A Programming Approach to Fertilizer Sector Planning

November 1978

World Bank Staff Working Paper No. 305

The views and interpretations in this document are those of the authors and should not be attributed to the World Bank, to its affiliated organizations or to any individual acting in their behalf.
The views and interpretations in this document are those of the authors and should not be attributed to the World Bank, to its affiliated organizations or to any individual acting in their behalf.

WORLD BANK

Staff Working Paper No. 305

November 1978

A PROGRAMMING APPROACH TO FERTILIZER SECTOR PLANNING

This paper was prepared for the Ministry of Chemicals and Fertilizers Workshop on Fertilizer Sector Planning in India held in Delhi in December 1977. It is a non-technical discussion of the methodology for sector planning developed in the World Bank under the research project "Programming in the Manufacturing Sector" (Ref. No. 670-24). The approach focuses on selected aspects of the investment planning problem in the presence of economies of scale, viz, the scale, location, time phasing and technology of fertilizer plants. In addition, the economic implications of various production and trade strategies can be determined. The results of the most recent case studies undertaken (for Egypt and the ASEAN Countries) are discussed to highlight the practical applications of this approach.

Prepared by: Armeane M. Choksi
Alexander Meeraus
Development Policy Staff; Res. 670-24

Copyright © 1978
The World Bank
1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. The Analytical Framework</td>
<td>2</td>
</tr>
<tr>
<td>3. An Overview of the Model</td>
<td>6</td>
</tr>
<tr>
<td>4. The Uses of the Model and Application Possibilities</td>
<td>13</td>
</tr>
<tr>
<td>5. Case Studies Undertaken at the World Bank</td>
<td>20</td>
</tr>
<tr>
<td>6. Conclusion</td>
<td>28</td>
</tr>
</tbody>
</table>

References
1. Introduction

The purpose of this paper is to outline the objectives and the organization of planning the fertilizer sector in a developing country. The focus is on planning the scale, location, timing and the choice of technology associated with the major investment projects in that sector. Given the increasing domestic demand for fertilizers in many developing countries, such an approach would, therefore, attempt to answer the question: what is the most efficient way for a country to meet its future demand? In other words, should it produce or import the products? If it is advantageous to produce, which product(s) should be produced? What should be the scale and location of the plant or plants? What is the "best" technology, given the environment of the sector? And when should the various plants come on-stream?

The answers to these questions define the "optimal" investment program in the fertilizer sector. In most cases, programs, by their very nature, have to be educated guesses and must be revised periodically. Depending upon the nature and quality of information incorporated into the analysis, the investment programs determined here will, hopefully, be much more than guesses. The periodic incorporation of new information and the updating of old is, however, intrinsic to the planning process and, therefore, cannot be avoided. It should, however, be made clear, at the outset, that the technique used here (i.e. mathematical programming) is not an alternative to common sense; it cannot replace it and it should not. However, it does supplement common sense, particularly with regard to the orders of

1/ The authors have benefitted from the various discussions held with W. Sheldrick, E. Stoutesdijk, and L. Westphal.
magnitude involved; an attempt is made, through this analysis, to incorporate all relevant available information which should be put to use. The aim of programming is, therefore, to arrive at a framework of figures for the possible development of the sector.

The rest of this paper is organized as follows: the next section, which is the second of six sections in this paper, describes the analytical framework; this is a general discussion of the model and the justifications for the technique to be used in the study. The third section presents an overview of the model, how it is designed and what are the various factors that are included and how they interact with one another. The section following this describes the uses of the model and the various application possibilities within an operational environment. The fifth section presents a discussion of the previous work undertaken by the World Bank in the fertilizer sector using this type of a model; it concentrates on the case studies undertaken in Egypt and the ASEAN Countries. Section six concludes the paper.

2. The Analytical Framework

The aim of this approach is to present a consistent and coherent framework for the general development of the fertilizer sector. This is carried out by using a mathematical programming model developed at the World Bank [3, 4]. The use of such a (programming) model implies the simultaneous evaluation of investment projects in the fertilizer sector. This is in contrast to the logic that underlies the Little-Mirlees approach [10] or the UNIDO method [6] where the focus is on the appraisal of individual projects. At the other extreme from this project-by-project approach, lies the evaluation of those projects whose impacts are sufficiently great that
they must be evaluated within an economy-wide framework. This is discussed by various authors, including Goreux and Manne [7]. The approach taken in this study is an intermediate one in which all possible projects within the fertilizer sector only are simultaneously evaluated.

There are two justifications for this intermediate approach of what might be called sectoral programming. One stems from the fact that it permits the identification of projects within a sector for cost-benefit analysis. In general, one may ask if it is sufficient to do an individual project-by-project analysis. If the answer is in the affirmative, then how does one perform the task of identifying the "correct" project, i.e. selecting the scale, location, timing, product mix, choice of technology, raw materials, etc.? 1/ These various aspects of project identification are not obvious for they depend upon the choices being made elsewhere in the sector. If they are obvious, and this is very rare, the number of potential projects that need to be evaluated and appraised becomes exceeding large; this necessitates a cumbersome and laborious process of project appraisal on a project-by-project basis. 2/ Therefore, to correctly identify the "best" project (or set of projects) a simultaneous evaluation of all projects within the sector becomes necessary.

1/ In this context a project is defined as an investment that is specified in terms of scale, location, timing, product mix and production technology. Altering any one of these parameters constitutes a new project. Therefore, a urea plant in location A is one project, exactly the same plant in location B is another. Similarly a TSP plant in location A built in year t is one project, the same plant at that location built in year t+1 is another project.

2/ A simple example will illustrate this point. Suppose a "produce/import" decision is to be made with respect to two plants to be located at either one or both of two locations and in either one or both of two time periods, then 32 investment programs would have to be appraised on a project-by-project basis.
The second justification is based on the existence of economies of scale that are present in most investment projects in the fertilizer sector. Scale economies lead to a number of complications in the design of projects due to three forms of interdependence: spatial, temporal and interprocess interdependence. 1/ These complications are briefly discussed below.

The problem created by spatial interdependence is the trade-off between large production units and high transport costs. Economies of scale tend to favor large production units over small ones, but the former have associated with them high transport costs. On the other hand, a geographically dispersed demand structure and high unit transport costs tend to favor decentralized production in order to minimize transport costs. In order to evaluate the trade-offs between the advantages of large scale production on the one hand and the costs of excess capacity and transportation on the other, it becomes necessary to evaluate alternate investment programs defined over time and space rather than single projects.

Temporal interdependence arises from the fact that under growing demand conditions, in the presence of economies of scale, it may be efficient to build plants with excess capacity in order to take advantage of the declining average costs of production. Thus, the trade-offs arise from the choice between large production units with low average costs of production and the costs of carrying excess capacity. 2/

1/ These aspects have been discussed in greater detail by Chenery [1, 2], Kendrick [8], Manne [11, 12], Westphal [15], and Stoutjesdijk and Westphal [14].

2/ Chenery [2] has shown that in the presence of economies of scale total costs may be minimized by investing in excess capacity.
Interprocess interdependence results from the input-output relationships between various processes. The price of an intermediate good produced domestically under economies of scale depends upon the demand from other plants requiring this intermediate product as an input. On the other hand, the net benefit of a using plant, and therefore the decision to build this plant, depends upon the price of the input. Thus, the optimal size of the plant with economies of scale, as well as the decision to build such a plant, depends upon the size of the (using) plant requiring the input and vice-versa. When an investment gives rise to such pecuniary external economies, its private profitability understates its social desirability. To eliminate the wedge between private and social profitability, the expansion of both plants must be integrated and planned together. Therefore, this type of interdependence necessitates the determination of the optimal investment program for the entire set of activities rather than individual project analysis.

Theoretically, in individual project analysis, these forms of interdependence may be handled by imputing a value to the external economies generated by the project. However, this tends to be difficult and, therefore, has not found much practical application. This is particularly true when there are economies of scale in a number of related projects. Hence, there is the need to formulate and apply a dynamic inter-industry optimization model which will endogenize the external economies, and which can therefore be used

---

1/ The greater the demand for the final product, the greater will be the demand for the intermediate input, thus, necessitating a larger plant for this input and permitting it to take advantage of the economies of scale. This of course assumes that the marginal cost of the intermediate input is less than its import price but greater than the export (f.o.b.) price. If the f.o.b. price were also greater than the marginal cost, then the size of the plant would be determined by both domestic and foreign demand.
to design and evaluate major projects with economies of scale. This will then eliminate the need to associate benefits and costs with particular projects through imputing a value to external effects.

Thus, the approach to project planning proposed is one that concentrates on projects subject to economies of scale and uses analytical techniques which permit a systematic evaluation and screening of a large number of alternative projects. The selection is then made of those projects that are superior to others in terms of a given selection criterion. 1/

3. An Overview of the Model

This section discusses the model that will be used in the analysis of the fertilizer sector. It presents the basic design and characteristics of the model and the various aspects of the fertilizer sector that are incorporated into it. This discussion is entirely qualitative in nature; however, the formal mathematical model is presented in Choksi, Meeraus and Stoutjesdijk [3, 4].

Investment planning in the fertilizer industry is a complex problem. It must take into account the issues of substitution in final consumption and in the production structure of the industry, and also the interdependencies that arise from the presence of economies of scale. These three issues are briefly discussed below.

First, the basic nutrients demanded by the agricultural sector may be provided by a variety of final fertilizer products, some of which may contain one or two or all three nutrients. Thus, there is considerable

1/ This criterion is discussed in Section 3.
scope for substitution in final consumption, particularly if the present consumption pattern does not reflect the most efficient use of final products. Second, the production of each of these fertilizer products faces several technological options, each of which has different economic implications in terms of foreign and domestic resources. This gives rise to the possibility of substitution in technology; the selection of the appropriate technology could result in considerable cost savings. Finally, as discussed before, the interdependencies necessitate the simultaneous determination of the location, size, timing and technological process associated with the investment projects in the industry.

The multiplant dynamic planning model consists of a set of mathematically specified relationships that define the essential characteristics of the fertilizer sector and its environment. Its purpose is to evaluate a number of interrelated activities for meeting, with the minimum use of resources, the exogenously specified, geographically dispersed demand for fertilizer nutrients and products over a specified planning period. The model considers the choice, over time, between imports and the production of final and intermediate products of the fertilizer industry, the choice among alternative processes for producing these products, and the choice regarding the location of production units and inter-regional product flows. The objective of the model is, therefore, the selection of projects from among a number of alternatives based on the criterion of cost minimization.

It is recognized that cost minimization is one of many objectives that may be considered to be important in the development of the fertilizer sector. Other objectives may include income distribution, maximization of
employment and other social and political criteria. 1/ The important aspect to note is the need for a uniform method or criterion of determining priorities, no matter what that criterion may be; this approach satisfies that need.

A frequent handicap to the selection of the best project is a lack of uniformity in the criteria applied by the various ministries of any country. This lack may be due to past political decisions, preconceived ideas about the type of investment or to a particularly strong personality among the administrators. This may lead to an unjustified preponderance of certain types of plants or preference for certain individual projects. This leads to waste and necessitates the need for a uniform method of appraising the projects presented by the various ministries. A complete uniform appraisal will be impossible, especially as far as the unmeasurable aspects are concerned; final choices often require subjective evaluations by those who are politically responsible. However, as far as the measurable aspects are concerned, uniformity can be attained, and the results can be taken into account by the policy-makers as one important item of information, together with other information.

The model provides this uniform criterion. It optimizes over plant size, process choice, location, timing, imports and exports so as to meet estimated regional demands, at different points in time, at a minimum cost to the sector. The optimum selection of these activities is affected by several factors, some of which are exogenously specified to the model. They include regional demand patterns, relative world prices of products,

1/ If necessary, some of these can be taken into consideration by the model.
investment costs of various processes and the relative costs of transporting products using different modes. These, and some other aspects relating to the model, are discussed in some detail below.

3.1. The Technology

The technological choice available to the fertilizer industry is presented in the model in terms of activity analysis. An engineering production function is used to indicate the input-output relationships between the various processes. The choice of technology, in the model, is determined by the inputs used in a particular process. For example, in the case of ammonia production the feedstocks that may be used include natural gas, fuel oil and naphtha. The optimum choice of the input and the process is, therefore, determined by the relative input price and the investment and operating costs of the plant using that input.

3.2. The Plants

The production processes in the model are disaggregated to the plant level; each plant or productive unit is explicitly considered. This permits a detailed specification of the production structure at each location and an explicit consideration of (intermediate) product flows between plants at the same location as well as between plants at different locations. Thus, an intermediate (e.g. ammonia or phosphoric acid) may be produced at one location using a specified technology and transported to another location as an input into the production of the final project; i.e. interplant shipments of intermediates are permitted. These shipments between producing regions are included to prevent the construction of too much excess capacity. The proper time-phasing of plant construction within the various regions makes it possible, in
part, to use plant capacity in excess of regional demand. The use of this plant capacity will temporarily satisfy the growth of demand in other areas where demand exceeds regional production.

The disaggregation to the plant (or productive unit) level also permits specification of investment and operating costs for each plant. This yields plant-specific (and time-specific) shadow prices of production which allocate the country's resources over space and time. Further, this disaggregation also permits the incorporation of capacity constraints that are plant-specific, and which take into account a maximum capacity-utilization factor. This factor is varied over time and it permits a plant, over the period under consideration, to gradually attain its maximum capacity-utilization rate. This is based on the fact that attaining high capacity-utilization in the fertilizer industry is a "learning-by-doing" process, particularly for the new technologically advanced plants.

Capacity-sharing is also permitted in this analysis. For example, a calcium ammonium nitrate unit may produce either the 31% variety or the 33.5% variety or a linear combination of the two, in each time period. Two other units also possess this characteristic, viz., the ammonium phosphate unit and the single superphosphate unit. The products involved with the former are monoammonium phosphate (MAP) and diammonium phosphate (DAP), and with the latter, single superphosphate, double superphosphate or powdered triple superphosphate.

3.3 Domestic Demand

The regional domestic demand for the fertilizer nutrient has been treated as exogenous for each point in time. The intermediate product demand, however, is endogenous to the system. Several demand points, corresponding
to the various states or districts of a country, can be considered for each nutrient and fertilizer product. Consumption restrictions for new fertilizers may also be imposed over all the demand regions. These restrictions take some account of the farmers' resistance to new fertilizers, their resistance declining over time due to increased education and extension services.

3.4 Foreign Trade

Similar to domestic production, there are problems of choice associated with foreign trade; they are also non-trivial. These are the choices associated with the imports and exports of raw materials, intermediate products and final products. For example, the imports of final products depend on the relative prices of raw materials, intermediate and final products. Relative world prices may be such that importing the raw material (or intermediate product), rather than the final product, saves foreign and domestic resources. In that case it may be efficient to build a new plant to process the imported raw material or intermediate product to produce the final product.

Trade choice is, therefore, endogenous in the model, and foreign trade options include the activities of importing (or exporting) final products, intermediate products and raw materials from several points of entry (or exit) over the entire planning period. Further, the products in the model can be treated as competitive or as non-competitive imports. 1/ Thus, the model can be used to determine, at various points in time, the optimal...

1/ Non-competitive imports are defined as those imports for which there are (or will be) no domestic substitutes. This, in general, applies to raw materials. For example, if it is "optimal" to produce sulphuric acid using elemental sulphur, and there is no domestic availability of this raw material over the period under consideration, then elemental sulphur is considered to be a non-competitive import.
import levels of the non-competitive imports, the imports and exports of intermediates, such as sulphuric or phosphoric acid, and of the major final products.

3.5. Transportation

Given the geographical distribution of the composition of demand for fertilizers, the structure of production is determined, in part, by locational considerations. Further, since the demand for an intermediate product, say, ammonia, is determined by the availability and cost of alternative inputs, such as natural gas, fuel oil or coke oven gas, the choice of technology associated with ammonia manufacture depends upon the regional distribution of these resources. Therefore, an important determinant in the location of fertilizer plants is the structure of the transport costs for the various products and inputs. The plants may, in principle, be located at the source of the inputs or near the source of final product demand, or anywhere in between. The relative transport costs may vary among the different modes of transportation and the location of the plants would, therefore, depend upon whether it is cheaper to transport the raw materials to the plants or the finished products to the markets.

3.6. Costs

Since economies of scale are explicitly considered in this model, the investment and labour cost functions are non-linear. Thus, the model has a non-convex objective function. This implies that unit costs vary with the level of the activity. 1/ The capital costs for new investments

1/ The non-linearity of the objective function necessitates the use of mixed-integer programming rather than the traditional linear programming. For a detailed discussion see Kendrick and Stoutjesdick [9] and Westphal [15].
are charged to the model on an annual basis through the use of a capital recovery factor; they are added to the current costs to yield the marginal cost of production. For existing plants, capital costs are treated as sunk costs; they, therefore, do not contribute to the marginal costs of production. All import and export prices in the model are exogenously given as are the costs associated with domestic raw materials, miscellaneous inputs and transportation. The prices of the primary factors of production (i.e. foreign exchange, capital and labor) are adjusted by using accounting or shadow prices. The marginal costs of the intermediate inputs and final products are, therefore, endogenously determined by the model. The exogenous world prices in the model, thus, constitute the "reference" prices with which the marginal production costs are compared to determined whether the plant should be built or the product imported instead.

4. **The Uses of the Model and Application Possibilities**

The uses of the programming model presented in the previous section may be divided into two categories: (i) as a tool for project and program selection, and (ii) as a simulation device. These categories are discussed separately below.

4.1. **Project and Program Selection**

The application of the model for project selection corresponds to the complete use of the model; i.e. the model is used to simultaneously investigate all the issues relating to plant size, location, time-phasing of capacity expansion, technology choice, and product-mix, without imposing
restrictions on these particular parameters. 1/ Within this context, optimization of the model involves the selection of the optimal values of the following variables at each plant location and for each time period:

(i) the production levels of fertilizer products and production processes used;
(ii) the production levels of intermediate products and the processed used;
(iii) the size or scale of the final and intermediate product plants;
(iv) the investments in the sector;
(v) the shipment of final products from plants to markets and shipment of intermediate products between plants;
(vi) the domestic purchases of raw materials, labour, and miscellaneous inputs;
(vii) the domestic purchases of intermediate products from outside the fertilizer sector;
(viii) the exports of final and intermediate products to each export region;
(ix) the imports of intermediate products, raw materials and labour; and finally,
(x) the imports of final products to each market area in each time period.

1/ This issue is take up later.
The selection of these variables implies the determination of an optimal investment program over time. This investment program includes the dynamic issues associated with production, consumption, distribution and foreign trade. With respect to foreign trade, the selection of the activities is based on the principle of comparative advantage.

The model derives its main advantage from the fact that full account is taken of the interdependencies among the set of activities and of the circular relationship between demand and costs (prices). By incorporating the spatial and temporal aspects simultaneously, it presents an integrated approach to the fertilizer sector and, thus, makes one aware of the completeness of the picture. This helps to reveal those elements of information which may be lacking and provides hints as to where to look for these elements.

Apart from the element of completeness is that of consistency. The figures for the development of the sector have to obey a number of conditions of consistency. For example, the total resources to be employed in the development of the sector cannot exceed the available quantities; production cannot demand more resources than can possibly be made available. Final (or intermediate) products produced and imported have to be sold; in order to accomplish that, their prices have to satisfy certain conditions; and these prices are dependent on the prices of the various inputs taken into consideration. In addition, the activities of certain plants have to be interrelated, and therefore, coordinated, since one plant may use the products of the other or since both may supply products to the third. These are only some of the examples relating to consistency. The approach taken here is an attempt to establish a set of figures satisfying these and other conditions.
It can, therefore, be seen that, if a provisional program cannot be brought into line with such requirements, it will have to be revised. As a result, large errors may be avoided if such revisions are made in advance and are not forced upon the policy-makers by unexpected events. Thus, an important use that is derived from this approach is to test whether a program "fits" into the general picture of the sector's development. A determination can, therefore, be made in order to advise the various fertilizer companies about their declared intentions and how these intentions would affect each other and the entire sector.

It is, therefore, the completeness and the consistency characteristics of this approach that will open by advantageous lines of production, trade or other activities. The absence of complete and consistent information about all possible projects constitutes a handicap to selecting the best projects, for it may well be that some unknown project would have been better than some of those chosen.

The full use of the model, however, is not essential. Sometimes the problem of project selection is narrowed down by institutional restrictions. These may be implicitly or explicitly expressed preferences of the policy-makers. For example, the size of an ammonia/urea plant may be predetermined by the domestic capital goods industry. Thus, the issue of selecting the optimal size does not arise. Or, in the interest of developing local technology, only one particular technology of production may be prescribed, eliminating the selection of the process choice. Finally, the issue of timing may be moot because the policy-maker may instruct the project-formulator to come up with a project immediately. These are examples of "fixing" the variables, and this reduces the problem of optimal selection.
However, such restrictions have associated with them certain opportunity costs, and it may be that the decision-maker could change his/her mind if the perceived benefits do not exceed the costs. One of the tasks of the project planner is, therefore, to inform the policy-maker of the cost implications of such restrictions. In some cases these costs may not be significant and can be ignored; in other cases they may be very large. This is the topic dealt with in the following section which describes the use of the model as a simulation device.

4.2. Simulation

In some senses, the use of the model as a simulation tool may be even more useful than project selection. However, as will be discussed later, the knowledge of what constitutes an "optimal" program is often very useful in evaluating alternate strategies.

Two major characteristics of the model make it a very useful tool. The first is reproducibility and the second is internal consistency. This permits us to identify and evaluate the importance of some factors which may be crucial to the development of the sector. Examples of these factors lie in the set of the exogenously specified parameters such as world market prices, availability and prices of domestic resources and factors of production such as labour, capital and foreign exchange, and the exogenous demand parameters for the nutrients and final products. Since this is a planning tool, future prices, availabilities and demands have to be forecast. With any forecast there is an element of uncertainty attached to it. In addition, there may be fluctuations (expected or actual) in world market prices or demand or any key exogenous parameter. In order to show what influences can be exerted by the changes in such factors, it is often useful to draw up a number of alternate investment programs; each of these is based on a specific assumption of these
parameters. The existence of these alternate programs will demonstrate whether some of these factors are important or not. This would be very useful if some factors turn out to be less favourable or more favourable than was originally anticipated. In this way it would be possible to determine the relative ranks of various programs.

This procedure may also be used to illustrate the influence of uncertainty in some of the data. For example, the determination of the opportunity costs of capital, labour and foreign exchange is often open to question. The above procedure may be used to perform a single parameter breakeven analysis which would provide us with a range for the values of that particular parameter for which the optimal program remains unchanged. This permits a determination of the bounds on any parameter whose value is uncertain. If the range over which the optimal program remains unchanged is large, then less attention needs to be placed on that parameter. If, on the other hand, the range is small, then that parameter is now identified as a crucial one and its value would have to be more carefully determined in order to minimize uncertainty.

Another use of the model is in the evaluation of the costs and benefits of alternate policies by simulating various government proposals regarding foreign trade, production and consumption strategies. The evaluation is performed by comparing the optimal investment program to the proposed strategy and determining whether there is a cost or a benefit associated with the proposal. In this manner certain institutional restrictions, discussed before, can be evaluated. For example, if a decision is made to construct a plant at a particular location, which in fact turns out to be non-optimal, then it is possible to determine what is the total opportunity cost to the sector
of this non-optimal location. The policy-maker is now in a better, more informed position to determine whether the benefits of his decision outweigh the costs. Similarly, in the foreign trade area, a policy of complete import substitution may be evaluated, or the benefits of an aggressive export strategy may be determined. Therefore, various policy questions of interest to the sector planners regarding production, transportation, regional location and foreign trade may be investigated within this framework.

The use of the model in this section has been based on the properties of reproducibility and consistency. Each of the alternative programs has been evaluated with the aid of the same, internally consistent technique. This approach, therefore, provides an effective mode of communication among interested parties with divergent opinions concerning a desirable development path of the sector. The various opinions can be easily simulated on the model, and the costs or benefits attached to each may be rapidly determined.

Finally, the model is a useful organizational framework for gathering the right amount and the right type of data crucial for planning decisions in the fertilizer sector. This is an important consideration, given the large data requirements necessary in any detailed analysis. Thus, significant economies may be achieved in data gathering organized around a formal planning framework.

The discussion, so far, has been in general terms. The model has been applied and used within the World Bank for a number of countries. The next section briefly highlights the application of the model in some of these countries.
5. Case Studies Undertaken at the World Bank

Several case studies have been undertaken at the World Bank. The countries whose sectors were investigated were the East African countries [14], Egypt [3,4] and the ASEAN countries in Southeast Asia [5, 13]. Studies are currently underway in India and in the Andean common market in Latin America. The East African study was the first one conducted under the research program instituted by the Bank for this purpose and is described in some detail in a forthcoming monograph [14]. The results of this study turned out to be of great help in obtaining a more comprehensive insight into the sectoral investment planning problem.

The most detailed and comprehensive application was done for Egypt where the model was specified jointly with the Egyptian sector planners. The results of this study are outlined below to give the reader an indication of the type of information that can be extracted from such a study and how the model can be used to evaluate production and trade strategies.

The first part of this study attempted to highlight the most salient characteristics of the fertilizer industry in Egypt in 1975. It was static in nature and incorporated the actual production and consumption patterns of final products for five operating plants and twenty states or governorates. Since this part of the study was intended to be positive and not normative, viz., it analyzed what the existing situation was and not what it ought to be, the economic data incorporated into the study were based on market prices and not shadow prices.

The analysis of the existing situation in Egypt, using the static model, indicated that the total cost of supplying 1742 thousand tons of
fertilizer to the twenty governorates of Egypt was LE 57.6 million. 1/ This domestic demand was met by the production of 824,000 tons of fertilizer and the imports of 919,000 tons. Thus, imports accounted for 52.75 percent of total fertilizer demand; the cost of these imports was LE 40.4 million, which was approximately 70 percent of the total cost of the sector. The fertilizer sector was, therefore, shown to be very dependent on imports and on the availability of foreign exchange.

In order to investigate whether there was anything that could be done, in the short run, to conserve foreign exchange and move away from the strong import bias, the static model was used to determine the production, consumption and import patterns of final products necessary to meet the demand for nutrients (rather than the demand for final products) in each governorate. The most significant result was that the existing production and consumption patterns of final products were not "optimal", and that superior patterns could be attained with the existing production capacity. Such a pattern resulted in a 17 percent decline in the import costs; this involved a foreign exchange saving to the sector of LE 7.02 million ($17.55 million at the official exchange rate). This saving was brought about by a shift in the import pattern away from what were then the more expensive nitrogen fertilizers to the relatively cheaper ones.

The second part of this study was a normative one (i.e., what ought to be the optimal investment pattern); it used a model which incorporated the temporal dimension. Being normative, it became essential that the prices imputed to the various inputs (and outputs) reflect their true

1/ This excluded all committed costs.
cost to the society; therefore, shadow prices, rather than market prices were used. Thus, this model represented a dynamic social cost/benefit analysis of the fertilizer sector, performed simultaneously across several potential projects. Eight plant locations were considered in this part of the study. The number of demand regions or governorates remained the same at twenty and three different modes of transport were incorporated. The planning period considered was from 1979 to 1987.

Within the context of this model, several scenarios were investigated and compared to the "reference solution". The latter was the solution for optimal capacity expansion given realistic (or "most likely") assumptions regarding the fertilizer sector. The seven scenarios subsequently considered were used to relax or alter these assumptions to determine the robustness of the investment program and evaluate the costs or benefits of certain strategies.

The major conclusions that emerged from this analysis were as follows:

(i) Egypt was completely self-sufficient in nitrogen fertilizer with the existing capacity up to 1987. However, there would be need for imports of triple superphosphate in the periods 1982-1984 at the rate of 18,000 tons per year and in 1985-1987 at the rate of 68,000 tons per year.

(ii) The nitrogen fertilizer industry should produce calcium ammonium nitrate with 33.5 percent nutrient content and, thus, move away from the 31 percent variety.

(iii) Ammonia production at one location using coke-oven gas was not an economic proposition, neither was it advisable to convert the production process to one using natural gas. It was more economical to produce the required ammonia at
another location and ship it to this particular one over the entire planning period. Thus, it became obvious that Egypt had to build the necessary ammonia shipment facilities.

(iv) Calcium nitrate production at Suez was optimal at the level of 23,000 thousand tons per year in the period 1979-1981 and only at 1,000 tons per year and 2,000 tons per year in the two subsequent periods. 1/ The erection of a nitrophosphate (NP) complex producing an equal weight NP (20-20-0)/CN mixture was not optimal and involved an additional cost of £E 2.5 million to the entire fertilizer sector over the planning period, 1979-1987. A minimum level (150,000 tons per year) of calcium nitrate production at Suez also entailed an additional cost to the sector of £E 1.9 million over the planning period. Thus, if some activity other than the optimal production pattern mentioned above had to be undertaken at Suez, calcium nitrate production was found to be superior to a NP/CN production activity.

(v) The phosphorus demand could be adequately taken care of by the erection of a phosphoric acid plant of 134,000 tons per year (as 54% P$_2$O$_5$ acid) capacity at Abu-Zaabal in the first time period (1979-1981) at a cost of $23 million. This had to be accompanied by a subsequent change in the production of the final product (at Abu-Zaabal) from single

1/ In practical terms, since the plant could not operate at such low levels, these figures implied that it must shut down.
superphosphate to powdered triplesuperphosphate. This acid plant was very robust (in the sense that it appeared in all capacity expansion scenarios) and had a very high rate of return, 31.4 percent, associated with it. It, thus, represented one of the most important conclusions of this study.

(vi) The production of this acid and powdered TSP at Abu-Zaabal and the continued production of single superphosphate at Kafr El-Zayaat and Assiout would satisfy domestic demand for phosphorus up to 1981. Thus, no imports would be required. From 1982 to 1987 imports of TSP would be necessary. A policy of complete import-substitution (or complete self-sufficiency), however, would cost the sector an additional LE 1.38 million over the planning period. Such a policy entailed the erection of a larger phosphoric acid plant at Abu-Zaabal in the first time period (1979-1981), and the subsequent erection of a sulphuric acid plant in the second time period (1982-1984) at the same location. This expansion had to be accompanied by a conversion to powdered TSP production at Abu-Zaabal in the first time period and at Kafr El-Zayaat in the second time period.

(vii) In all the scenarios considered, an export-oriented strategy turned out to be very beneficial to the sector, for Egypt possessed considerable comparative advantage in nitrogen production. An export strategy without any capacity expansion would result in a cost saving of LE 14 million over the period under considerations, if Egypt could capture
the required export market for urea. However, as domestic demand increased, this would result in her relinquishing the captured export market to her competitors. In order to capture and to at least preserve an export market of 500,000 tons per year of final product, a phosphoric acid plant at Abu-Zaabal and an ammonia-urea complex at Suez would have to be erected. The urea capacity expansion would have to be phased in between the second and third time periods. Such a strategy would result in a saving to the sector of LE 19 million. Capturing and maintaining a small export market of 250,000 tons per year would result in a (smaller) saving of LE 15 million and entail the erection of only the phosphoric acid plant at Abu-Zaabal. Thus, the sooner Egypt could exploit her comparative advantage in nitrogen fertilizer production, the better.

(viii) Considerable concern had been voiced over the transport sector being the major bottleneck in the distribution of fertilizers. The study indicated that the existing (1975) total transport capacity used by the sector was sufficient to transport fertilizers up to 1984. It was only in the last time period, 1985-1987, that the existing transport capacity was exceeded. The conversion to the higher analysis fertilizers permitted the desired distribution of the fertilizers to all the governorates as more nutrients

---

1/ The saving refers to the difference in the discounted total cost between the optimal capacity expansion case and the one incorporating the export strategy.
were transported per ton of final product. Therefore, the necessary distribution of fertilizers could be accomplished with the existing transport capacity, and apart from replacement costs, major new investments would not be required for the transport of fertilizers until 1985.

(ix) Finally, a cost saving of LE 5 million could be achieved over the plan period if the farmers were prepared to use urea as its production came on-stream, instead of the traditional fertilizer. Therefore, the education of the farmers could prove to be beneficial, so long as the associated costs were less than LE 5 million.

Another, more recent, case study undertaken at the Bank was that of the ASEAN fertilizer sector [5]. The issue that was investigated was the location, timing and the technology of new nitrogen fertilizer capacity in the four ASEAN countries: Indonesia, Malaysia, Philippines and Thailand. The complex was predetermined to be an ammonia/urea one producing 1725 tons/day. As part of the ASEAN regional co-operation program, the locations, Aceh in Indonesia and Miri/Bintulu in Malaysia, were and still are under active consideration. Within the model, however, other new sites were also considered. The planning horizon in this study covered the period 1982 to 1990 and the model was specified as an annual one.

The major conclusions that emerged from this study were that:

(i) There is sufficient regional and foreign demand to accommodate four new plants in the region. In addition, these plants could produce urea competitively with respect to world prices
due to the availability of cheap natural gas. One plant should ideally be constructed at Aceh in Indonesia in 1982 and the other three at Miri/Bintulu in East Malaysia; these should be phased in as follows: one in 1982, one in 1985 and one in 1988.

(ii) If, however, all four plants were to be constructed at Miri/Bintulu only (two in 1982 and the others in 1985 and 1988 as before), then the incremental cost to the region would be very insignificant.

(iii) If the policy makers decided, for whatever reason, that there was potential for co-operation in only one ASEAN project (as opposed to the optimal four mentioned above), then that project could be located at either Aceh or Miri/Bintulu. This implies that the policy-makers would require some non-quantifiable variables to make the final decision regarding the location.

(iv) Co-operation among the ASEAN countries was of prime importance. If the optimal policy of co-operation on four projects was possible, then the savings to the sector resulting from such a co-operative effort would amount to $300 million over the planning period. Even co-operation on only one project (Aceh or Miri/Bintulu) would result in a total regional benefit of $80 million.

(v) Even if no decision could be arrived at with respect to co-operation on new projects, arrangements for co-operation based on existing capacity, in the form of inter-regional trade, would result in a savings of $260 million over the years 1982 to 1990.
(vi) If a policy of national autarky was to be instituted, then there would be no new capacity expansion in Indonesia; there is sufficient capacity in place to supply the domestic demand up to 1990. However, one new plant would be necessary to supply the nutrient demand in Malaysia; this would be located at Miri/Bintulu in 1982 and would be based on natural gas. The Philippines, in order to supply its own domestic demand, would have to build two new plants based on fuel oil in 1982 and 1985; and Thailand would require one new fuel oil plant in 1985. Each of these would be competitive with urea imported from outside the ASEAN region.

(vii) Finally, it was shown that, as more nitrogen capacity came on-stream in the region, the pattern of imports, in all four countries, shifted away from urea and DAP to primarily TSP.

6. Conclusion

This paper has attempted to highlight the programming approach to sector planning. This approach is at the other end of the spectrum of the project-by-project approach; the latter, in the presence of scale economies, leads to severe complications associated with externalities generated by the projects.

One major benefit of such an approach is a rational and consistent method of defining the optimal investment program over a given planning period. Thus, projects within the sector can be identified over space and time permitting the policy-maker to determine whether a particular program "fits" into the general picture of the sector's development. The model can
also be used to determine which of the many factors that affect the fertilizer sector are of significant importance within any particular environment. In addition, it can be used to illustrate the influence of uncertainty in some of the data.

The model is also a useful tool to evaluate various production, consumption and trade strategies that may be of interest to the sector planners. Examples of such strategies have been presented in the case of Egypt. Further, as the case of the Southeast Asian countries demonstrates, the model can also be used to investigate issues of regional (project) integration. Thus, the approach provides a consistent, comprehensive and flexible analytical framework which can be used in a variety ways. By evaluating the costs or benefits of different policies or strategies, this approach presents a mode of communication for the various agencies with divergent opinions as to the capacity expansion of the sector.
References


References (Continued)


<table>
<thead>
<tr>
<th>No.</th>
<th>Title of Paper</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>279</td>
<td>India - Occasional Papers</td>
<td>M. Ahluwalia, J. Wall, S. Reutlinger, M. Wolf, R. Cassen (consultant)</td>
</tr>
<tr>
<td>280</td>
<td>Educational Effects of Class Size</td>
<td>W.D. Haddad</td>
</tr>
<tr>
<td>281</td>
<td>Relieving Traffic Congestion: The Singapore Area License Scheme</td>
<td>P.L. Watson, E.P. Holland</td>
</tr>
<tr>
<td>282</td>
<td>World Trade and the International Economy: Trends, Prospects and Policies</td>
<td>B. Balassa</td>
</tr>
<tr>
<td>283</td>
<td>Urban Land Policy Issues and Opportunities</td>
<td>H. Dunkerley, A. Walters, J. Courtney, W. Doebele, D. Shoup, M.D. Rivkin (consultants)</td>
</tr>
<tr>
<td>284</td>
<td>Pakistan: Forestry Sector Survey</td>
<td>S.A. Draper, A.J. Ewing, J. Burley, G. Grayum (consultants)</td>
</tr>
<tr>
<td>285</td>
<td>The Leisure Cost of Electric Power Failures</td>
<td>M. Munasinghe</td>
</tr>
<tr>
<td>286</td>
<td>Shadow Pricing and Power Tariff Policy</td>
<td>M. Munasinghe, J. Warford</td>
</tr>
<tr>
<td>287</td>
<td>Wages Capital Rental Values and Relative Factor Prices in Pakistan</td>
<td>S. Guisinger (consultant)</td>
</tr>
<tr>
<td>288</td>
<td>Educational Reform in the Soviet Union: Implications for Developing Countries</td>
<td>I. Blumenthal, C. Benson (consultants)</td>
</tr>
<tr>
<td>289</td>
<td>Petroleum and Gas in Non-OPEC Developing Countries: 1976-1985</td>
<td>R. Vedavalli</td>
</tr>
<tr>
<td>290</td>
<td>Major Reforms of the Swedish Education System</td>
<td>A. Heidenheimer (consultant)</td>
</tr>
<tr>
<td>291</td>
<td>Industrialization, Technology and Employment - China</td>
<td>T.G. Rawski (consultant)</td>
</tr>
<tr>
<td>292</td>
<td>Development and Income Distribution - Zambia</td>
<td>C. Blitzer</td>
</tr>
<tr>
<td>293</td>
<td>World Potash Survey</td>
<td>W. Sheldrick, H. Stier</td>
</tr>
<tr>
<td>294</td>
<td>The Economic Dimensions of Malnutrition in Young Children</td>
<td>M. Selowsky</td>
</tr>
<tr>
<td>295</td>
<td>The Technology of Rural Development</td>
<td>J.P. McInerney (consultant)</td>
</tr>
<tr>
<td>No.</td>
<td>TITLE OF PAPER</td>
<td>AUTHOR</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------------------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>295</td>
<td>The Financial Cost of Agricultural Credit: A Case Study of Indian Experience</td>
<td>C.D. Datey (consultant)</td>
</tr>
<tr>
<td>297</td>
<td>Agricultural Sector Planning Models: A Selected Summary and Critique</td>
<td>A.C. Egbert</td>
</tr>
<tr>
<td>298</td>
<td>Textbooks and Achievement: What We Know</td>
<td>S.P. Heyneman. J.P. Farrell, A. Sepulveda-Stuardo (consultants)</td>
</tr>
<tr>
<td>299</td>
<td>An Economic and Social Analysis of the Chao Phya Chao Phya Irrigation Improvement Project II</td>
<td>C. Bruce Y. Kimaro</td>
</tr>
<tr>
<td>300</td>
<td>Two Studies of Development in Sub-Saharan Africa</td>
<td>S. Acharya B. Johnston (consultant)</td>
</tr>
<tr>
<td>301</td>
<td>The Intermediate Sector, Unemployment, and The Employment-Output Conflict: A Multi-Sector Model</td>
<td>W.F. Steel Y. Takagi (consultant)</td>
</tr>
<tr>
<td>302</td>
<td>The Economic Theory of the Household and Impact Measurement of Nutrition and Related Health Programs</td>
<td>D. Chernichovsky</td>
</tr>
<tr>
<td>303</td>
<td>Trade Restrictions and International Price Instability</td>
<td>M. Bale E. Lutz</td>
</tr>
<tr>
<td>304</td>
<td>Intergovernmental Fiscal Relations in Developing Countries</td>
<td>R. Bird (consultant)</td>
</tr>
</tbody>
</table>