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The transshipment formulation of the general linear programming model with a cost minimization objective function is used as the basic analytical tool. Solutions for both the custom's union situation and the six countries behaving independently under protection were claimed for the supply and demand situations expected to exist in the years 1975, 1980, and 1985.

Economic integration in the form of a custom union results in net "welfare gains" in terms of lover costs of processing and distributing fertilizers of 3.5, 6.5, and 6.5 million dollars for 1975, 1980, and 1985, respectively.

The evaluation of tariffs, quotas, subsidies, and subsidy-tariff combinations as alternative protection policies in Colombia, Ecuador, and Peru shows that for the purpose of lower fertilizer prices in the process of economic integration, a direct subsidy is the preferred policy. To solve the problem of lack of government revenues, consideration should be given to a mixed subsidy-tariff policy.

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ANDEAN GROUP ECONOMIC INTEGRATION: THE CASE OF THE NITROGENOUS FERTILIZER INDUSTRY

By

CARLOS ARTURO BAANANTE

1974

NORTH CAROLINA STATE UNIVERSITY
AT RALEIGH

ABSTRACT

BAANANTE, CARLOS ARTURO. Andean Group Economic Integration: The Case of the Nitrogenous Fertilizer Industry. (Under the direction of RICHARD LEE SIMMONS).

This study is devoted to the economic analysis of a regionally-integrated nitrogenous fertilizer industry for the Andean Group countries: Bolivia, Colombia, Chile, Ecuador, Peru and Venezuela. In particular, the effects of economic integration in a Custom's Union context are analyzed in terms of costs of processing and distributing nitrogenous fertilizers, plant locations and capacities, and trade patterns. Results are also used to evaluate alternative protection policies for importing countries.

The transshipment formulation of the general linear programming model with a cost minimization objective function is used as the basic analytical tool. Solutions for both the Custom's Union situation and for the six countries behaving independently under protection were claimed for the supply and demand situations expected to exist in the years 1975, 1980 and 1985.

Economic integration in the form of a Customs Union results in net "welfare gains" in terms of lower costs of processing and distributing fertilizers of 3.5, 6.5 and 6.5 million dollars for 1975, 1980 and 1985, respectively. The closing down of some small plants in the importing countries, Colombia, Peru and Ecuador, is required. Venezuela is the main exporter with Chile and Bolivia becoming exporters by 1980 if plants at Punta Arenas and Yacuiba are built. Ammonia and urea plants in Venezuela must export to the rest of the world market in order to allow them to operate at full capacity. Also the economic

feasibility of the ammonia-urea complex at Yacuiba, Bolivia, depends on exports to Argentina and, in general, to the rest of the world market.

The evaluation of tariffs, quotas, subsidies and subsidy-tariff combinations as alternative protection policies in Colombia, Ecuador and Peru shows that for the purpose of lower fertilizer prices to farmers and less difficulties for governments to change policies in the process of ecnomomic integration, a direct subsidy is the preferred policy. To solve the problem of lack of government revenues, consideration should be given to a mixed subsidy-tariff policy.

TO MY PARENTS AND WIFE

BIOGRAPHY

The author was born December 9, 1939 in Trujillo, Peru. He received his secondary education at "Colegio Militar Leoncio Prado" in Lima, Peru. In June 1963, he graduated as an Agricultural Engineer from the National Agrarian University in Lima. In 1964 he was awarded a research assistantship to study at North Carolina State College. In September 1965, he received the Master of Science degree in Economics. From that time until December 1966, he was employed by the German Company Salzgitter Industriebeau G.M.B.H. to work in the agricultural planning of an irrigation project in the north of Peru.

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The author married Miss Olinda Rocca in 1965.

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CHAPTER 1
INTRODUCTION

The success of the European Common Market has contributed greatly to Latin American interest in integration. Regional integration involving elimination of trade barriers and coordination of investment has long been recognized by Latin Americans as a means of benefiting from an expanded market, economies of scale, specialization, and optimum location considerations.

So far the sectoral approach to integration is being undertaken by the countries that form the Andean Group Common Market: Bolivia, Colombia, Chile, Peru, Ecuador, and Venezuela. This approach, by placing emphasis on integration of a single sector, such as the fertilizer industry, makes it possible to concentrate on a limited objective and gradually expand the area of economic integration. The main criticism of this approach is that integration in just one sector leads to factor reallocation only in that sector, because of persistence of trade barriers in other sectors. Therefore, some of the participating countries would benefit while others would suffer welfare losses, balance of payments pressures, and unfavorable factor movements.

The chemical fertilizer industry has particular characteristics which make it a good example of the gains which can be achieved by regional economic integration of the Andean countries group. These characteristics are:

(a) Fertilizer production is a key factor in a region which places a high priority on increased agricultural production. Considering that increased fertilizer use has been a major factor in

increasing crop yields in many of the technologically more advanced countries, increased fertilizer production will facilitate agricultural production development of this region and would contribute to the overall strengthening of its economic structure.

(b) The fertilizer industry requires larger investments and larger markets than can be found within most individual countries, if the industry is to be efficient. The existence of substantial economies of scale makes it necessary to have large markets in order to establish an efficient fertilizer industry.

(c) Present conditions of supply and demand justify a concerted effort in this field. There are indications that increased fertilizer production will be necessary to satisfy a rapidly expanding demand. Surveys indicate the existence of natural resources to supply a large portion of the region's fertilizer requirements.

The development of the fertilizer industry in the member countries of the Andean Common Market has been taking place under the protection of high tariffs and trade restrictions, these being the principal source of high fertilizer prices. Other factors, such as high transport costs and poorly organized marketing and distribution also contribute to high prices. The relationship between fertilizer cost and the accompanying added returns from fertilizer use is, of course, important. High fertilizer prices are a serious deterrent to greater utilization of fertilizers in these countries. (U.N. Economic Commission for Latin America and U.N. Food and Agriculture Organization, 1966). Regional integration of the fertilizer industry would reduce the trade barriers among participating countries and, it is

believed, reduce fertilizer prices by allowing the fertilizer industry to benefit from a larger market and economies of scale.

Member countries of the Andean Group have been following a policy of developing their domestic fertilizer production to satisfy domestic demand to the greatest extent possible with little thought of regional coordination. An analysis of the economics of regional integration in regard to costs, plant locations and capacities, and trade patterns or marketing flows of a regionally-integrated nitrogenous fertilizer industry for the Andean Group countries is the main subject of this study.

The basic analytical tool used in this study is the transshipment formulation of the general linear programming model with a cost minimization objective function. Estimates of processing costs at existing and planned production facilities, consumption projections, and transportation costs, which comprise data inputs into this model, are discussed in chapters 4, 5 and 6, respectively.

The model is used to obtain two alternative solutions which minimize processing and distributing costs of nitrogenous fertilizers for the Andean Group countries, given situations of supply and consumption expected to exist in these countries in the years 1975, 1980 and 1985. One solution is for the case of a regionally-integrated nitrogenous fertilizer industry for the Andean Group countries in a Customs Union context. The alternative solution is obtained for each country operating independently under import protection so that no imports from other countries could take place until all domestic fertilizer production capacity is first exhausted. In

chapters 7 through 9, the results of these solutions are analyzed in terms of: marketing flows of intermediate (ammonia) and final products, plant production levels and excess capacities, cost structures and "welfare" gains (losses), and implications of tariffs, quotas, subsidies and tariff-subsidy as alternative policies for protection of the domestic fertilizer industry. Chapter 10 contains a summary and the conclusions of the study.

CHAPTER 2
REVIEW OF LITERATURE

Programming Models

Several models have been developed to deal with the complex set of relationships involving production functions for raw materials, intermediate and final products, regional demand functions for final products, and transfer costs that tie regions together into spatial equilibrium. However, these models have not been able to solve directly the problem of including economies of scale. Carnoy (1972) used a modified linear programming model to calculate optimum production locations for nitrogen fertilizers in the Andean Group countries, introducing dichotomous variables (0 or 1) with respect to construction of plants, and minimizing fixed and variable costs of production at all states of production and the transportation costs between stages and between each stage and final markets. One location and one market per country were assumed. However, as Carnoy (1972, p. 234) points out, the problem of accounting for economies of scale was not handled directly:

> Because of the intercept term in the production cost curve, the solution to the relatively simple problems of minimizing total variable costs does not necessarily represent the minimum of variable plus "fixed" costs. To minimize total costs, economies of scale must be accounted for. This makes it necessary to enumerate all solutions to the linear programming model.

Enumeration of all solutions to the linear programming model becomes almost unmanageable for a problem as large as the present study.

A similar model using the mixed-integer programming formulation of the linear programming model was adapted by Frank, Meeraus and Stoutjesdijk in their study of the chemical fertilizer industry in East Africa.[1] This formulation poses severe limitations on the dimensions of the model. As the authors indicate:

> Computational experience with this type of model is fairly limited, and no satisfactory algorithm exists to solve large-scale problems. In most cases, the number of integer variables has been limited to below 20. Clearly, if one wants to consider an interdependent set of industrial activities, in a multiregional and dynamic context, the danger of ending up with an unmanageably large model is very real.[2]

A simplification procedure was therefore adopted to solve the various versions of the model. Economies of scale were explicitly taken into account and were approximated by assuming a fixed charge to arise in the construction of a plant. However, as they point out:

> The term 'solved' needs some clarification. Strictly speaking, an optimization problem is solved once a proven optimal solution is obtained. In the case of a mixed-integer programming model, moreover, one needs to insure that the optimum found is global rather than local.

They add:

> However, in no case have we been able to prove that the 'best' solution identified is in fact the global optimum, due to financial constraints that were institutionally and rationally inspried.[3]

---

[1] C. Frank, A. Meeraus, and A. Stoutjesdijk, Planning in the Chemical Industries, the Case of Fertilizers in East Africa. Unpublished draft of a forthcoming publication by the Interamerican Bank for Reconstruction and Development, Washington, D. C.

[2] Ibid., p. 22.

[3] Ibid., p. 60.

The large dimensions of our problems and the difficulties of these models directed us to consider alternative models. Reactive Programming (King and Ho, 1972) has been used to solve several problems of spatial equilibrium based on demand and supply functions and a linear programming subroutine is used to allocate supplies among markets. However, in this program supplies (at producing sites) must be treated as fixed or entered in functional form with positive slopes.

The transshipment formulation of the general linear programming model was selected as our model (Perrin, 1970). It does not take account of economies of scale. Hence the quality of the results in this respect will have to be judged in terms of the correspondence between processing cost assumptions and plant capacities (outputs) in the solutions obtained. However, the transshipment model is particularly effective in handling the problem of intermediate products.

Supply Estimates and Consumption Projections

The adoption of standardized assumptions derived from previous experiences is well established as a procedure in estimating processing costs of ammonia and final fertilizer products. Studies made by the Tennessee Valley Authority (Davis, et al., 1970, and Patterson et al., 1969) have used standardized assumptions to obtain cost estimates and to insure that various alternative processes and supply systems are evaluated on the same basis.

Also, all cost estimates presented by Bixby, et al., (1966) were made through the use of uniform assumptions to increase

comparability. It is emphasized, however, that economies for a plant of a particular type and given capacity may vary considerably due to different situations associated with plant locations.

Cost estimates made under standardized assumptions may not be as reliable for some specific situations as more in-depth estimates. This can be observed by comparing the cost estimates by McCamy and Waggoner (1970) for the fertilizer complex at Barrancabermeja, Colombia, with those that could be obtained by using standardized assumptions only.

Input-output ratios, as specified for the different processing techniques, have been obtained from the United Nations Fertilizer Manual (United Nations Industrial Development Organization, 1967) for the case of raw materials as well as intermediate products.

Estimates of future fertilizer consumption for developing countries varies widely. Some fertilizer consumption projections have been based on past growth rates and fertilizer consumption goals (Instituto Latino-Americano de Planificacion Economica y Social, 1972) so that consumption projections are heavily affected by how these consumption goals are pre-established. Other demand projections (Russel, et al., 1970) are obtained by considering physical factors such as area planted to various crops, soil fertility, climatic conditions, etc., and assessment of developmental and attitudinal factors affecting fertilizer consumption.

Kearney and Co., Inc. (1970) carried out consumption projections following a more sophisticated forecast methodology based on growth rates for regions with similar land and weather conditions,

adjustments for planned land redistribution by crops and regions or provinces, and an evaluation of the basis for recommended levels of fertilization. This estimation procedure probably provides more accurate consumption projections, but availability of more detailed, reliable information is required. In any problem of making projections there are two basic sources of error, one arising from the estimation procedure and its assumptions (statistical error) and the other from the data used (observation error). To select a forecast methodology careful consideration must be given to them.

CHAPTER 3
METHODOLOGY

General Procedure

The nitrogenous fertilizer industry is composed of a complex set of relationships involving (a) production functions for raw materials, intermediate and final products (b) regional demand functions for final products, and (c) transfer costs for raw materials, intermediate and final products which tie regions together into a spatial model.

Given existing and planned production facilities in the six countries that form the Andean Group Common Market, estimates of consumption requirements at main distribution centers were obtained, and the problems of identifying levels of production at processing facilities and optimal flow patterns were formulated as a transshipment model to minimize the costs of processing and distributing nitrogenous fertilizers to selected distribution centers.

The general procedure consists of the following steps:

(a) Estimation of costs of production or supply functions for intermediate and final products.

(b) Estimation of demand requirements for years 1975, 1980, and 1985 at each selected distribution center.

(c) Estimation of transfer or transport costs for intermediate and final products included in the study.

(d) Formulation and solution of the transshipment model, assuming first, that the Andean Group Countries operate as a Customs Union, and, second, that each country develops its own fertilizer industry with a specific level of protection necessary to keep in operation all existing and planned plants[4] as required by its own demand.

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[4]For the cases of 1980 and/or 1985 situations.

Steps (a), (b), and (c) are discussed in following chapters. The rest of the present chapter is dedicated to the explanation of the model and its assumptions.

The Model

The basic analytical tool, which incorporates the processing costs estimation, demand projections, and transportation costs, is the transshipment formulation of the general linear programming model with a cost minimization objective function. The model finds the least cost way of supplying projected demands, given transport costs and production capacities and costs.

Assumptions for the General Model

In order to apply this theoretical model, like any other, it is necessary to make simplifying assumptions to permit a workable real-world counterpart. The principal assumptions made in this study are the following:

(a) All participants are assumed to behave in a perfectly competitive manner.

(b) All final products -- Urea, Ammonium Nitrate, Ammonium Sulfate, Compounds--are expressed in ammonia equivalent metric tons, that is, they are standardized on the basis of the ammonia required to produce a metric ton of each.

(c) All possible demand and supply areas are represented by a single point, and pairs of producing sites and distribution centers are separated by a transportation cost per metric ton of ammonia and per metric ton of ammonia equivalent for final products. These transfer costs are known and are independent of volume transferred.

(d) All ammonia and final products are assumed to be homogeneous, i.e., they are assumed to be perfect substitutes in consumption. Thus, processors and consumers are indifferent about their sources of supply.

(e) The input-output ratios or rates at which raw materials are converted into ammonia and this into final products are known and constant for all levels of processing.

(f) All costs are expressed in 1970 constant dollars at nominal official exchange rates for the case of raw materials and transport.

(g) The relative prices of various inputs at each location and the relative price of each input at various locations remain unchanged between the base year 1970 and the projected years 1975, 1980, and 1985. The relative effects of technological change are implicitly equal.

(h) The relative exchange rates between Andean Group countries currencies will not vary.

(i) External economies of diseconomies are equal at all producing sites for each product.

(j) Per unit processing costs are assumed to be constant as if the producing plants were operating at full capacity, i.e., effects of economies of scale and problems of excess capacity are not accounted for by the model and will be discussed in relation to each solution obtained.

(k) The production capacities at producing sites, transportation costs, and demanded quantities at each distribution center are assumed to be correct estimates for each of the selected years 1975, 1980, and 1985.

The Basic Model

Elements of the basic model includes one intermediate product, ammonia; five final products that are substitutes, Urea, Ammonium Nitrate, Ammonium Sulfate, Compounds, and Chilean Nitrates; and two intermediate processing activities.

In order to specify the model in mathematical form, let us assume the following notations:

c_i^a = per unit cost of production of ammonia in location i, $i = 1, 2, \ldots, v$

c_j^u = cost of transforming one metric ton of ammonia into urea-nitrogen at location j, $j = 1, 2, \ldots, p$

c_j^n = cost of transforming one metric ton of ammonia into ammonium nitrate-nitrogen at location j

c_j^s = cost of transforming one metric ton of ammonia into ammonium sulfate-nitrogen at location j

c_j^e = cost of transforming one metric ton of ammonia into compounds-nitrogen at location j

c_j^{nt} = cost of transforming one metric ton of ammonia into nitrates-nitrogen at location j

$X_{ij}^{a,u}$ = quantity of ammonia shipped from location i to production of urea at location j; $i = j$

$X_{ij}^{a,n}$ = quantity of ammonia shipped from location i to location j for production of ammonium nitrate-nitrogen

$X_{ij}^{a,s}$ = quantity of ammonia shipped from location i to location j for production of ammonium sulfate-nitrogen

$X_{ij}^{a,c}$ = quantity of ammonia shipped from location i to j for production of compounds-nitrogen

$X_{ij}^{a,nt}$ = quantity of ammonia shipped from location i to location j for production of nitrates-nitrogen

X_{jt}^{u} = quantity of urea-nitrogen, expressed in metric tons of ammonia equivalents, shipped from location j to distribution center in location t

X_{jt}^{n} = quantity of ammonium nitrate-nitrogen, expressed in metric tons of ammonia equivalents, shipped from location to distribution center in location t

X_{jt}^{s} = quantity of ammonium sulfate-nitrogen, expressed in metric tons of ammonia equivalents, shipped from location j to distribution center in location t

X^c_{jt} = quantity of compounds-nitrogen, expressed in metric tons of ammonia equivalents, shipped from location j to distribution center in location t

X^{nt}_{jt} = quantity of Chilean nitrates-nitrogen, expressed in metric tons of ammonia equivalents, shipped from location j to distribution center in location t

T^a_{ij} = transport cost for shipping one metric ton of ammonia from location i to location j

T^u_{jt} = transport cost for shipping one metric ton of urea-nitrogen ammonia equivalent from location j to distribution center in location t

T^n_{jt} = transport cost for shipping one metric ton of ammonium nitrate-nitrogen ammonia equivalent from location j to distribution center in location t

T^s_{jt} = transport cost for shipping one metric ton of ammonium sulfate-nitrogen ammonia equivalent from location i to distribution center in location t

T^c_{jt} = transport cost for shipping one metric ton of compound-nitrogen ammonia equivalent from location j to distribution center in location t

T^{nt}_{jt} = transport cost for shipping one metric ton of nitrate-nitrogen ammonia equivalent from location g to distribution center in location t

R^a_i = processing capacity of ammonia plant, in metric tons of ammonia, at location i

R^u_j = processing capacity of urea plant, in metric tons of ammonia equivalents, at location j

R^n_j = processing capacity of ammonium nitrate plant, in metric tons of ammonia equivalents, at location j

R^s_j = processing capacity of ammonium sulfate plant, in metric tons of ammonia equivalents, at location j

R_j^c = processing capacity of compounds plant, in metric tons of ammonia equivalents, at location j

R_j^{nt} = processing capacity of Chilean nitrates plant, in metric tons of ammonia equivalents, at location j

D_t = quantity of nitrogen, expressed in metric tons of ammonia equivalents, demanded at distribution center in location t.

Using this notation, the mathematical form of the transshipment formulation of the general linear programming model is the following:

Minimize:

$$F(X) = \sum_{i=1}^{v} \sum_{j=1}^{p} X_{ij}^{a,u} (C_i^a + T_{ij}^a) + X_{ij}^{a,n} (C_i^a + T_{ij}^a) +$$

$$+ X_{ij}^{a,s} (C_i^a + T_{ij}^a) + X_{ij}^{a,c} (C_i^a + T_{ij}^a) + X_{ij}^{a,nt} (C_i^a + T_{ij}^a) +$$

$$+ \sum_{j=1}^{p} \sum_{t=1}^{m} X_{jt}^u (C_j^u + T_{jt}^u) + X_{jt}^n (C_j^n + T_{jt}^n) +$$

$$+ X_{jt}^s (C_j^s + T_{jt}^s) + X_{jt}^c (C_j^c + T_{jt}^c) +$$

$$+ X_{jt}^{nt} (C_j^{nt} + T_{jt}^{nt}) \qquad (1)$$

Subject to the following restraints:

$$0 \leq \sum_{j=1}^{p} X_{ij}^a \leq R_i^a \qquad \text{for all } i \qquad (2)$$

$$0 \leq \sum_{t=1}^{m} X_{jt}^u \leq R_j^u \qquad \text{for all } j \qquad (3)$$

$$0 \leq \sum_{t=1}^{m} X_{jt}^n \leq R_j^n \qquad \text{for all } j \qquad (4)$$

$$0 \leq \sum_{t=1}^{m} X_{jt}^{s} \leq R_j^{s} \qquad \text{for all } j \qquad (5)$$

$$0 \leq \sum_{t=1}^{m} X_{jt}^{c} \leq R_j^{c} \qquad \text{for all } j \qquad (6)$$

$$0 \leq \sum_{t=1}^{m} X_{jt}^{nt} \leq R_j^{nt} \qquad \text{for all } j \qquad (7)$$

Production levels of ammonia and final products are nonnegative and cannot be greater than plant processing capacities.

$$\sum_{i=1}^{v} X_{ij}^{a,u} = \sum_{t=1}^{m} X_{jt}^{u} \qquad \text{for all } j = i \qquad (8)$$

$$\sum_{i=1}^{v} X_{ij}^{a,n} = \sum_{t=1}^{m} X_{jt}^{n} \qquad \text{for all } j \qquad (9)$$

$$\sum_{i=1}^{v} X_{ij}^{a,s} = \sum_{t=1}^{m} X_{jt}^{s} \qquad \text{for all } j \qquad (10)$$

$$\sum_{i=1}^{v} X_{ij}^{a,c} = \sum_{t=1}^{m} X_{jt}^{c} \qquad \text{for all } j \qquad (11)$$

$$\sum_{i=1}^{v} X_{ij}^{a,nt} = \sum_{t=1}^{m} X_{jt}^{nt} \qquad \text{for all } j \qquad (12)$$

The total quantity of ammonia inshipments to a final product processing site is equal to the total quantity of outshipments of final product to distribution centers, expressed in metric tons of ammonia equivalents.

$$X_{ij}^{a,u} = 0 \qquad \text{for all } i \neq j \qquad (13)$$

Urea must be processed in a location where ammonia is produced and the necessary inputs CO and CO_2 are generated; therefore, processing capacity of urea must be smaller or equal to ammonia processing capacity in a given location. Inshipments of ammonia, from other locations, for urea processing are not feasible.

$$0 \leq \sum_{j=1}^{m} X_{jt}^{u} + X_{jt}^{n} + X_{jt}^{s} + X_{jt}^{c} + X_{jt}^{nt} \geq D_t \quad \text{for all } t \qquad (14)$$

The quantity of final products, expressed in metric tons of ammonia equivalents, shipped to a distribution center is nonnegative and it is greater than or equal to the quantity demanded.

$$X_{ij}^{a,u};\ X_{ij}^{a,n};\ X_{ij}^{a,s};\ X_{ij}^{a,c};\ X_{ij}^{a,nt} \geq 0 \qquad (15)$$

$$X_{jt}^{u};\ X_{jt}^{n};\ X_{jt}^{s};\ X_{jt}^{c};\ X_{jt}^{nt} \geq 0 \qquad (16)$$

All ammonia and final products shipments are nonnegative. Also, the following qualifications of parameters are considered:

$$D_t \geq 0 \quad \text{for all } t \qquad (17)$$

All quantities demanded at each distribution center are nonnegative.

$$R_i^{a};\ R_j^{u};\ R_j^{n};\ R_j^{s};\ R_j^{c};\ R_j^{nt} \geq 0 \qquad (18)$$

All ammonia and final products processing capacities are nonnegative.

The basic model as formulated will handle individual country problems as well as problems for the Andean group countries as a whole.

Limitations of the Model and Sources of Error

The limitations of the model arise primarily from the simplifying assumption set up to permit a workable real-world counterpart of the theoretical model.

The assumption that the nitrogen coming from different final products is homogeneous, and, therefore, all final products are assumed to be perfect substitutes in consumption, is rather strong, especially if compound fertilizers were to be included in the analysis. Compound fertilizers contain phosphorous and potassium, so, their consumption is rather a function of demand for these nutrients in addition to nitrogen. However, since they are also a source of supply of nitrogen, their production cannot be excluded from this study. Even though nitrogen produced in the form of compound fertilizers is rather small compared to the supply of nitrogen in the other final products, and even though cost adjustments have been made in this study to take care of the supply of other nutrients, results obtained on these fertilizers production and use still must be taken with caution. Even sources of nitrogen such as urea and ammonium sulfate cannot be considered as perfect substitutes because of restrictions imposed by soil and ecological conditions. For simple nitrogen fertilizers, however, the assumption does not seem to imply much error.

The expression of all costs in terms of 1970 constant dollars at nominal official exchange rates tend to bias upwards the costs for countries with overvaluation of domestic currencies; which seems

to be the case for Colombia, Ecuador, Peru, Chile, and Bolivia in different degrees. On the other hand, countries with a tendency to undervaluation of domestic currencies, such as Venezuela in recent years, cause their costs to be bias downwards. These distortions, which may in some cases result in alternations of "optimum" flow patterns, are not accounted for by this model. Nevertheless, if the Andean Group Common Market is going to be successful, some degree of harmonization of monetary policies, or more specifically, of foreign exchange policies, will have to be achieved. It is expected, then, that these distortions will not significantly affect the conclusions of this study.

To assume that the relative prices of various inputs at each location and the relative price of each input at various locations will remain unchanged between the base year 1970 and the projected years 1975, 1980, and 1985 is undoubtedly a source of error. Attempting to foresee all sorts of changes and indirect effects that may take place over time poses a special problem in developing countries. Technology will not remain the same and relative prices will change in directions and magnitudes that are difficult to predict. These sources of error are not inherent to the model itself, but to the more general problem of making projections.

Another limitation of the model arises from its inability to account either for economies of scale or from the assumption that per unit processing costs are constant as if all producing plants were operating at full capacity. This tends to bias results in favor of production and outshipments from large size plants, the magnitude

of the bias (or error) depending on the ability of producing plants with excess capacity to export to the rest of the world market. If these plants have processing costs to enable them to compete in the world market, this assumption will be correct; if this were not the case, errors will be included in the solutions. An analysis of the results with an evaluation of export possibilities of plants with excess capacities will indicate how reasonable this assumption is and/or the inability of the model to account for economies of scale.

Uses of the Model

Solutions of minimum cost flow patterns, levels of production and excess capacities of existing and planned production facilities of the nitrogenous fertilizer industry, for independent country cases as well as for the Andean Group countries operating as a Custom Union can be obtained. Also, "welfare gains" or resources saved by Andean Group countries as a result of a common market can be estimated. Effects of alternative policies of protection such as quotas, tariffs, or subsidies can be evaluated in terms of transfers between surpluses of consumers, producers, and government. The model permits estimation of these magnitudes by comparing results of independent country solutions with those implied by a Custom Union solution.

Sensitivity to changes in transport costs, degrees of overvaluation or subvaluation of domestic currencies, and demand projections may be evaluated as to their impact on minimum cost flow patterns, levels of production of facilities, and resource savings.

CHAPTER 4
THE SUPPLY SYSTEM

Production Facilities of the Nitrogenous Fertilizer Industry in Andean Group Countries

Basic information on the availability of production facilities has been obtained from publications of "La Junta del Acuerdo Cartagena"[5] and directly from interviews of producers and institutions in charge of planning and supervising fertilizers production and/or marketing such as the "Instituto Venezolano de Petroquimica." Also, information has been obtained from Tennessee Valley Authority publications of studies made in these countries.

Table 1 shows production facilities of ammonia and final products; urea, ammonium nitrate, ammonium sulfate, and compounds; available in the Andean Group countries. All of these plants can be considered to be under operation, with the exception of the planned ammonia plants at Puerto La Cruz in Venezuela, Yacuiba in Bolivia, and Punta Arenas in Chile; and urea plants in Yacuiba and Punta Arenas. Size of plants or plants' processing capacities are expressed in terms of metric tons of material, nitrogen nutrient, and ammonia equivalents per year. As established by the model, the relevant capacities are those expressed in metric tons of ammonia equivalents per year.

In addition to the production facilities shown in Table 1, facilities to produce other intermediate products necessary for the

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[5]See Junta del Acuerdo de Cartagena (1973) and Instituto Latino-Americano de Planificacion Economica y Social (1972).

Table 1. Production facilities of ammonia and final products of the nitrogenous fertilizer industry in Andean Group countries

Country	Plant location	Product	Size of plant		
			Metric tons of material per year	Metric tons of nitrogen nutrient per year	Metric tons of ammonia per year
Venezuela	Maracaibo	Ammonia	297,000		297,000
	Maracaibo	Ammonia	297,000		297,000
	Maracaibo	Urea	396,000	180,180	227,027
	Maracaibo	Urea	396,000	180,180	227,027
	Moron	Ammonia	198,000		198,000
	Moron	Urea	247,500	112,612	141,891
	Moron	Compounds	58,400	26,280	33,113
	Pto. La Cruz	Ammonia	495,000		495,000
Colombia	Cartagena	Ammonia	132,000		132,000
	Barrancabermeja	Ammonia	17,800		17,800
	Barrancabermeja	Urea	12,800	5,824	7,338
	Barrancabermeja	Ammonia/nitrate	23,290	8,268	10,418
	Barranquilla	Urea	89,100	40,540	51,080
	Barranquilla	Compounds	43,554	19,600	24,696
	Monomeros	Compounds	99,000	45,000	56,700
Ecuador	Guayaquil	Ammonium sulfate	32,234	6,930	8,732
	Guayaquil	Compounds	33,000	15,000	18,900
Peru	Talara	Ammonia	99,000	76,440	99,000
	Talara	Urea	168,300		96,315
	Callao	Ammonia	29,700		29,700

Table 1 (continued)

Country	Plant location	Product	Size of plant		
			Metric tons of material per year	Metric tons of nitrogen nutrient per year	Metric tons of ammonia per year
Peru	Callao	A. nitrate	39,600	14,234	17,934
	Callao	Ammonium sulfate	14,500	3,120	3,929
	Cachimayo	Ammonia	11,183		11,183
	Cachimayo	Ammonium nitrate	25,000	8,875	11,183
Bolivia	Yacuiba[a]	Ammonia	198,000		198,000
	Yacuiba[a]	Urea	297,000	135,135	170,270
Chile	Antafogasta	Nitrates		97,500	122,850
	Punta Arenas[a]	Ammonia	198,000		198,000
	Punta Arenas[a]	Urea	297,000	135,135	170,270

[a]Plants in planning stage, expected to be in operation by 1980.

manufacturing of final products are required, as shown by Figure 1. Some of these facilities available in Andean Group countries are listed in Table 2. All of the processing facilities of these intermediate products are not included since they are also imputs to other industries.

Processing Activities and Input-Output Relations

Many different materials are capable of supplying Nitrogen as a fertilizer, but economics and other factors have narrowed the list so that most the world's commercial fertilizer is supplied by a few forms of material. During the last 15 years significant changes have occurred in the world fertilizer industry. Ammonium sulfate has been displaced as the principal source of fertilizer nitrogen by urea, and ammonium nitrate is now the second most important nitrogen fertilizer.

A very simple scheme of the relationships among raw materials, intermediate products, and final products implied by different processing activities is presented in Figure 1. Ammonia is the principal form in which fixed nitrogen is available for the manufacture of fertilizers in the world today. Different raw materials such as natural gas, naphtha, heavy fuel oil, coal, electrolytic hydrogen, etc., and associated processing techniques can be used in the production of ammonia. With the exception of ammonia plants at Callao and Cachimayo in Peru, and Barrancabermeja in Colombia, all ammonia plants in Andean Group countries use natural gas as raw materials.

It is not the purpose of this study to discuss in detail the technological aspects of manufacturing intermediate and final fertilizer

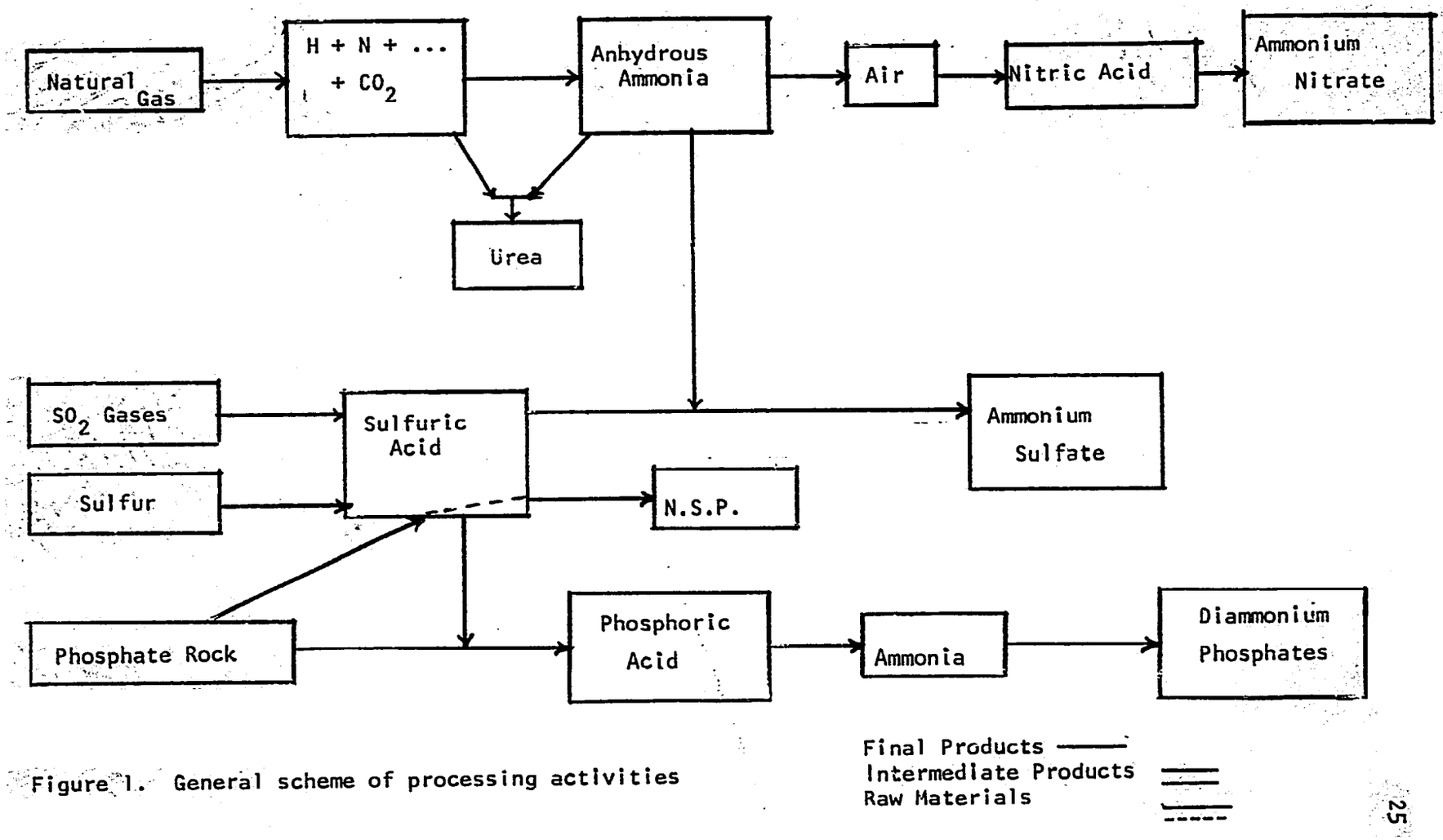

Figure 1. General scheme of processing activities

Table 2. Some production facilities of other intermediate products of the nitrogenous fertilizer industry in Andean Group countries

Country	Plant location	Product	Size of Plant Metric tons of material per year
Venezuela	Moron	Sulfuric acid	198,000
	Moron	Sulfuric acid	198,000
	Moron	Nitric acid	49,500
Colombia	Cartagena	Nitric acid	49,500
	Barrancabermeja	Nitric acid	30,100
	Barranquilla	Nitric acid	74,580
Ecuador	Guayaquil	Sulfuric acid	41,000
Peru	Callao	Nitric acid	8,250
	La Oraya	Sulfuric acid	66,000
Chile	Chuquicamata	Sulfuric acid	165,000
	Aconcagua	Sulfuric acid	33,000

products. However, certian input-output relationships must be specified in order to understand better the processing activities included in the model. Following the "processing flow" of Figure 1 the main input-output relations are described in Table 3. These input-output relations between intermediate and final products are basically independent of the processing technology adopted. The small variations that may exist are assumed to be insignificant.

Ammonia and sulfuric acid are used in the processing of ammonium sulfate, nitric acid, and ammonia in the manufacturing of ammonium nitrate, and only ammonia in production of urea. The last two rows of Table 3 are the input-output relations of ammonia contained in nitric acid and total ammonia, respectively; developed to standardize units in terms of ammonia equivalents (metric tons of ammonia). Input-output relations expressing outputs in units of fertilizer material and nitrogen nutrient are presented.[6]

For the case of compound fertilizers, it is necessary to point out that the input-output relation's expressing output in fertilizer material units may be misleading since they vary substantially with the type of fertilizer considered. However, relations expressing output in terms of nitrogen nutrient units are rather accurate. Input-output relations expressing output in terms of nitrogen nutrient units are used to standardize units to ammonia equivalents. Thus, not many errors, if any, are brought about by these relations.

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[6] Input-output relations developed from information in: United Nations Industrial Development Organization (1967) and Bixby et al., (1966).

Table 3. Main input-output relations

Inputs/outputs	Nitric acid	Ammonium nitrate		Ammonium sulfate		Urea		Compounds	
		Material	Nitrogen	Material	Nitrogen	Material	Nitrogen	Material	Nitrogen
Ammonia	0.29	0.22	0.61	0.26	1.26	0.58	1.26	0.23	0.62
Sulfuric acid				0.757	3.60				
Nitric acid		0.80	2.25					0.33	2.2
Ammonia in nitric acid		0.23	0.65					0.24	0.64
Total ammonia		0.45	1.26	0.26	1.26	0.58	1.26	0.47	1.26

Costs of Production Estimation

As pointed out before, this study is designed to compliment the planning and decision making process of governments and policy makers of Andean Group countries by emphasizing the interrelationships between nitrogenous fertilizers (and plants) of these countries and by illustrating the industry-wide consequences of alternative policies, including the establishment of a common market (Custom Union). Hence, emphasis is given to using costs and technical relationships which are generally representative of the industry as a whole, rather than trying to represent accurately any specific firm or plant. For obvious reasons, it is quite impossible to obtain precise information on economic costs of production for each plant. Estimated costs of production must, therefore, be derived using engineering data and a set of standardized assumptions.

In some instances the manufacturing and investment cost estimates considered by this study may differ slightly from values computed by other studies. They may not be as reliable for some specific situations as more in-depth estimates by others. However, the use of somewhat standardized assumptions which are believed to be reasonably accurate and reliable insure that the various alternative processes and supply systems are evaluated on the same basis.

Assumptions and Procedures

Basically, factors are categorized as "fixed" and "variable" consistent with the economic meaning of these terms. That is, fixed factors are inputs to a process or activity that do not vary directly

with the level of output, whereas the quantity used of a variable factor varies directly in proportion to the level of the output of that activity.

Production facilities or plants are assumed to be already built at corresponding points in time. Fixed factor costs or fixed costs of production are assumed to be the following:

(a) Operating labor: assumed to be a fixed cost since very small changes of operating labor cost, if any, occur by changing levels of output. A rate of $3 per man-hour is assumed, even when in developing countries a lower rate would apply. Experience indicates that larger numbers of personnel would be used at lower wage rates and the total cost should be about the same.

(b) Analysis: cost assumed to be equal to 20 percent of operating labor cost.

(c) Handling: in-plant handling cost is assumed to be equal to 4 percent of operating labor cost.

(d) Overhead: assumed to be equal to 100 percent of operating labor cost.

(e) Depreciation: 15 years straight line depreciation or 6.67 percent of plant investment.

(f) Interest: assumed to be 8 percent of one-half of plant investment or 4 percent of plant investment per year.

(g) Maintenance: assumed to be equal to 5 percent of plant investment.

(h) Supplies: assumed to be equal to 10 percent of operating labor cost.

These assumptions were developed from several studies made by the Tennessee Valley Authority in Andean countries.

The main variable factors or variable costs are assumed to be the following:

(a) raw materials such as natural gas, heavy oil, etc.

(b) electrical power

(c) cooling water

(d) boiler feed water

(e) steam

(f) fuel

(g) catalysts and chemicals

(h) other variable factors inherent to each processing activity

Per unit cost of variable factors were estimated for each country. Assumptions about investment estimates are the following:

(a) The battery limits investment cost (cost of processing equipment and its installation) of various plant units in the Andean countries was assumed to be 1.3 times corresponding United States battery limits costs.

(b) The cost of auxiliary facilities (steam, power, water, supply, etc.) was assumed to be 25 percent of the total battery limits cost of the plant unit.

(c) The cost of supporting facilities (roads, civil works, office and administrative buildings, etc.) is assumed to be 25 percent of the total battery limits cost plus 25 percent of auxiliary facilities cost.

(d) Investment cost of existing plants was estimated taking as a basis the year in which the plant was built. An additional assumption is that no return on investment above interest cost is to be obtained, i.e., 0 percent return on investment is assumed for all cost estimates.

Using input-output relations as specified in Table 3 and the above assumptions, processing costs for ammonia and final products were estimated by simple budgeting.

Estimates of Ammonia Processing Costs and Economies of Scale

Estimates of processing costs of ammonia at production facilities in Andean Group countries are shown in Table 4. These costs are estimated as if plants were operating at full capacity. Average total

Table 4. Processing costs of ammonia at production facilities

Inputs	Input units	Input-output ratios	Venezuela: Maracaibo 297,000 m.t./year: Per unit input cost (dols.)	Maracaibo: Dols. per m.t. of ammonia	Moron 198,000 m.t./year: Per unit input cost (dols.)	Moron: Dols. per m.t. of ammonia	Puerto La Cruz 495,000 m.t./year: Per unit input cost (dols.)	Puerto La Cruz: Dols. per m.t. of ammonia
Natural gas	1,000 $ft.^3$	38.50	0.15	5.78	0.15	5.78	0.15	5.78
Electricity	KWH	50.00	0.015	0.75	0.015	0.75	0.015	0.75
Cooling water	1,000 gal.	75.00	0.02	1.50	0.02	1.50	0.02	1.50
Boiler feed water	1,000 gal.	0.53	0.40	0.21	0.40	0.21	0.40	0.21
Catalysts				0.50		0.50		0.50
Average variable cost				8.74		8.74		8.74
Operating labor				2.20		2.62		2.61
Analysis				0.44		0.52		0.52
Handling				0.09		0.11		0.11
Overhead				2.20		2.62		2.62
Depreciation				6.50		6.68		6.02
Interest				3.90		4.00		3.61
Maintenance				4.87		5.00		4.51
Supplies				0.22		0.27		0.26
Insurance				0.17		0.17		0.15
Average fixed cost				20.59		21.99		20.41
Average total cost				29.33		30.73		29.15
Plant investment		28,950,000			19,810,000		44,687,000	

Table 4. (continued)

Inputs	Input units	Input-output ratios	Colombia: Cartagena[a] 132,000 m.t./year: Per unit input cost (dols.)	Colombia: Cartagena[a] 132,000 m.t./year: Dols. per m.t. of ammonia	Colombia: Barrancabermeja[b] 17,800 m.t./year: Per unit input cost (dols.)	Colombia: Barrancabermeja[b] 17,800 m.t./year: Dols. per m.t. of ammonia	Peru: Talara 99,000 m.t./year: Per unit input cost (dols.)	Peru: Talara 99,000 m.t./year: Dols. per m.t. of ammonia
Natural gas	1,000 ft.^{3}	38.50	0.21	8.09			0.20	7.68
Electricity	KWH	50.00	0.015	0.75			0.015	0.76
Cooling water	1,000 gal.	75.00	0.016	1.21			0.029	2.18
Boiler feed water	1,000 gal.	0.53	0.28	0.15			0.38	0.20
Catalysts				0.50				0.50
Average variable cost				10.70		16.64		11.32
Operating labor				2.80				3.00
Analysis				0.56				0.56
Handling				0.11				0.11
Overhead				2.80				3.00
Depreciation				5.91				10.51
Interest				3.55				6.30
Maintenance				4.43				7.87
Supplies				0.28				0.28
Insurance				0.15				0.27
Average fixed cost				20.59		34.65		31.90
Average total cost				31.29		51.84		43.22
Plant investment			11,700,000[a]				15,600,000	

Table 4. (continued)

Inputs	Input units	Input-output ratios	Peru: Callao[c] 29,700 m.t./year: Per unit input cost (dols.)	Peru: Callao[c] 29,700 m.t./year: Dols. per m.t. of ammonia	Peru: Cachimayo[d] 25,000 m.t./year: Per unit input cost (dols.)	Peru: Cachimayo[d] 25,000 m.t./year: Dols. per m.t. of ammonia
Bunker & oil				12.75		
Natural gas	1,000 ft.^{3}	38.50	0.02			
Electricity	KWH	50.00	0.02	1.50		
Cooling water	1,000 gal.	75.00	0.38	0.11		
Boiler feed water	1,000 gal.	0.53		1.48		
Catalysts						
Average variable cost				15.84		
Operating						
Labor				3.00		
Analysis				0.60		
Handling				0.12		
Overhead				3.00		
Depreciation				14.60		
Interest				8.75		
Maintenance				10.94		
Supplies				0.30		
Insurance				0.38		
Average fixed cost				41.69		
Average total cost				57.53		80.00
Plant investment			6,500,000			

Table 4. (continued)

Inputs	Input units	Input-output ratios	Bolivia: Yacuiba 198,000 m.t./year: Per unit input cost (dols.)	Bolivia: Yacuiba 198,000 m.t./year: Dols. per m.t. of ammonia	Bolivia: Yacuiba 330,000 m.t./year: Per unit input cost (dols.)	Bolivia: Yacuiba 330,000 m.t./year: Dols. per m.t. of ammonia	Chile: Punta Arenas 198,000 m.t./year: Per unit input cost (dols.)	Chile: Punta Arenas 198,000 m.t./year: Dols. per m.t. of ammonia
Bunker & oil								
Natural gas	1,000 ft.^{3}	38.50	0.20	7.70	0.20	7.70	0.10	3.85
Electricity	KWH	50.00	0.02	1.00	0.02	1.00	0.01	0.50
Cooling water	1,000 gal.	75.00	0.02	1.54	0.02	1.54	0.02	1.50
Boiler feed water	1,000 gal.	0.53	0.40	0.21	0.40	0.21	0.47	0.25
Catalysts				0.50		0.50		0.50
Average variable cost				10.95		10.95		6.60
Operating labor				2.61		2.18		2.61
Analysis				0.51		0.43		0.51
Handling				0.10		0.09		0.10
Overhead				2.61		2.18		2.61
Depreciation				6.69		6.01		6.69
Interest				4.00		3.60		4.00
Maintenance				5.00		4.51		5.00
Supplies				0.28		0.23		0.28
Insurance				0.17		0.16		0.17
Average fixed cost				21.97		19.39		21.97
Average total cost				32.92		30.34		28.57
Plant investment			19,810,000		29,740,000		19,810,000	

Table 4. (continued)

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[a]Investment cost estimated for plant built in 1962.

[b]Estimated from data in: McCamy and Waggoner (1970).

[c]Different processing technique using Bunker & oil, rather than natural gas, as basic raw material.

[d]Different processing technique: electric hydrogen process.

cost or cost of processing ammonia per metric ton varies from $28.57 in projected plant at Punta Arenas, Chile, to an estimated $80 at Cachimayo--these plants being of different size and using different processing technology and raw materials. Most of the plants, however, use natural gas as raw material. For these plants estimated costs of ammonia processing per metric ton varies from $28.57 in Punta Arenas, Chile, to $43.22 in Talara, Peru. These differences arise mainly from differences in size (198,000 metric tons per year for the plant at Punta Arenas versus 99,000 metric tons for the plant at Talara) and also due to differences in the most important element of in-plant costs, that is, the cost of natural gas ($.20 per 1,000 cubic feet in Talara versus $.10 in Punta Arenas). Differences in average variable costs among plants using natural gas as raw material are due basically to differences in costs of natural gas. Other variable costs such as electricity, boiler feed water, etc., represent a rather small proportion of total costs. Although some differences in costs of these factors exist among countries, they can not be considered great enough to affect total costs of production significantly.

Estimated average variable costs indicate that Chile and Venezuela have a significant advantage in production costs at their plant sites.

In reference to economies of scale in the production of ammonia, the average fixed cost for various plant sizes using the same production techniques provides an estimate of the economies of scale in the production of ammonia. Assumptions on operating labor costs and other fixed costs make these costs independent of the prices of fixed factors in each country. However, if the average total cost is used as a

measure of economies of scale, this would not be the case since total costs are then a function of the prices of variable factors which are different among countries.

The slope of an average cost curve at any given level of production is equal to the derivative of the average cost function with respect to the quantity produced. Assuming a linear total cost curve, it is possible to compare changes in average cost at a given output for different plants: Let: A.F.C. = average fixed cost

T.F.C. = total fixed cost

q = output

then:

$$A.F.C. = \frac{(T.F.C.)}{q}$$

$$\frac{d(A.F.C.)}{dq} = - \frac{T.F.C.}{q^2} = - \frac{(A.F.C.)q}{q^2} = - \frac{A.F.C.}{q}$$

To compare the slope of average fixed cost curves of ammonia plants using natural gas as raw material at an annual output of 96,000 metric tons of ammonia, we let q = 96,000. Then it is possible to obtain:

Ammonia plants location	Plant size (m.t./year)	Slope of average fixed cost curve ($/thousand m.t.)
Talara	99,000	-0.34
Moron	198,000	-0.47
Maracaibo	297,000	-0.66
Puerto La Cruz	495,000	-1.10

The slope of the average fixed cost curve of each plant size can be taken as a measure of the economies that take place in unit processing cost by increasing output from a given level q, in this case 96,000 metric tons of ammonia per year. However, it is necessary to make a

clear separation between economies of scale in physical production units and the slope of an average cost curve showing changes in costs from increasing output. Assuming the same technology and prices of other factors constant, economies of scale can be expressed in terms of annual output of ammonia in metric tons per unit of capital investment. Let one unit of capital equal $1,000 of plant investment; then for the same plants we have:

Ammonia plants	Size (m.t./year)	Annual output per unit of capital (m.t. of ammonia/year/$1,000)
Talara	99,000	6.34
Moron	198,000	9.99
Maracaibo	297,000	10.26
Puerto La Cruz	495,000	11.08

Annual output per unit of capital can be taken as an estimate of economies of scale in physical production units.

Estimates of Final Products Processing Costs and Economies of Scale

Urea: Estimates of Urea processing costs net of ammonia cost, at different processing facilities in the Andean Group countries, are shown in Table 5. Average unit costs are estimated as if the plants were operating at full capacity and are expressed in dollars per metric ton of urea, nitrogen nutrient and ammonia equivalents. Costs per metric ton of ammonia equivalents are the relevant ones to be used in the model and they represent the cost of transforming one metric ton of ammonia into urea. Costs per metric ton of ammonia equivalent have been derived from the costs of processing one metric ton of urea given the 45.5 percent of nitrogen nutrient content in urea

Table 5. Processing costs of urea at production facilities

Inputs	Input units	Input-output ratios, input/ m.t. urea	Venezuela					
			Maracaibo 227,027 m.t. of am.eq.			Moron 141,891 m.t. of am.eq.		
			Dols. per m.t. of urea	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.	Dols. per m.t. of urea	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.
Electricity	Kwh	170	2.55			2.55		
Cooling waters	1,000 gal.	32	0.64			0.64		
Steam	1,000 gal.	4.2	1.68			1.68		
Av. variable cost			4.87	10.70	8.49	4.87	10.70	8.49
Operating labor			2.50			2.50		
Analysis			0.50			0.50		
Handling			0.10			0.10		
Overhead			2.50			2.50		
Depreciation			3.49			4.06		
Interest			2.09			2.73		
Maintenance			2.62			3.40		
Supplies			0.25			0.24		
Insurance			0.09			0.10		
Average fixed cost			14.14	31.08	24.66	16.13	35.47	28.15
Average total cost			19.01	41.78	33.15	21.00	46.17	36.64
Plant investment			20'720,000			17'053,000		

Table 5. (continued)

Inputs	Input units	Input-output ratios, input/ m.t. urea	Barranquilla 51,080 m.t. of am.eq.			Barrancabermeja[a] 7,338 m.t. of am.eq.		
			Dols. per m.t. of urea	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.	Dols. per m.t. of urea	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.
Electricity	Kwh	170	2.60					
Cooling waters	1,000 gal.	32	0.58					
Steam	1,000 gal.	4.2	1.95					
Av. variable cost			5.13	11.27	8.94	30.59	67.23	53.35
Operating labor			2.64					
Analysis			0.53					
Handling			0.11					
Overhead			2.64					
Depreciation			5.88					
Interest			3.52					
Maintenance			4.41					
Supplies			0.26					
Insurance			0.15					
Average fixed cost			20.14	44.25	35.13	14.32	31.47	24.98
Average total cost			25.27	55.53	44.07	44.91	98.70	78.33
Plant investment			7'850,000					

Table 5 (continued)

Inputs	Input units	Input output ratios, input/ m.t. urea	Peru Talara 96,315 m.t. of am.eq. Dols. per m.t. of urea	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.
Electricity	Kwh	170	3.40		
Cooling waters	1,000 gal.	32	0.64		
Steam	1,000 gal.	4.2	1.68		
Av. variable cost			5.72	12.57	9.98
Operating labor			2.55		
Analysis			0.51		
Handling			0.10		
Overhead			2.55		
Depreciation			5.24		
Interest			3.14		
Maintenance			3.93		
Supplies			0.25		
Insurance			0.14		
Average fixed cost			18.41	40.46	32.11
Average total cost			24.13	53.03	42.09
Plant investment			13'203,120		

Table 5 (continued)

Inputs	Input units	Input output ratios, input/ m.t. urea	Bolivia: Yacuiba 170,270 m.t. of am.eq. Dols. per m.t. of urea	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.	Yacuiba 283,783 m.t. of am.eq. Dols. per m.t. of urea	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.
Electricity	Kwh	170	3.40			3.40		
Cooling waters	1,000 gal.	32	0.64			0.64		
Steam	1,000 gal.	4.2	1.68			1.68		
Av. variable cost			5.72	12.57	9.98	5.72	12.57	9.97
Operating labor			2.22			2.20		
Analysis			0.44			0.44		
Handling			0.09			0.09		
Overhead			2.22			2.20		
Depreciation			4.25			3.99		
Interest			2.55			2.39		
Maintenance			3.18			2.99		
Supplies			0.22			0.22		
Insurance			0.11			0.11		
Average fixed cost			15.30	33.63	26.69	14.63	32.17	25.54
Average total cost			21.02	46.20	36.67	20.35	44.74	35.51
Plant investment			18'910,000			29'433,600		

Table 5 (continued)

Inputs	Input units	Input-output ratios, input/ m.t. urea	Chile: Punta Arenas 170,270 m.t. of am.eq. Dols. per m.t. of urea	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.
Electricity	Kwh	170	1.71		
Cooling waters	1,000 gal.	32	0.64		
Steam	1,000 gal.	4.2	2.14		
Av. variable cost			4.49	9.87	7.83
Operating labor			2.22		
Analysis			0.44		
Handling			0.09		
Overhead			2.22		
Depreciation			4.25		
Interest			2.55		
Maintenance			3.18		
Supplies			0.22		
Insurance			0.11		
Average fixed cost			15.30	33.62	26.68
Average total cost			19.79	43.49	34.51
Plant investment			18'910,000		

[a]Modified old plant using different processing technique.

and the input-output relation of 1.26 metric tons of ammonia per metric ton of nitrogen nutrient. This is:

$$\text{Dols./m.t. of nitrogen} = \frac{\text{Dols./m.t. of urea}}{0.455}$$

$$\text{Dols./m.t. of ammonia equivalents} = \frac{\text{Dols./m.t. of nitrogen}}{1.26}$$

Hence:

$$\text{Dols./m.t. of ammonia equivalent} = \frac{\text{Dols./m.t. of urea}}{0.5733}$$

Except for the case of Barrancabermeja's plant, which uses a different processing technique, average variable costs are similar among plants. The small differences which exist are due to variation in the costs of electricity among countries.

Average total cost of processing urea, net of ammonia, in dollars per metric ton of ammonia equivalent, varies from $78.33 at Barrancabermeja to $33.15 at Maracaibo. Exclusion of the Barrancabermeja plant reduces cost variations from $33.15 at Maracaibo to $42.09 at Talara, these fluctuations being basically due to differences in plant size. Average total costs as specified in Table 5 represent points on the long-run average total cost curve.

Following the same procedure used for the case of ammonia plants, the slope of the averrag fixed cost curve can be taken as a measure of the economies that take place by increasing production from a given level of output. For an annual output level of 96,000 metric tons of ammonia equivalents we have:

Urea plants	Plant size	Slope of average fixed cost curve
Talara	96,315	-0.33
Moron	141,891	-0.43
Yacuiba	170,270	-0.49
Maracaibo	227,027	-0.61

Comparing these results to those of ammonia processing at plants in Talara, Moron, and Maracaibo; economies associated with output increments, as measured by the slope of the average fixed cost curve, are a little smaller in urea processing than in ammonia production.

Ammonium Nitrate. Estimates of processing costs of ammonium nitrate are presented in Table 6. These estimates do not include the cost of ammonia used in processing nitric acid. Neither do they include the cost of ammonia used directly in ammonium nitrate processing.

Plants at Barrancabermeja and Cachimayo have faced technical operating difficulties. This and differences in processing techniques have made it necessary to use data from other studies to derive estimates of processing costs. A specific study made by The Tennessee Valley Authority in Colombia (McCamy and Waggoner, 1970) and an evaluation of the Cachimayo plant in Peru were used for this purpose. For the plant at Callao, however, our standardized assumptions were applied. For all cases, adjustments in nitric acid costs (net of ammonia cost) were made.

Average processing costs are expressed in dollars per metric ton of ammonium nitrate, nitrogen nutrient, and ammonia equivalents. Costs per metric ton of ammonia equivalents are derived in the same fashion as those for the case of urea, using this time a nutrient nitrogen content of 35.5 percent and an input-output relation of 1.26 metric tons of ammonia per metric ton of nitrogen nutrient processed in the form of ammonium nitrate.

$$\text{Dols./m.t. of ammonia equivalent} = \frac{\text{Dols./m.t. of ammonium nitrate}}{1.26\ (0.355)}$$

Table 6. Processing costs of ammonium nitrate at production facilities

Inputs	Input units	Input-output ratios, input/ m.t. material	Colombia			
			Barrancabermeja[a] 10,418 m.t. of am. eq.			
			Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.
Netric acid	m.t.	0.80				
Electricity	Kwh	30.00				
Steam	1,000 gal.	0.54				
Average variable cost				34.28	96.58	76.65
Operating labor						
Analysis						
Handling						
Overhead						
Depreciation						
Interest						
Maintenance						
Supplies						
Insurance						
Average fixed cost				17.52	49.32	39.15
Average total cost				51.80	145.91	115.80
Plant investment						

Table 6 (continued)

Inputs	Input units	Input-output ratios, input/ m.t. material	Peru: Callao 17,934 m.t. of am. eq. Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nitrogen	Dols. per m.t. of am. eq.
Netric acid	m.t.	0.80	21.59	17.27		
Electricity	kwh	30.00	0.02	0.60		
Steam	1,000 gal.	0.54	0.50	0.27		
Avêrage variable cost				18.14	51.12	40.56
Operating labor				1.20		
Analysis				0.24		
Handling				0.05		
Overhead				1.20		
Depreciation				3.29		
Interest				1.97		
Maintenance				2.46		
Supplies				0.12		
Insurance				0.09		
Average fixed cost				10.62	29.91	23.74
Average total cost				28.76	81.03	64.31
Plant investment			2'220,000			

Table 6 (continued)

Inputs	Input units	Input-output ratios, input/ m.t. material	Peru: Cachimayo[b] 11,183 m.t. of am. eq. Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nitrogen	Dols. per m.t. of am. eq.
Netric acid	m.t.	0.80				
Electricity	Kwh	30.00				
Steam	1,000 gal.	0.54				
Average variable cost						
Operating labor						
Analysis						
Handling						
Overhead						
Depreciation						
Interest						
Maintenance						
Supplies						
Insurance						
Average fixed cost						
Average total cost				47.59	134.07	106.4
Plant investment						

[a]Different processing technique: Ammonia produced from electrolytic hydrogen and netric acid derived from the pressure oxidation of ammonia.

[b]Modified old plant using different processing technique.

Although our cost estimates are not adequate to obtain estimates of economies of scale in ammonium nitrate processing, other studies (United Nations Industrial Development Organization, 1967) show that these are smaller than those for ammonia and urea processing.

Ammonium Sulfate. Processing cost estimates of ammonium sulfate net of ammonia cost are shown in Table 7 for the two processing facilities or plants in the Andean Group countries.

Avearge cost estimates are expressed in dollars per metric ton of ammonium sulfate, nitrogen nutrient, and ammonia equivalents, the last one to be used in the model. Costs per unit of ammonia equivalent are derived from the estimated cost per metric ton of fertilizer material, given that ammonium sulfate has a 21 percent nitrogen nutrient content and that 1.26 metric tons of ammonia are required to process one metric ton of nitrogen nutrient in the form of ammonium sulfate.

$$\text{Dols./m.t. of ammonia equivalent} = \frac{\text{Dols./m.t. of ammonium sulfate}}{1.26\ (0.21)}$$

$$= \frac{\text{Dols./m.t. of ammonium sulfate}}{0.2646}$$

Variations in estimated average variable costs are due to differences in costs of sulfuric acid, which have been estimated on the basis of the sulfuric acid plants in Ecuador and Peru with annual outputs of 41,000 and 66,000 metric tons, respectively.

Economies of scale cannot be estimated adequately because the plants were built at different points in time. However, they are, in general, smaller than those of ammonia and urea processing.

Table 7. Processing costs of ammonium sulfate at production facilities

Inputs	Input units	Input-output ratios, input/ m.t. of material	Ecuador Guayaquil 8,732 m.t. of am.eq. Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.
Sulfuric acid	m.t.	0.76	21.07	16.01		
Water	1,000 gal.	6.0	0.02	0.12		
Electricity	kwh	8.0	0.02	0.16		
Average variable cost				16.29	75.79	60.15
Operating labor				0.72		
Analysis				0.14		
Handling				0.03		
Overhead				0.72		
Depreciation				3.62		
Interest				2.17		
Maintenance				2.71		
Supplies				0.07		
Insurance				0.10		
Average fixed cost				10.28	47.81	37.95
Average total cost				26.57	123.50	98.10
Plant investment				914,000		

Table 7 (continued)

Inputs	Input units	Input-output ratios, input/ m.t. of material	Peru Callao 3,929 m.t. of am.eq.			
			Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nitrogen	Dols. per m.t. of am.eq.
Sulfuric acid	m.t.	0.76	26.07	19.81		
Water	1,000 gal.	6.0	0.02	0.12		
Electricity	kwh	8.0	0.02	0.16		
Average variable cost				20.09	93.47	74.18
Operating labor				0.72		
Analysis				0.14		
Handling				0.03		
Overhead				0.72		
Depreciation				4.94		
Interest				2.96		
Maintenance				3.71		
Supplies				0.07		
Insurance				0.13		
Average fixed cost				13.42	62.41	49.53
Average total cost				33.51	155.88	123.71
Plant investment				1'112,000		

Compound Fertilizers. Fertilizer materials such as nitrophosphates and diamonium phosphates have been designated in this study under the name of compound fertilizers. These fertilizers, in addition to nitrogen, contain phosphorous and/or potassium nutrients.

Differences in processing technology among existing plants, and in combinations or grades of nutrient content of products produced by each plant, make it very difficult to obtain precise estimates of processing costs.

To estimate processing costs for the plant at Moron, producing diamonium phosphate, the following assumptions were made:

1. Nutrient grade: 18-46-0
2. Plant capacity: 146,000 m.t./year
3. Processing technique: Tennessee Valley Authority

Given these three assumptions, which correspond to the plant at Moron, engineering information was used to derive the estimated processing costs presented in Table 8. Average costs are expressed in dollars per metric ton of fertilizer material, total nutrient content and ammonia equivalents. In order to derive the cost per metric ton of ammonia equivalent, it has been assumed that one unit of nitrogen nutrient is worth as much as one unit of phosphorus nutrient, so that, the total nutrient content can be taken as if it were nitrogen nutrient; in this case, 64 percent of nutrient content and the input-output relation of 1.26 of ammonia per unit of nitrogen nutrient were used to derive the average costs per metric ton of ammonia equivalent:

$$\text{Dols./m.t. of ammonia equivalent} = \frac{\text{Dols./m.t. of fertilizer material}}{(0.64)\ 1.26}$$

$$= \frac{\text{Dols./m.t. of fertilizer material}}{0.8064}$$

Table 8. Processing costs of compounds at production facilities

Inputs	Input units	Venezuela				
		Moron 33,113 m.t. of am.eq.				
		Input-output ratios	Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nutrient	Dols. per m.t. of nutrient
Phosphoric acid	m.t.	0.96		35.66		
Phosphate rock						
Potassium choloride						
Netric acid						
Electricity	Kwh	22	0.015	0.33		
Fuel	Gal.	3.3	0.12	0.40		
Steam						
Cooling water						
Average variable cost				36.39	56.86	45.12
Operating labor						
Analysis						
Handling						
Overhead						
Depreciation						
Interest						
Maintenance						
Supplies						
Insurance						
Average fixed cost				3.61	5.64	4.48
Average total cost				40.00	62.50	49.60

Table 8 (continued)

Inputs	Input units	Ecuador				
		Guayaquil 18,900 m.t. of am.eq.				
		Input-output ratios	Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nutrient	Dols. per m.t. of am.eq.
Phosphoric acid	m.t.					
Phosphate rock						
Potassium chloride						
Netric acid						
Electricity						
Fuel						
Steam						
Cooling water						
Average variable cost						
Operating labor						
Analysis						
Handling						
Overhead						
Depreciation						
Interest						
Maintenance						
Supplies						
Insurance						
Average fixed cost						
Average total cost				68.43	152.08	120.70

Table 8 (continued)

Inputs	Input units	Colombia				
		Barranquilla 24,696 m.t. of am. equiv.				
		Input-output ratios	Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nutrient	Dols. per m.t. of am.eq.
Phosphoric acid	m.t.	0.062	213.83	13.25		
Phosphate rock	m.t.	0.237	7.69	1.82		
Potassium chloride	m.t.	0.237	33.06	7.83		
Netric acid	m.t.	0.33	45.24	14.93		
Electricity	Kwh	30	0.015	0.45		
Fuel	Gallons		0.012	1.08		
Steam	1,000 gal.			0.12		
Cooling water	1,000 gal.	2	0.02	0.04		
Average variable cost				39.52	86.86	68.94
Operation labor				0.66		
Analysis				0.13		
Handling				0.03		
Overhead				0.66		
Depreciation				0.85		
Interest				0.51		
Maintenance				0.64		
Supplies				0.06		
Insurance				0.02		
Average fixed cost				3.56	7.82	6.21
Average total cost				43.08	94.68	75.15
				1'800,000		

Table 8 (continued)

Inputs	Input units	Colombia Monomeros 56,700 m.t. of am.eq. Input-output ratios	Per unit input cost (dols.)	Dols. per m.t. of material	Dols. per m.t. of nutrient	Dols. per m.t. of am.eq.
Phosphoric acid	m.t.	0.095	213.83	20.31		
Phosphate rock	m.t.	0.168	7.69	1.29		
Potassium chloride	m.t.	0.250	33.06	8.26		
Netric acid	m.t.	0.33	39.39	13.00		
Electricity	Kwh	47.5	0.015	0.71		
Fuel	Gallons	4.0	0.12	0.48		
Steam	1,000 gal.			0.04		
Cooling water	1,000 gal.	0.8	0.02	0.02		
Average variable cost				44.11	196.95	76.94
Operating labor						
Analysis						
Handling						
Overhead						
Depreciation						
Interest						
Maintenance						
Supplies						
Insurance						
Average fixed cost				3.92	8.61	6.84
Average total cost				48.03	105.56	83.78
			2'000,000			

Processing cost estimates, also using engineering information, were obtained for compound plants at Barranquilla and Monomeros. Both plants are assumed to produce nitrophosphates of nutrient grade 15-15-15. However, they differ in processing techniques and size of plant.

The plant at Barranquilla has an annual capacity of 140,000 metric tons of fertilizer material and is a plant of the type used by "Societe Potasse et Engrais Chimiques," whereas the plant at Monomeros has an annual capacity of 300,000 metric tons of fertilizer material and is basically a plant of the type used by The Tennessee Valley Authority.

Average cost estimates are presented in Table 8. Costs expressed in dollars per metric ton of ammonia equivalent have been derived following the same procedure as for the previously described case of the plant at Moron considering 45 percent of total nutrient content as if it were nitrogen nutrient and the input-output relation of 1.26 units of ammonia per unit of nitrogen processed in the form of nitrophosphate.

The plant at Guayaquil has been operating under strongly protective policies on domestically produced phosphoric and sulfuric acid. Processing costs are, therefore, quite high. For the purpose of this study, however, estimates of costs of production have been based on those of Monomeros with an upward adjustment for (a) greater costs of variable factors, and (b) smaller size of plant.

Economies of scale in compounds processing are very small. Variations in prices of some variable factors may easily offset the

reductions in average costs brought about by economies of scale. High proportion of variable factors cost (average variable cost) is very clear in this processing activity.

CHAPTER 5
THE TRANSPORTATION SYSTEM

The six countries that form the Andean Group stretch along the full 4,500 mile length of South America covering almost two million square miles. Large distances separate most population centers. The high, rugged Andes mountain range is the backbone of the region and the cause of many of its transportation problems. Overhead access between the Andean countries is poor. The only international railways are those linking Bolivia with Peru and Chile, and the only international road connection is provided by the Pan-American Highway. Inter-country transport of fertilizer materials is made by sea. In general, nine-tenths of the merchandise traded among the Andean countries is carried by sea. This pattern is typical of almost all Latin American countries. Chile, Peru, Ecuador, and Colombia all have ports on the Pacific, and Colombia and Venezuela have Atlantic ports. Bolivia is the only country completely landlocked but has access to the Pacific through Chilean and Peruvian ports.

Transport Cost of Final Fertilizer Products

In order to obtain transport cost estimates of shipping fertilizer materials from processing plant sites to distribution centers, transport costs were divided into:

1. Intra-country transport costs or costs of transporting fertilizers from plant site to port and from port to distribution center, and
2. Inter-country transport costs, which, in general, are composed of port charges and ocean freight costs.

Intra-Country Transport Costs

The importance of the different means of Andean intra-country transport varies from country to country depending mainly on

population, geographical, and topographical features. Colombia, with large population centers (distribution centers) in the highlands and the Magdalena River navigable from the Atlantic coast almost to Bogota, relies mainly on road and river transport. Chile, with distribution centers mainly along the long coastline, relies on coastal shipping and railways for most of its transport needs. Peru, Ecuador, Bolivia, and Venezuela rely mainly on rail and road transport. These factors in addition to some differences in quality of transportation among countries explain variations in intra-country transport costs.

Intra-country transport costs, that is, transport costs of fertilizer materials from plant sites and importing ports to distribution centers, and from plant sites to exporting ports, within each country are presented in Appendix A. These cost estimates have been derived from data in previous country studies, updating them to year 1970. Nominal 1970 exchange rates were used to estimate costs in terms of dollars per metric ton of fertilizer material.

The decision to use direct information to estimate transport costs, although more costly in terms of data gathering, was made in order to obtain more precise estimates. Estimation by using transport cost functions is expected to provide estimates with a greater degree of error. In the Andean Group countries transport costs for a given means of transportation are not only a function of distance. Geographical and topographic characteristics of a country, and even within a region of the country, are very important variables affecting transport costs and sources of error for cost estimates obtained from transport

cost functions. For example, transport cost per metric ton of fertilizer from La Paz to Cochabama, in Bolivia, is $10.87 while that from Cochabamba to La Paz is $12.68, although the distance remains constant. Stratification of data for routes, with respect to topographic characteristics and the estimation of several transport cost functions, or, the use of "dummy" variables in a generalized transport cost function, may be an alternative estimation procedure. However, data needs for these procedures are almost as great as those of obtaining direct information on transport costs between the geographical points necessary for the purpose of the model used in this study.

Inter-Country Transport Costs

Inter-country transport costs may be divided into port charges and ocean freight costs. These two components will be discussed in turn.

Port Charges. Andean countries port charges account for from 50 to 70 percent of total ocean transport costs (Brown, 1966). Estimated port charges for Andean countries ports are presented in Table 9. These figures do not take account of ship turnaround time, nor do they include surcharges on particular ports, which change frequently and can be significant. Surcharges of up to six dollars per ton and three dollars per ton plus 15 percent of the freight rate were in effect as Callao, Peru, and Valparaiso, Chile, respectively, around 1964 (Brown, 1966, p. 250).

Table 9. Port charges: Estimated costs of loading, unloading, and assumed port charges in dollars per metric ton of fertilizer materials

Country	Ports	Loading	Unloading	Assumed port charges[a]
Venezuela	Maracaibo			8.00
	Puerto Cabello			6.00
Colombia	Buenaventura	3.50	3.50	4.00
	Barranquilla	3.00	2.50	3.00
	Cartagena			3.00
Ecuador	Guayaquil	4.00	3.50	4.00
Peru	Callao	10.00	12.00	10.00
	Paita			4.00
	Salaverry			4.00
	Chimbote			4.00
	Pisco			4.00
	Matarani			4.00
Chile	Valparaiso	10.00	10.00	10.00
	Antofagasta			5.00
	San Antonio			5.00
	Talcahuano			4.00
	Pt. Montt			4.00
	Punta Arenas			4.00

[a]Estimates assumed for port charges do not take account of the different lengths of time needed to load and unload a ship in different ports, nor do they include surcharges which change frequently. Estimates for ports without available information were made on similarities of cargo handled and location.

Source: United Nations Economic Commission for Latin America (1969).

Ocean Freight Costs. Ocean freight charges are believed to be higher for trade within Latin American countries than for trade between Latin American countries and the rest of the world. Two main reasons have been suggested for the high cost of ocean freight: low volume of traffic, and discrimination by shipping conferences which are dominated by foreign companies (Dell, 1966).

Information on ocean freight costs of fertilizer materials between Andean countries is very limited. With the exception of sodium nitrate from Chile no other significant trade of fertilizer materials has taken place among Andean countries. Estimation of ocean freight costs for fertilizer materials in general was made on the basis of information on sodium nitrate freight charges. This information (United Nations Economic Commission for Latin America, 1969) has been plotted and presented in Figure 2 in the form of a piecewise linear ocean freight cost function, which was used to estimate ocean freight costs among Andean country ports shown in Table 10, with some adjustments.

The basic data plotted in Fiture 2 corresponds to ocean freight costs for shipments from Valparaiso, Chile, to Buenaventura and Barranquilla in Colombia, and to Guayaquil and Callao in Ecuador and Peru, respectively. Specifically, this information is the following:

Origin	Destination	Ocean Freight Dols./m.t.	Distance Statute miles
Valparaiso	Barranquilla	17.00	3,685
Valparaiso	Buenaventura	16.00	3,000
Valparaiso	Guayaquil	14.00	2,335
Valparaiso	Callao	12.00	1,502

Adjustments for the estimation of ocean freight costs presented

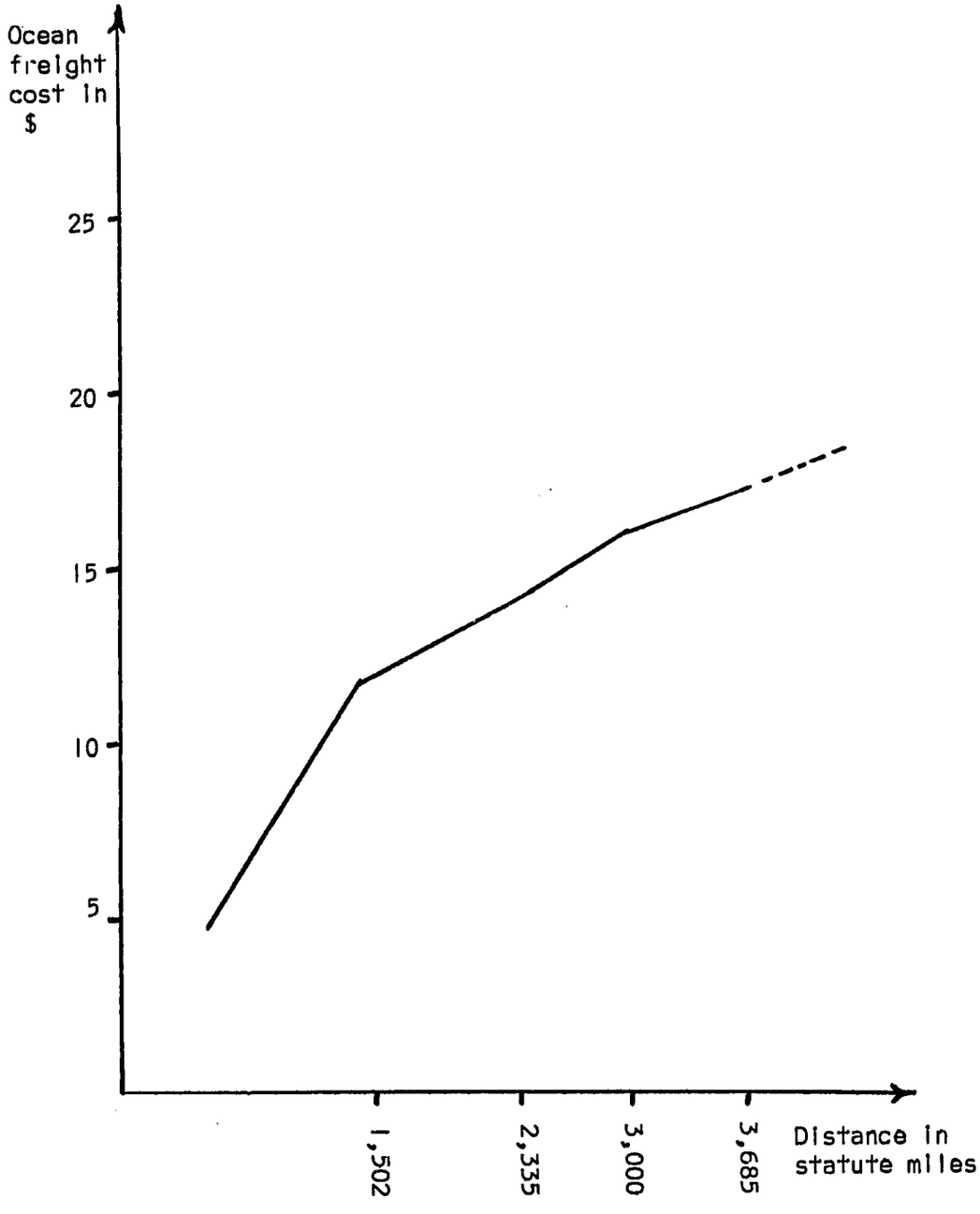

Figure 2. Piecewise ocean freight cost function

Table 10. Estimated ocean freight costs among Andean countries ports, in dollars per metric ton of fertilizer material

Importing ports	Puerto Cabello	Maracaibo	Barranquilla	Guayaquil	Paita	Callao	Matarani	Punta Arenas	Antofagasta
Maracaibo			5.00	12.00	12.00	13.00	16.00	27.00	20.00
Barranquilla	6.00	5.00		9.00	9.00	12.00	15.00	24.00	16.00
Buenaventura	10.00	8.00	6.00	5.00	6.00	10.00	12.00	22.00	13.00
Guayaquil	12.00	12.00	9.00			6.50	10.00	19.00	12.00
Paita	12.00	12.00	9.00			5.00	8.00	17.00	10.00
Salavery or Pimentel	13.00	12.00	11.00	5.00			7.00	16.90	10.00
Chimbote	14.00	12.50	11.50	6.00			6.00	16.50	8.00
Callao	14.00	13.00	12.00	6.50	5.00		6.00	14.00	7.00
Pisco	14.00	13.00	12.00	7.00	6.00			14.00	6.00
Matarani	17.00	16.00	15.00	10.00	8.00	6.00		13.50	5.00
Antofagasta	20.00	20.00	16.00	12.00	10.00	7.00	5.00	13.50	
Valparaiso	23.00	23.00	17.40	15.00	13.00	10.00	8.00	12.40	
San Antonio	23.00	23.00	17.40	15.00	13.00	10.00	8.00	12.00	
Talcahuano	24.00	24.00	18.00	16.00	14.00	11.00	9.00	10.50	
Puerto Montt	25.40	25.40	20.00	17.40	15.40	12.40	10.40	8.40	
Punta Arenas	27.00	27.00	24.00	19.00	17.00	14.00	12.00		13.50

distances between ports. For all ports not separated by more than 300 miles, a fixed rate was assumed irrespective of distance. Between ports more than 300 miles apart, the freight rate was made a function of distance as indicated in Figure 2.

Given the lack of information, it is very difficult to estimate ocean freight costs. The use of the rate-setting process by shipping conferences as an estimation procedure is almost impossible to adopt. It seems generally agreed that conference freight rates are based not on any single criterion or "formula" but rather that they are derived in an ad hoc fashion using a number of criteria: Brown (1966, p. 118) lists 28 factors which play some role in rate determination.

Estimation of Transport Costs from Plant Sites to Distribution Centers

Transport costs from each plant site to each distribution center were estimated by adding up corresponding intra-country transport costs, port charges, and ocean freight costs for each possible plant site-distribution center combination. When alternative means of transportation were possible, the cheapest cost was selected. These estimates, in dollars per metric ton of fertilizer material, are shown in Table 11 following a matrix-like format. However, transport costs to be used in our model must be expressed in terms of dollars per metric ton of ammonia equivalent. Different nitrogen nutrient content among fertilizer materials makes it necessary to carry out some transformations that will affect transport costs per metric ton of ammonia equivalent in inverse relation with the nitrogen content of

able 11. Transportation costs of fertilizer materials from plant sites to distribution centers, in dollars per metric ton

	Maracaibo	Moron	Puerto La Cruz	Monomeros	Barrancabermeja	Barranquilla	Guayaquil	Callao	Talara	Cachimayo	Yacuiba	Punta Arenas
alera	4.61	8.61	20.40	20.61	12.20	25.61	27.61	33.11	27.80	41.61	72.36	43.61
. Cristobal	10.10	14.00	23.90	19.88	6.80	24.88	33.00	41.60	33.30	47.10	77.85	49.10
carigua	10.00	5.40	17.00	19.75	18.81	24.75	26.75	34.45	26.95	40.75	70.50	41.75
arquisim.	6.80	4.00	15.60	18.35	16.81	23.35	25.35	33.35	25.55	39.35	69.10	40.35
aracay	13.45	3.35	8.25	17.70	26.85	22.70	24.70	32.70	24.90	38.70	68.45	39.70
aturin	22.40	12.30	3.00	26.65	35.80	31.65	33.65	41.65	33.85	47.65	77.40	48.65
. Bolivar	25.45	13.15	4.50	27.50	36.65	32.50	34.50	42.50	34.70	48.50	78.25	49.50
aracaibo	0.00	10.10	21.70	16.00	16.81	21.00	23.00	31.50	22.00	28.00	63.75	39.00
ogota	29.25	27.50	27.25	13.25	6.65	18.23	26.75	37.75	28.05	42.75	77.50	43.75
ucaram.	23.91	22.26	20.91	7.91	2.59	12.91	23.91	32.91	23.31	38.91	73.66	38.91
ali	22.20	22.55	22.20	16.12	9.47	21.12	16.20	27.20	17.60	32.20	67.35	33.20
bague	28.80	29.15	28.80	12.62	7.05	17.62	22.80	33.80	24.20	38.80	73.55	39.80
anizales	28.00	28.35	28.00	16.20	11.11	21.20	22.00	33.00	23.40	38.00	72.75	39.00
edellin	27.33	25.68	24.33	11.33	5.64	16.33	27.33	36.33	26.73	42.33	77.48	32.33
eiva	30.67	29.02	27.67	14.67	8.85	19.67	30.67	39.67	30.07	45.67	80.42	45.67
asto	29.00	29.35	29.00	26.25	19.62	31.25	23.00	34.00	24.40	39.00	73.75	40.00
unja	28.08	26.43	25.08	12.08	9.53	17.08	28.08	37.08	27.48	43.08	77.82	43.08
artagena	16.00	14.35	13.00	6.76	13.08	11.76	16.00	25.00	15.40	31.00	65.75	31.00
uayaquil	33.00	31.35	31.00	26.00	39.08	31.00	10.00	30.50	16.00	37.00	71.75	37.00
iura	22.40	20.75	20.40	15.40	29.68	20.40	16.00	10.00	0.80	25.60	60.05	26.30
rujillo	24.20	22.55	22.20	18.20	28.28	23.20	13.00	5.20	6.00	21.20	58.95	25.10
iiclayo	24.20	22.55	22.20	18.20	28.28	23.20	13.20	7.00	4.00	23.00	58.95	35.20
iimbote	24.50	22.85	22.50	18.50	31.58	23.50	14.00	4.00	6.60	18.30	57.75	24.50
azca	26.80	25.15	24.80	20.80	33.88	25.80	15.80	4.50	15.70	11.60	42.20	25.80
allao	31.00	29.35	29.00	25.00	38.08	30.00	20.50	0.00	11.00	16.00	47.06	30.00
uzco	35.00	35.35	35.00	31.00	44.08	36.00	27.00	16.40	26.50	0.30	30.66	31.00
uancayo	36.00	34.35	34.00	30.00	33.08	35.00	25.50	5.00	16.00	21.00	51.56	35.00
equipa	27.80	28.15	27.80	23.80	36.88	28.80	19.80	9.00	19.00	12.20	25.60	23.80
ucre	54.42	52.77	52.42	48.42	61.50	53.42	44.42	34.00	44.00	16.50	15.15	48.42
ochabamba	52.66	51.00	50.66	46.66	59.74	55.66	42.66	33.00	43.00	18.00	26.00	46.66
a Paz	41.74	40.09	39.74	35.74	38.82	44.74	31.74	28.40	39.40	14.00	26.20	35.74
uro	46.14	44.50	44.14	40.14	53.22	49.14	36.14	32.00	42.00	15.50	21.80	40.14
otosi	52.00	50.35	50.00	46.00	59.08	55.00	42.00	32.50	42.50	16.00	13.80	46.00
ta. Cruz	63.53	61.88	61.53	57.53	70.61	66.53	53.33	43.00	53.00	28.00	11.45	57.53
arija	59.40	57.75	57.40	53.40	66.48	62.40	49.40	43.00	53.00	28.00	6.50	53.40
ntofaga.	33.00	30.35	30.00	23.50	36.58	28.50	21.00	22.00	20.80	23.00	57.75	22.50
valle	43.75	45.10	44.75	37.15	50.23	42.15	35.75	36.75	33.55	34.75	69.50	33.15
ncagua	34.10	35.45	35.10	27.50	40.58	32.50	26.10	27.10	25.90	28.10	62.85	23.10
s Angeles	37.90	35.25	34.90	26.90	39.98	31.90	25.90	26.90	25.70	27.90	62.65	20.40
. Montt	37.40	34.75	34.40	27.00	40.08	32.00	25.40	26.40	25.20	27.40	62.15	16.40
ta. Arenas	39.00	36.35	35.00	31.00	44.08	36.00	27.00	28.00	25.00	29.00	63.75	0.00

similiar to those used in estimating processing costs per metric ton of ammonia equivalent, are the following:

For urea and compounds transport costs:

$$\text{Dols./m.t. of ammonia equivalent} = \frac{\text{Dols./m.t. of fertilizer material}}{1.26\ (0.455)}$$

$$= \frac{\text{Dols./m.t. of fertilizer material}}{0.5733}$$

For ammonium nitrate transport costs:

$$\text{Dols./m.t. of ammonia equivalent} = \frac{\text{Dols./m.t. of fertilizer material}}{1.26\ (0.355)}$$

$$= \frac{\text{Dols./m.t. of fertilizer material}}{0.4473}$$

For ammonium sulfate transport costs:

$$\text{Dols./m.t. of ammonia equivalent} = \frac{\text{Dols./m.t. of fertilizer material}}{1.26\ (0.21)}$$

$$= \frac{\text{Dols./m.t. of fertilizer material}}{0.2646}$$

For Chilean nitrates transport costs:

$$\text{Dols./m.t. of ammonia equivalent} = \frac{\text{Dols./m.t. of fertilizer material}}{0.34}$$

Estimates of transport costs in dollars per metric ton of ammonia equivalents are shown in Tables 12, 13, and 14 for urea and compounds, ammonium nitrate, and ammonium sulfate and Chilean nitrates, respectively. These estimates are the ones used in the final products transportation activities of our model.

Transport Costs of Ammonia

The possibility for ocean transportation of anhydrous ammonia by specially designed cargo vessels has been considered in this study.

Table 12. Transportation costs of urea and compounds from plant sites to distribution centers, in dollars per metric ton of ammonia equivalents

	Maracaibo	Moron	Monomeros	Barrancabermeja	Barranquilla	Guayaquil	Talara	Yacuiba	Punta Arenas
Valera	8.041	15.018	35.950	21.280	44.671	48.1598	48.4912	126.217	76.068
S. Cristobal	17.617	24.420	34.676	11.861	43.398	57.5615	58.0848	135.793	85.645
Acarigua	17.443	9.419	34.450	32.810	43.171	46.6597	47.0085	122.972	72.824
Barquisim.	11.861	6.977	32.008	29.321	40.729	44.2177	44.5665	120.530	70.382
Maracay	23.461	5.843	30.874	46.834	39.595	43.0839	43.4328	119.396	69.248
Maturin	39.072	21.455	46.485	62.445	55.207	58.6953	59.0441	135.008	84.860
C. Bolivar	44.392	22.937	47.968	63.928	56.689	60.1779	60.5268	136.490	86.342
Maracaibo	0.000	17.617	27.909	29.321	36.630	40.1186	38.3743	111.198	68.027
Bogota	51.020	47.968	23.112	11.600	31.886	46.6597	48.9273	135.182	76.313
Bucaram.	41.706	38.828	13.797	4.518	22.519	41.7059	40.6593	128.484	67.870
Cali	38.723	39.334	28.118	16.518	36.839	28.2575	30.6995	117.478	57.910
Ibague	50.235	50.846	22.013	12.297	30.734	39.7698	42.2118	128.292	69.423
Manizales	48.840	49.451	28.257	19.379	36.979	38.3743	40.8163	126.897	68.027
Medellin	47.671	44.793	19.763	9.838	28.484	47.6714	46.6248	135.147	56.393
Neiva	53.497	50.619	25.589	15.437	34.310	53.4973	52.4507	140.276	79.662
Pasto	50.584	51.195	45.788	34.223	54.509	40.1186	42.5606	128.641	69.771
Tunja	48.980	46.102	21.071	16.623	29.792	48.9796	47.9330	135.740	75.144
Cartagena	27.909	25.031	11.791	22.815	20.513	27.9086	26.8620	114.687	54.073
Guayaquil	57.561	54.683	45.351	68.167	54.073	17.4429	27.9086	125.153	64.539
Piura	39.072	36.194	26.862	51.770	35.583	27.9086	1.3954	104.744	45.875
Trujillo	42.212	39.334	31.746	49.328	40.467	22.6757	10.4657	102.826	43.782
Chiclayo	42.212	39.334	31.746	49.328	40.467	23.0246	6.9771	102.826	61.399
Chimbote	42.735	39.857	32.269	55.085	40.991	24.4200	11.5123	100.733	42.735
Nazca	46.747	43.869	36.281	59.096	45.003	27.5597	27.3853	73.609	45.003
Callao	54.073	51.195	43.607	66.422	52.329	35.7579	19.1872	82.086	52.329
Cuzco	61.050	61.661	54.073	76.888	62.794	47.0958	46.2236	53.480	54.073
Huancayo	62.794	59.916	52.329	57.701	61.050	44.4793	27.9086	90.110	61.050
Arequipa	48.491	43.102	41.514	64.329	50.235	34.5369	33.1415	44.654	41.514
Sucre	94.924	92.046	84.458	107.274	93.180	77.4812	76.7486	26.426	84.458
Cochabamba	91.854	88.959	81.388	104.204	97.087	74.4113	75.0044	45.351	81.388
La Paz	72 807	69.928	62.341	67.713	78.039	55.3637	68.7249	45.700	62.341
Oruro	80.381	77.621	70.016	92.831	85.714	63.0385	73.2601	28.825	70.016
Potosi	90.703	87.825	80.237	103.053	95.936	73.2601	74.1322	24.071	80.237
St. Cruz	110.815	107.937	100.349	123.164	116.047	93.3717	92.4472	19.972	100.349
Tarija	103.611	100.733	93.145	115.960	108.844	86.1678	92.4472	11.338	93.145
Antofagasta	57.561	52.939	40.991	63.806	49.712	36.6300	36.2812	100.733	39.246
Ovalle	76.313	78.667	64.800	87.616	73.522	62.3583	58.5208	121.228	57.823
Rancagua	59.480	61.835	47.968	70.783	56.689	45.5259	45.1770	109.628	40.293
Los Angeles	66.108	61.486	46.921	69.737	55.643	45.1770	44.8282	109.280	35.583
Pto. Montt	65.236	60.614	47.096	69.911	55.817	44.3049	43.9560	108.407	28.606
Pta. Arenas	68.027	63.405	54.073	76.888	62.794	47.0958	43.6072	111.198	0.000

Table 13. Transportation costs of ammonium nitrate from plant sites to distribution centers, in dollars per metric ton of ammonia equivalents

Distribution centers	Plant sites		
	Barrancab.	Callao	Cachimayo
Valera	27.27	74.02	93.02
S. Cristobal	15.20	93.00	105.30
Acarigua	42.05	77.02	91.10
Barquisimeto	37.58	74.55	87.97
Maracay	60.03	73.10	86.51
Maturin	80.04	93.11	106.53
C. Bolivar	81.94	95.01	108.43
Maracaibo	37.58	70.42	62.60
Bogota	14.87	84.39	95.57
Bucaramanga	5.79	73.57	86.99
Cali	21.17	60.81	71.99
Ibague	15.76	75.56	86.74
Manizales	24.84	73.78	84.95
Medellin	12.61	81.22	94.63
Neiva	19.78	88.69	102.10
Pasto	43.86	76.01	87.19
Tunja	21.31	82.90	96.31
Cartagena	29.24	55.89	69.30
Guayaquil	87.37	68.19	82.72
Piura	66.35	22.36	57.23
Trujillo	63.22	11.62	47.39
Chiclayo	63.22	15.65	51.42
Chimbote	70.60	8.94	40.91
Nazca	75.74	10.06	25.93
Callao	85.13		35.77
Cuzco	98.55	36.66	0.67
Huancayo	73.95	11.17	46.95
Arequipa	82.45	20.12	27.27
Sucre	137.49	76.01	36.89
Cochabamba	133.56	73.78	40.24
La Paz	86.79	63.49	31.30
Oruro	118.98	71.54	34.65
Potosi	132.08	72.65	35.77
S. Cruz	157.85	96.13	62.60
Tarija	148.62	96.13	62.60
Antofagasta	81.78	49.18	51.42
Ovalle	112.30	82.16	77.69
Rancagua	90.72	60.58	62.82
Los Angeles	89.38	60.14	62.37
P. Montt	89.60	59.02	61.25
P. Arenas	98.55	62.60	64.83

Table 14. Transportation costs of ammonium sulfate and Chilean nitrates from plant sites to distribution centers, in dollars per metric ton of ammonia equivalents

Distribution centers	Plant sites		
	Ammonium sulfate		Chilean nitrates
	Guayaquil	Callao	Antofagasta
Valera	104.35	125.13	109.73
S. Cristobal	124.72	157.22	126.76
Acarigua	101.10	130.20	105.15
Barquisimeto	95.80	126.04	101.03
Maracay	93.35	123.58	99.12
Maturin	127.17	157.41	125.44
C. Bolivar	130.38	160.62	127.94
Maracaibo	86.92	119.05	97.06
Bogota	101.10	142.67	105.15
Bucaramanga	90.36	124.38	86.50
Cali	61.22	102.80	71.18
Ibague	86.71	127.74	90.59
Manizales	83.14	124.72	88.23
Medellin	103.29	137.30	96.56
Neiva	115.91	149.92	106.32
Pasto	86.92	128.50	91.18
Tunja	106.12	140.14	98.76
Cartagena	60.47	94.48	63.23
Guayaquil	37.80	115.27	91.18
Piura	60.47	37.79	86.47
Trujillo	49.13	19.65	56.47
Chiclayo	49.89	26.45	85.88
Chimbote	52.91	15.12	50.00
Nazca	59.71	17.01	49.41
Callao	77.47		61.76
Cuzco	102.04	61.98	67.64
Huancayo	96.37	18.90	76.47
Arequipa	74.83	34.01	46.47
Sucre	167.88	128.50	118.88
Cochabamba	161.22	124.72	113.70
La Paz	119.95	107.33	81.59
Oruro	136.58	120.94	94.53
Potosi	158.73	122.83	111.76
S. Cruz	202.30	162.51	145.12
Tarija	186.70	162.51	133.52
Antofagasta	79.36	83.14	
Ovalle	135.11	138.89	52.50
Rancagua	98.64	102.42	38.53
Los Angeles	97.88	101.66	40.29
P. Montt	95.99	99.77	34.70
P. Arenas	102.04	105.82	66.17

Technical achievement has made it economically feasible to transport shiploads of anhydrous ammonia over long distances at a relatively low unit cost per ton (Haude, W. J., 1964). However, transportation of anhydrous ammonia among Andean countries has not taken place. Therefore, in order to include this possibility in our model, estimated anhydrous ammonia transport costs for other routes (United Nations Industrial Development Organization, 1967) were used to derive estimates for the possible Andean countries routes. This basic information is the following:

Loading/discharging	nautical miles	Estimated anhydrous ammonia transport cost (dollars per ton)
Trinidad/Wilmington, N.C.	1,703	4.50
Kuwait/Madras	2,612	6.10
Trinidad/London	4,010	9.30
Kuwait/Manila	5,166	11.00
Kuwait/London	6,545	15.80
Trinidad/Melbourne	9,130	21.20

These estimates, however, were made for the year 1966 and adjustments were made to update them to 1970 using industry economic indicators of costs. A scale-up factor of 1.17 was used. It was then possible to derive the estimates shown in Table 15.

Interpolation was then used to estimate anhydrous ammonia transport costs among Andean countries ports.

In order to obtain estimates of total ammonia transport costs from one plant to another, terminal charges must be considered. A general assumption was set up for this purpose: Storage capacity of 10,000 metric tons and storage throughput of 49,500 metric tons

Table 15. Basic estimates used to derive ammonia transport costs

Loading/discharging	Steaming distance (statute miles)	Estimated anhydrous ammonia transport cost (dollars per ton)
Trinidad/Wilmington, N.C.	1,958	5.26
Kuwait/Madras	3,000	7.14
Trinidad/London	4,611	10.88
Kuwait/Manila	5,940	12.87
Kuwait/London	7,527	18.49
Trinidad/Melbourne	10,500	24.80

per year was used to estimate terminal charges of $5.90 per metric ton of anhydrous ammonia (Patterson et al., 1969).

Estimated total transport costs (including terminal charges) of anhydrous ammonia among Andean countries ports closest to ammonia processing plants and/or ammonia using plants are presented in Table 16.

Table 16. Estimated anhydrous ammonia transport costs in refrigerated ocean-going ships from Andean country ports closest to ammonia processing facilities to ports closest to ammonia using facilities

Outshipping ports	Destinations		
	Barranquilla	Guayaquil	Callao
	(dollars per metric ton)		
Pto. La Cruz	14.50	16.60	18.50
Pto. Cabello	14.50	16.40	18.30
Maracaibo	14.50	16.20	18.20
Barranquilla		15.30	17.20
Paita	15.60	14.50	14.50
Callao	17.20	14.50	
Punta Arenas	24.20	21.70	19.50

CHAPTER 6
NITROGENOUS FERTILIZER CONSUMPTION PROJECTIONS

Factors Affecting Fertilizer Consumption

Several factors have been found to be important in determining future fertilizer consumption in Andean countries. Estimation of demand projections for fertilizers in these countries should, in general, take into consideration the following factors:

- Economic returns to fertilizer use
- The availability of fertilizer at the time the farmer needs it, i.e., quality of distribution system (available or to be established)
- General attitude of government officals, extension workers and farmers concerning the need for increased production
- Physical factors of area planted to various crops, soil fertility, climatic conditions, farming methods, previous experience with fertilizers, response of different crops and varieties to fertilizer, etc.

To the extent that statistical data are available the physical factors could be quantified but attitudinal factors would have to be based on intuitive assessment and judgment.

It is important to point out that in this study when we refer to consumption projections we are not talking about demand projections in the usual sense of free market demand, which respond to price and income consideration, but rather to consumption projections based on the actual use of fertilizers and its rate of growth as compared with recommended levels of use even though the rate of growth of fertilizers use is implicitly affected by prices and income. The factors mentioned above are specified within this context.

These consumption projections are directed toward specific future periods of time: 1975, 1980 and 1985.

Estimation of Consumption Projections

The normal procedure to estimate consumption projections for each Andean country should have been to pre-establish an estimating method or procedure to be applied uniformly to each one of the Andean countries. However, in some countries the required data are quite unreliable or do not exist at all. Therefore, the estimating procedure has been left to be dependent on such factors as the availability of data and existence of previous studies on fertilizer consumption projections. Thus, a uniform estimating procedure has not been used for every country.

As a general rule the estimated projections have been checked against other estimates, mainly against those presented by each country to "La Junta Acuerdo Cartagena."[7] Also, in some cases they have been discussed with persons related to fertilizer processing and marketing activities as well as agronomists of promotional government organizations in these countries.

Whatever method is used to estimate consumption projections, the further one moves into the future (1985) the greater the error that may be expected in the estimates.

Consumption projections were estimated for each selected distribution center in every Andean country. Selection of distribution centers was made on the basis of amounts of fertilizers sold in previous years in the different distribution centers. Estimated

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[7]Technical body of the Cartagena Agreement.

consumption projections for each country were then allocated to each distribution center proportionally to sales in previous years, i.e., it was assumed that distribution patterns will remain stable over time in proportional terms. Detailed consumption estimations for each region within each country would require additional assumptions.

Consumption Projections for Venezuela

Consumption projections for Venezuela have been obtained using time series data on nitrogen nutrient consumed during the last decade (1962-1972). Unpublished estimates obtained by the Tennessee Valley Authority in its projections were adopted. For these estimates a regression equation of the following form was used for estimating projections:

$$Q_{dt} = \alpha + \beta_1 + \beta_2 t^2 + \xi \qquad (19)$$

where:

Q_{dt} = nitrogen nutrient consumed in year t, expressed in m.t.

t = 1 for year 1962

t = 2 for year 1963

t = 11 for year 1972

ξ = random error

Ordinary least squares yielded the estimating equation:

$$\hat{Q}_{dt} = 8090.7 + 1246.2\ t + 74.2\ t^2 \qquad (20)$$

which implies that annual increments of nitrogen consumption have been increasing in this decade. This equation was used to project quantities of nitrogen demanded for years 1975, 1980 and 1985, which implicitly assumes that all the factors affecting fertilizer consumption

up to 1985 are going to be similar to those that have existed during the decade 1962-1972. (Appendix B gives the graphic representation of estimating equations.)

The projected quantities demanded are:

For 1975, t = 14, then $\hat{Q}d_{14} = 8090.7 + 1246.2(14) + 74.2(14)^2$

$\hat{Q}d_{14} = 40{,}086$ m.t. of nitrogen.

For 1980, t = 19, then $\hat{Q}d_{19} = 8090.7 + 1246.2(19) + 74.2(19)^2$

$\hat{Q}d_{19} = 58{,}565$ m.t. of nitrogen.

For 1985, t = 24, then $\hat{Q}d_{24} = 8090.7 + 1246.2(24) + 72.4(24)^2$

$\hat{Q}d_{24} = 80{,}738$ m.t. of nitrogen.

These estimates used in this study are, however, substantially lower than those presented by Venezuela to the "Junta del Acuerdo Cartagena."[8] It has not been possible to obtain information about the methodology used in these estimations. In any case substantial changes in physical as well as attitudinal factors concerning fertilizer consumption in the next fifteen years must have been considered. In general, estimations of demand projections in these countries have been based on goals or objectives as to levels of fertilization and cropland areas to be reached at given future points in time, by assuming annual rates of growth in fertilizer use. Past experience shows that in most cases these projections have proven to be overestimates of actual consumption.[9] Nevertheless, the projections for Venezuela used in this study must be taken with caution. They may well be considered as underestimates if "positive" changes in factors affecting consumption

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[8]Consumption projections presented by Venezuela were 50,600, 89,100 and 157,000 metric tons of nitrogen for years 1975, 1980 and 1985, respectively.

[9]F.A.O. projections for 1970 were in general greater than actual

of fertilizers in Venezuela actually take place during the next fifteen years.

Eight distribution centers were selected for Venezuela, according to the distribution of fertilizer sales by region for year 1970 and 1971 (Food and Agriculture Organization Fertilizer Mission to Venezuela, 1972). Estimated proportions (percentages) of sales were used to "allocate" the projected consumption for the country into projected consumption for each distribution center. Consumption projections for years 1975, 1980 and 1985 by distribution centers, expressed in metric tons of nitrogen and ammonia equivalents, are presented in Table 17.

Consumption Projections for Colombia

Estimates obtained by the T.V.A. following an estimation procedure identified to the one used for Venezuela were used to estimate nitrogen consumption projections for Colombia. Time series data of nitrogen consumption during the last decade were used. In this case the ordinary least squares estimating equation was the following:

$$\hat{Q}dt = 32{,}647.2 + 294.6 + 336.6\ t^2 \qquad (21)$$

This estimating equation has similar characteristics to that of Venezuela. However, in this case, annual increments of nitrogen consumption are increasing more rapidly. Using this estimating equation the projected quantities of nitrogen consumption by Colombia are:

For year 1975, t = 14, hence:

$$\hat{Q}d_{14} = 32{,}647.2 + 294.6(14) + 336.6(14)^2$$

$$\hat{Q}d_{14} = 102{,}738 \text{ m.t. of nitrogen.}$$

Table 17. Consumption projections for Venezuela, by distribution centers, for years 1975, 1980 and 1985

Distribution centers	Proportion of country demand	1975		1980		1985	
		Nitrogen m.t.	Am.eq. m.t.	Nitrogen m.t.	Am.eq. m.t.	Nitrogen m.t.	Am.eq. m.t.
	(percent)						
Valera	2	802	1,010	1,757	2,214	2,422	3,052
San Cristobal	7	2,806	3,536	4,685	5,903	6,459	8,138
Acarigua	11	4,410	5,557	5,856	7,379	8,074	10,173
Barquisimeto	22	8,819	11,112	11,713	14,758	16,148	20,346
Maracay	47	18,840	23,738	25,769	32,469	35,524	44,760
Maturin	5	2,004	2,525	4,100	5,166	5,652	7,121
C. Bolivar	4	1,603	2,020	2,928	3,689	4,037	5,087
Maracaibo	2	802	1,010	1,757	2,214	2,422	3,052
Country total	100	40,086	50,508	58,565	73,792	80,738	101,729

For year 1980, t = 19, then:

$$\hat{Q}d_{19} = 32,647.2 + 294.6(19) + 336.6(19)^2$$

$$\hat{Q}d_{19} = 159,744 \text{ m.t. of nitrogen.}$$

For year 1985, t = 24, then:

$$\hat{Q}d_{24} = 32,647.2 + 294.6(24) + 336.6(24)^2$$

$$\hat{Q}d_{24} = 233,598 \text{ m.t. of nitrogen.}$$

The rapidly increasing annual increments in nitrogen consumption implied by estimating equation (21) result in quite high levels of annual increments for the period 1980-1985. A comparison of our estimates with those presented by Colombia to the "Junta del Acuerdo Cartagena" shows substantial differences for the 1985 projection. An alternative linear (time trend) estimating equation was then tested:

$$Qdt = \gamma' + \beta_1' \, t + \xi_t \qquad (22)$$

$$\hat{Q}dt = 23,896.5 + 4,333.4t \qquad (23)$$

So that:

$$\hat{Q}d'_{14} = 84,564$$

$$\hat{Q}d'_{19} = 106,230$$

$$\hat{Q}d'_{24} = 127,897$$

This estimating equation fits the data less accurately and, according to other nitrogen consumption projections made for Colombia,[10] it seems to underestimate projected consumption.

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[10]Demand projections made by the Latin American Institute of Economic and Social Planning (ILPES) for 1975, 1980 and 1985 are 95,000; 133,000, and 170,000 m.t. of nitrogen, respectively. Corresponding demand projections presented by Colombia to "Junta del Acuerdo de Cartagena" were: 104,000; 153,000, and 195,000 m.t. of nitrogen.

Given these results, estimating equation (21) was used to obtain nitrogen consumption projections for years 1975 and 1980. For the year 1985, however, the arithmetic mean of both estimates was adopted as our projection, that is:

$$\hat{Qd}_{24} = \frac{\hat{Qd}_{24} + \hat{Qd}'_{24}}{2} = \frac{233,598 + 127,897}{2}$$

$$\hat{Qd}_{24} = 180,747 \text{ metric tons of nitrogen.}$$

Ten distribution centers or markets of fertilizers were selected for Colombia following the same procedure as the one used for Venezuela. However, proportions for allocations of projected country consumptions among distribution centers were based on data about estimated consumption of fertilizers by Departments (Urrego, 1973) in 1970, assuming the following correspondence between distribution centers and Departments:

Distribution centers	Departments
Bogota	Cundinamarca and Meta
Bucaramanga	Santander and Norte de Santander
Cali	Valle del Cauca
Ibague	Tolima and Quindio
Manizales	Caldas and Risaralda
Medellin	Antioquia
Neiva	Huila
Pasto	Narino and Cauca
Tunja	Boyaca
Cartagena	Atlantico, Magdalena, Bolivar, Cordova, Cesar, La Guajira and Sucre.

Table 18 shows the consumption projections for years 1975, 1980 and 1985, by distribution centers, expressed in metric tons of nitrogen and ammonia equivalents.

Consumption Projections for Ecuador

Different sets of nitrogen consumption projections for Ecuador have been considered in selecting the consumption prjections used in this study. Tennessee Valley Authority (T.V.A.) projections based on a linear time trend estimating equation (22) obtained from time series data on nitrogen consumption for the decade 1962-1972 provides the following estimates:

For year 1975, t = 14, then:

$$\hat{Q}d_{14} = 753.7 + 2{,}263(14) = 32{,}436 \text{ m.t. of nitrogen.}$$

For year 1980, t = 19, then:

$$\hat{Q}d_{19} = 753.7 + 2{,}263(19) = 43{,}751 \text{ m.t. of nitrogen.}$$

For year 1985, t = 24, then:

$$\hat{Q}d_{24} = 753.7 + 2{,}263(24) = 55{,}065 \text{ m.t. of nitrogen.}$$

However, differences between the data used by T.V.A. and that provided by the Agricultural Ministery of Ecuador are important. The estimated projections provided by this institution were (in m.t. of nitrogen):

	Maximun	Minimun
For 1975	27,000	31,000
For 1980	56,000	72,800

While, nitrogen consumption projections presented by Ecuador to "La Junta del Acuerdo Cartagena" were:

For 1975	25,900 m.t. of nitrogen
For 1980	59,300 m.t. of nitrogen
For 1985	135,700 m.t. of nitrogen

Table 18. Consumption projections for Colombia, by distribution centers, for the years 1975, 1980 and 1985

Distribution centers	Proportion of country demand	1975		1980		1985	
		Nitrogen m.t.	Am.eq. m.t.	Nitrogen m.t.	Am.eq. m.t.	Nitrogen m.t.	Am.eq. m.t.
	(percent)						
Bogota	26	26,712	33,657	41,534	52,333	46,994	59,149
Bucaramanga	5	5,137	6,473	7,987	10,064	9,037	11,387
Cali	11	11,301	14,239	17,572	22,141	19,882	25,051
Ibague	14	14,383	18,123	22,364	28,179	25,305	31,884
Manizales	7	7,192	9,062	11,182	14,089	12,652	15,941
Medellin	11	11,301	14,239	17,572	22,141	19,882	25,051
Neiva	3	3,082	3,883	4,792	6,038	5,423	6,833
Pasto	7	7,192	9,062	11,182	14,089	12,652	15,941
Tunja	12	12,328	15,533	19,169	24,153	21,690	27,329
Cartagena	4	4,110	5,179	6,390	8,051	7,230	9,110
Country total	100	102,738	129,450	159,744	201,278	180,747	227,676

The projection for 1985 is in conflict with the estimated 79,000 metric tons of potential consumption of nitrogen, made by ILPES in 1971. Considering similarities and discrepancies among these estimates, the following nitrogen demand projections to be used in this study were "selected":

	m.t. of nitrogen	m.t. of am. equivalents
For 1975:	31,000	39,060
For 1980:	56,000	70,560
For 1985:	65,065	81,900

The data necessary to estimate sales or use of fertilizers by regions were not available. Therefore, Guayaquil was assumed to be the only fertilizer distribution center for Ecuador.

Consumption Projections for Peru

Data available on physical factors affecting fertilizer consumption such as crop distribution by regions, rate of cropland expansion, present levels of fertilizer used by crops and region, and soil fertility and recommended levels of fertilization were used to estimate nitrogen consumption projections for 1975, 1980 and 1985. It is assumed that cropland expansion is going to continue at the same average annual rate of 37,000 hectares maintained during 1951 to 1965 (Diamond et al., 1968) until 1980, and that this annual increment is distributed proportionally according to the size of existing irrigation projects. Assuming also that crop distribution to each region is to remain stable over time, it is possible to estimate nitrogen demand projections for 1975, 1980 and 1985, taking into consideration that 90 percent of average recommended levels of fertilization per hectare for the coastal departments and 80 percent of recommended levels of fertilization for

the "Sierra" Departments[11] can be reached by 1990, following a constant rate of growth (linear). The following nitrogen consumption projections, used in this study, were thus estimated:

For 1975:	133,740 metric tons
For 1980:	171,238 metric tons
For 1985:	196,486 metric tons

Comparing these projections with others, it is observed that they are greater than those presented by Peru to "La Junta del Acuerdo Cartagena" but smaller than projections made by U.N.I.D.O. (United Nations Organization for Industrial Development) and by the F.A.O.[12] Nine fertilizer distribution centers were selected for Peru distributing projected nitrogen country consumption according to expected fertilized crop areas and average levels of fertilization per hectare by regions. Nitrogen consumption projections by distribution center expressed in metric tons of nitrogen and ammonia equivalents, are presented in Table 19. The following correspondence between distribution centers and Departments was assumed:

Distribution centers	Departments supplied
Piura	Piura and Tumbes
Trujillo	La Libertad and Cajamarca
Chiclayo	Lambayeque, Cajamarca, Amazonas and San Martin

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[11] Average recommended levels of fertilization per hectare by region obtained from Diamond, et al. (1968).

[12] Other nitrogen consumption projections, in metric tons of nitrogen, are:

	J.A. Cartagena	U.N.I.D.O.	F.A.O.
For 1975:	121,100	190,000	160,000
For 1980:	151,700	310,000	
For 1985:	184,100		

Table 19. Consumption projections for Peru, by distribution centers, for the years 1975, 1980 and 1985

Distribution Centers	1975			
	Fertilized areas (hectares)	Level of fertilizing (m.t. of N/ha.)	Projections	
			Nitrogen m.t.	Am.eq. m.t.
Piura	164,540	0.097	15,960	20,110
Trujillo	259,158	0.057	14,772	18,613
Chiclayo	388,754	0.057	22,159	27,920
Chimbote	203,960	0.051	10,401	13,105
Nazca	191,570	0.109	13,735	17,306
Callao	130,810	0.105	20,881	26,310
Cuzco	142,380	0.082	12,955	16,323
Huancayo	446,750	0.029	11,202	14,114
Arequipa	311,160	0.036	11,675	14,710
Country total			133,740	168,511

Table 19 (continued)

Distribution Centers	1980			
	Fertilized areas (Hectares)	Level of fertilizing (m.t. N/ha.)	Projections	
			Nitrogen m.t.	Am.eq. m.t.
Piura	179,540	0.106	19,031	23,979
Trujillo	280,164	0.067	18,771	23,651
Chiclayo	420,254	0.067	28,157	35,478
Chimbote	226,460	0.065	14,720	18,547
Nazca	201,570	0.114	16,331	20.577
Callao	145,810	0.112	22,978	28,952
Cuzco	177,380	0.092	19,603	24,700
Huancayo	466,750	0.042	15,329	19,314
Arequipa	326,160	0.047	16,318	20,561
Country total			171,238	215,759

Table 19 (continued)

Distribution centers	1985			
	Fertilized areas (hectares)	Level of fertilizing (m.t. N/ha.)	Projections	
			Nitrogen m.t.	Am.eq. m.t.
Piura	179,540	0.115	20,647	26,015
Trujillo	280,164	0.077	21,573	27,182
Chiclayo	420,254	0.077	32,359	40,772
Chimbote	226,460	0.079	17,890	22,541
Nazca	201,570	0.119	17,351	21,862
Callao	145,810	0.119	23,986	30,222
Cuzco	177,380	0.102	25,671	32,345
Huancayo	466,750	0.055	18,917	23,835
Arequipa	326,160	0.058	18,092	22,796
Country total			196,486	247,570

Chimbote	Ancash
Callao	Lima
Nazca	Ica
Cuzco	Cuzco, Apurimac, Ayacucho and Puno
Huancayo	Huancavelica, Junin, Pasco and Huamuco
Arequipa	Arequipa, Moquegua and Tacna

Consumption Projections for Bolivia

Nitrogen consumption projections for Bolivia used in this study are basically those obtained by the Tennessee Valley Authority (T.V.A.) in a study on the agriculture and fertilizers in Bolivia (Russel et al., 1970). The consumption projection for 1985 was obtained by assuming a constant annual rate of growth of consumption of 7 percent between 1980 and 1985. The following nitrogen consumption projections were obtained:

For 1975:	7,995 m.t. of nitrogen
For 1980:	14,148 m.t. of nitrogen
For 1985:	19,920 m.t. of nitrogen

The selection of the seven fertilizer distribution centers for Bolivia and their consumption projections have also been derived from the T.V.A. study and are presented in Table 20 expressed in metric tons of nitrogen and ammonia equivalents.

Consumption Projections for Chile

Nitrogen consumption projections in Chile for 1975 and 1980 have been adopted from a study made by Kearney and Co., Inc. (1970) which did explore the crop production and fertilizer use data in considerable

Table 20. Consumption projections for Bolivia, by distribution centers for the years 1975, 1980 and 1985

Distribution centers	1975		1980		1985	
	Nitrogen m.t.	Am.eq. m.t.	Nitrogen m.t.	Am.eq. m.t.	Nitrogen m.t.	Am.eq. m.t.
Sucre	1,131	1,425	2,018	2,543	3,050	3,843
Cochabamba	1,722	2,170	2,498	3,147	3,130	3,944
La Paz	798	1,005	1,155	1,455	1,415	1,783
Oruro	370	466	472	595	600	756
Potosi	1,423	1,793	2,260	2,847	3,050	3,843
Santa Cruz	2,013	2,536	4,641	5,848	7,050	8,883
Tarija	538	678	1,104	1,392	1,625	2,047
Country total	7,995	10,073	14,148	17,827	19,920	25,099

detail. The 1985 consumption projection was estimated by assuming a 3 percent average annual growth rate between 1980 and 1985.

Distribution centers were selected by their geographical location with respect to the region or Provinces they were assumed to supply:

Distribution centers	Provinces
Antofagasta	Tarapaca, Antofagasta and Atacama
Ovalle	Coquimbo, Aconcagua and Valparaiso
Rancagua	Santiago, O'Higgins, Colchagua, Curiaco and Talca
Los Angeles	Linares, Maule, Nuble, Concepcion Arauco, Bio-Bio, Malleco and Cautin
Puerto Montt	Valdivia, Osorno, Llanquihue and Chiloe
Punta Arenas	Aysen and Magallanos

Consumption projections for nitrogen by distribution center were obtained from the consumption projections by Provinces, as estimated by the Kearney study. Nitrogen consumption projections by distribution center adapted for the purpose of this study are shown in Table 21 expressed in metric tons of nitrogen and ammonia equivalents. These projections are, however, substantially smaller than those presented by Chile to the "Junta del Acuerdo Cartagena," which were: 159,900; 228,400; and 280,000 metric tons of nitrogen for years 1975, 1980 and 1985, respectively.

Table 21. Consumption projections for Chile, by distribution centers, for the years 1975, 1980 and 1985

Distribution centers	1975		1980		1985	
	Nitrogen m.t.	Am.eq. m.t.	Nitrogen m.t.	Am.eq. m.t.	Nitrogen m.t.	Am.eq. m.t.
Antofagasta	1,150	1,449	1,468	1,850	1,702	2,144
Ovalle	8,800	11,088	11,231	14,151	13,020	16,405
Rancagua	35,400	44,604	45,180	56,927	52,375	65,992
Los Angeles	38,400	48,384	49,009	61,751	56,815	71,587
Pto. Montt	5,100	6,426	6,509	8,201	7,545	9,507
Punta Arenas	1,150	1,449	1,468	1,850	1,702	2,144
Country total	90,000	113,400	114,865	144,730	133,159	167,779

CHAPTER 7
MARKETING FLOWS, PRODUCTION LEVELS AND EXCESS-CAPACITIES OF LEAST COST SOLUTIONS FOR PROCESSING AND DISTRIBUTING NITROGENOUS FERTILIZERS IN ANDEAN GROUP COUNTRIES

The Solutions

Two alternative least cost solutions for processing and distributing nitrogenous fertilizers in the Andean group countries were analyzed. First, an Andean Group Custom Union (A.G.C.U.) solution was obtained, assuming free trade among Andean countries, i.e., no restrictions and/or trade barriers were assumed to exist among Andean countries. Second, an "Independent Country" solution was obtained assuming that trade barriers were in effect so as to permit exhaustion of each country's domestic final products processing capacities before any imports could take place. Costs of imports resulting from this solution were estimated on the basis of import prices implied by the corresponding Andean Group Custom Union solution. These two alternative solutions were obtained for the expected consumption and supply situations for years 1975, 1980 and 1985, given the assumptions and limitations of the model. The results of these solutions are analyzed in this chapter in terms of marketing flows of ammonia and final products and levels of production and excess capacities of plants.

The Andean Group Custom Union Solution

Given the assumptions and limitations of the model (see chapter 3) the objective function (1) was minimized for the supply and consumption situations specified for the years 1975, 1980 and 1985. Supply situations for 1980 and 1985 were modified only by the entry into operation of ammonia-urea complexes "planned" at Yacuiba, Bolivia,

and Punta Arenas, Chile. Consumption situations were modified according to the consumption projections.

Marketing flows of ammonia and final products (expressed in metric tons of ammonia equivalents) that minimize the costs of processing and distributing nitrogenous fertilizers in the Andean Group countries are presented in Tables 22, 23 and 24 for the years 1975, 1980 and 1985, respectively. Marketing flows of ammonia can be observed by reading the upper part of the tables from left to right and upwards, whereas those of final products can be identified in the lower part of these tables, reading from top to bottom.

With the exception of 17,934 metric tons of ammonia shipped from Maracaibo, Venezuela, to Callao, Peru, for the processing of ammonium nitrate, all ammonia is used at the same plant site locations in the processing of urea. This is the case for every year for which solutions were obtained.

Numbers shown in these tables within parentheses indicate costs of using alternative non-optimum "routes" at the margin, that is, the additional costs associated with activating these "routes" by one unit of ammonia equivalent. They can be used as indicators of the sensitivity of marketing flows to changes in the pre-established costs of processing and transport. By restriction (13), ammonia allocated for the processing of urea at the same plant locations is sensitive to cost changes only through the sensitivity of flows of final products to cost changes. However, shipments of ammonia to plants manufacturing fertilizers other than urea are also sensitive to costs of ammonia itself (given the marketing flows of final products). Ammonia shipment from Maracaibo to Callao is sensitive

Table 22. Marketing flows of ammonia and final products in metric tons of ammonia equivalents for 1975, Andean Group Custom Union solution, and costs of using alternative routes at the margins, in dollars

	Final product production sites by countries							
	Urea					Ammonium nitrate		
	Venezuela		Colombia		Peru	Colombia	Peru	
Ammonia sources	Moron	Maracaibo	Barranca-bermeja	Barran-quilla	Talara	Barranca-bermeja	Callao	Cachimayo
Venezuela:								
Moron	33,840						(1.50)	
Maracaibo		310,384					17,934	
Colombia:								
Cartagena				51,080			(0.96)	
Barrancab.			(28.27)			(51.84)		
Peru:								
Callao							(10.00)	
Talara					96,315		(10.19)	
Cachimayo								(63.57)
Final products destinations by country								
Venezuela	33,840	16,668	(33.66)	(44.97)	(63.89)	(50.90)	(112.76)	(122.95)
Colombia	(1.84)	78,370	(1.36)	51,080	(23.20)	(17.20)	(72.47)	(93.62)
Ecuador	(2.01)	39,060	(50.03)	(15.70)	(1.57)	(83.16)	(61.03)	(85.49)
Peru	(2.01)	54,262	(47.10)	(17.45)	96,315	(68.09)	17,934	(0.01)
Bolivia	(2.00)	10,073	(51.74)	(17.37)	(12.88)	(67.27)	(31.44)	(2.30)
Chile	(0.20)	111,951	(43.08)	(8.72)	(6.78)	(76.61)	(44.14)	(56.40)
Totals	33,840	310,384		51,080	96,315		17,934	

Table 22 (continued)

Ammonia sources	Final product production sites by countries							Ammonia production m.t./year
	Ammonium sulfate			Compounds			Nitrates	
	Peru	Ecuador	Venezuela	Colombia		Ecuador	Chile	
	Callao	Guayaquil	Moron	Barranquilla	Monomeros	Guayaquil	Antofagasta	
Venezuela:								
Moron	(49.03)	(18.84)	(12.96)	(38.67)	(38.71)	(47.13)		33,840
Maracaibo	(47.53)	(17.24)	(26.06)	(37.27)	(37.31)	(45.53)		328,318
Colombia:								
Cartagena	(48.49)	(18.30)	(28.02)	(24.73)	(24.77)	(46.59)		51,080
Barrancab.								
Peru:								
Callao	(57.53)	(43.74)	(58.06)	(68.17)	(68.21)	(72.03)		
Talara	(57.72)	(29.43)	(' .15)	(53.16)	(53.20)	(57.72)		96,315
Cachimayo								
Final products destinations by country								Projected demand by countries
Venezuela	(174.09)	(147.08)	(0.01)	(44.96)	(44.72)	(89.89)	(143.49)	50,508
Colombia	(125.30)	(86.39)	(1.84)	(0.01)	(0.01)	(47.67)	(87.60)	129,450
Ecuador	(73.66)	(44.15)	(2.03)	(15.72)	(15.48)	(18.06)	(88.76)	39,060
Peru	(10.82)	(71.33)	(2.01)	(17.43)	(17.19)	(39.07)	(53.13)	168,511
Bolivia	(93.37)	(110.96)	(1.94)	(17.43)	(17.19)	(40.76)	(63.87)	10,073
Chile	(89.30)	(88.19)	(0.24)	(8.77)	(8.53)	(37.27)	1,449	113,400
Totals							1,449	511,002

Table 23. Marketing flows of ammonia and final products in metric tons of ammonia equivalents for 1980, Andean Group Custom Union solution, and costs of using alternative routes at the margins, in dollars

	Final products production sites by countries						
	Urea						
	Venezuela		Colombia		Peru	Bolivia	Chile
Ammonia sources	Moron	Maracaibo	Barrancabermeja	Barranquilla	Talara	Yacuiba	Punta Arenas
Venezuela:							
Moron	48,703						
Maracaibo		302,096					
Pto. La Cruz							
Colombia:							
Cartagena				51,080			
Barrancab.							
Peru:							
Callao							
Talara					96,315		
Cachimayo							
Bolivia:							
Yacuiba						37,548	
Chile:							
Punta Arenas							170,270
Final products destinations by country							
Venezuela	48,703	25,089	(61.93)	(44.97)	(64.42)	(115.78)	(64.93)
Colombia	(1.84)	150,198	(28.27)	51,080	(23.72)	(85.16)	(15.19)
Ecuador	(2.01)	70,560	(78.30)	(15.70)	(2.10)	(74.68)	(13.44)
Peru	(2.01)	56,249	(65.70)	(17.45)	96,315	19,721	25.540
Bolivia	(37.42)	(35.32)	(82.55)	(44.41)	(47.65)	17,827	(16.00)
Chile	(12.12)	(11.85)	(85.75)	(23.19)	(22.32)	(64.05)	144,730
Totals	48,703	302,096		51,080	96,315	37,548	170,270

Table 23 (continued)

Ammonia sources	Final products production sites by countries				
	Ammonium nitrate			Ammonium sulfate	
	Colombia	Peru		Peru	Ecuador
	Barrancabermeja	Callao	Cachimayo	Callao	Guayaquil
Venezuela:					
Moron		(1.50)		(49.03)	(42.90)
Maracaibo		17,934		(47.53)	(41.30)
Pto. La Cruz		(0.02)		(47.65)	(41.52)
Colombia:					
Cartagena				(48.49)	(42.36)
Barrancab.		(0.96)			
Peru:					
Callao		(10.00)		(57.53)	(67.80)
Talara		(10.19)		(57.72)	(53.49)
Cachimayo			(64.07)		
Bolivia:					
Yacuiba					
Chile:					
Punta Arenas		(0.54)		(48.07)	(46.04)
Final products destinations by country					
Venezuela	(102.74)	(113.28)	(122.44)	(174.09)	(123.02)
Colombia	(69.04)	(73.00)	(93.12)	(125.30)	(62.33)
Ecuador	(135.00)	(61.56)	(84.98)	(73.66)	(20.09)
Peru	(119.40)	17,934	(0.00)	(10.29)	(46.74)
Bolivia	(139.15)	(61.61)	(38.33)	(115.71)	(106.94)
Chile	(141.25)	(54.41)	(65.53)	(98.71)	(73.54)
Totals		17,934			

Table 23 (continued)

Ammonia sources	Final products production sites by countries					Ammonia production
	Compounds				Nitrates	
	Venezuela	Colombia		Ecuador	Chile	
	Moron	Barranquilla	Monomeros	Guayaquil	Antofagasta	
Venezuela:						
Moron	(0.00)	(38.67)	(38.71)	(47.13)		48,703
Maracaibo	(13.10)	(37.27)	(37.31)	(45.53)		320,030
Pto. La Cruz	(12.92)	(37.09)	(37.13)	(45.75)		
Colombia:						
Cartagena	(15.06)	(24.73)	(24.77)	(46.59)		51,080
Barrancab.						
Peru:						
Callao	(45.10)	(68.17)	(68.21)	(72.03)		
Talara	(29.19)	(53.16)	(53.10)	(57.72)		96,315
Cachimayo						
Bolivia:						
Yacuiba						37,548
Chile:						
Punta Arenas	(22.84)	(46.21)	(46.25)	(50.27)		170,270
Final products destinations by country						Projected demand by countries
Venezuela	(12.96)	(44.96)	(44.72)	(89.89)	(143.49)	73,792
Colombia	(14.80)	(0.01)	(0.01)	(47.68)	(87.60)	201,278
Ecuador	(14.99)	(15.72)	(15.48)	(18.06)	(88.76)	70,560
Peru	(14.97)	(17.43)	(17.18)	(38.70)	(53.64)	215,759
Bolivia	(34.94)	(44.47)	(44.23)	(60.81)	(83.91)	17,827
Chile	(25.03)	(23.27)	(22.23)	(49.11)	(9.41)	144,730
Totals						723,946

Table 24. Marketing flows of ammonia and final products in metric tons of ammonia equivalents for 1985, Andean Group Custom Union solution, and costs of using alternative routes at the margins, in dollars

	Final products production sites by countries						
	Urea						
	Venezuela		Colombia		Peru	Bolivia	Chile
Ammonia sources	Moron	Maracaibo	Barrancabermeja	Barranquilla	Talara	Yacuiba	Punta Arenas
Venezuela:							
Moron	67,141						
Maracaibo		391,569					
Pto. La Cruz							
Colombia:							
Cartagena				51,080			
Barrancab			(28.27)				
Peru:							
Callao							
Talara					96,315		
Cachimayo							
Bolivia:							
Yacuiba						57,444	
Chile:							
Punta Arenas							170,270
Final products destinations by country							
Venezuela	67,141	34,588	(33.66)	(44.97)	(67.55)	(115.80)	(65.44)
Colombia	(1.84)	176,596	(0.00)	51,080	(26.85)	(85.16)	(15.70)
Ecuador	(2.01)	81,900	(50.03)	(15.70)	(5.23)	(74.68)	(13.95)
Peru	(2.01)	98,485	(34.30)	(17.43)	96,315	32,345	2,491
Bolivia	(37.42)	(35.32)	(82.55)	(44.41)	(50.78)	25,099	(16.51)
Chile	(11.61)	(11.34)	(56.97)	(22.68)	(24.94)	(61.62)	167,779
Totals	67,141	391,569		51,080	96,315	57,444	170,270

Table 24 (continued)

Ammonia sources	Final products production sites by countries				
	Ammonium nitrate			Ammonium sulfate	
	Colombia	Peru		Peru	Ecuador
	Barrancabermeja	Callao	Cachimayo	Callao	Guayaquil
Venezuela:					
Moron		(1.50)		(49.03)	(42.39)
Maracaibo		17,934		(47.53)	(40.79)
Pto. La Cruz		(0.12)		(47.65)	(41.01)
Colombia:					
Cartagena		(0.96)		(48.49)	(41.85)
Barrancab.	(51.84)				
Peru:					
Callao		(10.00)		(57.53)	(67.29)
Talara		(10.19)		(57.72)	(52.98)
Cachimayo			(64.08)		
Bolivia:					
Yacuiba					
Chile:					
Punta Arenas		(0.54)		(48.07)	(45.53)
Final products destinations by country					
Venezuela	(50.90)	(116.42)	(122.44)	(174.09)	(123.53)
Colombia	(17.20)	(76.13)	(93.12)	(125.30)	(62.84)
Ecuador	(83.16)	(64.69)	(84.98)	(73.66)	(20.60)
Peru	(64.43)	17,934	(0.00)	(7.17)	(47.25)
Bolivia	(87.31)	(64.74)	(38.33)	(115.71)	(107.45)
Chile	(88.90)	(57.03)	(65.02)	(98.20)	(73.54)
Totals		17,934			

Table 24 (continued)

Ammonia sources	Final products production sites by countries					Ammonia production
	Compounds				Nitrates	
	Venezuela	Colombia		Ecuador	Chile	
	Moron	Barranquilla	Monomeros	Guayaquil	Antofagasta	
Venezuela:						
Moron	(0.00)	(38.67)	(38.71)	(47.13)		67,141
Maracaibo	(13.10)	(37.27)	(37.31)	(45.53)		409,503
Pto. La Cruz	(12.92)	(37.09)	(37.13)	(45.75)		
Colombia:						
Cartagena	(15.06)	(24.73)	(24.77)	(46.59)		51,080
Barrancab.						
Peru:						
Callao	(45.10)	(68.17)	(68.21)	(72.03)		
Talara	(29.19)	(53.16)	(53.20)	(57.72)		96,315
Cachimayo						
Bolivia:						
Yacuiba						57,444
Chile:						
Punta Arenas	(22.84)	(46.21)	(46.25)	(50.27)		170,270
Final products destinations by country						Projected demand by countries
Venezuela	(12.96)	(44.96)	(44.72)	(89.89)	(143.49)	101,729
Colombia	(14.80)	(0.01)	(0.01)	(47.68)	(87.60)	227,676
Ecuador	(14.99)	(15.72)	(15.48)	(18.06)	(88.76)	81,900
Peru	(14.96)	(17.42)	(17.19)	(38.71)	(53.13)	248,570
Bolivia	(34.94)	(44.47)	(44.23)	(60.81)	(83.91)	25,099
Chile	(24.53)	(22.76)	(21.72)	(48.60)	(8.90)	167,779
Totals						849,753

to changes in costs of ammonia processing and/or transport. For the year 1975, an overestimate of ammonia cost from Cartagena or an underestimate of ammonia cost from Maracaibo greater than $.0.96 per metric ton overall would lead to shipments of ammonia from Cartagena to Callao rather than from Maracaibo, assuming all other costs constant. In order to simplify this, and the forthcoming analysis of results, let us name this magnitude ($.0.96 per metric ton in previous paragraph) "cost estimation error" which can be defined as:

- Underestimation in processing and/or transport costs of active route (optimum route) given all other costs constant and correct.
- Overestimation in processing and/or transport costs of alternative route (non-optimum route) given all other costs constant and correct.
- Underestimation in processing and/or transport costs of active route (optimum route) plus overestimation of these costs for alternative (non-optimum route) given all other costs constant and correct.

Keeping these definitions in mind we can continue with the analysis of ammonia marketing flows. Results for years 1980 and 1985 show that shipments of ammonia from Maracaibo to Callao are even more sensitive to changes in costs. The entry in operation of the planned ammonia plant at Puerto La Cruz results in that a "cost estimation error" greater than $0.12 per metric ton of ammonia may lead to shipments of ammonia from Puerto La Cruz rather than Maracaibo. To activate the ammonia plant at Callao, however, a "cost estimation error" greater than $10.00 per metric ton of ammonia would be required.

The marketing flows of final products are, however, the basic determinants of ammonia use and shipments. The small size of plants manufacturing nitrogenous fertilizers other than urea resulted in high processing costs, which, in addition to high transport costs due to lower grades of nitrogen, helped determine the selection of urea as the main source of nitrogen to be used in order to minimize costs of processing and distributing nitrogenous fertilizers in the Andean countries. In spite of large low-cost ammonia plants at Venezuela, and the possibility of its transport to plants producing nitrogenous fertilizers others than urea, all but the ammonium nitrate plant at Callao are excluded by the minimum cost solutions.

Marketing flows of final products from plants to each country are shown in the lower part of these tables.[13] They indicate the use of urea as the main source of nitrogenous fertilizer. Venezuela, and more specifically the ammonia-urea fertilizer complex at Maracaibo, is the main supplier of nitrogenous fertilizer for the Andean countries. For the years 1980 and 1985, the entry into operation of planned ammonia-urea fertilizer complexes at Yaculba, Bolivia, and Punta Arenas, Chile, reduces the relative importance of the Maracaibo complex as a supplier, although increased consumption results in increased quantities of exports to other Andean countries. Chile and Bolivia are transformed from importers in 1975 to exporters in 1980 and 1985. Colombia, Ecuador and Peru remain as the importing countries, facing, also, substantial excess capacities in terms of

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[13]Due to large numbers, marketing flows are now shown with respect to distribution centers.

high-cost, small size plants available to produce, mainly, nitrogenous fertilizers other than urea.

Costs of using alternative "routes" at the margin were obtained with respect to each distribution center. However, since marketing flows in these tables are presented with respect to each country; the smallest cost of using alternative "routes" by each plant with respect to distribution centers within a country were selected, and are shown within the parentheses as indicators of the sensitivity of the flow of final products with respect to changes in costs.

Marketing flows to supply Venezuela are rather stable to changes in costs except for the case of the compound plant at Moron, which could be activated by a "cost estimation error" greater than $0.01 per metric ton of ammonia equivalent. The same could be said for Colombia, with the exception of the compounds plants at Barranquilla and Monomeros. However, even though these plants could be activated by small changes in costs their levels of production would be low, resulting in much higher unit costs than those pre-established under the assumption of full capacity production levels. It is now necessary to evaluate this assumption in the light of the solutions obtained.

Levels of production and excess capacities, expressed in metric tons of ammonia equivalents, resulting from Andean Group Custom Union solutions for years 1975, 1980 and 1985 are shown in Table 25. The considerable excess capacities shown for the ammonia and urea plants at Moron and Maracaibo in Venezuela with respect to consumption of Andean countries could easily vanish if exports to the rest of the world market are considered. The large size of these plants and low costs of raw materials (natural gas) in Venezuela make

Table 25. Levels of production and excess capacities in metric tons of ammonia equivalents, as implied by Andean Group Custom Union solutions, for 1975, 1980 and 1985

Plants	1975			
	Plant capacity	Production levels	Excess capacity	Percentage ex. capacity
Ammonia:				
Moron	198,000	33,840	164,160	83
Maracaibo	594,000	328,318	265,682	45
P. La Cruz				
Cartagena	132,000	51,080	80,920	61
Barrancab.	17,800		17,800	100
Callao	29,700		29,700	100
Talara	99,000	96,315	2,685	2
Cachimayo	11,183		11,183	100
Yacuiba				
Punta Arenas				
Urea:				
Moron	141,891	33,840	108,051	76
Maracaibo	454,054	310,384	143,670	32
Barrancab.	7,338		7,338	100
Barranqui.	51,080	51,080	0.00	0.00
Talara	96,315	96,315	0.00	0.00
Yacuiba				
Punta Arenas				

Table 25 (continued)

Plants	1980			
	Plant capacity	Production levels	Excess capacity	Percentage ex. capacity
Ammonia:				
Moron	198,000	48,703	149,297	75
Maracaibo	1,188,000	320,030	867,970	73
P. La Cruz	495,000		495,000	100
Cartagena	132,000	51,080	80,920	61
Barrancab.	17,800		17,800	100
Callao	29,700		29,700	100
Talara	99,000	96,315	2,685	2
Cachimayo	11,183		11,183	100
Yacuiba	198,000	37,548	160,452	81
Punta Arenas	198,000	170,270	27,730	14
Urea:				
Moron	141,891	48,703	93,188	66
Maracaibo	454,054	302,096	151,958	33
Barrancab.	7,338		7,338	100
Barranqui.	51,080	51,080	0.00	0.00
Talara	96,315	96,315	0.00	0.00
Yacuiba	170,270	37,548	132,722	78
Punta Arenas	170,270	170,270	0.00	0.00

Table 25 (continued)

Plants	1985			
	Plant capacity	Production levels	Excess capacity	Percentage ex. capacity
Ammonia:				
Moron	198,000	67,141	130,859	66
Maracaibo	1,188,000	409,503	778,497	65
P. La Cruz	495,000		495,000	100
Cartagena	132,000	51,080	80,920	61
Barrancab.	17,800		17,800	100
Callao	29,700		29,700	100
Talara	99,000	96,315	2,685	2
Cachimayo	11,183		11,183	100
Yacuiba	198,000	57,444	140,556	71
Punta Arenas	198,000	170,270	27,730	14
Urea:				
Moron	141,891	67,141	64,750	53
Maracaibo	454,054	391,569	62,485	14
Barrancab.	7,338		7,338	100
Barranqui.	51,080	51,080	0.00	0.00
Talara	96,315	96,315	0.00	0.00
Yaculba	170,270	57,444	112,826	56
Punta Arenas	170,270	170,270	0.00	0.00

Table 25 (continued)

Plants	1975			
	Plant capacity	Production levels	Excess capacities	Percentage ex. capacity
Ammonium nitrate:				
Barrancab.	10,418		10,418	100
Callao	17,934	17,934	0.00	0.00
Cachimayo	11,183		11,183	100
Ammonium sulfate:				
Callao	3,929		3,929	100
Guayaquil	8,732		8,732	100
Compounds:				
Moron	33,113		33,113	100
Barranqui.	24,696		24,696	100
Monomeros	56,700		56,700	100
Guayaquil	18,900		18,900	100
Nitrates:				
Antofagasta	122,850	1,449	121,401	99

Table 25 (continued)

Plants	1980			
	Plant capacity	Production levels	Excess capacities	Percentage ex. capacity
Ammonium nitrate:				
Barrancab.	10,418		10,418	100
Callao	17,934	17,934	0.00	0.00
Cachimayo	11,183		11,183	0.00
Ammonium sulfate:				
Callao	3,929		3,929	100
Guayaquil	8,732		8,732	100
Compounds:				
Moron	33,113		33,113	100
Barranqui.	24,696		24,696	100
Monomeros	56,700		56,700	100
Guayaquil	18,900		18,900	100
Nitrates:				
Antofagasta	122,850		122,850	100

Table 25 (continued)

Plants	1985			
	Plant capacity	Production levels	Excess capacities	Percentage ex. capacity
Ammonium nitrate:				
Barrancab.	10,418		10,418	100
Callao	17,934	17,934	0.00	0.00
Cachimayo	11,183		11,183	100
Ammonium sulfate:				
Callao	3,929		3,929	100
Guayaquil	8,732		8,732	100
Compounds:				
Moron	33,113		33,113	100
Barranqui.	24,696		24,696	100
Monomeros	56,700		56,700	100
Guayaquil	18,900		18,900	100
Nitrates:				
Antofagasta	122,850		122,850	100

them able to compete well in the world market. Although they have recently begun production, most of their output is in fact being exported to the world market as well as to other Andean countries.

Excess capacity of 61 percent for the ammonia plant at Cartagena, Colombia, is probably the most important single source of error in our solutions as they stand in Tables 22 to 24. If a restriction based on demands for phosphorous were established to keep the compound plants at Barranquilla and Monomeros in operation, the excess capacity of the ammonia plant at Cartagena would be very small, and imports from Venezuela would be substantially reduced.[14] However, the value of the objective function would increase. This problem will be discussed later in the analysis of costs associated with the least cost solution.

For the years 1980 and 1985 substantial excess capacities are observed for the ammonia and urea plants at Yaculba, Bolivia. However, the economic feasibility to build this complex depends very heavily on a priori arrangements to export to the Argentine market, so that excess capacities should be very small, if any.

Excess capacity of the ammonia plant at Punta Arenas, Chile, is rather small and would be even smaller if consumption of ammonia for other uses were included. All other plants would be either operating at full capacity or idle.

Construction of the ammonia plant at Puerto La Cruz, Venezuela, which shows 100 percent excess capacity in 1980 and 1985, should be

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[14]For the year 1975, the solution for Colombia as a part of the Andean Group Custom Union would be equal to that for Colombia as an "Independent-Country" (see Table 26).

evaluated only in terms of its ability to export to the rest of the world market.

The existence of plants with 100 percent excess capacity as a result of the "optimum" solution implies that in order to derive estimates of "gains" in terms of lower costs associated with the A. G. C. U. solutions, all costs for these plants must be variable from the year 1975 on. The assumptions adopted to estimate the processing costs shown in Tables 4 through 8 indicate that the only costs that would be incurred after closing down a plant would be depreciation and interest. In this study estimates of "gains," costs and transfer that take place under the Customs Union situation are derived under the assumption that from 1975 on a new cost structure is in effect for these plants: new maintenance costs are assumed to be increased in an amount equal to previously estimated depreciation and interest costs so that if these plants are closed down, total costs would be saved. The following facts make this assumption a very reasonable one:

(1) These plants were built in the early sixties. The ammonia - urea - ammonium nitrate complex at Barrancabermeja was originally built in 1952 and modified (equipment replacement) in 1962 and 1966 (McCamy and Waggoner, 1970). Plants at Callao, Guayaquil and Caclumayo were built in 1960, 1962 and 1965, respectively. Most of these plants are therefore substantially depreciated out. Continued operation would require substantial replacement of parts and equipment, as it is shown in the McCamy and Waggoner study of the Barrancabermeja complex. It is thus reasonable to assume that from

1975 on the maintenance cost will increase substantially in the form of parts and equipment replacement.

(2) Consideration has been given to discrete observations (results) for the years 1975, 1980 and 1985. That is, a gap of 5 years exists between these observations. It is reasonable to assume that costs which are normally considered to be "fixed" within a given year are actually variable for the five-year period. Actual fixed costs for these plants are, therefore, expected to be insignificant. Nevertheless, it is important to point out that the decision to close down a particular plant will have to be based on detailed, precise information about processing costs in that plant and a clear-cut distinction must be made between fixed and variable costs. With respect to the compound plants with 100 percent excess capacities in the solution, their operation will actually depend on the demands for phosphorous and potassium nutrients. As suppliers of nitrogen, however, the results do imply that these plants should close down (Moron, Barranquilla, Monomeros and Guayaquil). Processing costs of compounds, however, are mostly variable. Only 8 percent of the total costs are fixed (Table 8), and only 3 to 4 percent correspond to depreciation and interest costs. Thus, no significant errors in estimating "gains" and transfers are expected to be incurred by assuming all costs are variable for the purpose of closing down these plants.

It is necessary at this point to specify some important qualifications to these and forthcoming results. First, the long-run problem of optimum plant location for the years 1980 and 1985 imply that plant locations should be considered as variable. In this study, however, plant locations are pre-determined according to specific

possibility studies. Two main reasons can be presented for inclusion of pre-determined plant locations:

(1) The nitrogenous fertilizer industry is basically a raw-material oriented industry. Plant locations are normally restricted to raw material production sites (natural gas, sulfurs, etc.), while markets or distribution centers are geographically scattered.

(2) Variable plant location studies require the use of programming models which are not able (so far) to handle large size problems and still guarantee an optimal solution.[15]

Another important qualification of the results related to long-run considerations is the problem of technology changes over time. In this study it is assumed that technology will remain constant; however, technological changes would probably take place in the next 10 years, modifying the results of this study in directions that are difficult to predict. Results for 1980 and 1985 (like any other projections) must be taken with caution.

The "Independent-Country" Solution

The "independent-country" solution was obtained by applying the model to each country situation, introducing an import activity with costs high enough to force exhaustion of domestic final products processing capacities before any imports could take place. The value of the objective function was then adjusted to account for differences in costs of imports. Import "prices" as implied by the Andean Group Custom Union solution were used for this purpose as well as to determine intercountry marketing flows. The solutions obtained for

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[15] Unpublished Frank etal. paper, see footnote 1

each country were then aggregated to have an "independent-country" solution for the Andean Group countries as a whole. Solutions were thus obtained for 1975, 1980 and 1985.

Following the same design as in Tables 22, 23, and 24, marketing flows of the independent-country solutions are presented in Tables 26, 27 and 28, for the years 1975, 1980 and 1985, respectively. In this case, costs of using alternative routes at the margin were obtained only for plant-distribution centers "routes" within each country. Therefore, they are not shown in these tables.

Marketing flows of ammonia presented in these tables indicate that for the Andean Group Custom Union solutions ammonia is mainly used for the processing of final products at the same plant sites. Shipments of ammonia are restricted mainly to those from Maracaibo to Guayaquil, Ecuador, for processing of ammonium sulfate and compounds, Ecuador being a non-ammonia-producing country. A small shipment of ammonia from Maracaibo to Monomeros, Colombia, is, however, included for the 1980 and 1985 solutions.

Marketing flows of final products are, of course, determined basically by the forcing of domestic output consumption in each country before any imports take place. For the year 1975 the excess consumption over domestic production are satisfied by imports from Maracaibo, Venezuela. The entry in operation of the ammonia-urea complexes at Yacuiba, Bolivia and Punta Arenas, Chile, by 1980 makes these countries exporters of urea to Peru, while expansion of demands also resulted in increased imports by Peru, Colombia, and Ecuador, from Venezuela.

Table 26. Marketing flows of ammonia and final products in metric tons of ammonia equivalents for 1975, "Independent-Country" solution

Ammonia sources	Final product production sites by countries				
	Urea				
	Venezuela		Colombia		Peru
	Moron	Maracaibo	Barranca-bermeja	Barran-quilla	Talara
Venezuela:					
Moron	33,840				
Maracaibo		77,319			
Colombia:					
Cartagena				51,080	
Barrancab.					
Peru:					
Callao					
Talara					96,315
Cachimayo					
Final products destinations by country					
Venezuela	33,840	16,668			
Colombia				51,080	
Ecuador		11,428			
Peru		39,150			96,315
Bolivia		10,073			
Chile					

Table 26 (continued)

Ammonia sources	Final product production sites by countries				
	Ammonium nitrate			Ammonium sulfate	
	Colombia	Peru		Peru	Ecuador
	Barranca-bermeja	Callao	Cachimayo	Callao	Guayaquil
Venezuela:					
Moron					
Maracaibo					8,732
Colombia:					
Cartagena					
Barrancab.					
Peru:					
Callao		17,934		3,929	
Talara			11,183		
Cachimayo					
Final products destinations by country					
Venezuela					
Colombia					
Ecuador		17,934	11,183		8,732
Peru				3,929	
Bolivia					
Chile					

Table 26 (continued)

Ammonia sources	Final product production sites by countries					Ammonia production m.t./year
	Compounds				Nitrates	
	Venezuela	Colombia		Ecuador	Chile	
	Moron	Barranquillla	Monomeros	Guayaquil	Antofagasta	
Venezuela:						
Moron						33,840
Maracaibo				18,900		104,951
Colombia:						
Cartagena		21,670	56,700			129,450
Barrancab.						
Peru:						
Callao						21,863
Talara						96,315
Cachimayo						11,183
Final products desintations by country						Projected demand by countries
Venezuela						50,508
Colombia		21,670	56,700			129,450
Ecuador				18,900		39,060
Peru						168,511
Bolivia						10,073
Chile					113,400	113,400

Table 27. Marketing flows of ammonia and final products in metric tons of ammonia equivalents for 1980, "Independent-Country" solution

Ammonia sources	Final products production sites by countries						
	Urea						
	Venezuela		Colombia		Peru	Bolivia	Chile
	Moron	Maracaibo	Barrancabermeja	Barranquilla	Talara	Yacuiba	Punta Arenas
Venezuela:							
Moron	48,703						
Maracaibo		171,384					
Pto. La Cruz							
Colombia:							
Cartagena				51,080			
Barrancab.			7,338				
Peru:							
Callao							
Talara					96,315		
Cachimayo							
Bolivia:							
Yacuiba						26,364	
Chile:							
Punta Arenas							170,270
Final products destinations by country							
Venezuela	48,703	25,089					
Colombia		51,046	7,338	51,080			
Ecuador		42,928					
Peru		52,321			96,315	8,537	25,540
Bolivia						17,827	
Chile							144,730

Table 27 (continued)

Ammonia sources	Final products production sites by countries				
	Ammonium nitrate			Ammonium sulfate	
	Colombia	Peru		Peru	Ecuador
	Barrancabermeja	Callao	Cachimayo	Callao	Guayaquil
Venezuela:					
Moron					
Maracaibo					8,732
Pto. La Cruz					
Colombia:					
Cartagena					
Barrancab.	10,418				
Peru:					
Callao		17,934		3,929	
Talara					
Cachimayo			11,183		
Bolivia:					
Yacuiba					
Chile:					
Punta Arenas					
Final products destinations by country					
Venezuela					
Colombia	10,418				8,732
Ecuador		17,934	11,183		
Peru				3,929	
Bolivia					
Chile					

Table 27 (continued)

Ammonia sources	Final products production sites by countries					Ammonia production
	Compounds				Nitrates	
	Venezuela	Colombia		Ecuador	Chile	
	Moron	Barranquilla	Monomeros	Guayaquil	Antofagasta	
Venezuela:						
Moron						48,703
Maracaibo			476	18,900		199,492
Pto. La Cruz						0
Colombia:						
Cartagena		24,696	56,224			132,000
Barrancab.						17,756
Peru:						
Callao						21,863
Talara						96,315
Cachimayo						11,183
Bolivia:						
Yacuiba						26,364
Chile:						
Punta Arenas						170,270
Final products destinations by country						Projected demand by countries
Venezuela						73,792
Colombia		24,696	56,700			201,278
Ecuador				18,900		70,560
Peru						215,759
Bolivia						17,827
Chile						144,730

Table 28. Marketing flows of ammonia and final products in metric tons of ammonia equivalents for 1985, "Independent-Country" solutions

Ammonia sources	Final products production sites by countries						
	Urea						
	Venezuela		Colombia		Peru	Bolivia	Chile
	Moron	Maracaibo	Barrancabermeja	Barranquilla	Talara	Yacuiba	Punta Arenas
Venezuela:							
Moron	67,141						
Maracaibo		260,856					
Pto. La Cruz							
Colombia:							
Cartagena				51,080			
Barrancab.			7,338				
Peru:							
Callao							
Talara					96,315		
Cachimayo							
Bolivia:							
Yacuiba						46,261	
Chile:							
Punta Arenas							170,270
Final products destinations by country							
Venezuela	67,141	34,588					
Colombia		77,444	7,338	51,080			
Ecuador		54,268					
Peru		94,556			96,315	21,162	2,491
Bolivia						25,099	
Chile							167,779

Table 28 (continued)

Ammonia sources	Final products production sites by countries				
	Ammonium nitrate			Ammonium sulfate	
	Colombia	Peru		Peru	Ecuador
	Barrancabermeja	Callao	Cachimayo	Callao	Guayaquil
Venezuela:					
Moron					
Maracaibo					
Pto. La Cruz					8,732
Colombia:					
Cartagena					
Barrancab.	10,418				
Peru:					
Callao		17,934		3,929	
Talara					
Cachimayo			11,183		
Bolivia:					
Yacuiba					
Chile:					
Punta Arenas					
Final products destinations by country					
Venezuela					
Colombia	10,418				
Ecuador					8,732
Peru		17,934	11,183	3,929	
Bolivia					
Chile					

Table 28 (continued)

Ammonia sources	Final products production sites by countries					Ammonia production
	Compounds				Nitrates	
	Venezuela	Colombia		Ecuador	Chile	
	Moron	Barran-quilla	Monomeros	Guayaquil	Antofagasta	
Venezuela:						
Moron						67,141
Maracaibo			476	18,900		288,964
Pto. La Cruz						
Colombia:						
Cartagena		24,696	56,224			132,000
Barrancab.						17,756
Peru:						
Callao						21,863
Talara						96,315
Cachimayo						11,183
Bolivia:						
Yacuiba						46,261
Chile:						
Punta Arenas						170,270
Final products destinations by country						Projected demand by countries
Venezuela						101,729
Colombia		24,696	56,700			227,676
Ecuador				18,900		81,900
Peru						247,570
Bolivia						25,099
Chile						167,779

Production levels and plants with excess capacities resulting from "independent-country" solutions are shown in Table 29. Excess capacities are expressed in metric tons of ammonia equivalents and percentages. Evaluating the validity of our processing costs estimation assumption about full capacity levels of operation, we can observe that substantial excess capacities are implied for ammonia and urea plants at Maracaibo and Moron in Venezuela, and at Yacuiba in Bolivia. Full capacity operation levels for the Venezuelan plants, as previously noted, can be justified in terms of exports to the rest of the world market, given the large size of these plants and the relative low costs of raw materials. Levels of operation at full capacity for the plants at Yacuiba, Bolivia, can be justified on the grounds that this plant has been planned with the idea of supplying the Argentine market.

The next highest excess capacity, percentagewise, is observed for the ammonia plant at Callao (26 percent), which could be reduced substantially if consumption of ammonia for other uses were considered.

Excess capacities shown for other plants are smaller than 15 percent, most of them operating at full capacity. As expected, these solutions result in very few idle plants even when output is destined solely for Andean Group countries. The plants showing substantive excess capacity are the ammonia plant to be built at Puerto La Cruz, Venezuela, which would have to depend on exports to the rest of the world market, the compound plant at Moron, Venezuela, whose operation will actually depend on demand for phosphorous rather than nitrogen fertilizers, and the nitrates production in Chile, which is becoming more dependent on the demand of this product for other industrial uses rather than as a fertilizer.

Table 29. Levels of production and excess capacities in metric tons of ammonia equivalents, as implied by "Independent-Country" solutions, for 1975, 1980 and 1985

Plants	1975		
	Production levels	Excess capacities	
		m.t.	Percent
Ammonia:			
Moron	33,840	164,160	83
Maracaibo	104,951	489,049	82
P. La Cruz			
Cartagena	129,450	2,550	2
Barrancab.		17,800	100
Callao	21,863	7,837	26
Talara	96,315	2,685	2
Cachimayo	11,183	0.00	0.00
Yaculba			
Punta Arenas			
Urea:			
Moron	33,840	108,051	76
Maracaibo	77,319	376,735	83
Barrancab.		7,338	100
Barranquilla	51,080	0.00	0.00
Talara	96,315	0.00	0.00
Yacuiba			
Punta Arenas			
A. nitrate			
Barrancab.		10,418	100
Callao	17,934	0.00	0.00
Cachimayo	11,183	0.00	0.00
A. sulfate:			
Callao	3,929	0.00	0.00
Guayaquil	8,732	0.00	0.00
Compounds:			
Moron		33,113	100
Barranquilla	21,670	3,026	13
Monomeros	56,700	0.00	0.00
Guayaquil	18,900	0.00	0.00
Nitrates:			
Antofagasta	113,400	9,450	7

Table 29 (continued)

Plants	1980		
	Production levels	Excess capacities	
		m.t.	Percent
Ammonia:			
Moron	48,703	149,297	75
Maracaibo	199,492	988,508	83
P. La Cruz		495,000	100
Cartagena	132,000	0.00	0.00
Barrancab.	17,756	0.00	0.00
Callao	21,863	7,837	26
Talara	96,315	2,685	2
Cachimayo	11,183	0.00	0.00
Yaculba	26,364	171,636	87
Punta Arenas	170,270	27,730	14
Urea:			
Moron	48,703	93,188	66
Maracaibo	171,384	282,670	62
Barrancab.	7,338	0.00	0.00
Barranquilla	51,080	0.00	0.00
Talara	96,315	0.00	0.00
Yaculba	26,364	143,906	84
Punta Arenas	170,270	0.00	0.00
A. nitrate:			
Barrancab.	10,418	0.00	0.00
Callao	17,934	0.00	0.00
Cachimayo	11,183	0.00	0.00
A. sulfate:			
Callao	3,929	0.00	0.00
Guayaquil	8,732	0.00	0.00
Compounds:			
Moron		33,113	100
Barranquilla	24,696	0.00	0.00
Monomeros	56,700	0.00	0.00
Guayaquil	18,900	0.00	0.00
Nitrates:			
Antofagasta		122,850	100

Table 29 (continued)

Plants	1985		
	Production levels	Excess capacities	
		m.t.	Percent
Ammonia:			
Moron	67,141	130,859	66
Maracaibo	288,964	899,036	76
P. La Cruz		495,000	100
Cartagena	132,000	0.00	0.00
Barrancab.	17,756	0.00	0.00
Callao	21,863	7,837	26
Talara	96,315	2,685	2
Cachimayo	11,183	0.00	0.00
Yaculba	46,261	151,739	77
Punta Arenas	170,270	27,730	14
Urea:			
Moron	67,141	74,750	53
Maracaibo	260,856	193,198	42
Barrancab.	7,338	0.00	0.00
Barranquilla	51,080	0.00	0.00
Talara	96,315	0.00	0.00
Yaculba	46,261	124,009	73
Punta Arenas	170,270	0.00	0.00
A. nitrate:			
Barrancab.	10,418	0.00	0.00
Callao	17,934	0.00	0.00
Cachimayo	11,183	0.00	0.00
A. sulfate:			
Callao	3,929	0.00	0.00
Guayaquil	8,732	0.00	0.00
Compounds:			
Moron		33,113	100
Barranquilla	24,696	0.00	0.00
Monomeros	56,700	0.00	0.00
Guayaquil	18,900	0.00	0.00
Nitrates:			
Antofagasta		122,850	100

Effects of Andean Group Custom Union Solution

The effects of the Andean Group Custom Union solution with respect to the "Independent-Country" solution in terms of marketing flows, levels of production and excess capacities can be summarized as follows:

(a) Ammonia production is used mainly for urea processing rather than for processing fertilizers other than urea. Urea thus becomes the main source of nitrogenous fertilizer for the Andean countries.

(b) All plants producing nitrogenous fertilizers other than urea, except for the ammonium nitrate plant at Callao, would have 100 percent excess capacity (that is, would not be producing).

(c) For 1975, Venezuela would be the exporting country for ammonia and urea, all other countries in the Andean Group being the importers. However, with the entry in operation of ammonia-urea complexes at Yaculba and Punta Arenas, Bolivia and Chile will also become exporters. The effect of the A.G.C.U. solution is shown in terms of the considerable increase in imports of urea by the importing countries, Peru, Colombia, and Ecuador (the main source of supply being Venezuela.

(d) Levels of production of ammonia and urea plants at Maracaibo and Moron in Venezuela and at Yaculba in Bolivia would increase, with resulting reduction in excess capacities, i.e., the degree of dependency of these plants on world markets would be reduced.

CHAPTER 8
COST STRUCTURE OF SOLUTIONS AND BALANCE OF TRADE IMPLICATIONS

Cost Structure of "Independent-Country" Solutions and Effects of Andean Group Custom Union Solutions

In order to carry out a more detailed analysis about the effects of the Andean Group Custom Union solution, the value of the objective function for the different solutions has been decomposed into processing costs, inter-country transport costs and intra-country transport costs for each country.

Results obtained for the two alternative solutions are presented in Tables 30, 31 and 32 for the years 1975, 1980 and 1985, respectively.

Solutions for the year 1975 show that total costs of processing and distributing fertilizers in the Andean Group countries would be reduced by $8.7 million per year under an Andean Group Customs Union situation. This cost reduction arises from a decrease in the processing costs of nitrogenous fertilizers of $14.7 million mainly due to imports of urea from Venezuela to Ecuador, Colombia, Peru and Chile in place of higher cost, domestically produced fertilizers other than urea. The considerable increment in inter-country transport costs (and a small decrease in intra-country transport costs) causes total transport costs to increase by $6.0 million, offsetting partially the gains from lower processing costs. Transport costs as a proportion of the total costs of nitrogenous fertilizers increases from 22 percent for the "independent-country" solution to 36 percent for the Andean Group Custom Union solution due to greater volume of inter-country trade.

Table 30. Effects of Andean Group Custom Union (A.G.C.U.) solution on cost of fertilizers in 1975, as compared with the "Independent-Country" solution (thousands of dollars)

Item	Processing costs[a]			Inter-country transport costs		Intra-country transport costs	
	Independent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution	Independent-Country solution	A.G.C.U. solution	Independent-Country solution	A.G.C.U. solution
Venezuela	3,321.1	3,321.1				493.7	493.7
Colombia	12,680.3	8,745.9	- 3,934.4		2,531.3	3,759.9	2,869.5
Ecuador	4,662.3	2,440.5	- 2,221.8	906.1	1,657.0	858.9	681.2
Peru	15,644.4	13,286.3	- 2,358.1	1,681.2	2,414.4	1,256.4	1,718.0
Bolivia	629.4	629.4		450.9	450.9	181.6	181.6
Chile	13,335.8	7,165.1	- 6,170.7		6,762.6	4,568.1	452.3
Totals: Indep.-Country solution	50,273.3			3,038.2		11,118.6	
A.G.C.U. solution		35,588.3			13,726.2		6,396.3
Effects of A.G.C.U. solution			-14,685.0				

Table 30 (continued)

Item	Total transport cost			Total cost		
	Independ-ent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution	Independ-ent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution
Venezuela	493.7	493.7		3,814.8	3,814.8	
Colombia	3,759.9	5,400.8	+ 1,640.9	16,440.2	14,146.7	-2,293.5
Ecuador	1,765.0	2,248.2	+ 483.2	6,427.3	4,688.7	-1,738.6
Peru	2,937.6	4,132.4	+ 1,194.8	18,582.0	12,418.7	-1,163.3
Bolivia	632.5	632.5		1,261.9	1,261.9	
Chile	4,568.1	7,214.9	2,646.8	17,903.9	14,380.0	-3,523.9
Totals:						
Indep.-Country solution	14,156.8			64,430.1[b]		
A.G.C.U. solution		20,122.5			55,710.8[b]	
Effects of A.G.C.U. solution			5,965.7			-8,719.3

[a]Processing costs of fertilizer demanded by each country.

[b]Value of objective function.

Table 31. Effects of Andean Group Custom Union (A.G.C.U.) solution on costs of fertilizers in 1980, as compared with the "Independent-Country" solution (thousands of dollars)

Item	Processing costs[a]			Inter-country transport costs		Intra-country transport costs	
	Independent-Country solution	A.G.C.U. solution	Effects of of A.G.C.U. solution	Independent-Country solution	A.G.C.U. solution	Independent-Country solution	A.G.C.U. solution
Venezuela	4,848.8	4,848.8				751.2	751.2
Colombia	18,892.6	13,233.7	- 5,658.9	1,468.5	4,754.3	4,923.0	3,806.1
Ecuador	6,630.6	4,408.6	- 2,222.0	2,169.9	2,830.8	1,408.3	1,230.6
Peru	18,672.4	16,393.8	- 2,278.6	3,825.4	4,134.8	1,223.7	1,945.0
Bolivia	1,240.6	1,240.6				500.1	500.1
Chile	9,129.6	9,129.6				5,616.0	5,616.0
Totals:							
Indep-Country solution	59,414.6			7,453.8		14,422.3	
A.G.C.U. solution		49,255.1			11,719.9		13,849.0
Effects of A.G.C.U. solution			-10,159.5				

Table 31 (continued)

Item	Total transport cost			Total cost		
	Independent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution	Independent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution
Venezuela	751.2	751.2		5,600.0	5,600.0	
Colombia	6,391.5	8,560.4	+ 2,168.9	25,284.1	21,794.1	- 3,490.0
Ecuador	3,578.2	4,061.4	+ 483.2	10,208.8	8,470.0	- 1,738.8
Peru	5,049.1	6,079.8	+ 1,030.7	23,721.5	22,473.6	- 1,247.9
Bolivia	500.1	500.1		1,740.7	1,740.7	
Chile	5,616.0	5,616.0		14,745.6	14,745.6	
Totals:						
Indep-Country solution	21,886.1			81,300.7[b]		
A.G.C.U. solution		25,568.9			74,824.0[b]	
Effects of A.G.C.U. solution			+ 3,682.8			- 6,476.7

[a]Processing costs of fertilizer demanded by each country.

[b]Value of objective function.

Table 32. Effects of Andean Group Custom Union (A.G.C.U.) solution on costs of fertilizers in 1985, as compared with the "Independent-Country" solution (thousands of dollars)

Item	Processing costs[a]			Inter-country transport costs		Intra-country transport costs	
	Independent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution	Independent-Country solution	A.G.C.U. solution	Independent-Country solution	A.G.C.U. solution
Venezuela	6,684.3	6,684.3				1,035.9	1,035.9
Colombia	20,541.9	14,883.0	- 5,658.9	2,410.5	5,635.3	5,043.1	3,993.9
Ecuador	7,339.2	5,117.1	- 2.222.1	2,624.8	3,285.8	1,616.1	1,428.4
Peru	20,735.8	18,457.3	- 2,278.5	5,437.4	5,730.3	1,339.0	2,079.1
Bolivia	1,746.6	1,746.6				683.7	683.7
Chile	10,583.3	10,583.3				6,510.4	6,510.4
Totals: Indep.-Country solution	67,631.1			10,472.7		16,218.2	
A.G.C.U. solution		57,471.6			14,651.4		15,731.4
Effects of A.G.C.U. solution			-10,159.5				

Table 32 (continued)

Item	Total transport costs			Total cost		
	Independent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution	Independent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution
Venezuela	1,035.9	1,035.9		7,720.2	7,720.2	
Colombia	7,453.6	9,629.2	+ 2,175.6	27,995.5	24,512.2	- 3,483.3
Ecuador	4,230.9	4,714.2	+ 483.3	11,570.1	9,831.3	- 1,738.8
Peru	6,776.4	7,809.4	+ 1,033.0	27,512.2	26,266.7	- 1,245.5
Bolivia	683.7	683.7		2,430.3	2,430.3	
Chile	6,510.4	6,510.4		17,093.7	17,093.7	
Totals: Indep.-Country solution	26,690.9			94,322.0[b]		
A.G.C.U. solution		30,382.8			87,854.4[b]	
Effects of A.G.C.U. solution			+ 3,691.9			- 6,467.6

[a]Processing costs of fertilizer demanded by each country.

[b]Value of objective function.

Intra-country transport cost decreases for the Andean Group Custom Union solution because of their lower transport cost for urea with a higher nitrogen content compared with other nitrogenous fertilizers.

The countries that gain more from the A.G.C.U. solution in terms of lower costs for fertilizers are precisely those that end up with more excess capacities in the form of idle plants (Colombia, Ecuador, Peru and Chile). Of course, the producers operating inefficient plants would be the losers and producers of exporting countries the gainers.

Solutions for 1980, presented in Table 31, are modified by the entry of ammonia-urea complexes at Yaculba, Bolivia, and Punta Arenas, Chile, as well as by changes in consumption. The reduction in total costs of supplying nitrogenous fertilizers to the Andean countries, resulting from the Andean Group Custom Union situation, $6.5 million per year, is smaller than that obtained in 1975 because no gains in terms of lower costs of fertilizers are incurred for Chile and Bolivia. Gains in these terms are restricted to Colombia, Ecuador and Peru. Greater gains are observed for Colombia because higher consumption brings into operation a high-cost fertilizer complex at Barrancabermeja under the "independent-country" solution.

Other results have similar characteristics to those obtained for 1975. Reductions in costs of fertilizers for Andean countries brought about the A.G.C.U. solution in 1980 arise from lower processing costs of fertilizers supplied ($10.2 million per year) which are only partially offset by higher transport costs ($3.7 million). The proportions of transport costs to total costs are 27 percent for the "independent-country" solution and 34 percent for the A.G.C.U. solution. The difference between these proportions compared with

that for 1975 has been reduced, due to the fact that changes in marketing flows for Chile and Bolivia reduces inter-country transport costs from $13.7 to $11.7 million for the A.G.C.U. solution, despite the increased consumption in 1980.

Results of solutions for 1985 are shown in Table 32. The only change from 1980 was the increased consumption requirements. Therefore, the cost structure is quite similar to that obtained for 1980. Higher values of the objective function, higher processing costs and transport costs, resulting from effects of increased consumption, are, of course, obtained.

Gains in terms of reduced costs of fertilizers to be consumed by Andean countries in 1985 as a result of the A.G.C.U. situation are, however, almost equal to those obtained for 1980. This is because consumption estimated for 1980 will actually exhaust domestic processing capacities of Colombia, Ecuador and Peru, under the "independent-country" solution, so that, consumption increases in these countries from 1980 to 1985 will have to be satisfied by imports, whether the "independent-country" solution or the A.G.C.U. solution is applied. For both cases, it is assumed that imports will come from exporting countries within the Andean Group. Small changes, however, are observed due to adjustments in transport cost (variations in marketing flows with respect to distribution centers).

If, as a special case, it is considered that the substantial excess capacity of the ammonia plant at Cartagena resulting from the A.G.C.U. solution for 1975 is not acceptable (the "Preferred" solution for Colombia being the one that corresponds to the "independent-country" solution for 1975), then gains from the A.G.C.U. situation would be overestimated by about $2.3 million per year.

Balance of Trade Implications

Although the total volume of trade that might develop in fertilizers among the Andean Group countries represents only a rather small proportion of the total trade among these countries[16] it is interesting to analyze the solutions in this respect.

The effects of Andean Group Custom Union solutions on the balance of trade for each country are presented in Tables 33, 34, and 35, for the years 1975, 1980 and 1985, respectively.

As expected, values of trade are smaller for the "independent-country" solutions as a result of the implicit protection policies assumed. This is also observed in terms of the "cost-value" of domestic processing, or cost of fertilizer output produced by each country. Importing countries have a much greater "cost value" of domestic processing under protection ("independent-country solution") than under an Andean Group Custom Union situation.

The solutions for 1975 presented in Table 33 show that for the "independent-country" solution exports by Venezuela will amount to $4.6 million while imports by Ecuador, Peru and Bolivia will amount to $7.6 million, the difference being the inter-country transport cost which is assumed to be paid by the importing countries. In the A.G.C.U. solution the value of exports from Venezuela is increased by $14.3 million. Colombia and Chile become importers and represent the main source of increase in exports from Venezuela to the Andean Group countries as a result of the A.G.C.U. solution.

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[16] Volume of trade among Andean Group countries amounted to $26 million in 1968 in agricultural products alone.

Table 33. Effects of Andean Group Custom Union solution on domestic processing and balance of trade for 1975 (thousands of dollars)

Country	"Cost-value" of domestic processing			Effects on balance of trade among member countries: Independent-Country solution		
	Independent Country-solution	A.G.C.U. solution	Effects of A.G.C.U. solution	exports (+)	imports[a] (-)	Balance of trade
	(1)	(2)	(3)	(4)	(5)	(6)
Venezuela	7,921.2	22,198.5	+14,277.3	4,599.9		+4,599.9
Colombia	12,680.2	3,849.4	- 8,830.8			
Ecuador	3,137.8		- 3,137.8		2,430.6	-2,430.6
Peru	13,198.3	9,370.0	- 3,828.3		4,127.3	-4,127.3
Bolivia					1,080.2	-1,080.2
Chile	13,335.8	170.4	-13,165.4			
Total	50,273.3	35,588.3	-14,685.0	4,599.9	7,638.1	

Table 33 (continued)

Country	Effects on balance of trade among member countries				
	A.G.C.U. solution			Effects of A.G.C.U.	
	Value of exports (+)	Value of imports (-)	Balance of trade	Value of exports	Value of imports[a]
	(7)	(8)	(9)	(10)	(11)
Venezuela	18,877.4		18,877.4	+14,277.5	
Colombia		7,427.8	- 7,427.8		+ 7,427.8
Ecuador		4,007.5	- 4,007.5		+ 1,576.9
Peru		6,330.7	- 6,330.7		+ 2,203.4
Bolivia		1,080.2	- 1,080.2		
Chile		13,757.3	-13,757.3		+13,757.3
Total	18,877.4	32,603.5		14,277.5	24,965.4

[a] Inter-country transport paid by importing countries.

Table 34. Effects of Andean Group Custom Union solution on domestic processing and balance of trade for 1980 (thousands of dollars)

Country	"Cost-value" of domestic processing			Effects on balance of trade among member countries		
				Independent-Country solution		
	Independent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution	Value of exports (+)	Value of imports[a] (-)	Balance of trade
	(1)	(2)	(3)	(4)	(5)	(6)
Venezuela	14,820.9	22,682.1	+ 7,861.2	9,972.1		+ 9,972.1
Colombia	15,682.3	3,849.4	-11,832.9		4,699.3	- 4,699.3
Ecuador	3,137.8		3,137.8		5,662.5	- 5,662.5
Peru	13,198.3	9,370.0	- 3,828.3		9,299.5	- 9,299.5
Bolivia	1,834.7	2,613.0	+ 778.3	594.1		+ 594.1
Chile	10,740.6	10,740.6		1,611.0		+ 1,611.0
Total	59,414.6	49,255.1	-10,159.5	12,177.2	19,631.3	

Table 34 (continued)

Country	Effects on balance of trade among member countries				
	A.G.C.U. solution			Effects of A.G.C.U.	
	Value of exports (+)	Value of imports[a] (-)	Balance of trade	Value of exports	Value of imports[a]
	(7)	(8)	(9)	(10)	(11)
Venezuela	17,833.3		+17,833.3	+ 7,861.2	
Colombia		14,138.6	-14,138.6		+ 9,469.3
Ecuador		7,239.4	- 7,239.4		+ 1,576.9
Peru		11,158.6	-11,158.6		+ 1,859.1
Bolivia	1,372.4		+ 1,372.4	778.3	
Chile	1,611.0		+ 1,611.0		
Total	20,816.7	32,536.6		8,639.5	12,905.3

[a]Inter-country transport paid by importing countries.

Table 35. Effects of Andean Group Custom Union solution on domestic processing and balance of trade for 1985 (thousands of dollars)

Country	"Cost-value" of domestic processing			Effects on balance of trade among member countries: Independent Country solution		
	Independent-Country solution	A.G.C.U. solution	Effects of A.G.C.U. solution	Value of exports (+)	Value of imports[a] (-)	Balance of trade
	(1)	(2)	(3)	(4)	(5)	(6)
Venezuela	21,653.0	29,514.3	+ 7,861.3	21,653.0		+21,653.0
Colombia	15,682.3	3,849.4	-11,832.9		7,249.2	- 7,249.2
Ecuador	3,137.8		- 3,137.8		6,826.0	- 6,826.0
Peru	13,198.3	9,370.0	- 3,828.3		12,974.9	-12,974.9
Bolivia	3,219.3	3,997.5	+ 778.2	1,472.6		+ 1,472.6
Chile	10,740.6	10,740.6		157.1		+ 157.1
Total	67,631.3	57,471.8	-10,159.5	23,282.7	27,050.1	

Table 35 (continued)

Country	Effects on balance of trade among member countries				
	A.G.C.U. solution			Effects of A.G.C.U.	
	Value of exports	Value of imports[a]	Balance of trade	Value of exports	Value of imports[a]
	(7)	(8)	(9)	(10)	(11)
Venezuela	29,514.3		+29,513.3	+ 7,861.3	
Colombia		16,669.0	-16,669.0		+ 9,419.8
Ecuador		8,402.9	- 8,402.9		+ 1,576.9
Peru		14,817.6	-14,817.6		+ 1,842.7
Bolivia	2,250.9		+ 2,250.9	+ 778.3	
Chile	157.1		+ 157.1		
Total	31,922.3	39,889.5		8,639.6	12,839.4

[a]Inter-country transport paid by importing countries.

Bolivia, without available processing capacity for 1975, remains an importer of Venezuelan urea under both solutions. The most affected countries in terms of foreign exchange needs for additional imports resulting from the A.G.C.U. solution would be Chile, Colombia, Peru and Ecuador, for which additional imports in millions of dollars amount to 13.8, 7.4, 2.2 and 1.6, respectively (assuming inter-country transport costs are paid by importing countries).

Assuming the "total" balance of trade of each country is in equilibrium in the independent-country solution the A.G.C.U. solution would, then, cause a surplus for Venezuela and a deficit for all of the other Andean countries.

The results of solutions for 1980, presented in Table 34, are modified by the entry in operation of ammonia-urea fertilizer complexes at Yacuiba, Bolivia, and Punta Arenas, Chile, and, by the increased consumption for nitrogenous fertilizers. These consumption increases cause the "cost value" of domestic processing for Colombia, Ecuador and Peru to reach a maximum for the "independent-country" solution. For Colombia a higher degree of substitution in consumption away from domestic processed fertilizers is implied by the A.G.C.U. solution. Therefore, the increment in the value of imports by Colombia (from Venezuela) as a result of the A.G.C.U. solution is greater than it was for 1975 (increase of about $2.0 million). Comparing both 1980 solutions with 1975, higher consumption causes values of exports and imports to increase. However, new sources of supply at Yacuiba and Punta Arenas change the inter-country marketing flows. Bolivia and Chile become exporters (to Peru) taking away from

Venezuela some of its export market. For the A.G.C.U. solution the value of exports from Venezuela is actually reduced from $18.9 million in 1975 to $17.8 million in 1980. Similar to the results for 1975, the 1980 A.G.C.U. solution implies a considerable increase in the value of imports and exports over the independent-country solution. However this increment in 1980 is smaller because of the self-sufficiency of Bolivia and Chile obtained by the operation of new processing facilities at Yacuiba and Punta Arenas. Value of exports amount to $14.3 and $8.6 million in 1975 and 1980, respectively.

Assuming balance of trade equilibrium, under protection ("independent-country" solution), the A.G.C.U. solution would result in surpluses for Venezuela and Bolivia and deficits for Peru, Ecuador and Colombia, this last country facing the highest deficit ($9.5 million).

Results of solutions for 1985 are presented in Table 35. In terms of the effects of the A.G.C.U. solution, they are very similar to those for 1980. However, higher consumption results in higher "cost-value" of domestic processing for the exporting countries, Venezuela and Bolivia (the urea plant at Punta Arenas, Chile, is already operating at full capacity in 1980), and higher values of exports and imports. For both solutions the volume of trade increases from 1975 to 1986. Measured in terms of value of exports trade will increase from $4.6 million in 1975 to $23.3 million in 1985 for the "independent-country" solutions, and from $18.9 million in 1975 to $31.9 million in 1985 under the A.G.C.U. solution.[17]

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[17]These results should be considered as a sort of "lower bound estimate" since export prices of fertilizers will be determined by supply and demand situations at these points in time. They will also depend on the precision of our consumption projections and unexpected changes in supply within the Andean countries.

CHAPTER 9
EVALUATION OF ALTERNATIVE PROTECTION POLICIES BY COUNTRY

Analytical Procedure

The analysis focuses on estimating the effects of alternative policies that governments of Andean countries may adopt (or are actually using) to protect their domestic nitrogenous fertilizer industry. Estimates are based on results obtained by the solutions. Thus, import prices facing each country are assumed to be those resulting from the A.G.C.U. solution, while levels of production of domestic industry and imports under protection are assumed to be those provided by the "independent-country" solution. Policy effects are measured in terms of resulting transfers among consumers, producers and government, and in terms of prices of fertilizers to consumers. Additional costs to each country's economy compared with the A.G.C.U. solution are not modified by these policies, since each country's objective of exhausting all domestic processing capacities before any imports could take place is assumed to remain.

A typical situation of an importing country in a generalized form is represented in Figure 3, where:

$S_d(Q)$ = domestic supply function or "marginal cost" as a function of output Q. The supply curve is upward sloping, since at higher prices small, higher-cost plants will come into operation.

S_a = the rest of the Andean Group supply, assumed to be perfectly elastic at the import-price (P_m) implied for this country by the A.G.C.U. solution.

T = tariff or tariff-equivalent resulting from protection policy, equal to FD.

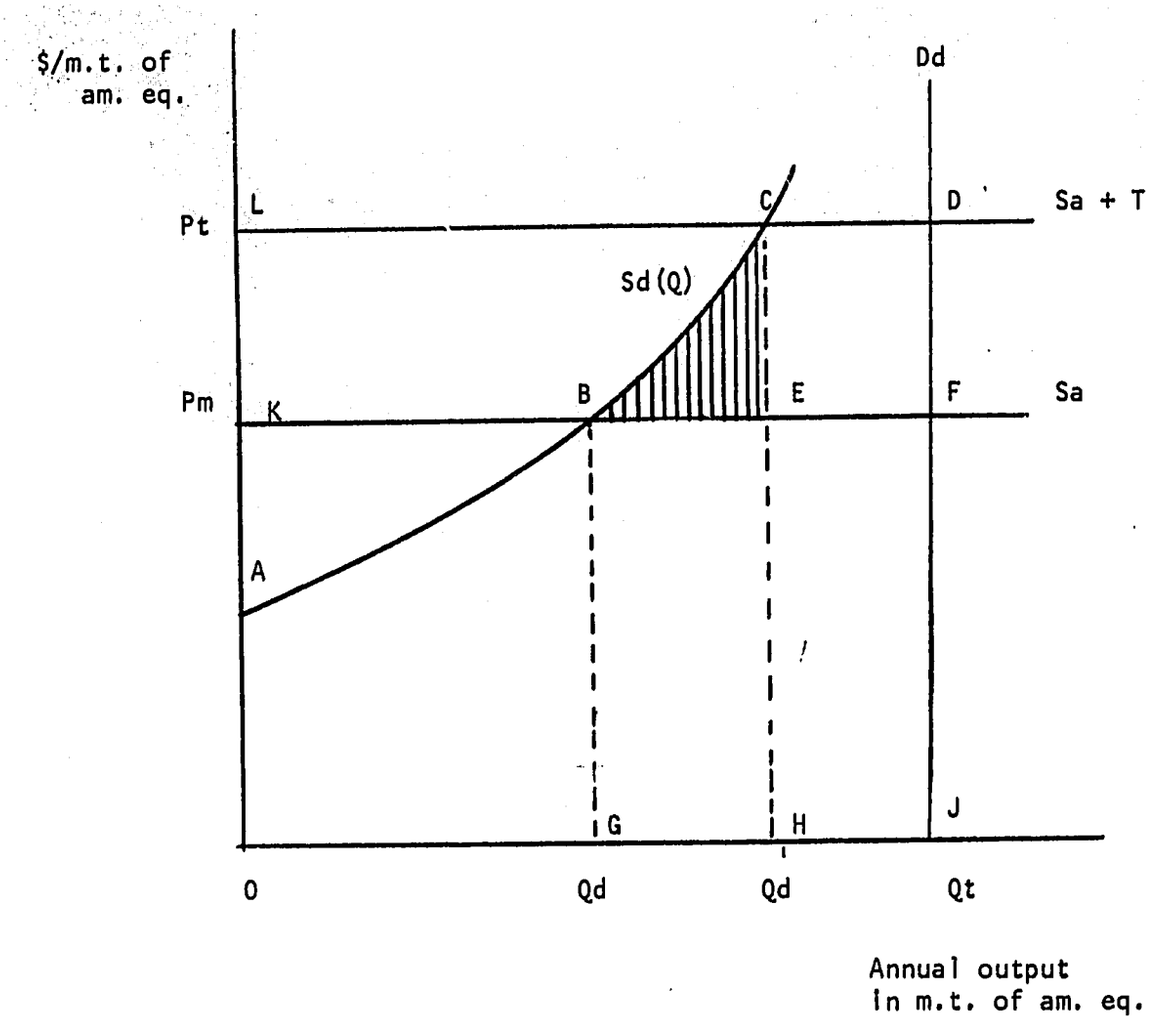

Figure 3. Generalized form of effects of domestic industry protection policy

$S_a + T$ = the rest of the Andean Group supply under domestic industry protection policy.

D_d = perfectly inelastic country demand, Q_t being the fixed quantity demanded.

P_m = import-price as implied by the A.G.C.U. solution.

P_t = price of fertilizer per metric ton of ammonia-equivalent given domestic industry protection policy (tariff T on imports).

For this generalized form the following extimates could be made:

(a) Cost of fertilizers to consumers excluding changes in intra-country transport cost:

$$\left(P_t\right) \times \left(Q_t\right) \tag{24}$$

(b) Additional processing of domestic fertilizers produced under protection policy:

$$\int_{Q_d}^{Q_d'} S_d(Q)\, dQ - \int_{Q_d}^{Q_d'} P_m . dQ \tag{25}$$

or, the shaded area BCE in Figure 3.

(c) Transfer from fertilizer consumers to government if a policy of a tariff on imports is considered, or from consumers to importers if a quota on imports is adopted:

$$(P_t - P_m) \times (Q_t - Q_d') \tag{26}$$

(d) Domestic producers surplus under protection policy:

$$\left[(P_t) \times (Q_d')\right] - \int_{o}^{Q_d'} S_d(Q).dQ \tag{27}$$

or, in Figure 3, area ABCL.

(e) Domestic producers surplus without protection, that is, under the A.G.C.U. solution:

$$\left[(P_m) \times (Q_d)\right] - \int_0^{Q_d} S_d(Q)\, dQ \qquad (28)$$

or, in Figure 3, area ABK.

(f) Transfer from consumers of fertilizers to domestic producers as a result of domestic industry protection policy:

$$\begin{pmatrix}\text{Domestic producers}\\ \text{surplus under protection}\end{pmatrix} - \begin{pmatrix}\text{Domestic producers}\\ \text{surplus without protection}\end{pmatrix}$$

This is, substracting (28) from (27), or the area KBCL in Figure 3.

This generalized form represented in Figure 3, can now be transformed into the "linearized" form implied by the application of the linear programming model used to obtain our least cost solutions. Such corresponding representation for a typical importing country is presented in Figure 4. This "linearized" form and the results from "independent-country" and A.G.C.U. solutions were used to obtain the estimates necessary to evaluate alternative protection policies for each Andean Group country. The following computations were made:

(a) Costs of fertilizers to consumers excluding changes in intra-country transport costs:

$$(P_t) \times (Q_t)$$

or, area LDJO in Figure 4.

(b) Additional processing costs of domestic fertilizers produced under protection policy:

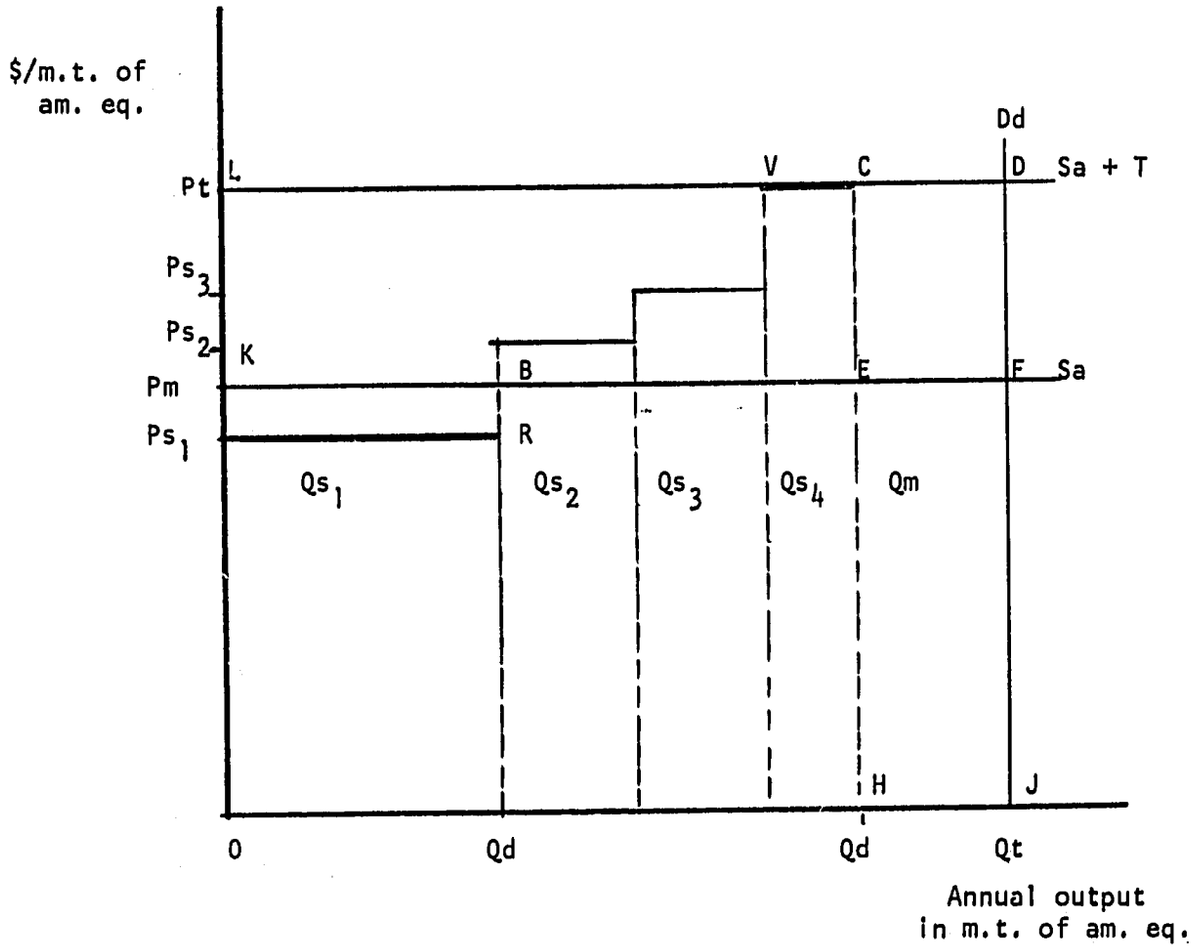

Figure 4. Linearized form of effects of domestic industry protection policy.

$$\sum_{j}^{n} Q_{sj} P_{sj} - P_m \cdot \sum_{j}^{n} Q_{sj} \quad \text{for all } P_{sj} > P_m \tag{29}$$

where: $\sum_{j}^{n} Q_{sj} = Q_d' - Q_d$

Q_{sj} = output supplied, under protection, by final product domestic processing facility j at P_{sj} unit processing cost, greater than import price P_m.

In Figure 4 this is:

$$Q_{s_2} \cdot P_{s_2} + Q_{s_3} \cdot P_{s_3} + Q_{s_4} \cdot P_{s_4} - P_m \cdot (Q_{s_2} + Q_{s_3} + Q_{3_4})$$

or shaded area BCE.

These costs, however, were computed from results previously obtained by subtracting from the decrease in "cost-value" of domestic processing (column (3) in Tables 33, 34 and 35), the increase in value of imports (column (11) in Tables 33, 34, and 35) as a result of the A.G.C.U. solution (for the years 1975, 1980 and 1985, respectively). That is, the value of substituting imports was substracted from the cost of substituted domestic output resulting from the A.G.C.U. solution.

(c) Transfers from fertilizer consumers to the government or to importers if a tariff or quota on imports, respectively, is adopted were estimated by:

$$P_t \ (Q_t - Q_d') - \text{Import value net of ammonia imports under independent-country solution} \tag{30}$$

or, the area ECDF in Figure 4.

That is, the cost of imported fertilizers to consumers under protection policy minus the import cost of these fertilizers to the government or to importers.

(d) Domestic producers surplus under protection policy was obtained by using:

$$\left[(P_t) \times (Q_d')\right] - \sum_j^n Q_{sj} \cdot P_{sj} \qquad (31)$$

or the area ALVR in Figure 4

where

$\sum_j^n Q_{sj} \cdot P_{sj}$ = "cost-value" of domestic processing under the independent-country solution, including value of ammonia imports if any.

(e) Domestic producers surplus without protection was estimated by using:

$$\left[(P_m^*) \times (Q_d)\right] - \sum_j Q_{sj} \cdot P_{sj} \quad \text{for all } P_{sj} \leq P_m \qquad (32)$$

where

$$\sum_j Q_{sj} = Q_d$$

$$P_m^* = \frac{\text{Value of imports net of ammonia imports value under A.G.C.U. solution}}{Q_t - Q_d}$$

and $\sum_j Q_{sj} \cdot P_{sj}$ for all $P_{sj} \leq P_m^*$, is equal to

"cost-value" of domestic processing under A.G.C.U. solution including value of ammonia imports if any.

In Figure 4 this is area AKBR.

(f) Transfers from fertilizer consumers to domestic producers as a result of protection policy are finally estimated by substracting domestic producers surplus without protection (32) from that resulting under protection policy (31).

Estimates were thus obtained for each Andean Group country for the years 1975, 1980 and 1985 on the basis of corresponding solutions. These results will now be analyzed in the light of alternative protection policies. Tariffs and quotas on imports, subsidies to domestic processing facilities, and a mixed policy of tariff and subsidy are considered.

Tariffs and Quotas on Imports of Final Products

Tariffs or quotas on imports adopted to keep domestic final products plants in operation yield the same results in terms of cost of fertilizers to consumers, additional processing costs of fertilizers consumed (social cost), and transfers, if under the quota system the government is the only importer. Otherwise, the available transfer from fertilizer consumers to the government will actually go instead to importers receiving quotas. Keeping in mind this important difference, the results of a tariff policy on import are analyzed first.

In Table 36 domestic and import prices (P_t, P_m^*) and quantities (Q_t, Q_d' and Q_d) resulting from the adoption of a tariff on imports for 1975, 1980 and 1985 are shown for the main importing countries, Colombia, Ecuador and Peru. These prices and quantities were used in the estimating procedure previously described to obtain the results presented in Tables 37, 38 and 39 for the years 1975, 1980 and 1985, respectively.

In order to illustrate better the effects of a tariff on imports to protect the domestic fertilizer industry, results for Colombia in 1980 (from Table 38) are approximated graphically in Figure 5. A

Table 36. Domestic and import prices in dollars, and quantities in metric tons of ammonia equivalents, resulting from a tariff on imports protection policy

Year	Variable	Colombia	Ecuador	Peru
1975	P_t^a	115.07	166.23	186.40
	P_m^{*b}	94.78	102.60	100.96
	Q_t^c	129,450	39,060	168,511
	$Q_d^{'d}$	129,450	27,632	129,361
	Q_d^e	51.080		114,249
	T^f	20.29	63.63	85.44
1980	P_t	167.64	166.23	186.40
	P_m^*	94.13	102.60	101.00
	Q_t	201,278	70.560	215,759
	Q_d'	150,232	27,632	129,361
	Q_d	51.080		114,249
	T	73.51	63.63	
1985	P_t	167.64	166.23	186.40
	P_m^*	94.39	102.60	104.74
	Q_t	227,676	81,900	247.570

Table 36 (continued)

Year	Variable	Colombia	Ecuador	Peru
	Q_d'	150,232	27.632	129,361
	Q_d	51,080		114,249
	T	73.51	63.63	81.66

[a]Price of fertilizer per metric ton of ammonia equivalent in dollars per m.t.

[b]Average import price as implied by the A.G.C.U. solution in dollars per m.t.

[c]Total quantity demanded in m.t. of ammonia equivalents.

[d]Domestic output produced under protection policy in m.t. of ammonia equivalents.

[e]Domestic output produced as implied by A.G.C.U. solution in m.t. of ammonia equivalents.

[f]Tariff on imports in dols. per m.t. of ammonia equivalent.

Table 37. Costs and transfers resulting from protection of domestic industry as implied by A.G.C.U. solution and "Independent-Country" solutions in 1975 (thousands of dollars)

Country	Cost of fertilizer to consumers under protection (Pt)x(Qt)	Additional cost of fertilizer produced under protection[a]	Additional cost in intra-country transport cost	Transfer from consumers to government[c]
	(1)	(2)	(3)	(4)
Venezuela	3,321.2			
Colombia	14,895.8	1,403.0	890.4	
Ecuador[h]	6,492.9	1,560.9	177.7	727.2
Peru[h]	31,410.4	1,624.9	- 461.6	3,170.4
Bolivia	1,261.8			
Chile	13,335.8	- 591.8	4,115.9	
Total	70,717.9	3,997.0	4,722.4	3,897.6

Table 37 (continued)

Country	Producers surplus			Additional cost to economy[g]
	Under protection[d]	Without protection[e]	Transfer from consumers to producers[f]	
	(5)	(6)	(7)	(8)
Venezuela				
Colombia	2,215.6	992.0	1,223.6	2,293.4
Ecuador[h]	197.3		197.3	1,738.6
Peru[h]	10,914.4	2,557.2	8,357.2	1,163.3
Bolivia				
Chile				3,524.1
Total	13,327.3	3,549.2	9,778.1	8,719.4

[a]Calculated by subtracting column (10) or (11) from column (3) in Table 33.

[b]From intra-country transport costs in Table 30.

[c]Calculated by using equation (30).

[d]Calculated by using equation (31).

[e]Calculated by using equation (32).

[f]Calculated by subtracting column (6) from (5).

[g]Calculated by adding columns (2) and (3).

[h]Adjustments made for imports of ammonia.

Table 38. Costs and transfers resulting from protection of domestic industry as implied by A.G.C.U. solution and Independent-Country solutions in 1980 (thousands of dollars)

Country	Cost of fertilizer to consumers under protection (Pt)x(Qt)	Additional cost of fertilizer produced under protection[a]	Additional cost in intra-country transport cost[b]	Transfer from consumers to government[c]
	(1)	(2)	(3)	(4)
Venezuela	4,848.8			
Colombia	33,742.2	2,373.1	1,116.9	3,740.1
Ecuador[h]	11,729.2	1,560.9	177.7	2,731.5
Peru[h]	40,217.5	1,969.2	721.3	6,607.7
Bolivia	1,240.6			
Chile	9,129.6			
Total	100,907.9	5,903.2	573.3	13,079.3

Table 38 (continued)

Country	Producers surplus			Additional cost to economy[g]
	Under protection[d]	Without protection[e]	Transfer from consumers to producers[f]	
	(5)	(6)	(7)	(8)
Venezuela				
Colombia	11,109.5	958.8	10,150.7	3,490.0
Ecuador[h]	197.3		197.3	1,738.6
Peru[h]	10,914.4	2,370.3	8,544.1	1,247.9
Bolivia				
Chile				
Total	22,221.2	3,329.1	18,892.1	6,476.5

[a]Calculated by subtracting column (10) or (11) from column (3) in Table 33.

[b]From intra-country transport costs in Table 31.

[c]Calculated by using equation (30).

[d]Calculated by using equation (31).

[e]Calculated by using equation (32).

[f]Calculated by subtracting column (6) from (5).

[g]Calculated by adding columns (2) and (3).

[h]Adjustments made for imports of ammonia.

Table 39. Costs and transfers resulting from protection of domestic industry as implied by A.G.C.U. solution and independent-Country solutions in 1985 (thousands of dollars)

Country	Cost of fertilizer to consumers under protection (Pt)x(Qt)	Additional cost of fertilizer produced under protection[a]	Additional cost in intra-country transport cost[b]	Transfer from consumers to government[c]
	(1)	(2)	(3)	(4)
Venezuela	6,684.3			
Colombia	38,167.6	2,434.1	1,049.2	5,692.9
Ecuador[h]	13,614.2	1,560.9	177.7	3,456.9
Peru[h]	46,147.0	1,985.6	- 740.1	9,059.5
Bolivia	1,746.6			
Chile	10,583.5			
Total	116,943.2	5,980.6	486.8	18,209.3

Table 39 (continued)

Country	Producers surplus			Additional cost to economy[g]
	Under protection[d]	Without protection[e]	Transfer from consumers to producers[f]	
	(5)	(6)	(7)	(8)
Venezuela				
Colombia	11,109.5	958.8	10,150.7	3,483.3
Ecuador[h]	197.3		197.3	1,738.6
Peru[h]	10,914.4	2,370.3	8,544.1	1,245.5
Bolivia				
Chile				
Total	22,221.2	3,329.1	18,892.1	6,467.1

[a]Calculated by subtracting column (11) from column (3) in Table 33.

[b]From intra-country transport costs in Table 32.

[c]Calculated by using equation (30).

[d]Calculated by using equation (31).

[e]Calculated by using equation (32).

[f]Calculated by subtracting column (6) from (5).

[g]Calculated by adding columns (2) and (3).

[h]Adjustments made for imports of ammonia.

tariff (T) of about \$73.51 per metric ton of ammonia equivalent imported ($P_t - P_m^*$) or \$42.14 per metric ton of urea,[18] would be required to keep all domestic processing facilities in operation, including the ammonium nitrate plant at Barrancabermeja. This policy results in a domestic fertilizer price of \$167.64 per metric ton of ammonia equivalent rather than \$94.13 under the A.G.C.U. solution. Additional total costs of fertilizers to domestic consumers resulting from this policy amount to \$16.3 million with \$10.15 million (column (7) in Table 38) in the form of transfers to domestic producers, \$3.7 million (column (4) in Table 38) as a transfer to the government, and \$2.4 million (column (2) in Table 38) due to increased processing costs resulting from keeping in operation all domestic processing facilities. This increase in processing cost can be considered as an estimate of the social cost or "welfare loss" ("welfare gain") resulting from the protection policy (A.G.C.U. solution) in terms of misallocation of resources in fertilizer production. An additional indirect effect of this protection policy is the increased intra-country transport cost that domestic consumers will have to pay amounting in this case to \$1.1 million (column (3) in Table 38). This cost is not shown in Figure 5. However, it may be considered as a "social cost" in terms of misuse of resources in the domestic transportation industry due to marketing flows

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[18] $42.14 = \frac{(73.51) \cdot (1.26)}{} (0.455)$ or

in general:

$$\text{Dols./m.t.urea} = (\text{Dols./m.t.Am.}) \left(\frac{\text{m.t. Am.}}{\text{m.t. nitrogen}} \right) \cdot \left(\frac{\text{m.t. nitrogen}}{\text{m.t. urea}} \right)$$

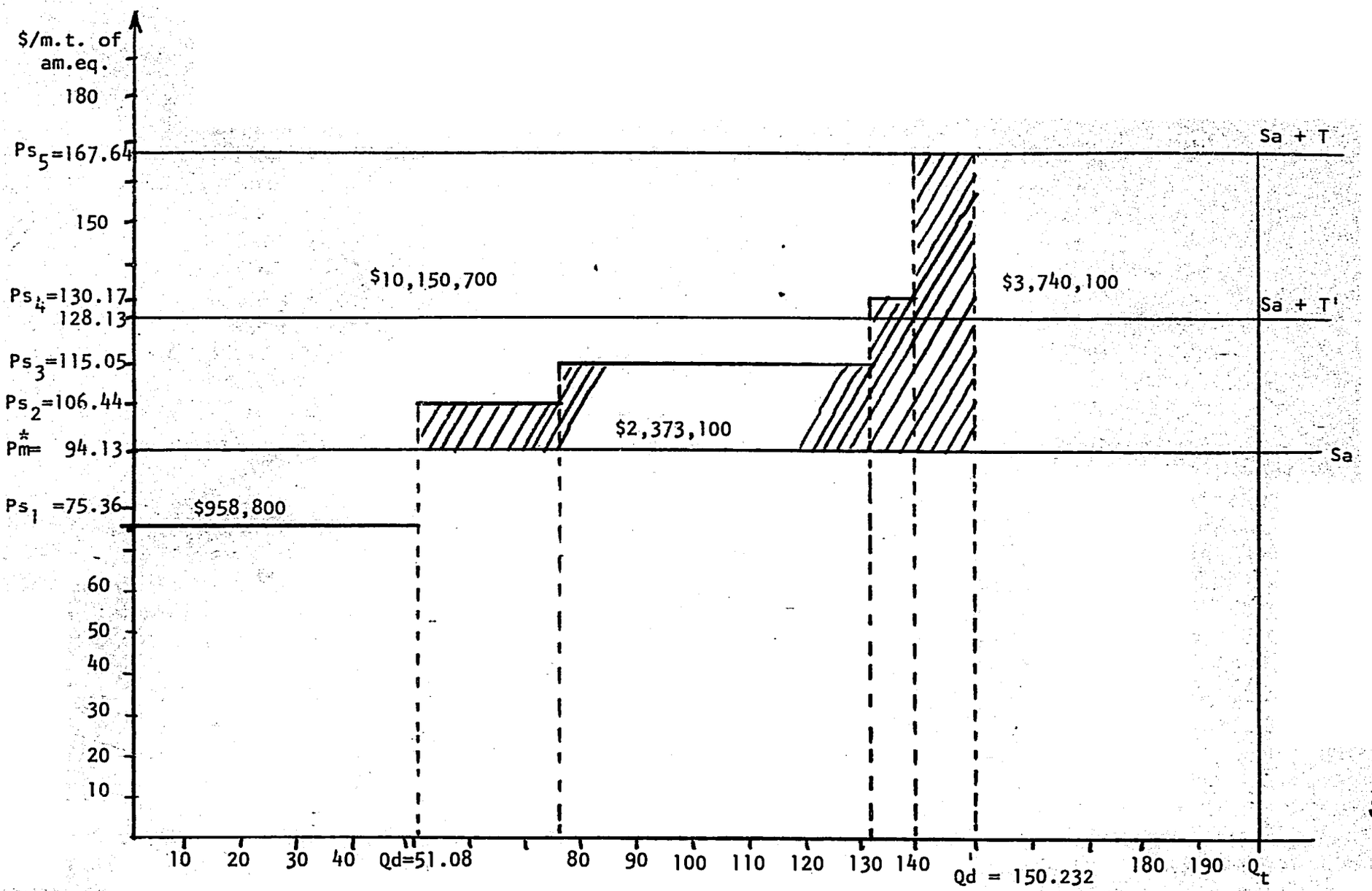

Figure 5. Effects of a tariff or quota on imports for Colombia in the year 1980

resulting from the protection policy. Therefore, total additional cost for the Colombian economy or total "social costs" amount to $3.5 million (column (8) in Table 38), $2.4 million in the form of increased processing costs of fertilizers, plus $1.1 million in the form of higher intra-country transport cost.

Magnitudes of transfers and "social costs" for Colombia in 1975 (Table 37) are substantially smaller because levels of consumption did not bring into production the fertilizer complex at Barrancabermeja for the "independent-country" solution. Thus, the tariff on imports required to keep other plants in operation is reduced to $20.29 per metric ton of ammonia equivalent (P_t = 115.07 minus P_m^* = 94.78). Results for 1985 (Table 39) are very similar to those for 1980, in terms of "social costs" and transfers from consumers to producers. However, transfers from consumers to government rise in proportion to import increases due to higher consumption.

Comparable results for Ecuador and Peru are shown in Tables 37 through 38. For Peru, results are similar to those of Colombia in 1980 and 1985, but with larger transfers from consumers to government increasing over time due to rising imports. However, "social costs" for Peru in terms of higher processing costs of fertilizers are partially offset by lower intra-country transport costs under protection policy. Results for Peru in 1975 are, however, different from those of Colombia, since Peru needs to import to satisfy 1975 estimated consumption requirements even if its domestic industry is operating at full capacity. For Ecuador, the existence of only two small high-cost processing facilities producing small outputs causes the country to be an importer from 1975 on. Producer surplus is small since the

difference in costs between plants is small. "Social costs," however, are relatively large due to high costs of domestic processing facilities. With the exception of transfers from consumers to the government that increase over time as consumption and imports rise, "social costs" and transfers from consumers to producers remain constant for 1980 and 1985.

The main problems associated with a policy of a tariff on imports compared with alternative protection policies can be summarized as follows:

- Higher prices of fertilizers to consumers, which will reduce fertilizer use and increase prices of farm products.
- Large transfers from consumers to producers which will generate "rents" to less inefficient domestic producers, making it more difficult for the government to change this policy. The larger these transfers the more opposition the government may expect to change this policy.
- Larger transfers from consumers to the government. This also increases the difficulties for policy changes, since the government would have to find substituting sources of revenue.

Under an "equivalent quota system" the only difference would be that transfers from consumers to government would be transformed into transfers from consumers to importers receiving quota assignments. Then, opposition to policy changes will arise not only from domestic producers but also from importers, in direct proportion to the magnitude of the transfers.

For Peru and Colombia the magnitudes of these transfers are quite important and can be taken as an indication of the degree of difficulty governments would have to face in carrying out economic integration when protection policies are in effect.

A note must be added about the "social cost" estimates resulting from domestic industry protection policies. Under the assumption of perfectly inelastic demands, estimated "social costs" are to remain constant for all alternative protection policies considered in this study.

Subsidies to Final Products Domestic Processing Facilities

Protection of domestic processing facilities can also be provided by direct subsidies from the government to the plants. The amounts of such subsidies are equal to the "social costs" of increased processing costs of fertilizers incurred by keeping in operation inefficient domestic processing facilities plus increased costs in intra-country transport costs.

These are shown in column (8) of Tables 37 through 39 for Colombia, Ecuador and Peru. For the case of Colombia in 1980, it is represented by the shaded area in Figure 5, plus the increase of $1.1 million in intra-country transport costs. Under this policy no transfers from consumers to producers nor from consumers to the government will take place. However, the government, and thus taxpayers in general, will have to pay domestic producers to keep them in operation. The cost of fertilizers to consumers will be equal to that resulting from the A.G.C.U. solutions.

The main results of a subsidy policy to domestic producers can be summarized as follows:

- Fertilizer prices to consumers will be basically equal to those resulting from imports of fertilizers.
- Since there are no transfers from consumers to producers nor from consumers to the government, it will be less difficult for governments to change this policy as well as to face the problems of regional economic integration.

In order to establish this policy governments must use other sources of fiscal revenues, which in most cases are difficult to obtain, and will have economic effects on the rest of the country's economy.

This problem suggests consideration of an alternative "mixed" policy of a tariff on imports and a subsidy on domestic industry.

"Mixed" Policy of a Tariff on Imports and a Subsidy to Domestic Processing Facilities

The problem of lack of government revenues necessary to carry out a subsidy protection policy can be solved by establishing a "mixed" policy of tariffs on imports to provide for revenues and a reduced subsidy to less efficient processing facilities not able to produce under the protection of this reduced tariff.

The case for Colombia in 1980, shown in Figure 5, was used to explain the effects of this policy. If a tariff T' equal to $34.00 per metric ton of ammonia equivalent is assumed to be in effect, then government revenues from it will amount to:

$$T'(Q_t - Q_d') = 34(51,046) = 1,735.6 \text{ thousands of dollars}$$

which can be used to pay subsidies to less efficient producers. Under the protection of this tariff (T'), the amount of subsidy will be reduced from that resulting under an only-subsidy policy. The estimated "prices" of imports given this tariff protection (P_m^{**}) will be equal to:

$$P_m^{**} = P_m^{*} + T = 94.13 + 34.00$$

$$P_m^{**} = \$128.13 \text{ per m.t. of am.eq.}$$

The amount of subsidy can now be estimated on the basis of unit processing cost of domestic processing facilities (P_s) shown in Figure 5, plant outputs, and P_m^{**}. These estimates are:

Subsidy to urea plant at Barrancabermeja:

$Qs_4\ (Ps_4 - P_m^{**}) = 7{,}338\ (130.17 - 128.13) = \$15{,}000.$

Subsidy to ammonium nitrate plant at Barrancabermeja:

$Qs_5\ (Ps_5 - P_m^{**}) = 10{,}418\ (167.64 - 128.13) = \$0.411$ million.

In addition, subsidies to different plants due to increased intra-country transport will have to be provided in the amount of $1.1 million (column (3), Table 38). A total susbidy of $1.5 million will be provided from revenues obtained from the tariff on imports, in this case more than enough to satisfy subsidy needs.

The effects of this policy as compared with considered alternative policies can be summarized as follows:

- "Prices" of fertilizers to consumers will be greater than those resulting under the A.G.C.U. solution or under the subsidy only policy. However, prices will still be substantially lower than those arising under the tariff only policy. For the case of Colombia these "prices" are:

  For tariff only policy: $. 167.64 m.t. of am.eq.
  For "mixed" subsidy tariff policy: $. 128.13 per m.t. of am. eq.
  For subsidy only policy: $. 94.13 per m.t. of am. eq.

- Transfers from consumers to producers will however, be substantially smaller than those resulting from the tariff only policy. Transfers from consumers to government might exist too, depending on the tariff (T') level. Therefore, some degree of difficulty in instituting policy changes will develop.

- The government will receive less revenue under the mixed policy than in the case of the tariff only policy, and the drain in revenues from the government would be less than in the case of an subsidy only policy. This policy may well be considered as a "compromise" policy between the other two "extremes."

The analysis made for Colombia can also be extended to the other importing countries, Peru and Ecuador. Using the same year 1980 and a tariff of $15 per metric ton of ammonia equivalent[19] (T'), the approximated results for Peru would be the following:

- Government revenues:

$$T' \ (Qt - Q'd) = 15(86,398) = 1.296 \text{ million dollars.}$$

- Estimated "prices" of imports given this tariff:

$$P_m^{**} = P_m^{*} + T' = \$101.00 + 15.00$$

$$P_m^{**} = \$116.00 \text{ per m.t. of am. eq.}$$

- Subsidies:

To ammonium nitrate plant at Callao:

$$17,934 \ (121.84 - 116.00) = 0.104 \text{ million dollars.}$$

To ammonium sulfate plant at Callao:

$$3,929 \ (181.23 - 116.00) = 0.256 \text{ million dollars.}$$

To ammonium nitrate plant at Cachimayo:

$$11,183 \ (186.40 - 116.00) - 0.787 \text{ million dollars.}$$

This makes up a total subsidy of 1.147 million dollars. However, if savings in intra-country transport costs associated with the

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[19] A lower tariff level would be required for Peru to generate government revenues since larger quantities of imports are expected to take place (86,398 m.t. of ammonia equivalents).

"independent-country" solution are considered, the amount of subsidy will be reduced by 0.721 million dollars (see Table 38). In any case, a $15 tariff on imports per metric ton of ammonia equivalent would generate more than enough government revenues to subsidize the less efficient domestic fertilizer industry.

For the case of Peru implied "prices" of fertilizers to consumers under alternative protection policies would be:

For tariff only policy: $186.40 m.t. of am. eq.
For "mixed" subsidy tariff policy: $116.00 per m.t. of am. eq.
For subsidy only policy: $101.00 per m.t. of am. eq.

Results for Ecuador in the same year 1980 given a tariff on imports of $25 per metric ton of ammonia equivalent (T'), are the following:

- Government revenues:

$$T'(Qt - Q'd) = 25(42{,}928) = 1.073 \text{ million dollars.}$$

- Estimated prices of imports given this tariff:

$$P_m^{**} = P_m^{*} + T' = 102.60 + 25.00$$

$$P_m^{**} = \$127.60 \text{ per m.t. of am. eq.}$$

- Subsidies:

To ammonium sulfate plant at Guayaquil:

$$8{,}732(143.63 - 127.60) = 0.140 \text{ million dollars.}$$

To compounds plant at Guayaquil:

$$18{,}900(166.23 - 127.60) = 0.730 \text{ million dollars.}$$

Hence, a total subsidy of $870,000 is required to keep in operation domestic processing facilities. Government revenues ($1,073,000) are, therefore, more than sufficient to pay for these subsidies.

"Prices" of fertilizers to consumers in Ecuador under alternative protection policies would be:

For tariff only policy: $166.23 per m.t. of am. eq.
For "mixed" subsidy tariff policy: $127.60 per m.t. of am. eq.
For subsidy only policy: $102.60 m.t. of am. eq.

CHAPTER 10
SUMMARY AND CONCLUSIONS

This study has been devoted to an analysis of the economics of regional integration for the chemical nitrogenous fertilizer industry in the Andean Group countries, Venezuela, Colombia, Ecuador, Peru, Bolivia and Chile. It has focused on the costs of processing and distributing these fertilizers in the region and the associated marketing flows or trade patterns, plant production levels and capacities, and welfare gains (losses). The analysis was also extended to evaluate alternative protection policies required for some countries to keep their domestic processing facilities in operation.

The transshipment formulation of the general linear programming model with a cost minimization objective function was the basic analytical tool used in this study. The model included one intermediate product, ammonia and five final products that are assumed to be perfect substitutes - urea, ammonium nitrate, ammonium sulfate, compounds, and Chilean nitrates - and two intermediate processing activities.

Solutions for the Andean Group countries operating as a Custom Union and for these countries behaving independently under protection were obtained. Consumption projections and supply situations expected to exist in the years 1975, 1980 and 1985 were used to carry out the analysis with respect to changes over time, i.e., to provide some dynamic aspect in the analysis. "Expected" supply situations were derived by accounting for existing plants and expansion plants in each country. Processing cost estimates

were obtained by using engineering data and standardized assumptions, while consumption projections were based mainly on evaluation of previous studies made for these countries.

On the basis of the results obtained in this study, it is concluded that the least cost system of processing and distributing nitrogenous fertilizers in the region is obtained when the Andean Group countries operate as a Custom Union. Net "welfare gains" in terms of lower processing costs and intra-country transport costs, as compared with the case of each country operating independently their own fertilizer industry under protection amounts to $3.5, $6.5 and $6.5 million for 1975, 1980 and 1985 respectively, assuming that in the long run all cost would be variable. Marketing flows or resulting trade patterns are rather stable. Small errors in processing cost estimates and/or transport costs do not modify trade patterns substantially. For 1975 Venezuela becomes the exporting country with the other five countries being importing countries. In 1980 the entry into operation of ammonia-urea fertilizer complexes at Yacuiba, Bolivia, and Punta Arenas, Chile allow the two countries to become self-sufficient and exporters. The Andean Group Custom Union solution results in considerable substitution of urea for other nitrogenous fertilizers because of the higher nutrient content and large plant sizes for urea. Therefore, considerable excess capacity in terms of idle plants of ammonium nitrate, ammonium sulfate, and compounds is generated, mainly in Colombia, Ecuador and Peru. Excess capacities in compounds processing should be taken with caution since operation of these plants would depend partially on the demand for phosphorous nutrients in addition to nitrogen.

Excess capacities in terms of idle ammonium nitrate and ammonium sulfate plants in Colombia, Ecuador and Peru imply that these plants would be closed down. Under the prospective of an Andean Group Common Market the decision about construction of new plants should not be based on import substitution but rather on the competitive ability of the processing facility under consideration.

Plant processing costs estimates under the assumption of output levels close to 100 percent of capacity were in general consistent with the solutions obtained. Although substantial excess capacities were observed for the Venezuelan ammonia and urea plants, output levels close to 100 percent of capacity can be reached by exports to the rest of the world markets. Low costs of raw material (natural gas) and large plant sizes make them able to compete well in the world market.

The decision to build larger ammonia-urea plants at Yacuiba, Bolivia, will have to be based on possible exports to the Argentine market. For the case of larger ammonia-urea plants at Punta Arenas, Chile, competition with Venezuela for the Peruvian market may develop but the decision should be based mainly on possibilities of exports to the rest of the world. In any case, excess capacity of the Andean Group countries as a whole will increase.

From the evaluation of tariffs, quotas, subsidies and subsidy-tariff as alternative policies for domestic industry protection in Colombia Ecuador and Peru, it is concluded that for the purposes of lower fertilizer "prices" to farmers and less difficulties for for governments (internal opposition from those receiving transfers under alternative policies) to change policies in a process of

economic integration, a direct subsidy to domestic processing facilities is the preferred policy. However, this policy is costly in terms of government revenues, which may lead to the consideration of a mixed subsidy-tariff policy as an alternative.

The evaluation of tariffs, quotas, subsidies and subsidy-tariff combinations as alternative protection policies in Colombia, Ecuador and Peru shows that for the purpose of lower fertilizer prices to farmers and less difficulties for governments to change policies in the process of economic integration, a direct subsidy is the preferred policy. To solve the problem of lack of government revenues, consideration should be given to a mixed subsidy-tariff policy.

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APPENDICES

Appendix A. Intra-country transport costs of fertilizer materials

Estimated transport costs from importing ports and plant sites to distribution centers, and from plant sites to exporting ports, are expressed in dollars per metric ton of fertilizer material.

Appendix A Table 1. Intra-country transport costs of fertilizer materials in Venezuela

Item	Plant sites and importing ports			
	Maracibo	Moron	Pto Cabello	Pto. La Cruz
Distribution Centers:				
Valera	4.61	8.61	9 96	20.40
San Cristobal	10.10	14.00	15 35	23.90
Acarigua	10.00	5.40	6 75	17.00
Barquisimeto	6.80	4.00	5.35	15.60
Maracay	13.45	3.35	4.70	8.25
Maturin	22.40	12.30	13 65	3.00
Ciudad Bolivar	25.45	13.15	14.50	4.50
Maracaibo		10.10	11 45	21.70
Exporting Ports:				
Puerto Cabello	11.45	1.35	1.35	13.00
Puerto La Cruz	21.70	11.60	13.00	

Source: Food and Agriculture Organization Fertilizer Mission To Venezuela (1972).

Appendix A Table 2. Intra-country transport costs of fertilizer materials in Colombia

Item	Plant sites and importing ports			
	Barranquilla	Barrancab.	Cartagena	Buenaventura
Distribution Centers:				
Bogota	13.25	6.65	15.28	13.75
Bucaramanga	7.91	2.59	9.70	19.30
Cali	16.21	9.47	17.14	3.20
Tbague	12.62	7.05	15.45	9.80
Manizales	16.20	11.11	18.84	9.00
Medellin	11.33	5.64	13.20	10.30
Neiva	14.67	8.85	17.71	15.00
Pasto	26.25	19.62	27.30	10.00
Tunja	12.08	9.53	17.48	17.80
Cartagena	6.76	13.08		22.88
Exporting Ports:				
Barranquilla		5.32	6.76	22.85
Buenaventura	22.85	12.67	22.88	

Sources: National Department of Planning (1971).

Appendix A Table 3. Intra-country transport costs of fertilizer materials in Peru

Item	Plant sites and importing ports								
	Talara	Cachimayo	Callao	Paita	Salaverry	Pimentel	Chimbote	Pisco	Matarani
Distribution Centers:									
Piura	0.80	25.60	10.00	0.40					
Trujillo	6.00	21.20	5.20		0.20				
Chiclayo	4.00	23.00	7.00			0.20			
Chimbote	6.60	18.30	4.00						
Nazca	15.70	11.60	4.50					1.80	
Callao	11.00	16.00							9.00
Cuzco	26.50	0.30	16.40						
Huancayo	16.00	21.00	5.00						1.80
Arequipa	19.00	12.20	9.00						
Exporting Ports:									
Callao									
Paita	0.40								
Pisco		13.40							

Source: Robertson (1968) and Diamond *et al*. (1968).

Appendix A Table 4. Intra-country transport costs of fertilizer materials in Bolivia

Item	Plant sites and importing ports		
	Yacuiba	Matarani	La Paz
Distribution Centers:			
Sucre	15.15	30.42	18.12
Cochabamba	26.00	28.66	10.87
La Paz	26.20	17.74	
Oruro	21.80	22.14	5.43
Potosi	13.80	28.00	16.30
Santa Cruz	11.45	39.53	21.74
Tarija	6.50	9.00	21.74

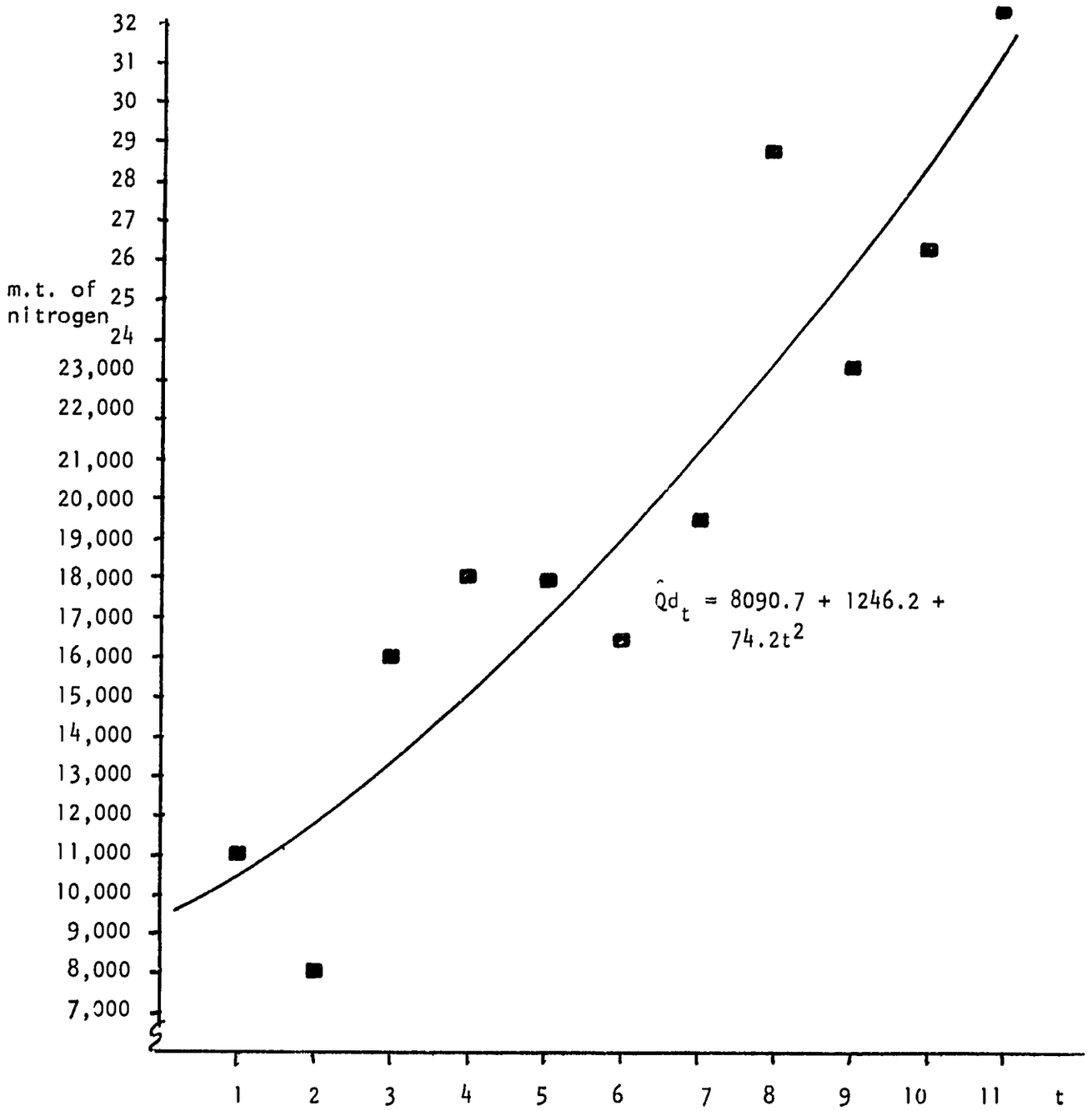
Source: Russel *et al*. (1970).

Appendix A Table 5. Intra-country transport costs of fertilizer materials in Chile

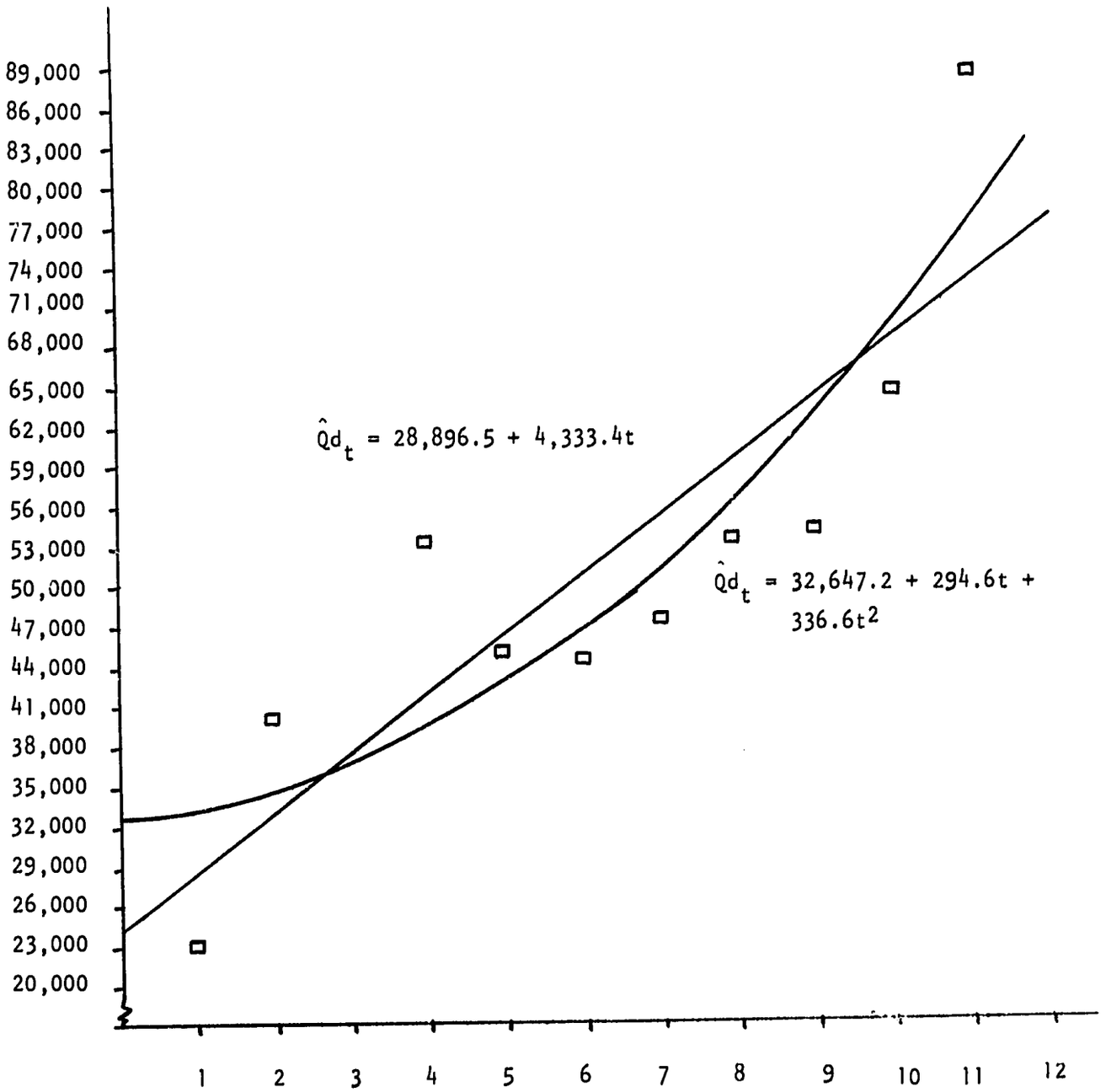
Item	Plant sites and importing ports					
	Punta Arenas	Antofaga.	Valparaiso	San Antonio	Talchuano	Pto. Montt
Distribution Centers:						
Antofagasta	22.50					
Ovalle	33.15	17.85	6.75			
Rancagua	22.10	13.10	2.10	2.10		
Los Angeles	20.40	13.70			1.90	
Perto Montt		11.80				0.00
Punta Arenas		22.50				
Exporting Ports:						
Punta Arenas	0.00					
Antofagasta		0.00				

Source: Kearney (1970) and Davis *et al*. (1970).

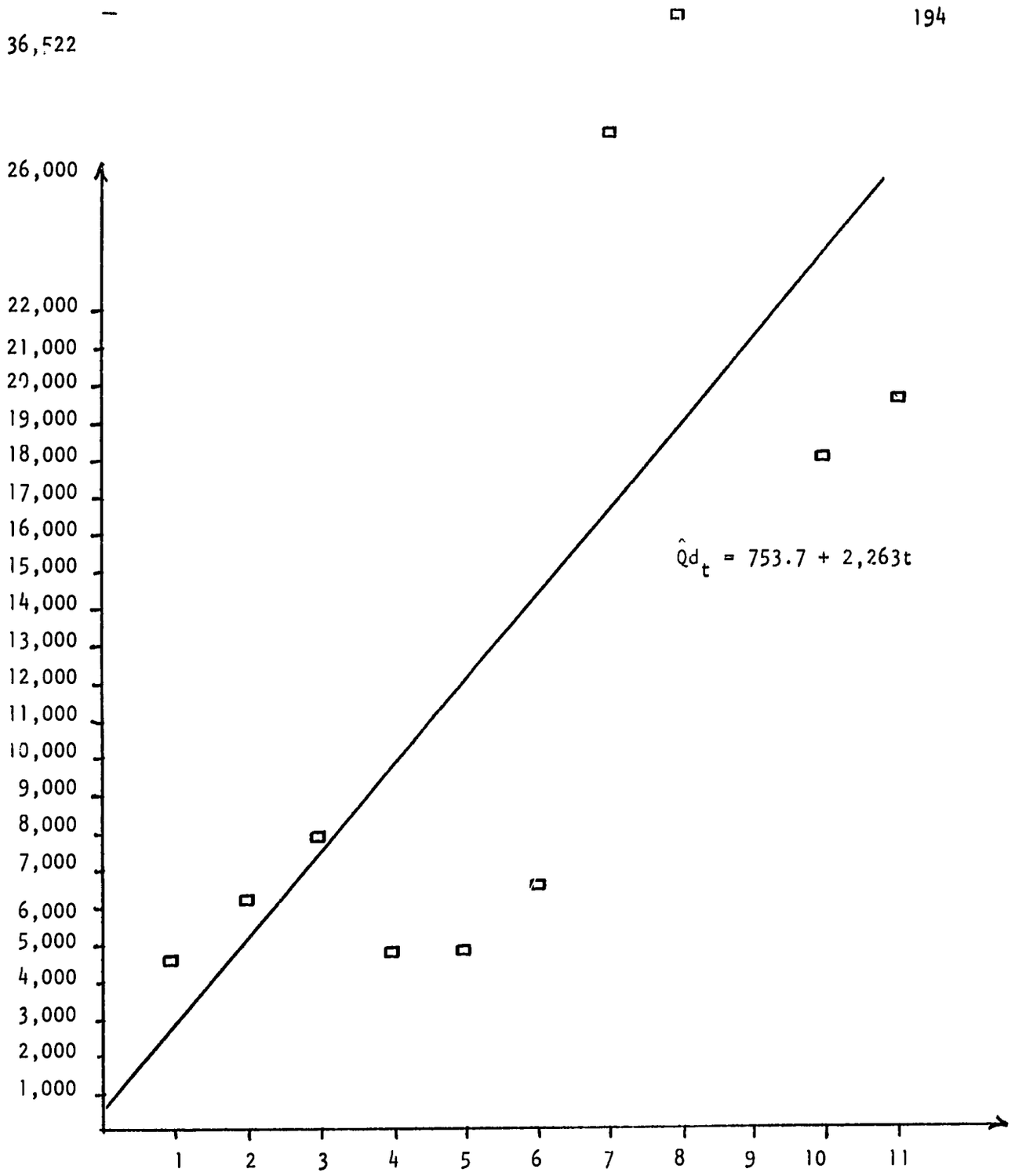
Appendix B. Consumption Projections



Appendix B Figure 1. Estimating equation of consumption projections for Venezuela



Appendix B Figure 2. Estimating equations of consumption projections for Colombia



Appendix B Figure 3. Estimating equation of consumption projections for Ecuador

Appendix C. Plant locations in the Andean Zone

Barranquilla
Cartagena
Maracaibo
Moron
P. Cabello
P. La Cruz
VENEZUELA
Barrancab.
COLOMBIA
ECUADOR
Guayaquil
Talara
Paita
PERU
Callao
Cachimayo
Pisco
Matarani
BOLIVIA
Yacuiba
Antafagasta
Valparaiso
CHILE
P. Montt
Punta Arenas