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PUBLIC ENTERPRISES AND THE TRANSFER OF TECHNOLOGY

IN THE AMMONIA INDUSTRY

by

Brian Levy

RM-88

November, 1983

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Research Memorandum No. 88
Center for Development Economics
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Williamstown, Massachusetts 01267

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Public Enterprises and the Transfer of Technology in the Ammonia Industry

Brian Levy,
Harvard University,
June 1983.

Public enterprises sometimes are regarded as panaceas for economic development. Many obstacles to development result, it can be argued, from disparities between social costs and benefits and the calculations of private returns on which profit-seeking firms base their behavior; it follows that public enterprises, basing their decisions on social returns, might undertake investments for which nett social returns, though not necessarily private profits, are positive.

This perspective appears excessively optimistic in the light of recent research on how public enterprises actually behave. [1/] The principal purpose of the present study, however, is not to review these research findings but rather to explore critically the grounds for one specific type of optimism, namely that public enterprises might significantly loosen the constraints on development that result from a dependence on technology imported from industrialized countries. The focus here is primarily on the divergence between the perceived and actual costs and benefits of the indigenous development of technology in developing countries, rather than on the specific patterns of behavior of public enterprises As a case study of the transfer of technology in a single industry, ammonia, this study is more in the nature of a cautionary tale than an attempt at overall generalization. But, in common with much other research on public enterprises, its central implication is a warning against easy optimism that public enterprises can overcome some apparent obstacles to development.

The Case of Ammonia

The ammonia industry has a number of advantages as a case study of the role of public enterprises in the transfer of technology to developing countries. For one thing, ammonia and the various nitrogen compounds it helps to form account for about one half of world fertilizer consumption;[2/] so a study of the industry has relevance for agricultural as well as industrial development. More importantly, public enterprises control over 70 percent of ammonia production in developing countries, making ammonia (along with steel) one of the few industries that is dominated by public enterprises throughout the developing world.[3/] This paper contrasts the strategies for the acquisition of ammonia technology in four countries - India, South Korea, Mexico and Brazil. As Table 1 shows, the production of nitrogen fertilizers has grown rapidly since 1965 in all four countries. This expansion largely has been entrusted to public enterprises: The state-owned company Pemex in Mexico, and subsidiaries of state-owned Petrobras in Brazil are the sole producers of ammonia in these two countries; enterprises that are entirely state-owned dominate the ammonia industry in

Table 1: Production of Nitrogen Fertilizers in India, Mexico, Brazil and South Korea (in thousands of tons)

Country	1965	1970	1975	1978
India	233	838	1,509	2,000
Mexico	155	330	607	611
Brazil	14	22	161	232
South Korea	75	386	541	669

Source: Food and Agricultural Organization, *Fertilizer Yearbook* (United Nations, FAO: Rome, various years)

India and account for more than half of Korea's ammonia production; joint ventures with multinational firms produce the remainder in Korea and about 15 percent of total Indian production; and private local firms account for a further 10 percent of Indian ammonia.

Unlike the broad similarities in ownership patterns, strategies for the transfer of ammonia technology have differed widely among the four countries. India's fertilizer program has long placed a high priority on developing local skills to design, manage and fabricate the equipment needed to build an ammonia plant. Table 2 overleaf reveals a gradual increase over time in the role of local firms, especially in the share of equipment that they supply. It also reveals, however, that the trend to indigenization has been highly erratic. Underlying these lurches from plant to plant in the extent of indigenous involvement lies a continual conflict within India over the extent to which indigenization should be pursued.

The state-owned Fertilizer Corporation of India was the strongest proponent of indigenization. From its inception, the FCI placed heavy emphasis on the development of indigenous technology, especially technology that was adapted to feedstocks available in India. The task of developing these technologies was entrusted to the corporation's Planning and Development division. By the late 1960s the FCI's strategy seemed to have paid off; its P and D division was assigned both engineering

Table 2: Relative Shares of Foreign and Local Suppliers of Equipment and Engineering in Selected Indian Ammonia Plants

		Equipment		Engineering	
Plant	Year on Stream	Foreign	Local	Foreign	Local
Trombay	1965	97.7%	2.3%	-	-
Gorakhpur	1969	98.1	1.9	-	-
Namrup	1969	78.9	21.1	-	-
Nangal	1978	68.5	31.5	66.0	34.0
Sindri	1978	68.6	31.4	49.1	50.9
Talcher	1978	43.4	56.6	52.5	47.5
Ramargundam	1978	48.5	51.5	55.6	44.4
Phulpur	1980	64.3	35.7	86.5	13.5
Hazira	1980	68.7	31.3	50.2	49.8

Sources: D.N. Daruvalla, "Design and Development of Fertilizer Plants in Developing Countries with Special Reference to India", in UNIDO, Fertilizer Production Technology and Use, (New York: United Nations, 1968) Table 3, p. 40; Usha Menon, "World Bank and Transfer of Technology", Economic and Political Weekly, August 23, 1980 p. 1438; and selected appraisal and completion reports written by Industrial Projects Division, World Bank.

and management responsibilities for ten new ammonia plants, three using coal as feedstock. By 1974 the staff of the P and D division exceeded 3,000 including over 300 scientists, and more than 60 engineers.[4/]

The FCI's eminence proved to be short-lived. Without field research, the reasons for its demise must perforce remain uncertain, although the high costs of indigenization (on which more later) doubtless played a major role. What is certain is that already in 1972 India's planners began to look for foreign technical and managerial assistance for their new plants. Finally, in 1977, after years of continual criticism levelled at the FCI, it was split into five separate companies; the P and D division was reconstituted as an independent company which was to compete with other engineering contractors on an equal footing.[5/]

Subsequent to the eclipse of the FCI, India's planners relied heavily on importing the skills needed to set up an ammonia plant. Foreign skills were used extensively in at least four new ammonia plants built between 1972 and 1979; there was, to be sure, some local participation, but the nurture of local skills no longer had as high a priority.[6/] By the end of the decade, however, policy began to shift again with a renewed emphasis on the development of indigenous capabilities. But unlike the earlier strategy of going it alone as rapidly and as extensively as possible, the emphasis now was on learning in close collaboration with foreign firms, an approach closely akin to that adopted in Brazil.[7/]

Brazil, like India, has placed a high priority on increasing local skills and participation; but (at least until the most recent shift in Indian strategy) it has gone about this very differently. One key difference was in timing. While efforts at indigenization in India were well underway by the mid-1960s, Brazilian efforts in ammonia have begun only recently. Firstly, as we shall see, by the time Brazil began to expand production, international competition among technology vendors to build ammonia plants had intensified, adding to the opportunities to secure favorable contract terms. Secondly, by the late 1970s, Brazil had already had extensive experience in other areas of the petrochemical industry. So local engineers were well placed to take advantages of opportunities for indigenization.

Another difference between the Indian and Brazilian approaches was in the strategy of acquiring basic technological know-how. As already noted India, at least until the most recent agreements, sought to go it alone as rapidly and extensively as possible. Brazil, by contrast, has sought to secure long-term access to the best-practice technology of overseas vendors: Brazil selected the U.S. firm M.W. Kellogg (which as will be seen dominated the supply of ammonia technology worldwise throughout the 1970s) as the major foreign contractor for three of its four most recent ammonia projects; the transactional advantages of building and maintaining a long-term relationship was a key incentive in inducing Kellogg to participate in a collaborative effort to transfer technology. Finally - and this is another important difference from the Indian approach - Brazil has insulated efforts to transfer technology from the construction of new ammonia plants. The five year agreement to collaborate on the transfer of technology that it signed with Kellogg in 1977 is a separate effort from Kellogg's contracts for the ammonia projects themselves.

The Mexican strategy[8/] has been similar to Brazil's in the way in which it focused its collaboration on a single overseas firm: Kellogg has won the contracts for all eight ammonia plants built for state-owned PEMEX since 1970. The strategy has been different in its weaker emphasis on indigenization. Mexico, has to be sure made some efforts to provide opportunities for learning and participation by local engineers and equipment fabricators. But, at least in the ammonia industry, these efforts do not appear to have the same high priority as in Brazil or India.

Like Mexico, South Korea also has not placed much emphasis on extending the use of indigenous resources in new ammonia plants; all equipment and engineering for most of the nitrogen plants undertaken in the 1970s came from abroad.[9/] This does not imply, however, that Korea also lacked indigenous capabilities in some of the less specialized activities needed to establish an ammonia plant. Indeed, as summary Table 3 shows, Korea has extensive capabilities in plant construction and management, as well as in the provision of general purpose equipment and machinery.

In order to evaluate the divergent strategies of the four countries, we must examine more closely what goals underly efforts to develop ammonia technology and what the costs of such efforts might be.

The Goals of Indigenous Development of Ammonia Technology

In general, there are three distinct sets of reasons why countries might pursue the indigenous development of technology - as an effort to develop technologies closely aligned to local economic conditions, in an attempt to shift the balance of bargaining power away from foreigners, and as part of a distinctive strategy of development. This section will examine in turn the relevance of each of these reasons to efforts to develop indigenous technology in the ammonia industry.

Appropriate technology. The starting point for proponents of appropriate technology is that technologies developed in industrialized countries do not fit the requirements of developing nations. The ratio of investment to labor utilization is too high, the minimum efficient scale is too large, and the level of

Table : Sources of Supply of Ammonia Technology for Brazil, India, Mexico and the Republic of Korea

	Brazil		India		Mexico		Republic of Korea	
	Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign
Pre-project Planning	X		X		X		X	X
Project Management	X	X	X	X	X	X	X	X
Engineering								
(i) Basic		X	X	X		X		X
(ii) Detail	X		X		X	X		X
Procurement	X	X	X	X	X	X		X
Equipment								
(i) Complex	X	X	X	X		X		X
(ii) General	X		X		X		X	
Catalysts		X	X	X		X		X
Construction	X		X		X		X	
Start-up	X	X	X	X	X	X	X	X
Technical Services	X	?	X	?	X	?	X	?

skills required for operation and repair too great given the abundant supply of labor, lack of experience with large-scale organization and shortages of technical skills in developing countries. A strategy of indigenous development of technology could lead to

> "the introduction of a more appropriate technology (that) would reduce the large disparities in control over resources, labor productivity and income distribution between different parts of the country... ..The major problems resulting from the distribution pattern - particularly those of imbalance in employment opportunities, the appearance of open unemployment as a chronic problem, and maldistribution of income disappear if appropriate technology, especially if accessible to all, were introduced. If the technology were efficient, the absolute level of incomes should also rise....[10/]

Notwithstanding these apparent advantages, in the countries studied here there have been no efforts to adapt ammonia technology to local conditions: The Brazilians have been quite explicit in their desire to absorb the state-of-the-art technology from abroad; as for India, even though until recently the strategy there was to go it alone as extensively as possible, from the first the goal was to master technology already in use abroad rather than to come up with alternative designs.

It is possible (although without field research the hypothesis cannot be tested) that bureaucratic slippage and a consequent failure to translate government goals into enterprise action (assuming, of course, that the development of appropriate technology is a goal of government), together with a desire on the part of engineering-oriented management to work at the technological frontier as defined in industrialized countries, account for a lack of interest in redesigning ammonia technology for local conditions. But a far more likely explanation has to do with the nature of ammonia technology itself: Ammonia falls in a class of process industries for which the unit costs of production decline substantially as scale and the ratio of capital to labor rise. Scherer summarizes the engineering logic that underlies this relationship:

> "The output of a processing unit tends within certain physical limits to be roughly proportional to the volume of the unit, other things being equal, while the amount of materials and fabrication effort (and hence investment cost) required to construct the unit is more apt to be proportional to the surface area of the unit's reaction chambers, storage tanks, connecting pipes and the like. Since the area of a sphere or cylinder of constant proportions varies as the two-thirds power of volume, the cost of constructing process industry plants can be expected to rise as the two-thirds power of their output capacity, at least up to the point where they become so large that extra structural reinforcement and special fabrication techniques are required...Energy usage also tends to rise less than proportionately with increases in processing vessel size....Moreover the crew required to operate a large processing unit or machine is often little or no larger than what is needed for a unit of smaller capacity, so labor costs per unit of output fall sharply with scale-up".[11/]

Advances in ammonia technology in the 1950s and the development of a new plant design in the 1960s led to continual increases in plant capacity and declines in production costs. The cost per ton of ammonia produced in a plant with a capacity of 1,000 tons per day based on the new design was 20 percent below the cost in a plant of 330 tons per day; one half of these saving came via economies of scale and the other half from the improved technology of the new design.[12/]

Bargaining power. A second reason to pursue the indigenous development of technology may be a desire to shift the balance of bargaining power away from foreigners. Two distinct types of costs for developing countries of foreign control of technology are relevant here - the need to accept the presence of multinational firms if production is to get underway locally, and the need to pay to foreigners a high proportion of the rents accruing from use of the technology in order to induce them to make it available for local production.[13/] To what extent does the desire to reduce these costs account for efforts to develop an indigenous capability in ammonia technology?

Foreign investment is extensive in most industries in which technology is continually advancing and is under the close control of only a few companies.[14/] The ammonia industry is different. Even though the industry is characterized by both close control and continually advancing technology, there has been very little direct foreign investment in either developing or industrialized countries. The reason is not simply a desire by governments to maintain national control in this basic sector of industry (desire, to be realized, requires the backing of bargaining power), but rather the unusual international organization of the industry: Since the end of the Second World War, the firms that control ammonia technology have, by and large, been different from the firms that produce ammonia. This is not the place to explore the reasons for the separation of control over technology from production;[15/] it is the consequences that are of special relevance here: The separation of control over technology from control over production undermined the incentive of firms active in the industry to invest abroad; arms-length deals between national firms (usually state-owned[16/]) from developing (and sometimes industrialized) countries and vendors of technology became the medium through which ammonia technology was diffused across national boundaries. In the ammonia industry, at any rate, it did not follow that if the balance of bargaining power lay entirely in the hands of technology vendors then developing countries would have to accede to foreign investment for production to get underway.

Even though unequal bargaining power in the ammonia industry did not have foreign investment as its consequence, vendors of technology were in a position to capture a high proportion of the rents from ammonia production for themselves. It does not follow, however, that the most efficient response to this imbalance is to try and develop an indigenous technological capability.

For one thing, the expected benefits of an increased share of rents must be weighed against the costs of developing technology at home; only if the present value of these benefits exceeds the costs of development (on which more later) would investment in technology lead to increased revenue for a developing country. Moreover, an increased domestic capability is not the only way through which a shift in bargaining power can occur: It could also result from an increase in the number of vendors and an ensuing rise in the degree of competition among them.

Competition among vendors of ammonia technology has increased substantially since the mid-1960s. In the mid-1960s M.W. Kellogg developed the radically new design for ammonia plants that was referred to earlier. With this new design Kellogg quickly began to dominate the world market for ammonia plants: One half of the additional ammonia capacity built worldwide between 1966 and 1978 was based on the new design; most of these plants were built by Kellogg itself or by one of the few other companies that Kellogg licensed to supply the design.[17/] Yet over time Kellogg's technological lead has been whittled away by competing technologies, developed first by European firms and then, in time, by other U.S. companies.[18/]

One consequence has almost certainly been a decline in the profitability of supplying ammonia plants abroad. Although direct evidence is hard to come by, the increase in competition among suppliers - to cite one example, in 1980 about a dozen companies sought to submit proposals for a new ammonia complex in Indonesia[19/] - makes such an outcome highly likely. A second consequence has been a growing willingness on the part of the vendors of ammonia technology to unbundle the supply of their services, thereby enabling developing countries to begin to develop their own technical capabilities: As long as only a few companies controlled the technology of ammonia plants, they could refuse to supply their special skills unless they also were hired to undertake other activities in plant construction for which they had no special advantage. But as competition grew, and as developing countries sought to increase the role of domestic firms in ammonia plant construction, technology vendors increasingly became willing to co-ordinate their activities with local firms from developing countries and undertake only those activities for which local firms lacked the skills. Indeed, as the example of Brazil illustrates, in return for the establishment of a long-term plant supply agreement with a developing country, they sometimes were willing to collaborate in the transfer of their most specialized technical skills.

For now, though, our task is not so much to outline the mechanisms through which technology transfer can be effected as it is to explain why some developing countries are so eager to take advantage of new opportunities to develop ammonia technology at home. As already noted, this desire appears unrelated to efforts to develop appropriate technology. Nor is it a response to a lack of bargaining power: Even when foreign bargaining power was at its zenith, local ownership remained the norm, and as the number of ammonia plants has increased the balance of bargaining (and thus most likely the distribution of rents) has shifted decisively in favor of developing countries.

Indigenous technology as development strategy. The desire for indigenous technological development appears to be part of a strategy of economic development that is oriented towards the development of heavy industries, including the expansion of engineering firms and the fabrication of sophisticated industrial equipment. The greater is the extent of the indigenous provision of the engineering and construction skills and equipment needed for an ammonia plant, the larger are the number of opportunities for learning by doing (not to mention production and profits) available to local vendors.

The heavy emphasis in India on going it alone as rapidly and as extensively as possible in the provision of skills and equipment for ammonia plants is consistent with the country's strategy of industrialization - a strategy which has been oriented towards rapid growth of these skill-intensive industries: Illustrative of this emphasis, between 1956 and 1976 engineering exports from India grew at an average rate of 25 percent per annum; by 1976 they comprised 19 percent of total exports of manufactures.[20/] The Indian strategy stands in sharp contrast to that adopted by Korea. South Korea has, until recently, placed little emphasis on developing sophisticated engineering and fabrication capabilities. The emphasis instead has been on production in light, labor-intensive sectors. The extraordinary growth rates and increases in employment that followed from this strategy have been thoroughly documented elsewhere.[21/] The cost of the strategy has been that local engineering and fabricating firms lost the opportunity to gain valuable experience as Korean ammonia capacity expanded.

But this is not the place for a comparative analysis of labor-intensive, export oriented and heavy industry, import substituting strategies of industrialization. Ammonia plants are not build solely for the employment they provide and for the externalities they generate. Their primary function is to supply nitrogen fertilizer to farmers at the lowest possible cost. What is the effect on the cost of ammonia production of efforts to rely heavily on indigenous technology in the erection of new plants? It is to this question that we now turn.

The Cost of Indigenization

The total costs of indigenization are not only the direct costs of investment in the development of indigenous skills in engineering and equipment fabrication. Efforts at indigenization often lead to delays in the start-up of new ammonia plants and can also contribute to low subsequent rates of capacity utilization once these plants are in operation. As will be seen, the costs of delays and of low capacity utilization could well be way in excess of the direct costs of investment in new skills.

Although it has not been possible to undertake the in-depth field research needed to measure accurately the overall costs of indigenization, some impressionistic evidence is available, especially for India, on the effects of indigenization on delays and subsequent rates of capacity utilization. As the next section shows, these effects appear to be substantial, but estimates of their magnitude are not sufficiently precise to estimate accurately their implications for the cost of ammonia. Instead, I use available evidence on the investment and production costs of ammonia in general to calculate the nett present value of an ammonia operation across varying levels of capacity utilization and delays in start-up; this nett present value declines sharply as delays lengthen and capacity utilization falls, confirming that indigenization can add substantially to the cost of producing ammonia.

Delays and production shortfalls: Some evidence. Indigenization obviously is not the only reason why delays in start-up or shortfalls in production might occur. Some problems can afflict all firms, public or private; others might be especially likely to affect public enterprises, irrespective of whether they are pursuing a strategy of indigenization. Typical examples of the first group of problems include the late delivery of equipment from abroad, power breakdowns forcing a plant to shut down, and government bureaucracies that restrict the availability of some input needed for production. To cite just one instance, a branch of the Banco de Brasil, following its standard procedures, insisted on gaining the approval of individual manufacturers before giving permission to import, thereby delaying one ammonia project by nine months.

India provides a number of examples of burdens that weighed especially heavily on public enterprises, at least in the 1960s. The FCI apparently had to apply afresh for foreign exchange for each large overseas purchase that it made, and to clear each of these purchases with prospective local suppliers; in at least two instances, the need for such clearance led to delays of almost ten months; foreign contractors, by contrast, had ready access to foreign exchange, sometimes from grants of aid, sometimes released in a lump sum by the Indian government. More generally, the ministries and committees which had been assigned as overseers subjected the FCI to endless queries, criticisms and delays in clearance to proceed even with routine activities.

Notwithstanding the proliferation of alternative explanations, there is convincing (if still only anecdotal and partial) evidence that efforts at indigenization have a major independent impact on delays and capacity utilization. Evidence on the length of delays is available for eight plants in which the FCI's P and D division played a major role in design and construction.[22/] All eight plants experienced long delays in completion. One was completed only three and a half years after its scheduled date; two more each were delayed for twenty seven months; a fourth was delayed for two years, and a fifth for fifteen months; two other plants has still not produced significant quantities of ammonia by 1980, even though work on them had begun in 1971.

Delays in the delivery of overseas equipment bedevilled almost all the plants. Although at first sight such delays might appear to have little to do with indigenization, they occured in part because international fabricators of engineering equipment did not place much importance on cultivating a reputation of reliability with the FCI. Inefficient service to a major international contractor carried the risk of losing substantial business, not only for ammonia plants but also the other petrochemical and heavy engineering projects undertaken by technology vendors. By contrast, the FCI seemed unlikely ever to become a major customer. Problems at home usually were a result of the lack of experience of indigenous fabricators with the sophisticated equipment used in ammonia plants. Long delays in the delivery of equipment produced locally forced the postponement of start-up in at least three plants.

Turning to low capacity utilization, here again much of the difficulty lay in problems with equipment. Crucial components sometimes failed to perform as efficiently as expected, keeping capacity utilization low. Often the failures were in equipment fabricated locally, though imports also gave their share of difficulties; and faulty design led to low utilization of capacity in at least two plants.

Table 4 presents data on the capacity utilization of ammonia plants in India. The table reveals a striking discrepancy between the performance of plants that are wholly government-owned

Table 4: The Capacity Utilization of Indian Ammonia Plants, Grouped by Owner and Source of Technology

Owner-Type	Capacity (tons)	PRODUCTION Actual 1980-1	PRODUCTION Projected 1981-2
A: Public Sector			
Foreign Contractors Dominate b/	1112	546.3 (49.1%) a/	746.9 (67.2%)
Substantial Local Sourcing c/	1323	398.3 (30.1)	766.1 (51.9)
Total Public Sector	2435	944.6 (38.8)	1513.0 (62.2)
B: Joint Sector d/	1314	867.4 (68.3)	1083.9 (82.5)
C: Private Sector	644	360.7 (56.0)	500.6 (77.7)

Source: Data on Capacity and production from Ministry of Petroleum Chemicals and Fertilizers, Department of Chemicals and Fertilizers, Annual Report 1981-2, pp. 28-29.

Notes :

a/ production as percentage of capacity.

b/ Plants included are Neyveli, Rourkela, Gorakhpur, Nangal 1, Bhatinda, Panipat, Namrup I, Udyogomandal and Trombay 1.

c/ Plants included are Sindri, Ramagundam, Talcher, Nangal 2, Durgapur, Barauni, Cochin 1 and Cochin 2

d/ Firms included are Madras Fertilizers, Gujarat State Fertilizers, Shiram Chemical and Fertilizers, Southern Petrochemical Industries and Indian Farmers Fertilizer Co-operative on the one hand and those that are joint ventures with private firms (and farmers co-operatives) or wholly privately owned on the other. What is more relevant for present purposes, however, is the difference in the average level of capacity utilization within the public sector between plants that were erected largely by foreign contractors and those for which there was substantial local sourcing: In 1980-81 the average levels of capacity utilization for the former group of plants was 19 percent higher than the latter; and the projected gap for the following year[23/] is in excess of 15 percent. It is also noteworthy that once the independent impact of indigenization is excluded, the production gap between the remaining public sector plands and plants in the private (though not joint) sector falls to only 7 percent. Evidence on capacity utilization in Mexico offers an additional indication that indigenization, rather than public ownership per se, is the primary explanation for low levels of performance of publicly-owned plants. As noted earlier, ammonia production in Mexico is wholly state-controlled; at the same time there have been only limited efforts at indigenization. As Table 5 shows, at no time between 1970 and 1980 did ammonia production in Mexico fall below 80 percent of rated capacity.

In all, the anecdotal evidence suggests that efforts at indigenization can lead to substantial delays and reductions in levels of capacity utilization. What remains to be shown is

Table 5: Mexican Ammonia Production as Percentage of Rated Capacity

Year	Capacity Utilization
1970	80.9%
1971	82.0
1972	90.0
1973	94.5
1974	93.6
1975	93.1
1976	100.5
1977	109.6
1978	90.2
1979	94.4
1980	107.5

Source: PEMEX, internal documents

the effect of delays and low levels of production on the cost of producing ammonia. It is to this issue that we now turn.

The Nett Present Value of an Ammonia Plant. Ammonia plants typically require high initial investments which yield a return via flows of revenue over the long-term. If interest rates (and thus the opportunity cost of capital) are positive, then from the perspective of a prospective investor a dollar of this revenue flow earned at one point in time is not equal to a dollar earned at another point in time. This distinction is especially relevant for this study, since the two parameters on which we focus - construction delays and variations in capacity utilization - affect the time path and the magnitude of the flow of revenues and costs of ammonia production; so some common benchmark is needed if we are to compare the cost implications of variations in these parameters. A measure of the nett present value of the flow of revenues and costs of an ammonia plant provides the appropriate benchmark.

In general, the present value of a revenue producing project can be characterized as follows:

$$NPV = \underbrace{\int_a^{a+b} P_t Q_t e^{-rt} dt}_{(2)} - \underbrace{\int_a^{a+b} C(Q_t) e^{-rt} dt}_{(3)} - \underbrace{\bar{C} \int_a^{a+b} e^{-rt} dt}_{(4)} \underbrace{- I_o}_{(5)} \qquad (1)$$

a = year of start-up
b = plant lifetime
P_t = output price in time t
Q_t = output in time t
r = annual compounded rate of discount
$C(Q_t)$ = variable costs
$\bar{C}$ = fixed annual overhead costs
I_0 = initial investment cost.

Term (2) measures the present value of the estimated stream of revenues over the plant's lifetime, term (3) the present value of the lifetime stream of variable costs, term (4) the present value of annual overhead costs, and (5) the initial cost of investment. NPV is greater than zero (and thus the project may be deemed profitable), if

(2) (3) + (4) + (5).

Of course, insofar as the erection of an ammonia plant generates positive externalities, a NPV less than zero calculated on the basis of market prices would not necessarily imply that a given project is socially inefficient. Table 6 presents estimates of the value of the above parameters for a 1650 ton per day ammonia-urea plant.[24/]

If we assume that the level of capacity utilization- $Q_t/1650$ - does not vary over the plant's lifetime, then (1) can be rewritten as

$$NPV = \left\{ \bar{Q}\left[\bar{P} - C(\bar{Q})\right] - \bar{C} \right\} \int_a^{a+b} e^{-rt}dt - I_o ,$$

Table 6: Parameter Estimates for a Natural Gas-based Ammonia-Urea Plant, 1980

Parameter	Value	Comments
I_o	\$300 million	Depending on the extent of existing infrastructure, this measure can range from \$200 - \$400 million
P	\$263 per ton	Average urea price between 1964 and 1980
C(Q)	\$121 per ton	\$105 per ton feedstock costs
C	\$15.4 million per annum	Maintenance, insurance and labor costs
b	30 years	an arbitrary assumption

Source: William F. Sheldrick, Fertilizer Unit, World Bank, Investment and Production Costs for Fertilizers, paper presented at FAO Commission on Fertilizers, Sixth Session, 1980 from which it is a simple matter to calculate the nett present value of an ammonia plant for selected levels of capacity utilization (and thus Q) and length of delays from initial investment to start-up (measured by a). Table 7 shows the results of these calculations, assuming an annual compounded rate of discount (r) of 10 percent.

The results in Table 7 reveal that the costs of delays and reduced capacity utilization are high: A one-year increase in the time from initial investment to the start-up of production reduces NPV by about $40 million; and for any given lead time, NPV falls by $50-$60 million for every decline of 10 percent in the rate of capacity utilization. The impressionistic evidence in the previous section suggests that a one year delay and a 10 percent loss of capacity are plausible (and perhaps even low) estimates of the consequences of India's efforts to develop indigenous ammonia technology. On the basis of the calculations in this section, the cost of these consequences amounted to the equivalent of an increase in $100 million in the initial investment in the plant, one-third of the initial capital requirement! If we add the direct additions to cost of reliance on domestic expertise (for which no estimates are available) then the burden imposed by a strategy of indigenization becomes even higher.

To what extent are estimates of the costs of delays and low utilization of capacity sensitive to assumptions as to the

Table 7: The Nett Present Value of an Ammonia Plant for Varying Lead Times and Levels of Capacity Utilization (r = 0.1)

Capacity Utilization	Lead Time: 2 years	2.5 years	3 years	4 years
90%	121.5	101.0	81.4	45.1
80	61.4	43.8	27.0	- 4.1
70	1.2	- 13.4	- 27.4	- 53.4
60	- 58.9	- 70.7	- 81.9	-102.6
50	-119.1	-127.9	-136.3	-151.9

rate of discount? As Table 8 shows, a reduction in the assumed rate of discount to 5 percent per annum increases substantially the NPV for each lead time and capacity level. But this reduction does not affect much the magnitude of the declines in NPV that result from increases in delays and reductions in capacity utilization: Now a one year rise in lead time reduces NPV by only $35 million; but a 10 percent decline in production reduces NPV by fully $110 million! In general, other things equal, as interest rates fall the NPV of any project that requires substantial initial investments increases; and it becomes marginally less costly to delay a project;[25] but since future revenues no longer are discounted as heavily, the costs of a reduced production potential rise substantially.

Indigenization: An Overall Evaluation

The benefits of indigenous development of ammonia technology turn out to be fewer than they might appear at first sight. Two potential nonpecuniary benefits are entirely absent: The engineering economies embedded in an ammonia plant undermine the incentive to experiment with small scale, less investment-intensive techniques of production; and the international organization of the industry makes foreign investment unlikely even in the absence of indigenous technological know-how. The value of the two remaining potential benefits appear to be either highly uncertain or

Table 8: The Nett Present Value of an Ammonia Plant for Varying Lead Times and Levels of Capacity Utilization (r= 0.05)

Capacity Utilization	Lead Time: 2 years	2.5 years	3 years	4 years
90	461.8	443.0	424.6	389.3
80	353.1	337.0	321.2	290.9
70	244.4	231.0	217.8	192.6
60	135.7	125.0	114.4	94.2
50	27.0	18.9	11.0	- 4.1

very limited: Indigenization appears to be part of a strategy of development that emphasizes the growth of heavy industry, and efforts to develop indigenous ammonia technology may well generate some important linkages; but there is no obvious way of knowing what value should be imputed to them. Also uncertain is the extent to which indigenization adds to the bargaining power of developing countries relative to foreign vendors of technology: In the 1960s there may have been some gains, but by the 1970s, once competition among vendors had intensified, the gains appear highly limited at best.

In evaluating the social efficiency of efforts at indigenization in the ammonia industry, benefits must, of course, be compared with costs. On the cost side the uncertainties are fewer. To be sure, no estimates are available of the direct costs of investment in indigenization, but the orders of magnitude of the indirect costs can be readily calculated: If efforts at indigenization cause a delay of one year in start-up and a subsequent loss of capacity of 10 percent, the indirect costs alone are in excess of $100 million. It is hard to imagine how a value of $100 million could be ascribed to the benefits listed above.

This is not to imply that all attempts to develop indigenous technology are misguided. For one thing, as the example of Brazil reveals, if competition among technology vendors is extensive there may be less costly ways to pursue indigenization than going it alone as rapidly and extensively as possible - although, of course, the rate of growth of skill-intensive sectors of industry is likely to be slower. More importantly, in many sectors the costs of indigenization are not likely to be as high, nor the benefits as low as they are in ammonia. The scope for adaptation - and thus the potential to reap the benefits of appropriate technology - may often be higher outside the continual process industries; and in many sectors the ratio of initial investment requirements to variable costs is lower than it is in ammonia, with corresponding reductions in the cost of delays and production below capacity. But nor should the cautionary value of the experience with technology transfer in the ammonia industry be underestimated. Ammonia is not likely to be the only industry for which the hidden costs of indigenization are high, while many of the purported benefits turn out to be chimerical.

ENDNOTES

1. For a review of this research, see Brian Levy, "New Directions in Public Enterprise Analysis", Harvard Institute for International Development, Development Discussion Paper, forthcoming 1983.

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3. Estimated from data provided by the Tennessee Valley Authority. For an overview of ownership trends in the fertilizer industry, see John T. Shields and E.A. Harre, "Capacity and Ownership Trends", Fertilizer Progress, Volume 9, Number 3, May-June 1978, pp. 11-34.

4. "Another 'Bechtel Deal'?", Economic and Political Weekly, October 28, 1972, p. 2177; "Goodbye to self-reliance in fertilizer technology?", Commerce, September 20, 1975, p. 480.

5. "Destruction of Fertilizer Corporation", Economic and Political Weekly, July 23, 1977, pp. 1168-1169; "Mess in Fertilizers", Economic and Political Weekly, May 10, 1980, pp. 839-840.

6. "Growth at all costs", Economic and Political Weekly, November 18, 1972, pp. 2264-2265; and "NFL comes of age", Commerce Special Feature, March 29, 1980.

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8. Information from interviews with PEMEX and Kellogg.

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10. Frances Stewart, Technology and Underdevelopment (Boulder: Westview Press, 1977), p. 108.

11. F.M. Scherer, Industrial Market Structure and Economic Performance (2nd edition) (Boston: Houghton Mifflin, 1980), pp. 82-3.

12. "Capacity surge, story of ammonia", Oil and Gas Journal March 18, 1968, pp. 78-84.

13. For a more detailed discussion, see Peter Evans, Dependent Development (Princeton: Princeton University Press, 1979), especially chapter 4.

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15. These have to do with the unusual history of the industry, in particular political interventions which led to the break-up and loss of market power of the highest companies, together with the special character of the transactions costs of turnkey deals which reduce the cost disadvantages of of arms-length over internal transactions.

16. Once again, I would argue that the reasons for state ownership have to do with market imperfections in the market for capital. Given the lack of development of capital markets in developing countries, private local firms typically cannot raise by themselves the capital needed to set up an ammonia plant.

17. Pullman Incorporated, 1978 Annual Report, p. 11

18. These firms include Imperial Chemicals Industries (ICI), Uhde, Haldor Topsoe, W.R. Grace, Fluor, Braun and Bechtel.

19. See "Contractors shortlisted for ASEAN project", European Chemical News, January 28, 1980, p. 27; "Toyo to build first ASEAN ammonia-urea complex" European Chemical News, November 3, 1980.

20. Sanjaya Lall, "Developing Countries as Exporters of Technology and Capital Goods: The Indian Experience", (Oxford University: Institute of Economics and Statistics, unpublished draft, June 1979) p. 13.

21. For example, Kwang Suk Kim and Michael Roemer, Studies in the Modernization of the Republic of Korea, 1945-75: Growth and Structural Transformation (Cambridge: Harvard University Press, 1977)

22. The discussion on delays and capacity utilization in India draws on "Goodbye to self-reliance in fertilizer technology?" Commerce, September 20, 1975, pp. 478-481; "Another 'Bechtel Deal'?", Economic and Political Weekly, October 28, 1972,

pp. 2177-2178; "Slaughter of Fertilizer Corporation", Economic and Political Weekly, April 5, 1975, pp. 571-572; "Ramagundam coal-based fertilizer plant", Commerce, August 23, 1975, pp. 328-329; and World Bank project reports.

23. Which presumably does not include losses in production for exogenous and unexpected reasons; in 1980-1981 it is possible that these fall disproportionately in the group with lowest capacity utilization.

24. Urea is the most common form in which nitrogen fertilizers are used.

25. Although no savings as a result of bureaucratic thoroughness are likely to come anywhere close to the $15 to $20 million that even a six month delay would cost.

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