STATE INSTITUTIONS, IDEOLOGY, AND AUTONOMOUS TECHNOLOGICAL DEVELOPMENT: Computers and Nuclear Energy in Argentina and Brazil*

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This article will examine the efforts made by Argentina and Brazil to attain a measure of technological autonomy in the fields of computers and nuclear energy. Grieco's study of the Indian computer industry[1] and separate studies of the Brazilian computer industry by Evans and Adler[2] have shown the inadequacy of the arguments raised by the dependency literature,[3] namely, that in areas of highly sophisticated technology, owned mainly by multinational corporations, the developing country will fail in any attempt to achieve domestic technological development.[4]

But case studies of domestic technological and industrial development in one sector may be of limited value in explaining why some developing countries succeed in domestic high-technology projects while other nations fail, despite their best efforts. To sharpen the question and make it more paradoxical: how can autonomous technological development be explained in cases where structural economic and technological conditions offered small potential for it while other cases with greater potential ended in failure?

Something other than structural factors must be involved. For example, why has Argentina maintained a consistent and successful nuclear policy since the 1950s and developed its nuclear-power potential into a fairly self-sufficient enterprise while Brazil has failed to do so? Budget allocations alone cannot explain this contrast, given the mammoth Brazilian investment in nuclear energy in the mid-1970s. Again, how does one account for the success of the Comisión Nacional de Energía Atómica (CNEA) in Argentina at a time of extreme domestic

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political and economic turmoil, when most other scientific and technological enterprises were being suffocated by negligence and inadequate action? One also wonders why Brazil ended up with a growing domestic computer industry and Argentina with almost none, despite the fact that the two countries developed an interest in computer technology at a time when Argentina was more advanced than Brazil in sophisticated electronics technology.

The answer to these questions is that analysts must look beyond the interaction between domestic and international structural factors to consider the role played by ideological groups and state institutions that catalyze the processes of technological and industrial development and become necessary, but not sufficient, conditions for success and failure. The historical questions, however, are not only what were the necessary conditions for the way things happened but how did they interact in order to bring about specific outcomes.

Through a dialectical process akin to that described by Albert Hirschman on more general development issues, the dependency that at first seems inevitable and totally determined in a structural reality may, because of ideological groups and their institutions, breed the quest for autonomy.[5] This supposition does not deny that power plays a crucial role in enabling ideological and institutional actors to achieve their goals. But power merely creates the opportunities and propensities for success. The "real" successes emerge from the perception by ideological actors of these opportunities and propensities, from their recognition that dependency is the problem and autonomy the solution, and from their harnessing the power of state institutions to their goal.

Ideologically motivated groups and state institutions may succeed in transforming technological dependence when, by directing political attention and support to the development of human resources and a technological infrastructure, they manage to develop a base that can help convince policymakers of the technological and industrial viability of domestic ventures. As Hirschman has suggested, by linking their "unprivileged problem" (such as technological autonomy) to "privileged problems" (such as economic growth, prestige, and national security) in the minds of the decision makers, these actors can use their scientific knowledge and technocratic skills within political structures to insulate the programs from political opposition and attain the status of "national projects" for them so that political leaders can only back these projects or injure national pride.[6] Technological autonomy may never be achieved, but in the process of trying to attain it, these actors may help bring about sufficient technological development to change industrial performance and achieve economic, social, and national security goals.[7]

THE ROLE OF THE "STATE"

Political economists are well acquainted with the fact that states matter and that they intervene in their economies for various reasons. "The question," Chalmers Johnson observed, "is how the government intervenes and for what purposes."[8] Achieving technological autonomy might be one of these purposes. The issue is therefore what specific structural, institutional, and ideological factors, relationships, and circumstances help create successful state intervention.

The notion that the state must be viewed as a relatively autonomous actor has also been well established.[9] But "state autonomy" is a dynamic concept and a changing condition[10] that, while it can explain the state's capacity for intervening in economic processes without becoming "a mere executive committee of a dominant class,"[11] cannot explain differences in performance and outcome in various cases when the state is relatively autonomous.

A theory of state intervention holding that there exists an "essential character of the state that can be deduced from some 'function' which 'needs' to be performed in society"[12] and viewing states as one-dimensional social structures and systems cannot be very useful either. Rather, analysts need to study state intervention by emphasizing institutions that make up the state, their histories, and collective understandings, which work together "neither 'for good' entirely nor 'for ill' entirely, but simply as their joint histories dictate."[13]

IDEOLOGY, INSTITUTIONS, AND THE STATE

By ideology I mean a set of beliefs and values about society, clearly a cognitive phenomenon. Whatever an individual believes and values about society will condition (at least partially) what he or she wants to achieve, why, and in what ways. Ideologies are important because they "have origins that cannot be reduced to material developments, . . . can have substantial and independent effects,"[14] and may have the "obvious potential to develop into political forces. This happens when a set of political doctrines is adopted by a group of people, assumes a critical position in their belief systems, and then becomes a guiding force behind their actions."[15]

Institutions are defined here as the "carriers" of ideologies, the source of the legitimation of the groups within them, and most important, the source of the financial and political means that help achieve desired aims. Thus, in a Weberian sense, institutions become repositories of a constellation of consciousness and collective understanding that, when integrated into institutional designs, become the preconditions of institutional behavior.

The main ideology of interest here is that oriented toward nationalism and antidependency. Because autonomy is viewed as the opposite of dependency, "it makes sense to talk about changes that represent differences of degree, such as relative increase or decrease in the autonomy or capacity for action of certain Latin American states."[16] This ideology is pragmatic in nature because it offers a prescription for action now. This perspective stands in contrast to a structural antidependency approach, which takes "world socialism" as the only solution to what is seen as a global structural problem—capitalism and its expansion into the Third World.

The pragmatic antidependency ideology, which is long-range and strategically oriented, should be contrasted with yet another ideology that emphasizes short-run interests—that of economic efficiency and the rules of economic competition and comparative advantage. In assuming that the best and most efficient technology (usually meaning foreign) should be used to obtain the best economic results, this ideology considers the issue of whether technology is indigenous or imported as beside the point and views the willingness of pragmatic anti-*dependentistas* to "reinvent the wheel" as utter stupidity. According to the ideology of economic efficiency, the state should get involved only as necessary to ensure an appropriate and viable educational and bureaucratic infrastructure.

The role of ideology and institutions in the quest for autonomy in Argentina and Brazil has been expressed by a "strategically located cadre of officials enjoying great organizational strength inside and through existing state organizations and also enjoying a unified sense of ideological purpose about the possibility and desirability of using state intervention to . . . promote national economic development."[17] A prominent member of one group of Latin American officials, who has been involved in science and technology at the national and international levels for many years, has remarked that "we are always trying to influence politicians to accept our ideas. . . . We work like guerrillas, creating space to maneuver. . . . We have to create a new ideology, to reinterpret the role of science and technology under conditions of underdevelopment."[18]

Those whom this Latin American friend has termed *guerrillas* represent what I call the pragmatic antidependency position because they maintain that dependency can be reduced now, rather than later or never. In their view, dependency can be managed and reduced by learning from others, controlling foreign investment and technology transfer, and strongly emphasizing autonomous technological and industrial development.

These pragmatic antidependency guerrillas, many of them scientists, technologists, and economists with authority in domestic and international forums, have used state power to mobilize the practical ex-

pertise of scientific and technological development and its industrial applications. Acting as benevolent conspirators who regard politicians as instruments for achieving certain aims, they have shaped collective beliefs and expectations within state institutions and at policy-making levels. In instances where their views were akin to those of the political elites, they had only to show the way. In many cases, however, their ideological motivations have differed from those of the political elites, and they have had to influence the ideological context of ideas indirectly or bring about the desired end by using their technocratic and persuasive skills.

It could be argued that military regimes might be particularly receptive to pragmatic antidependency guerrillas working within state institutions.[19] Although the military is likely to reject structural antidependency arguments, they may appreciate the nationalist side of pragmatic antidependency. For example, they may see autonomy projects as a way of achieving legitimation and prestige for themselves as well as for their regimes and nations. The military may also have fewer objections than civilians to state intervention and economic planning, if only because they may be more sensitive to the link between technological autonomy and military power. In other situations, however, the military may be inclined, whether by structural constraints or ideological reasons, to favor short-term projects oriented toward economic efficiency over long-range, strategically oriented technological projects and may discount projects for technological autonomy as desirable but unrealistic.

DOMESTIC COMPUTERS IN BRAZIL AND ARGENTINA

The cases to be studied here have a definite comparative appeal because Argentina decided to abort its domestic computer project at approximately the same time that Brazil decided to set up a domestic mini- and microcomputer industry, which eventually grew and prospered. At that time, Brazilians began to view computers as one product that they could not continue to import from multinational corporations, even though their own industry might not be cost-efficient in its initial stages. In contrast, Argentine decision makers chose to kill the computer project after a prototype had already been designed and assembled by a private domestic company and to rely instead on the efficiency of market mechanisms.

Brazil's Domestic Computer Industry

Only two years after the establishment of the Brazilian computer industry, domestic companies were producing systems (hardware and software), peripherals, terminals, modems, and special terminals. Be-

tween its inception in 1978 and 1982, the dollar sales of the domestic industry grew from 2 percent of the total to 19 percent. By 1982 domestic companies had produced 67 percent of installed computers and accounted respectively for 67 percent, 91 percent, 13 percent, and 1 percent of the dollar value of installed micro-, mini-, small, and medium computers.[20] By 1983 one hundred Brazilian computer companies were employing eighteen thousand people, twelve hundred of them in research and development, and were generating annual sales of 687 million dollars.[21] Although the extent of Brazilian dependency on international computer technology and companies has been reduced rather than overcome, a measure of autonomy has been achieved; Brazil has created domestic manufacturing capacity in computers as well as the ability to adapt foreign technology and to innovate.

Brazil's domestic computer industry was the ideological, industrial, and political outgrowth of a general science and technology policy aimed at attaining autonomy by strengthening Brazil's capacity to adapt and control foreign technology via innovation. Conceived by a group of economists at Brazil's Banco Nacional de Desenvolvimento Econômico (BNDE) led by José Pelúcio Ferreira, this policy received partial support from the military (in power since 1964), who were motivated by an ideology they called *segurança e desenvolvimento* (security and development). What made the BNDE diagnosis particularly appealing to the military was that it fit in with their perceptions and expectations that Brazil would soon become a world power.

Funds to proceed with technological development were available due to the "economic miracle."[22] But it was not inevitable that these funds would be channeled toward developing indigenous technology; this outcome was created by individuals and institutions imbued with an ideology of pragmatic antidependency. These actors pressed for funds to set up new research institutions, science and technology policy structures, and science and technology banks. Existing institutions were restructured, and the first two plans allocated close to three billion dollars for scientific and technological development.[23] An agency to study financing and projects, FINEP (Financiadora de Estudos e Projetos) was established in 1965 to support national technological development and to provide a liaison between the domestic technological infrastructure and industry. A science and technology fund was placed under FINEP's jurisdiction, and additional funds were created later within other institutions. The Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) became the heart of the science and technology program, with funds for research and fellowships being allocated through its network.

Meanwhile, BNDE planners identified minicomputers as a sector that might help develop Brazil's technological and industrial capabili-

ties. The Brazilian navy, which was using English Ferranti computers in its ships, agreed to initiate a joint project with BNDE for planning, developing, and manufacturing a prototype computer suitable for naval operations, preferably in association with Ferranti. FINEP, BNDE, CNPq, and other institutions provided the means to train cadres of professionals in computer engineering and related subjects. Within five or six years, these efforts produced a critical mass of computer experts.

In 1975, thanks to BNDE and navy initiatives, the government established Cobra S.A. to assemble computers under license from Ferranti (the 700 series) and from Sycor, a small American company (the 400 series). At the same time, a holding company called DIGIBRAS was set up to function as the industrial promotion agency for its national computer project. These efforts resulted in a national computer, its hardware developed by the Universidade de São Paulo and its software by the Pontifícia Universidade Católica do Rio de Janeiro. Computer terminals developed by the Serviço Federal de Processamento de Dados and the Universidade Federal do Rio de Janeiro became part of the computer system, which was later transferred to Cobra.

In April 1972, the Comissão da Coordenação das Atividades de Processamento Eletrônico (CAPRE) was created to manage data processing within the federal government, to maintain statistics on the national market, and to develop a program to encourage local industry. Aided by a growing balance-of-payments crisis, CAPRE soon assumed significant political power and began to affect the policies and direction of the computer-development program. CAPRE saw to it that imports were curtailed, tight control was established over data processing, public consciousness regarding the domestic computer industry was raised, and plans were drawn up to reserve the minicomputer market for domestic companies.

CAPRE's subordination under the Ministério do Planejamento (known as the Secretaria do Planejamento since 1974), under João dos Reis Velloso, was crucial to its ultimate success in developing a domestic computer industry because the ministry became CAPRE's source of political clout. Velloso, who opposed the internationalist position of the Ministério da Fazenda, became a political vehicle for antidependency ideas and their implementation. Ricardo Saur, CAPRE's executive secretary, was instrumental in the uphill battle to turn CAPRE's perspective into political action and an industrial reality. Thus CAPRE became more than an institution with a presidential mandate to regulate the computer sector; it became a sort of "guerrilla headquarters" for the ideologically assertive group that set itself up to sell ideas, raise consciousness, and use political power to achieve its goals.

While CAPRE's first formal steps were to create national programs for data-processing centers and computer training, thus identify-

ing the strengths and liabilities of the scientific and technological infrastructure,[24] the pragmatic antidependency guerrillas began their intellectual and political "attacks" by formulating a doctrine that only 100 percent national companies would be allowed and each item of foreign technology could be purchased only once. They infused the scientific and technological community and the political system with optimism—with the idea that "it can be done"—by acting as teachers at universities and technocrats in government agencies, emphasizing Brazil's few but significant technological successes in order to generate a positive feedback effect.

What made CAPRE so powerful was its ability to set guidelines and policies at its own level, without undue high-level interference, thereby presenting the higher echelons with new choices. At the time, Velloso and other high-ranking policymakers were not thinking of a totally domestic computer industry but a joint venture with foreign companies. The government wanted to exploit the technology of multinational corporations, but the corporations were not interested in such ventures.[25]

By mid-1976, International Business Machines (IBM) sensed the growing trend toward protectionism and the development of domestic minicomputers. IBM announced the manufacture in Brazil of a minicomputer (System 32) and even managed to sell several hundred of them. But CAPRE's reply was swift. In July 1976, it reserved the micro- and minicomputer sector of the market for Brazilian firms, while leaving the sector manufacturing larger machines to foreign companies, as in the past.

In the meantime, CAPRE's executive secretariat laid out a strategy with two lines of "containment." The first line was to choose only 100 percent Brazilian companies to produce domestic computers; the second was to allow multinational corporations to operate in Brazil only in partnership with domestic firms. It should be emphasized that this decision was not made by the CAPRE council and that those high up in the government knew nothing about it—the decision was strictly a guerrilla strategy.

Velloso in the Secretaria do Planejamento came under a great deal of pressure from opponents and supporters of the reserved market plan. While IBM and other multinational corporations were putting pressure on the highest political echelons, the media put CAPRE's case on the front pages, playing up the refusal of multinational corporations to enter into joint ventures with Brazilian nationals and IBM's "trick" with System 32. Once the matter went public, it became more difficult for the government to do anything that might suggest that it was yielding to pressures from the multinational corporations. CAPRE was also aided by pressure from powerful private banking consortiums that had

already invested money in Cobra in hopes of producing domestic banking computer systems as well as from key military personnel.

In the end, the CAPRE council and the ministers directly and indirectly involved in the data-processing sector decided to call for bids from domestic and foreign firms to produce minicomputers. It was understood that the final decision would be based on conditions specified by the Conselho de Desenvolvimento Econômico and that nationals would be preferred only if their bids were at least as good as those of the multinational corporations. CAPRE delivered its blow to the multinationals at the end of 1977: it chose four companies—the government's Cobra and three domestic consortiums that were either brand new or still in the process of being created.

The success of CAPRE and the guerrillas in giving birth to a national computer industry should be understood in the light of changes in international computer technology and markets, however.[26] Although the guerrillas envisioned only an industry of Brazilian minicomputers with licensed technology, they were aided by the emergence of the microprocessor and microcomputer and by the development of the international computer industry away from high concentration and oligopoly. By including microcomputers in its policy, Brazil entered into a segment of the industry that had become highly competitive.[27]

In 1979 CAPRE was replaced by the Secretaria Especial de Informática (SEI), which was to be linked to the Conselho de Segurança Nacional and report to the president. Heavily influenced by the intelligence community, the administration of João Figueiredo decided that CAPRE had too much independent political clout and that the computer industry should be controlled instead by the military and insulated from domestic pressures, unhappy consumers, economic interests linked to the multinational corporations, the corporations themselves, and the governments that lent political support to the international companies. Having perceived the strategic implications of computer technology and the political "weakness" of such civilian institutions as the Secretaria do Planejamento in confronting the multinational corporations, the military were only too happy to take over.

From the beginning, the SEI had to confront pressures from the computer associations, the guerrillas, and defenders of the market reserve, who wanted the domestic computer industry to be maintained and strengthened, as well as from some consumer groups and political actors who wanted the market reserve eliminated and the SEI scrapped. Between 1980 and 1984, the SEI calmed the fears of the former set of interests and enraged the latter by solidly supporting the infant domestic industry.

With the help of technocratic insulation and normative acts, the SEI deepened and widened the market reserve to include peripherals

and software. It set guidelines for data-processing imports, stipulated that governmental institutions must use domestic computers, and ordered all data-processing equipment to be registered. It also decided that approval of ventures for manufacturing computers would be linked to the market reserve in the micro- and minicomputer sectors and that domestic technology would be used in the larger-computer sector as well. The SEI later set up controls for approving all data-processing research and development, established a software registry and a microelectronics research center, and introduced a policy to promote the domestic production of the thirty-two-bit computers called "superminis." At the same time, the SEI approved applications by IBM and Burroughs to manufacture medium-sized computers in Brazil, although this approval contained some restrictions.

In October 1984, the SEI, supported by defenders of the domestic industry and market reserve, won an important victory: the Brazilian Congress passed a law maintaining the market reserve and import controls and setting up a presidential council to make computer policy. In 1986 this policy and law was reconfirmed by Congress. In the view of state officials, policymakers, industrial firms, and the general public, the Brazilian computer industry and the laws protecting it had become a "national project" embodying Brazil's long-range strategic interest and a vision of its destiny as a developed and powerful nation.

Argentina's Aborted Venture into Computers in the Mid-1970s

> [Argentina] has undergone one of the earliest processes of industrialization in Latin America and this is clearly reflected in its diversified industrial and service infrastructure. At the same time, it has had a traditionally high level of education of the general population as well as of technical and scientific expertise. These general conditions have been accompanied by a comparatively large home market, mainly urban, and an industrialization policy which encouraged the development of industries behind protective barriers. The combined effects of these factors explain why the initial conditions for the development of the electronics industry were favorable and [why Argentina's electronics industry at one time] ranked as the unchallenged number one in Latin America.[28]

But conditions favorable to Argentina's developing a domestic electronics project were of no avail when an Argentine firm decided to produce a locally developed computer. This event happened at a time of great political and economic turmoil, when many projects were affected by what Hirschman has called "fracasomanía . . . , the habit of interpreting as utter failure experiences that actually contain elements of both failure and success. The very tendency toward systematic fracasomanía is, of course, an important ingredient of the subsequent real fracasos."[29] Thus the Argentine computer died before it was born, not

for lack of capabilities but for lack of political support from elites that were ideologically opposed to protection.

FATE S.A., a private Argentine company that had made a fortune manufacturing tires, promoted and implemented the idea of a domestic computer. The history of FATE's aborted computer venture goes back to the early 1960s at the Universidad de Buenos Aires, where local scientists were doing research on electronics components, digital automation, and industrial electronics under Humberto Giancaglini and Alberto Biloti. These efforts came to a halt in 1966, after "la noche de los bastones largos," the Onganía government's purge of "leftists" from the universities. Many scientists quit the universities (and the country), while others went to work for multinational corporations or domestic electronics companies.

Oscar Varsavsky, a physicist and strong supporter of technological autonomy,[30] was given a free hand by the owner of FATE, Manuel Madanes, a nationalist and Peronist supporter, to recruit the best electronics scientists, create FATE Electrónica, and start producing electronic calculators and printed and integrated circuits. Varsavsky brought many of the scientists who used to work at the Universidad de Buenos Aires to FATE, including Roberto Zubieta, who became the leading ideological and technological force behind development of the computer. This process was occurring when the Onganía government had already received its death blow from the "Cordobazo" insurrection of 1969 and while nationalism was on the rise and a mildly antidependency science and technology policy was being implemented. Also relevant were the personal and financial ties to FATE of José Gelbard, who was to become economic czar under the second Peronist government in 1973.

Zubieta commanded a group of antidependency-minded scientists within a company whose management was close to the nationalist left in Argentina. The general idea was to turn FATE into an "island" for the production of Argentine technology. Indeed, FATE Electrónica's original success was due mainly to its policies based on assimilating technology, training its own technicians and engineers, providing space for university researchers, and producing products based on intensive research and development; FATE's success was also due to governmental protection. The company did not use foreign licenses and trademarks. Instead, it searched aggressively for nonproprietary technological information and sent technicians to study abroad. By 1974 the firm was producing between 15 and 20 percent of its requirements for integrated circuits; a year later, it had captured more than half of Argentina's calculator market, forcing Olivetti (FATE's major competitor) into a deep crisis.[31]

The next "obvious" step was computers. By 1974 a computer prototype called Serie 1000 was almost ready. Some of the military, especially air force personnel and the Instituto de Investigaciones Científicas y Técnicas of the armed forces, expressed interest in the development of domestic computers, but the military was not in power at that time. When they did come to power in 1976, their leaders were sold on a liberal ideology that emphasized the short range, economic efficiency, and comparative advantage. IBM (the largest computer company in Argentina) did not pressure the government in opposition to FATE Electrónica's computer venture because it did not feel threatened. Most of IBM's market was in large machines, whereas FATE was supposedly building a computer in a smaller range. Moreover, IBM did not believe that FATE would succeed in developing its computer.

The computer idea and prototype were scrapped between the end of 1975 and the March 1976 military coup. FATE started the electronics project on the ideological premise—nurtured by dynamic local scientists and engineers—that self-reliant development was possible and that the company could benefit from it. But these "guerrillas" who found a home within FATE lacked the backing of state institutions and state technocrats willing or able to play a supporting role, as happened in Brazil. Furthermore, Argentina lacked a systematic science and technology policy and governmental awareness of the strategic relevance of producing domestic computers.

FATE also suffered from the political and economic turmoil of the last year of Peronist rule, coupled with an embarrassing economic scandal over one FATE subsidiary, ALUAR. FATE owner Manuel Madanes, sensing the imminent political change, appointed a general manager whose ideology diverged totally from that of the group who had developed the computer. The new manager, R. Bargagna, was a strong believer in market forces and an enemy of protection. Unlike his Brazilian counterparts, he was convinced that technological change would make a domestic computer venture unviable. Moreover, the nationalist-oriented segment of the military and the government had refused to save the project with a loan of two and a half million dollars, which made the manager's decision even "simpler."

While the decision to kill the project was probably made before the military takeover, the coup sealed its fate, given the antinationalist, anti-Peronist, and liberal outlook of the military that took power. The links of FATE Electrónica executives and scientists with the Peronist regime also prevented FATE from proceeding with its computer project.

Whereas the case of Argentina's computer was one of a private initiative that failed to convince the government of its merits, the Brazilian case was one of a public initiative that nourished the private effort. The contest was not between a weak government and a strong one:

both governments were strong and interventionist. The difference lay in perceptions of development and the existence of state institutions that could manage a project of technological self-reliance. The Brazilians focused all along on reducing dependency while the Argentines emphasized efficiency and the market. In Brazil the ideological group that sold the computer idea had access to power and succeeded in converting its ideology into political power. In Argentina the autonomy-conscious scientists lacked political backing and political structures within which to mobilize support and political allies. In neither case was the state an instrument of local capital. In Brazil local capital responded to the public initiative because the weight of the state supported it. In Argentina a single local company identified with the nationalist left failed to garner state support not only when a rightist military regime took over but even when the Peronists were in power. After the Falklands/Malvinas War, Argentina asked Brazil for assistance in the computer field, and the integration treaty signed by the two nations in 1986 features "informatics" as one of the main fields of cooperation.

NUCLEAR ENERGY DEVELOPMENT IN ARGENTINA AND BRAZIL

Argentina and Brazil began their attempts to control the nuclear genie immediately after World War II. Both set up institutions to train nuclear scientists, founded atomic energy commissions, and pursued programs based on natural uranium technology. But the similar and almost parallel paths followed by the two countries in the early stages of nuclear development diverged in different political and technological directions, resulting in contrasting outcomes.

Argentina's Nuclear Energy Development

By the end of 1983, Argentina had come close to controlling the nuclear fuel cycle. With sufficient reserves of uranium concentrate ("yellow-cake") to fuel nine nuclear power stations during their thirty years of active life, Argentina had produced in a pilot plant its own uranium dioxide (UO_2), the basic raw material to make the fuel elements placed in the core of a reactor. This goal was accomplished with the help of German and some domestically developed technology.[32] Argentina produces its own fuel elements and the zircalloy tubes into which the fuel is inserted and is constructing a plant to produce heavy water. A pilot heavy-water plant already produces three tons of heavy water per year. Even though the two working nuclear reactors (Atucha I and Embalse) and a plant under construction (Atucha II) are heavy-water reactors, Argentina can also enrich its own uranium and has de-

veloped domestic reprocessing technology. An Argentine pilot reprocessing plant has yielded the first plutonium manufactured in Latin America.[33] Argentina plans to build two more nuclear reactors by the end of this century.

Among Argentina's biggest successes has been the training of nuclear technologists who can perform specialized activities. The metallurgy department of the Comisión Nacional de Energía Atómica (CNEA) has played a major role in training and also in developing and manufacturing all the fuel elements used for research and in solving hundreds of problems referred to it by the electro-mechanical-metallurgical industry.[34] The CNEA has developed eight research reactors, one of which was sold to Peru.

Argentina's domestic nuclear industry is presently helping to mine uranium, produce yellow-cake and fuel elements, provide sophisticated inputs for the construction of nuclear power plants, and make nuclear instrumentation and components. About sixty Argentine companies, many linked to the CNEA in capital and management, are engineering and producing nuclear plants, manufacturing generators, pressurizers, and reactor cooling systems, and producing capital goods for the industry.[35]

Large uranium supplies, a relatively developed industrial and scientific infrastructure, and the readiness of foreign companies to sell reactors and other technologies of the nuclear fuel cycle to developing countries even without international safeguards generated an environment favorable to Argentina's success in the nuclear area.[36] The United States, through its Atoms for Peace program initiated in 1953, provided know-how, training, and materials, and the Soviet Union also lent assistance. India's nuclear explosion in 1974 showed developing countries desiring nuclear autonomy that such a goal was not impossible. Moreover, the 1973 oil price hike made nuclear power much more appealing, thus aiding domestic supporters of the nuclear option.

These factors are nevertheless insufficient to explain why and how Argentina was able to come close to achieving its goal of nuclear autonomy during a period when most political, economic, and technological institutions were being shattered by fracasomanía. To explain Argentina's success in the nuclear field, it is necessary to focus on the institution that made it possible and the drive of its scientists and leaders to attain self-sufficiency in nuclear technology and nuclear-energy industrial development. Through careful policies of purchasing technology, training personnel, backing research and development (the CNEA became known in inner circles as the Comisión Nacional de Educación Atómica), setting up physics labs, establishing the nuclear engineering profession, and developing nuclear medicine, the CNEA

generated a critical mass of scientists and a technological infrastructure that enabled the organization to attain intermediate goals. Each success in turn generated political support for the project.

The CNEA's policies and choices should be attributed in part to its leadership (which from the beginning and up to 1983 came from the Argentine navy), especially to Admirals Oscar Quihillalt and Carlos Castro Madero, who were politically influential and provided dynamism and continuity. Quihillalt watched eight Argentine presidents rise and fall during his eighteen years at the head of the CNEA, which has had only four presidents in the first thirty years of its existence.

But leadership was only one relevant factor. The CNEA's success cannot be properly understood without taking into account the ideology of autonomous technological and industrial development that Jorge Sábato brought to the CNEA when he became the head of its metallurgy department in 1955. After choosing the scientists and engineers, whom he called *la murga* (a band of street musicians) to emphasize the improvisational nature of the enterprise, he defined the department's objectives: nuclear-technological and industrial autonomy, development of a science and technology infrastructure, and creation of collective awareness that domestic technological development is possible, even in a dependent (and politically and economically troubled) country—and even before structural economic changes have taken place.[37] Sábato and his group thus became pragmatic antidependency guerrillas, affecting and effecting the ideological, political, and technological processes that eventually helped Argentina develop an autonomous nuclear technological capacity.

The idea behind the metallurgy department was that Argentina should develop all types of metallurgy for the benefit of industry in general because only such a laboratory would be able to handle all the problems related to nuclear metallurgy. Sábato and his colleagues asked the CNEA authorities for a free hand in implementing this project, and Quihillalt agreed. Developing domestic nuclear energy had become a high-priority goal because of the Richter fiasco, among other reasons.[38] Therefore, all qualified personnel, both Peronists and anti-Peronists, were employed at the CNEA, creating a nonpartisan tradition that still exists.

The decision to use American technology to assemble Argentina's first nuclear research reactor at home proved to be the watershed in the country's autonomous nuclear development. When Quihillalt presented this idea to the metallurgy department, Sábato and his group embraced it enthusiastically, stating that they would be able to build the fuel elements despite their current lack of equipment and know-how. This decision created the tradition that Argentine research reactors

were to be built in Argentina. Process turned out to be more important than outcome, as CNEA scientists acquired invaluable skills and learned how to produce technology while building the reactor.

Sensing that CNEA know-how would have to be applicable to domestic industry in general before the nuclear-energy industry would have any chance of success, Sábato (with the help of an Argentine industrialist) convinced CNEA authorities to set up an institution for technology transfer, the Servicio de Asistencia Técnica para la Industria (SATI). Another critical choice was the decision to do the feasibility study on Atucha I in-house. Sábato said later, "We did not even know what a feasibility study was, but there was an understanding that we should do it if the CNEA was to learn how to produce technology."[39] As expected, the study called for the active participation of domestic industry, correctly forecasting that this step would be the starting point for a nuclear energy industry.

The participation of local industry was one of several key factors in the decision to buy a reactor from the West German company Siemens. To implement the agreement with Siemens, SATI organized a committee called the Grupo de Industrias Nacionales (GIN) and empowered it to evaluate the agreement and ensure that local industry would be adequately represented. The GIN also examined the domestic industry's capacity to contribute to the production of a nuclear plant. The report recommended that eighty-eight items be produced by domestic industry. In all, Atucha I had a 33 percent rate of domestic participation, a figure that rose to 58 percent in the case of Embalse and is expected to reach 65 percent when Atucha II is completed.[40] Another important decision on the road to autonomy was the choice of natural uranium heavy-water reactors over light-water reactors, which work with enriched uranium, even if the latter were cheaper. While reliance on heavy water implied a short-term dependence on foreign sources, the heavy-water reactors seemed likely to overcome the stalemate in domestic-uranium enrichment in the long run, thus comprising firmer (albeit slower) steps toward autonomy. When in 1973 the CNEA decided to purchase a Canadian Candu heavy-water reactor for its Embalse plant, the argument regarding the type of reactor to buy or produce was finally settled.

Work toward autonomy in nuclear technology continued, even when many scientists left the country during the troubled years of the Peronist government (1973–1976). When the military returned to power, they killed thousands of Argentines, including scientists. These repressive policies seriously damaged higher education and scientific and technological development. Although the CNEA did not escape some effects of this atmosphere, it succeeded in insulating itself from the turmoil more effectively than other technological institutions. During

this turbulent period, the CNEA under President Castro Madero took measures that brought Argentina very close to mastering the entire nuclear fuel cycle.

The CNEA and the ideological guerrillas in its midst were aided by the broad appeal enjoyed by nuclear energy in Argentina. All the power elites (except the hydroelectric lobby) viewed nuclear electricity as a boon to achieving major national goals. Turned into a "national project" that would redeem Argentina's pride, the program appealed to the nationalist right for strategic and prestige considerations as well as to the nationalist left, which applauded decreased dependency on capitalist countries. The program also appealed to the Argentine masses, who were seeking one success amidst so many fracasos. This broad consensus allowed the CNEA to insulate itself partially from intragovernmental rivalries, bureaucratic bargaining, and the political and ideological conflicts between right and left, Peronists and non-Peronists, and civilians and the military.

The CNEA's centralization of all areas of nuclear technology and industrial development, nuclear power generation, construction of nuclear plants, and training of human resources helped it to become even more insulated from political and economic turmoil and to pursue its goals with consistent determination. No less important was the fact that nuclear policy was being developed by the CNEA, rather than being imposed on it, and only then was policy "sold" to the highest decision makers. This political process, which ensured that the CNEA's work was not too seriously impaired by the changing moods and ideologies of Argentina's many presidents, was made possible by the CNEA's reputation and stability and by the fact that the nuclear issue was often too technical and complicated for the politicians, who preferred or had no choice but to refer it to the scientists at the CNEA.

By having the CNEA report to the office of the president, Argentine presidents were able to overrule most of the opposition encountered by the CNEA.[41] Pressure from the hydroelectric lobby was strong at times, however, as when the CNEA undertook the feasibility study for its Atucha I plant and when the Secretaría de Estado de Energía (a stronghold of the hydroelectric lobby) opposed construction of even a single nuclear power plant. After the secretariat lost this battle, the Servicios Eléctricos del Gran Buenos Aires (SEGBA) utility demanded that SEGBA run Atucha I but also failed to get its wish. At other times, the CNEA had to give in to some pressures and demands. In 1978, for example, an energy plan gave priority to hydroelectric power, whose lobby had succeeded in convincing the political leadership to halve the number of nuclear reactors planned by the end of the century.[42]

The military factor should neither be overlooked nor overstated. It is well known that Argentina's nuclear potential has made an Argen-

tine atomic bomb possible, as Castro Madero himself acknowledged,[43] and that some military groups would be delighted with such a development. Furthermore, Argentina has neither signed the Non-Proliferation Treaty nor ratified the Tlatelolco Treaty, which established a zone free of nuclear weapons in Latin America, decisions that indicate Argentina's intent to retain the option of developing nuclear weapons. Argentina would certainly not sit idle if Brazil were to produce a nuclear bomb. Nevertheless, the fact that some military factions wanted an option to develop nuclear weapons was not enough to ensure that the CNEA would achieve partial autonomy in nuclear technology. What helped achieve this objective was the civilian nature of the CNEA's project, which fostered a sense of solidarity and purpose among scientists and helped to maintain the CNEA's cohesiveness, as well as guaranteeing broad support for the project from the general public.

In 1984, as the economic crisis and foreign debt reached unprecedented proportions, President Raúl Alfonsín gave in to demands that the budget for developing nuclear power be reduced in line with general budget cuts and that the pace of the program be slowed down. A civilian was appointed to head the CNEA, and the Secretaría de Energía was given a say in the approval of the CNEA's budget. Argentina may also soon catch up with the fact that "rising construction and operating costs, a slumping world reactor market, and growing concern about the health and environmental impact of nuclear power plants have demonstrated that nuclear power is not the shining panacea it was thought to be in the 1950s and 1960s."[44] On the other hand, despite delays, cuts, and an uncertain future, the autonomy project is proceeding with its goals unchanged because it has proved to be too advanced, the technological, industrial, and strategic achievements too many, and the payoff in national pride too valuable to be halted.

Brazil's Nuclear Energy Development

Endowed with an advanced industrial infrastructure and a more sophisticated physics program than were available in Argentina,[45] Brazil was in a position to begin developing an independent nuclear program by the mid-1950s. But in contrast to the course of events in Argentina, Brazil's nuclear policy was pushed and pulled by various groups of civilian and military decision makers, research institutes, and state enterprises with clashing ideologies. No central institution existed with the political autonomy or leadership necessary to sell a nuclear independence plan to the ruling elites and ensure its implementation. Because it failed to become insulated from broad political, economic, and social issues (as were the Brazilian computer and Argentine nuclear

programs), Brazil's nuclear program became an arena for domestic and international political pressure.

Furthermore, having decided to link the Brazilian economy to the international economic system, Brazil's military rulers decided in 1967–68 to attach nuclear institutions to the electricity establishment, to exclude local scientists from the decision-making process, to kill a domestic program of nuclear development already under way, and to buy an American light-water reactor. After the U.S. decision to cut Brazil off from supplies of enriched uranium for reasons of nonproliferation, the Brazilian government became alarmed by the 1973 oil crisis because of Brazil's heavy dependence on foreign oil supplies. The Brazilian government, motivated by nationalist visions of *grandeza* (grandeur), utilized funds made available by the Brazilian economic miracle to sign an agreement with West Germany for the largest technology package ever to be transferred from a developed to a developing country.[46] The mammoth nuclear program that ensued was based on erroneous assessments and grossly exaggerated expectations that the program would achieve with one stroke technological independence, cheap electricity, and a strategic option—and all for "just" ten billion dollars.

Unable to escape from political and ideological fragmentation, surprised by the rise in interest rates, and coming to grips with the reality of the costs of nuclear power and the country's larger-than-expected hydroelectric reserves, Brazil had no choice but to scrap most of the still-unimplemented terms of its agreement with West Germany and to start developing a parallel nuclear program, this time "really" aiming at technological autonomy (although its critics claim its main goal is a nuclear-weapons option). Thus, after more than thirty-seven years of nuclear development, Brazil is still struggling to achieve a significant measure of self-sufficiency in the nuclear fuel cycle.

A look at Brazil's nuclear fuel cycle shows that the country's uranium reserves have increased greatly since 1975, in addition to already large reserves of thorium. The agreement with West Germany, which was to enable the Brazilians to master the technologies for the various stages of the nuclear fuel cycle, was either unable or slow to deliver these results. Major bottlenecks existed in the conversion of yellowcake to uranium hexafluoride (UF_6) and in uranium enrichment. By choosing to buy and build light-water reactors, Brazil became dependent on these technologies, mainly on enriching uranium. Brazilian leaders took a major gamble in deciding to purchase an enrichment process (jet-nozzle) that had not yet proven reliable at the industrial level. The facility for fabricating fuel elements was completed by the end of 1982 but has been standing almost idle, waiting for the other stages of the nuclear fuel cycle to catch up. Only in September 1987 was

it announced that Brazilian scientists had succeeded in enriching uranium with domestic technology.[47]

Since its inauguration, Brazil's single nuclear power plant, Angra I, has not worked at full capacity. Purchased from Westinghouse at the end of the 1960s, the light-water reactor plant suffered many technological problems and delays, and costs multiplied fivefold.[48] As part of the agreement with West Germany, Brazil bought two 1245-MW reactors to be located near Angra I, between Rio de Janeiro and São Paulo. By the end of 1981, however, after many delays and price increases, construction of Angra II was only 10 percent completed and Angra III had barely been started.[49] As of late 1987, neither is expected to be ready before 1990. In 1983 President Figueiredo decided to delay indefinitely the construction of two additional plants planned for the São Paulo region. Brazil has several nuclear research reactors, but most were purchased abroad rather than manufactured at home.

Success has also eluded major efforts so far to reprocess nuclear fuel domestically. Brazil has purchased reprocessing technology from West Germany, but the plant will probably not be ready before 1989. Meanwhile, it has been reported that a São Paulo research institute has built a pilot reprocessing plant that can handle five kilograms of plutonium a year and is ready to operate "cold."[50]

Between 1950 and 1955, Brazil pursued a political, institutional, and scientific program aimed at developing nuclear self-sufficiency. Led by Admiral Alvaro Alberto and supported by nuclear scientists, CNPq formulated policies to protect uranium reserves, develop and produce nuclear power, train personnel, and undertake research and development. Exports of nuclear minerals (mainly to the United States) were linked to training and transferring nuclear technology and hardware.[51] To implement this plan, Alberto wanted to purchase centrifuges used in uranium enrichment from Germany, but the deal was forestalled by U.S. intervention. These efforts ceased in 1955, when the Conselho de Segurança Nacional concluded that nuclear autonomy was not worth infuriating the United States and thereby jeopardizing U.S. support for Brazil's economic development and industrialization. Those opposed to the nuclear program came to believe that nuclear autonomy could be achieved only at the expense of higher economic goals. The idea that such autonomy was actually linked to economic and industrial development found few supporters.

When the Comissão Nacional de Energia Nuclear (CNEN) was created in 1956, it took over most of the political functions previously handled by CNPq. But the nuclear research institutes that the CNEN was supposed to work with in tandem—the Instituto de Pesquisas Radioativas (later called the Centro de Desenvolvimento de Tecnologia Nuclear), the Instituto de Engenharia Nuclear, the Instituto Militar de

Engenharia, and the Instituto de Pesquisas Energéticas e Nucleares—were scattered throughout the country. They were separated by ideological differences as well. The decision to reject a proposal to create a national nuclear energy laboratory to centralize nuclear research under one roof prevented Brazil from taking Argentina's institutional nuclear path and perpetuated the division of labor and fragmentation in policy and ideology among institutions.

Moreover, the CNEN did not enjoy the degree of stability and independence enjoyed by the Argentine CNEA. Although the CNEN started out as an independent agency attached to the president's office, it lost autonomy in 1960 when it was transferred to the newly created Ministério das Minas e Energia. Between 1962 and 1967, it existed as an autonomous federal agency until it was again placed under the jurisdiction of the Ministério das Minas e Energia.[52] Ideas were floated and plans made to build nuclear power reactors during the 1960s, but none were implemented. It would be a mistake, however, to conclude that Brazil's nuclear policy during these years was hampered only by lack of capabilities or by domestic and international constraints. An independent nuclear program might have been initiated without affecting other sectors adversely because it could have started by training individuals slowly and progressively.

An important crossroads in nuclear development was reached in the middle and late 1960s, when a nuclear research group called the Grupo do Tório designed a reactor prototype and made plans to develop an in-house reactor that would work with the thorium fuel cycle. The plan called for maximum participation of domestic industry and for input from local technology.

But in 1967, when the nuclear issue was once again placed on the political agenda, the Ministério das Minas e Energia and a state holding enterprise in the electrical sector, ELETROBRAS, had other ideas. Informed by an ideology of energy and economic efficiency and undisturbed by the prospect of nuclear-technological dependency, they presented the key political and military decision makers with a choice: to pursue the domestic path initiated by the Grupo do Tório or to start a nuclear program aimed at producing efficient energy resources as soon as possible. In 1968, with the CNEN's consent, the leading actors decided to scrap the domestic option, buy the Westinghouse reactor, and set a goal of producing fifty thousand megawatts of electric power by the year 2005.

The Brazilian nuclear scientists, most of whom favored autonomy in nuclear technology, resented the choice. With some exceptions, they have opposed this nuclear development policy and have refrained from participating in the government's nuclear program. Although lack of cohesive policy precluded the emergence of pragmatic

antidependency guerrillas in the 1950s, the policy choice since 1968 has been an additional factor preventing effective action. The domination by the Conselho de Segurança Nacional of the process of making nuclear policy in Brazil had a more deleterious effect here because it resulted in policy being developed through unofficial channels and behind the façade of institutions like the CNEN.

Brazil's chain of failures in the nuclear field cannot be understood fully without looking at the critical choices that canalized subsequent developments. According to Hartmut Krugmann:

> The decision to purchase the Angra I plant marked a turning point in Brazilian nuclear policy by introducing the enriched uranium-fueled reactor line and by opening Brazil to the international market of nuclear technology. It paved the way for the nuclear deal with West Germany several years later. Alarmed by unilateral cancellations of long-term enriched uranium fuel export contracts in 1974 by the United States, which in effect had an enrichment monopoly, Brazil sought to obtain the technology so as to become self-sufficient in this field.[53]

The chain of events that led to the Brazilian–West German agreement was affected by the 1973 oil crisis, the 1974 Indian nuclear explosion, and the Argentine decision to build its second nuclear power plant. At this time, Brazil was enjoying an increase in economic resources due to the economic miracle and the belief that electricity demand would continue to rise as in the miracle years (an average of 12 percent per year), which inspired the conviction that Brazil would soon become a superpower. Policymakers projected Brazil's hydroelectric resources as only 118 million kilowatts and the cost of nuclear power as only four hundred dollars per installed kilowatt. As a result of these projections and beliefs, Brazil planned in 1973 to install fifty-eight nuclear reactors by the year 2000 and decided to buy the technological package from the Germans.[54]

The institutional actor responsible for open and secret negotiations with the Germans was Itamaraty (the Brazilian foreign ministry). Having become involved in nuclear affairs when negotiating the Tlatelolco and Non-Proliferation treaties and wanting to take a position independent of the United States, Itamaraty became responsive to pro-German interests within Brazil that were pushing for closer relations between Brazil and West Germany. Having set up an institutional apparatus to deal with the nuclear issue by the early 1970s, Itamaraty was prepared to establish NUCLEBRAS when the 1975 agreement was signed.

Once in charge of implementing the 1975 nuclear agreement, NUCLEBRAS became the most important nuclear institution in Brazil, taking over employee training and the production of reactors and technologies of the nuclear fuel cycle from other institutions. This mandate

set NUCLEBRAS on a direct collision course with the CNEN, which until then had been the only institution claiming normative responsibility for nuclear development policy in Brazil. Since 1975 a host of additional organizations have become directly involved in making and implementing nuclear policy, including ELETROBRAS, Furnas (an ELETROBRAS subsidiary in charge of building and operating power stations), the Ministério das Minas e Energia, the Conselho de Segurança Nacional, the many nuclear research centers scattered around Brazil, and the seven companies created by NUCLEBRAS in association with West Germany. Such a setting was hardly compatible with effective decision making.

Brazil's nuclear scientists, this time in conjunction with domestic industry, opposed the 1975 nuclear agreement as unrealistic. Using their books and articles and the annual meetings of the Sociedade Brasileira para o Progreso da Ciência (SBPC) as their forum, the scientists decried the expectations of Brazilian technocrats who believed that thousands of megawatts of nuclear-generated electricity and technological nuclear autonomy could both be achieved with one "quick fix." The scientists also criticized the choice of light-water reactors, the fact that technical decisions were being made by foreign engineers, and the gamble on the unproven jet-nozzle process of uranium enrichment. Finally, they were appalled by the overall cost of the program.

Brazilian industrialists were up in arms because the joint ventures set up with West German companies would circumvent and even weaken the local nuclear-energy industry. As an example, they cited NUCLEP (NUCLEBRAS Fábrica de Equipamentos Pesados), which was established by NUCLEBRAS in association with European companies to manufacture heavy nuclear equipment and has never worked at more than 40 percent of capacity. The industrialists also pointed out that domestic industry had been undermined before, when Angra I was built with a nationalization index of only 8 percent.[55] They were even more disturbed that the 1975 agreement had been signed after a study commissioned by the Brazilian government concluded that close to 55 percent of the nuclear equipment, materials, and services could be provided domestically.

By 1981 technology transfer was taking place slowly, plants were idle, the completion of Angra II was not in sight and Angra III was only on the drawing board, the jet-nozzle technology had not yet been used in an industrial plant for uranium enrichment, estimates for completing the nuclear program as originally planned had jumped to somewhere between thirty and forty billion dollars,[56] and the country was sinking deeply into the largest foreign debt in the developing world. At this point, estimates of Brazil's hydroelectric reserves had been upgraded to 213 million kilowatts, enough to supply electricity at least until the end

of the century, and the technical problems of transporting electricity from the Brazilian Northeast to the Southeast had been solved. Only then did Brazil's political and military leaders decide to return to reality, pulling the rug from under the Germans and their still undelivered low-water reactors and from under NUCLEBRAS and its leadership. This change in direction boosted Brazil's nuclear "parallel program," undertaken since 1979 by the Instituto de Pesquisas Energéticas e Nucleares and the Instituto Tecnológico da Aeronáutica, among other research institutions, under the strict supervision of the Conselho de Segurança Nacional. Public acknowledgment that this program existed was made only at the end of 1986, with emphasis on its peaceful objectives. Along with this independent program, Brazil decided to develop a domestic nuclear research reactor and domestic reprocessing and enrichment facilities,[57] raising fears that Brazil may be developing its own nuclear-weapons option.

It is clear that the Brazilian military and even civilian leaders have had this option in mind since the early 1950s. The competitiveness between Brazil and Argentina in this area fostered the view that Brazil had no other choice. On the one hand, the insistence of the Brazilian military on achieving autonomy in the nuclear fuel cycle, recent measures taken by the parallel program (such as mastering uranium enrichment technology), press disclosures concerning the Brazilian plan to build an atomic submarine, and the existence in the Amazonas of an air force test site for nuclear weapons have all reinforced the sense that Brazil has not given up its "catch-up-with-Argentina" goals. On the other hand, although Brazil refused to sign the Non-Proliferation Treaty, it has accepted international safeguards of all nuclear facilities in the country covered by international agreements and has ratified the Tlatelolco Treaty.

Furthermore, competition in the nuclear field between Argentina and Brazil appears to be giving way to collaboration. The 1980 agreement for exchange of nuclear know-how and materials was followed in 1986 by an economic integration treaty that includes joint nuclear development and exports. It remains to be seen, however, whether Brazilian institutions and elites have at last made up their minds about nuclear technological autonomy, whether they are taking the right measures to implement it, and whether they will be able to overcome ideological and institutional divisions and pursue the program with firm consistency. It also remains to be seen whether nuclear-technological development in Argentina and Brazil will serve narrow military and prestige goals or whether these countries will rise above domestic and international pressures to implement the 1986 integration agreement, thereby leading Latin America to a much safer and probably more prosperous future.

CONCLUSIONS

The four cases juxtaposed here show that political, institutional, and cultural variables play important roles in the choices made by developing countries to pursue technological autonomy projects and in their subsequent successes and failures. The fact that two of the four projects achieved some technological development objectives is enough to prove that the concept of structural dependency is wrong. The fact that the other projects, even with the aid of structural opportunities, did not succeed proves that political, institutional, and ideological processes interact with structures to bring about the technological and industrial outcomes.

I have endeavored to demonstrate that although natural resources, political power, and economic and technological capabilities (not to mention economic crises, foreign debts, and international structural conditions) have created opportunities and constraints for attaining measures of autonomous technological development in Argentina and Brazil, success was related to the ideologies of key actors as well as to their perceptions of their country's ability to set and attain technological goals. Ideologically motivated groups of scientists and technocrats—referred to here as guerrillas—were able to realize the opportunities and overcome some of the constraints because, using their scientific knowledge as the basis for their authority, they were able to affect the decision-making processes of their state institutions. Beyond their contribution as knowledge-bearers, they succeeded in mobilizing the collective beliefs and expectations of politicians so as to bring about the desired outcomes.

These actors were able to use and even create political shelters, political trust, and political time because of several factors: a mixture of bureaucratic insulation and institutional centralization; a policy-making process that encouraged "low-level" policy to reach the top levels of decision making; active participation by local scientists and industry; strong military interests; the early development of a scientific and technological infrastructure; and good timing and a pragmatic approach. *Political shelter* refers to the structures and processes of government that insulate and protect programs from those who oppose them. *Political trust* implies a positive attitude of policymakers toward local scientists and science, which means giving local scientists at least one chance to produce results (as did the CNEA's Quihillalt with Sábato and his murga in Argentina, and the Brazilian ministers did with CAPRE and its guerrillas). *Political time* means a period long enough to develop an irreversible critical mass of scientists and scientific, technological, and industrial infrastructures before structural constraints or political opposition to the programs can gain the upper hand and kill them.

Bureaucratic insulation helped the institutions and guerrillas achieve their goals because it protected the programs from becoming the prey of clientelism and the victim of ideological and political attacks. Because CAPRE was located within the Secretaria do Planejamento, which has little relation to general economic policy, it was insulated from clientelism and short-term economic pressures and could thus develop long-range goals. When CAPRE was forced out and the SEI took over, the Conselho de Segurança Nacional protected the computer project from domestic and international opposition under the veil of national security. The CNEA, because it reported directly to the presidency, was insulated from Argentina's chronic political and economic turmoil and from the pressures of the hydroelectric lobby. This outcome contrasts with the fate of the CNEA's Brazilian counterpart, the CNEN, which was attached for long periods of time to the Ministério das Minas e Energia and was unable to free itself from short-term economic and political pressures.

The fact that decision making often started at the sectoral institutional level (as with CAPRE, the SEI, and the CNEA) and that the resulting policies were then "sold" to the policymakers through persuasion and skillful use of technical expertise proved crucial to the guerrillas. They could directly affect decision making within their own institutions by attaching their "unprivileged problem" to the coattails of the decision makers' "privileged problems." In many cases, the guerrillas' hand remained invisible while its impact on the political process was substantial.

Another crucial aspect was the fact that CAPRE, the SEI, and the CNEA sought to give and get mutual support from local private industry. For example, the CNEA transferred technology to local private industry through SATI and CAPRE, and the SEI offered effective protection to local private computer companies through a market reserve. Also, by setting up an industrial champion (Cobra) with public and private capital, the Brazilian policy-making institutions were able to link the fate of private capital investment to that of state investment. In this way, nationalist pressures to defend domestic technological development became by extension pressures to help private firms. In the case of FATE Electrónica, however, a local private capital initiative failed to gain the attention and support of state institutions, including the military, which decided that protecting a local firm was not worth jeopardizing economic efficiency.

The military played an important role in the technological successes, but its part should not be overestimated. Although the Brazilian navy's early interest in developing a domestic computer was important and the Conselho de Segurança Nacional kept Brazil's computer industry on its autonomy track after 1979, the autonomy policy was neverthe-

less consolidated by the present civilian government. Civilians played a crucial role all along the way in developing the computer industry's human resources and science and technology infrastructure. It is true that military governments actively supported the CNEA's nuclear development with a strategic option in mind, but all the civilian governments that were interspersed with military regimes between 1950 and 1987 have supported the autonomy goal of the program. Furthermore, when the Brazilian military came to power in 1964, it did not or could not prevent the nuclear program from being diverted from its original path toward autonomy. The Argentine military brought their preference for efficiency over domestic development when they took power in 1976, subsequently preventing FATE from continuing with its domestic technological project. Because the military perceived the anti-dependency scientists within FATE as Peronists and "leftists," rather than as resources for developing technology in Argentina, they went beyond not supporting these scientists to placing them on their "hit list."

An important reason for the guerrillas' existence and successes was the decision makers' readiness to involve local scientists in the technological development process. When local scientists were given an opportunity to produce domestic technology, as in the cases of Argentina's nuclear development and Brazilian computers, they were able to use their scientific authority to shape the program's autonomy goals. But when the scientists were shunted aside (as in the Brazilian nuclear program) or when their work was suddenly stopped (as with FATE Electrónica), the scientists' "attacks" on their governments were launched from outside the policy-making structure or process (and even from outside their countries), which rendered these attacks ineffectual.

The early emergence of capacities for research and development and human resources in the Brazilian computer and Argentine nuclear sectors was crucial for subsequent developments. The political decisions to reserve the mini- and microcomputer markets for local computer companies would probably not have been made without this technological base. In turn, the CNEA succeeded in maintaining its nonpartisanship through the years because by the late 1950s, it was already one of the most successful and prestigious scientific institutions in Argentina. As a result, a positive feedback process took place in which each stage in the project's development came to depend on the attainment of intermediate goals.

The timing of the Brazilian computer technocrats could not have been better. Before 1977 national and international conditions for developing a domestic computer industry were not ripe. But if the technocrats had waited a few more years, IBM and other multinational corpo-

rations would have started to fill the mini- and microcomputer market space, and Brazil probably would not have a domestic computer industry today. In contrast, the timing of FATE's venture into computers could not have been worse because FATE came out with its prototype at a time when Argentina was going through one of the most critical economic and political periods in its modern history. It should be noted that the timing variable is at odds with a pure structural explanation because it depends on perception. What Evans has called "moments of transition" can be perceived by some actors or can be disregarded or perceived differently by others.[58] Thus while the Brazilian technocrats were able to recognize the opportunities being generated by changes in international computer technology and markets, FATE's manager "saw" these same developments as an important reason to kill FATE's domestic computer venture.

Finally, pragmatism was a major feature of the successful cases. Both the CNEA in Argentina and CAPRE and the SEI in Brazil set goals that were characterized by learning by doing, incrementalism, and a pragmatic assessment of the possibilities. FATE's computer venture was not allowed to survive long enough to prove its pragmatism, but Brazil's nuclear program was characterized by hubris. It is clear that Brazil had the potential to develop an autonomous nuclear capacity gradually, as Argentina did, but it lacked the scientific and technological infrastructure to implement the massive program envisioned in the agreement with West Germany. Lack of pragmatism, coupled with incompetence, also characterized Brazil's assessments of its hydroelectric reserves and the costs of nuclear power.

It is now possible to summarize the role of the "state." The cases presented here help lay to rest undifferentiated notions of the state that explain policy as the "rational act" of a "rational actor." What appeared rational to the CNEA was seen as totally irrational by the Argentine hydroelectric lobby, and whatever seemed rational to CAPRE seemed irrational to the political actors who believed in the efficiency of the market.

The role played by state institutions and the guerrillas in their midst demonstrates that states are merely historical entities, represented at any given time by a certain set of institutions, procedures, and relationships, whose origins, purposes, interests, and ideologies may not only differ but be independent. What Bennett and Sharpe have called "state interests" actually describe the essentially historical, ideological, and institutional features of the state: "embedded orientations: dispositions to act in particular ways that are taken on by, and institutionalized in, various state agencies in response to problems or opportunities that arise."[59] Those interested in examining state action with

regard to technological development in large Latin American countries should pay attention to political, institutional, and cultural factors that, interacting with domestic and international structures, condition these countries' "journeys toward progress."

NOTES

1. Joseph M. Grieco, *Between Dependency and Autonomy: India's Experience with the International Computer Industry* (Berkeley and Los Angeles: University of California Press, 1984).
2. Peter B. Evans, "State, Capital, and the Transformation of Dependence: The Brazilian Computer Case," *World Development* 14, no. 7 (1986):791–808; and Emanuel Adler, "Ideological 'Guerrillas' and the Quest for Technological Autonomy: Brazil's Domestic Computer Industry," *International Organization* 40, no. 3 (Summer 1986):673–705. See also Emanuel Adler, *The Power of Ideology: The Quest for Technological Autonomy in Argentina and Brazil* (Berkeley and Los Angeles: University of California Press, 1987).
3. "By the late 1970s," wrote Martin Fransman, "the 'rigid' dependency view showed signs of becoming what [Imre] Lakatos refers to as a 'degenerating scientific research program': The 'hard core' of this program, containing amongst others the view that indigenous technological development was impossible as a result of the unavoidable reliance of Third World countries on imported technology, seemed increasingly to be untenable. In large part, the dependency program's degeneracy was attributable to its inability to explain . . . the apparent economic success of a number of more industrialized Third World countries." Martin Fransman, "Conceptualizing Technical Change in the Third World in the 1980s: An Interpretive Survey," *Journal of Development Studies* 21, no. 4 (July 1985):607–8.
4. See Peter Evans, *Dependent Development: The Alliance of Multinational, State, and Local Capital in Brazil* (Princeton, N.J.: Princeton University Press, 1979).
5. Albert Hirschman reminds us that a relationship exists between an initial asymmetry—such as the dependency of the weak and poor on the strong and rich—and some built-in tendency toward its elimination or reduction. He emphasizes that a basic economic disparity generates a disparity of attention that may favor the dependent country. See Albert O. Hirschman, "Beyond Asymmetry: Critical Notes on Myself as a Young Man and Some Other Old Friends," in Special Issue on Dependence and Dependency in the Global System, edited by James Caporaso, *International Organization* 32, no. 1 (Winter 1978):47.
6. Hirschman has pointed out that policymakers may decide to tackle different kinds of problems in accordance with their perception of their countries in the context of international dependency. In Latin America, merely paying attention to the problem is a problem-solving mechanism. Furthermore, observers tend to link problems in such a way as to enhance the attention given to the politically and economically underprivileged. Elaborate theories with a strong ideological content have been used to forge the causal link between privileged and "stepchild" problems. See Albert O. Hirschman, *Journeys toward Progress: Studies of Economic Policy-Making in Latin America* (New York: Norton, 1973), 229–31. The widely known "Sábato triangle," a regime for the development of domestic technology and industry based on interrelationships between the state, domestic scientific and technological infrastructure, and domestic industry, is a striking example of such a theory. See Jorge Sábato and Natalio Botana, *La ciencia y la tecnología en el desarrollo futuro de América Latina* (Lima: Instituto de Estudios Peruanos, 1970).
7. Technological and industrial projects can and should be evaluated by such criteria as industrial performance, the reduction of poverty, income inequality and unemployment, and the enhancement of national security. But this study, in trying to answer the paradoxical questions raised above, will focus only on the quest for and partial

attainment of domestic technological and industrial development. The autonomy concept used here does not mean total self-reliance but the ability of developing countries to adapt foreign technology and to innovate, so as to substitute domestic technology and products for foreign ones.

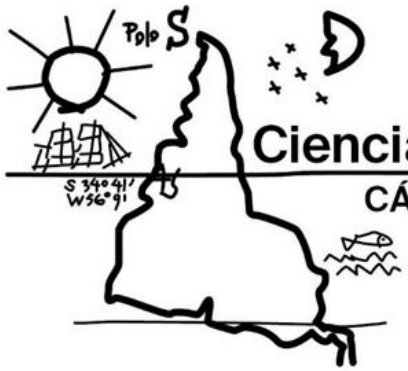
8. Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925–1975* (Stanford, Calif.: Stanford University Press, 1982), 18.
9. See, for example, David G. Becker, *The New Bourgeoisie and the Limits of Dependency: Mining, Class, and Power in "Revolutionary" Peru* (Princeton, N.J.: Princeton University Press, 1983), 6; Evans, "State, Capital, and the Transformation of Dependence," 905; and Theda Skocpol, "Bringing the State Back In: Strategies of Analysis in Current Research" in *Bringing the State Back In*, edited by Peter B. Evans, Dietrich Rueschemeyer, and Theda Skocpol (Cambridge: Cambridge University Press, 1985), 9–14.
10. Skocpol, "Bringing the State Back In," 14.
11. Becker, *New Bourgeoisie*, 6.
12. Douglas C. Bennett and Kenneth E. Sharpe, *Transnational Corporations versus the State: The Political Economy of the Mexican Auto Industry* (Princeton, N.J.: Princeton University Press, 1985), 250.
13. Stephen Toulmin, *Human Understanding: The Collective Use and Evolution of Concepts* (Princeton, N.J.: Princeton University Press, 1972), 350.
14. John S. Odell, *U.S. International Monetary Policy: Markets, Power, and Ideas as Sources of Change* (Princeton, N.J.: Princeton University Press, 1982), 362–63.
15. Lorand B. Szalay and Rita Mae Kelly, "Political Ideology and Subjective Culture: Conceptualization and Empirical Assessment," *American Political Science Review* 76, no. 3 (Sept. 1982):585.
16. Gary Gereffi, *The Pharmaceutical Industry and Dependency in the Third World* (Princeton, N.J.: Princeton University Press, 1983), 27–28.
17. Skocpol, "Bringing the State Back In," 9–10.
18. This statement was taken in an interview with a prominent official in Lima in May of 1980.
19. On the special relationship between technocrats and military regimes in Latin America, see Guillermo O'Donnell, *Modernization and Bureaucratic Authoritarianism: Studies in Latin American Politics* (Berkeley: Institute of International Studies, University of California, 1973).
20. SEI, *Boletim Informativo* 3, no. 11 (June–Sept. 1983):10–11.
21. *Data News*, 15 May 1984, p. 4; and Evans, "State, Capital, and the Transformation of Dependence," 796.
22. The "economic miracle" refers to the years 1968–1973, when Brazil's gross domestic product (GDP) grew at an average yearly rate of 10.1 percent. See Adler, "Ideological 'Guerrillas,'" 682.
23. See Simon Schwartzman, *Formação da Comunidade Científica no Brasil* (São Paulo: Editora Nacional, 1979), 302.
24. Ricardo A. C. Saur, mimeo issued by the Câmara dos Deputados in Brasília, 1977, on the hearings before the Câmara, p. 16.
25. Ibid., 4.
26. Evans has termed the opportunities generated by international, technological, and market changes *moments of transition*. See "State, Capital, and the Transformation of Dependence," 803–4. See also Adler, "Ideological 'Guerrillas,'" 682–86.
27. Evans, "State, Capital, and the Transformation of Dependence," 799.
28. Juan F. Rada, *The Impact of Microelectronics and Information Technology: Case Studies in Latin America* (Paris: UNESCO, 1982), 57, 70. In 1975 Argentina's electronics industry employed over twenty-one thousand persons, incorporated about 50 percent of value added (1974), compared with 29 percent for the Republic of Korea; and its productivity output per worker was valued at $12,400, compared with $2,450 in the Republic of Korea. The industry's development has been geared essentially to the internal market and has shown a high degree of integration among the different subsectors. Furthermore, its development was based to a great extent on local technology. In 1974 only 17 percent of the firms had entered into technology import contracts, and only 37 percent of the sector's total output was based on foreign

technology. During the same year, foreign firms controlled 30 percent of total output. See Rada, *Impact of Microelectronics*, 58–59.

29. Albert O. Hirschman, *Essays in Trespassing: Economics to Politics and Beyond* (Cambridge: Cambridge University Press, 1981), 140. *Fracasomanía* also means to "shut oneself off from newly emerging cues and insights as well as from the increased confidence in one's capabilities which should otherwise arise." See Hirschman, *Journey toward Progress*, 245.
30. Oscar Varsavsky, *Estilos tecnológicos* (Buenos Aires: Ediciones Periferia, 1974); and *Marco histórico constructivo* (Buenos Aires: Centro Editor de América Latina, 1975).
31. These data come from Eugenio Lahera Parada, "FATE y CIFRA: un estudio de caso en difusión y desarrollo de tecnología digital en Argentina," 1976 manuscript, 5–6, 16, 21.
32. CNEA, transcript of Rear Admiral Carlos Castro Madero's press conference, 1982, "Energía atómica: el uranio de los privados," *Mercado*, 11 Nov. 1982, 43–44.
33. Daniel Poneman, *Nuclear Power in the Developing World* (London: George Allen and Unwin, 1982), 74.
34. Jorge Sábato, "Atomic Energy in Argentina: A Case History," *World Development* 1, no. 8 (Aug. 1973):26.
35. See H. Leibovich, J. Coll, and K. Backhaus, "Good Experience of Transferring Technology," in CNEA, *The Argentine Nuclear Development Plan* (selected reprints from *Nuclear Engineering International*, Sept. 1982), Nov. 1982, p. 6; and José Mirabelli, "Argentina: Steady Progress amid National Turbulence," *International Herald Tribune*, 30–31 Oct. 1982, p. 9–S.
36. Countries that have signed the 1968 Non-Proliferation Treaty must fulfill international norms and rules regarding the transfer of nuclear technology. The International Atomic Energy Agency supervises the application of international safeguards.
37. Jorge Sábato, "Atomic Energy in Argentina," 25; see also his "Energía nuclear en Argentina, autonomía tecnológica y desarrollo industrial," paper presented at the Seminar on Industrial Energy Management, UNIDO, São Paulo, 18–21 Oct. 1982, 4.
38. Ronald Richter, an Austrian refugee physicist, turned Argentina's nuclear program into a world affair. He was named by President Juan Domingo Perón in 1949 to establish a laboratory on Huemul Island in Lake Nahuel Huapí for research and development on nuclear power. At a press conference in March 1951, Perón told the world that the laboratory had successfully carried out nuclear fusion. The whole affair turned out to be a fiasco, and an investigating committee appointed by Perón described it as a fraud. In 1952 Richter was dismissed and the laboratory was dismantled.
39. Personal interview with Jorge Sábato in Buenos Aires, 30 May 1980. At that time, Sábato was retired from the CNEA and the Bariloche Foundation.
40. Sábato, "Energía nuclear en Argentina," 3, 5.
41. Poneman, *Nuclear Power in the Developing World*, 191.
42. Poneman reports that even when the number of planned nuclear plants was being cut, some CNEA top personnel were happy because they feared that too many reactors built too quickly might have jeopardized the entire nuclear effort. Ibid., 184.
43. Ibid., 132.
44. Douglas L. Tweedale, "Argentina," in *Nuclear Power in Developing Countries*, edited by James Everett Katz and Onkar S. Marwah (Lexington, Mass.: Lexington Books, 1982), 92–93.
45. See, for example, Ricardo Guedes Ferreira Pinto, "Liliputianos e Lapucianos: Os Caminhos da Física no Brasil (1810 a 1949)," M.A. thesis, Instituto Universitário de Pesquisas do Rio de Janeiro, 1978; and James W. Rowe, "Science and Politics in Brazil: Background of the 1967 Debate on Nuclear Energy Policy," in *The Social Reality of Scientific Myth*, edited by Kalman H. Silvert (New York: American Universities Field Staff, 1969), 115.
46. The Brazilian–West German agreement included four 1245-MW pressurized water reactors, with an option for another four by 1990; the development of facilities for uranium enrichment; a uranium prospecting venture; the construction of a plant to produce fuel elements and a pilot plant for reprocessing nuclear fuel; the establish-

ment of an engineering firm to handle key segments in constructing the plants; and a plant to manufacture large components. The program was estimated at ten billion dollars and was expected to produce ten thousand megawatts of electricity by 1990. To implement the agreement, Brazil set up a governmental company called NUCLEBRAS, which cooperated with the West German companies to create joint ventures. For more information on the Brazil–West German agreement, see República Federativa do Brasil, *A Questão Nuclear: Relatório da Comissão Parlamentar de Inquérito do Senado Federal, Resolução 69/78*, Diário do Congresso Nacional, sec. 2, supplement to no. 104, Brasília, 17 Aug. 1982 (hereafter cited as *1982 Senate Nuclear Inquiry Report*).

47. See Alan Riding, "Brazil's Leader Reports Success in the Enriching of Uranium," *The New York Times*, 6 Sept. 1987, p. 25.
48. *Veja*, 19 Jan. 1983, 74.
49. Poneman, *Nuclear Power in the Developing World*, 45.
50. "The Nuclear Plan Mushrooms," *Latin American Weekly Report*, 31 July 1981, 9.
51. *1982 Senate Nuclear Inquiry Report*, p. 92. See also Jacqueline Pitanaguy Romani, "Apoio Institucional a Ciência e Tecnologia no Brasil" (preliminary draft), CET/SUP/CNPq, April 1977; and Maria Cristina Leal, "Caminhos e Descaminhos do Brasil Nuclear, 1945–1958," M.A. thesis, Instituto Universitário de Pesquisas do Rio de Janeiro, 1982.
52. For more information on the CNEN's first ten years, see Rowe, "Science and Politics in Brazil," 110–22.
53. Hartmut Krugmann, "The German-Brazilian Nuclear Deal," *Bulletin of the Atomic Scientists* 37, no. 2 (Feb. 1981):35.
54. Luiz Pinguelli Rosa, *A Política Nuclear e o Caminho das Armas Atômicas* (Rio de Janeiro: Zahar, 1985), 41.
55. *1982 Senate Nuclear Inquiry Report*, p. 259.
56. "A Aventura Nuclear," *O Estado de São Paulo*, 18 Oct. 1983, p. 4. The price per installed kilowatt of nuclear-generated electricity was estimated at three thousand dollars, according to Pinguelli Rosa, *A Política Nuclear*, 41.
57. "Brazilian Nuclear Power: Do-It-Yourself Reprocessing," *The Economist*, 24 Jan. 1987, 80.
58. See note 26.
59. Bennett and Sharpe, *Transnational Corporations versus the State*, 250.



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