercosul). There is a consensus that CEPEL will need to reinforce its position in selected technological niches where it is most competitive, such as software development for system planning and operation. Even so, the dominant belief is that Mercosul may create important opportunities for CEPEL: a regional free-trade zone may facilitate technology transfer and the exchange of investment and information; and CEPEL has an unique position as the only Center of its type and size in Latin America.

A third key variable is the context of macro economic and sector institutional crisis in which CEPEL is immersed. It is clear that the present crisis is an important threat to the Center. Financial resource flows have become more uncertain, making project planning and execution more difficult to manage. Research staff perceive low wages and scarce resources for projects.

Certainly in the short term, and possibly in the longer term, the development of human resources, equipment modernization and technological capabilities in general may suffer. It is noticeable that this adverse context has also acted as an inducement to reflect and make changes, through a process of discussion and strategic planning involving the technical and managerial staff.

Another important threat faced by CEPEL is in the possible institutional moves towards privatization and/or a diminished role for Eletrobrás in the Brazilian ESI. Aversion to technological risks has been stronger in the private sector, which can be an additional problem in the light of prospective rising levels of participation of private investors in the expansion of the power system (which may be justifiable on other grounds). Problems of uncertainty and appropriability of potential benefits may make R&D investment by CEPEL an even less attractive alternative than it has been under public ownership.

Apart from privatization, R&D funding may also be affected by a possible re-definition of attributions among actors in the public sector. Eletrobrás alone has been traditionally responsible for around 90% of resources allocated to supporting CEPEL activities, while the contribution by individual utilities has not been significant. As some proposals for sector reform have included a less important role for Eletrobrás — for instance, limiting its involvement in system expansion planning and coordination of operations — this might imply renewed financial difficulties for CEPEL.

Attempts by CEPEL to overcome these threats and turn the opportunities with which it is confronted to its benefit, depend on the combination of its strengths and weaknesses. Its major strength is a highly qualified human resource base, comparable to the best international institutions of its kind, according to the interviews not only in CEPEL but also with suppliers and utility officers.

The weaknesses of CEPEL may be divided into managerial restrictions and material and financial resource availability. Managerial problems are the inability to direct research efforts to commonly agreed and relevant objectives, and the absence of priority or strategies to transfer and commercialize innovations. The resource vulnerability has led to under-investment in research equipment and difficulties in avoiding the loss of qualified and experienced researchers.

With this line of reasoning, it may be argued that the strategic position of CEPEL is not good. Both management and technical staff have expressed their recognition of the need to change and their willingness to do so in order to overcome external threats and internal weaknesses. It is a question for the future whether changes will be implemented in the direction and with the efficiency required.

Concluding remarks

The issues discussed in the paper illustrate how the performance of public research institutions may be affected by lack of cooperation with potential users of R&D results, and by lack of integration between the R&D function and corporate strategy. In particular, lack of coordination in Brazil among suppliers of materials and equipment, power utilities and CEPEL has led to important inefficiencies in resource allocation for technological development.

The different actors seem to agree that changes are required in the mechanisms of interaction between them. In general, a central role is attributed to CEPEL in promoting change in the management of technology in the Brazilian ESI. However, it is not entirely clear whether CEPEL is prepared to respond to this challenge. Two favorable points in this respect are the good qualifications of its human resource base and the apparent consciousness that its own survival and growth will depend on how well it tackles the problems with which it is faced.

On the other hand, there are negative points which cannot be neglected. First, the past history of this R&D institution reveals significant weaknesses in the internal communication of objectives and operational policies as well as in the external communication flows regarding user needs and R&D results, a factor which was suggested to be of critical importance in research management.

Changes in the internal processes of complex organizations demand time, and the speed of reorganization is limited by the availability of managerial resources (Penrose, 1980). CEPEL has also been criticized for its project costs and lead-times, which places additional managerial burdens on its quest for efficiency. Another unfavorable aspect lies in the threats presented by the environment in which CEPEL, suppliers and utilities operate. A particularly important problem is the difficulty of mobilizing financial resources at appropriate levels, especially in a context

in which significant changes in the institutional framework of the power sector are expected to occur.

While there is a need for additional studies on R&D management in the Brazilian power sector, it is clear that an efficient technology strategy remains to be designed and implemented.

Note

1. In the last few years, Brazil has undertaken substantial economic reforms that are effectively reducing the role of these market imperfections.

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