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A QUANTITATIVE APPROACH TO AGRICULTURAL POLICY PLANNING*

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This paper examines the possible uses of a programming model for planning the Mexican agriculture sector. The model used (CHAC) is a fairly disaggregative one in terms of crops, technologies of production and producing locations, and it describes the supply and demand for 33 short-cycle crops and associated inputs. Resource endowments of the year 1968 were used as constraints and solutions were obtained for 1976 under alternative assumptions of the following policy parameters: rate of expansion of arable land, rate of change of yields per hectare for all crops, rates of GNP growth and rate of change of upper bound on export crops. The type of data used were cost of production at a cross-section farm level.

1. INTRODUCTION

Agriculture is traditionally a baffling sector for policy planners in all parts of the world. In developing nations, the problem is often exacerbated by conflicting goals. Agriculture is expected to carry many burdens: principally, to satisfy national food requirements, to provide employment, and to generate foreign exchange. In addition, the data base in the developing world is often inadequate for estimating the appropriate response parameters of the sector.

The usual approach to agricultural policy planning involves setting production targets by commodity in physical units and then attempting to trace the input requirements for the target level of production of each commodity separately. Several criticisms may be made against this procedure.† First, the traditional framework does not permit assessment of sector-wide aggregates, such as an aggregate supply function or an aggregate elasticity of factor substitution. Such measures are important for the evaluation of alternative sector programs in the light of national development goals. While individual commodity production targets may satisfy the food needs, and perhaps the foreign exchange goal, it is unlikely that they represent the best program for, say, employment purposes.

Second, even from the viewpoint of food requirements, efficient resource allocation may require that certain product prices are allowed to rise while others decline in relative terms. In other words, the sector faces not point demands but demand schedules. The position on the schedule should be found as a result of a constrained resource allocation problem. Third, proper planning in the face of balance of payments constraints may require varying mixtures of imported and domestic supply for each product, and this cannot be handled properly without considering all products simultaneously.‡

* Spanish title: "Una Metodología Cuantitativa de la Programación Agrícola." An earlier version of this paper was originally issued in Spanish as technical note no. 2 of the Comisión Coordinadora del Sector Agropecuario, Mexico, and in English as World Bank Staff Working Paper No. 180.

† See, for example, Mellor [12], pp. 382-384, for a critical view of the usual practice.

‡ An iterative procedure could be envisaged, in which the cumulated production/import programs were revised in each round, but it would be cumbersome, especially if it were to allow for the impact of changing cropping patterns on the opportunity cost of land and other fixed resources.

A fourth criticism of the usual approach is that attempting to add up resource requirements crop-by-crop ignores the substitution which may take place among crops on the supply side and hence can give quite biased aggregate estimates of resource needs. In monoculture zones, this is not a problem, but in other areas the supply side substitution effects can be important among short-cycle crops.

This paper presents a policy planning methodology which, while leaving many thorny problems unanswered, meets these four criticisms. To overcome data limitations, it relies heavily on the use of cross-section farm level production cost data instead of aggregate production time series. In this respect, it may be thought of as a procedure for translating micro-level data into macro-level (sectoral) statements.

The methodology has been used recently to formulate the agricultural portion of Mexico's new national economic guidelines.* The basic tool is the sector model CHAC, which describes supplies and demands for 33 short-cycle crops and associated inputs. A description of CHAC has been provided elsewhere [1], [5]; here we discuss (a) its modifications and uses as an aid to planning and (b) the approach to planning which has been made possible by the model. To illustrate the approach, an extensive set of numerical results is presented.

The policy problem as treated here involves both traditional macro-type policy instruments (interest rate, foreign exchange rate, etc.) and also crop-specific and input-specific policies. In some cases, the instruments are identified by region, but they do not go so far as particular investment projects in particular localities (although the aggregate sectoral investment budget is treated indirectly).

2. THE MEXICAN APPROACH

The Mexican plan† contains a good many measures of institutional reforms and other non-quantifiable programs, and it is unusual in that it specifies many concrete steps which already have been fully implemented. To confine this paper within reasonable bounds, we do not discuss these aspects, but only the quantitative framework of the plan.

Planning in the Mexican context means the coordinated use of available policy instruments to attain the plan's objectives. Specifically, there are six major categories of quantitative instruments for influencing sector performance:

- (a) investment programs in physical resources, (e.g., land and irrigation facilities);
- (b) investment programs in research and extension;
- (c) factor and product pricing policies;
- (d) trade policies (tariffs, export incentives);
- (e) in limited cases, factor allocations over crops and/or areas (e.g., short-term credit); and
- (f) land tenure policies, e.g., farm size determination.

*The plan document, entitled *Lineamientos para el Programa de Desarrollo Económico y Social*, was completed and released in November, 1973. It has a flexible planning horizon, but for the most part treats the interval up to 1980.

†While the word "plan" is employed here because of its widespread use in the economics profession, a better term would be "economic program" which in fact is the title of the official document.

In addition, the overall rate of GNP growth, which may be influenced by fiscal, monetary and other policies, affects sector performance through shifting the demand functions for agricultural products.

Each of these policy instruments, and the rate of GNP growth as well, is represented by a set of parameters in the model. For the Mexican plan, the instruments were tested by the procedure of solving CHAC under alternative assumptions regarding the values of the policy parameters. Solutions were made for two points in time (1968 and 1976) and the rate of growth of each target variable was calculated *ex post*. Thus, the planning analysis may be regarded as an exercise in comparative statics. The different policy assumptions were reflected in alternative values of selected parameters for 1976. In the case of policies whose impact is cumulative over time, annual rates of change were hypothesized and projected to form values for the year 1976. The model thus represents a simulation of the various impacts of these hypothetical policies. In agriculture, with all its interrelations on both the supply and demand sides, a fairly detailed model is required in order to make a reasonably realistic solution.

Since CHAC is fairly disaggregative in terms of crops, technologies of production, and producing locations, it has been possible to trace the potential consequences of hypothetical policies at a reasonably concrete level, where the judgement of agronomists and other specialists is applicable. This has been helpful both in model validation* and interpretation of projections.

3. CHAC: AN OVERVIEW

While CHAC is a mathematical programming model in terms of solution technique, it is best described as a behavioral simulation model. It attempts to describe how farmers will react, in the aggregate, to certain classes of economic policies which influence their cost/price structure and resource availabilities.

The main elements of CHAC may be summarized in a few paragraphs as follows:

(a) *Sectoral coverage*. It includes all sources of supply—domestic and imported—and all demands—domestic and export—for the 33 short-cycle crops analyzed. It does not include livestock, forestry, or long-cycle crops.

(b) *Interdependence on the supply side*. Supply is described as a process analysis technology set for each of twenty spatial entities. Alternatives on mechanization, planting dates, fertilization, and irrigation are included.† The total set of alternative technologies for the 33 crops and 20 spatial “submodels” is 2348. Due to the fact that each submodel contains a large number of crops which compete for use of the same local resource (land, water, and farm family labor), the implicit cross-elasticities of supply are generally non-zero. This is the process-analysis manner of capturing extensive interdependence within the supply set. In addition to the local resources, other agricultural inputs included in the model are day labor, chemical inputs, improved seeds, agricultural machinery services,

* For various pieces of evidence regarding validation of CHAC, see Bassoco *et al.* [2] and Duloy and Norton [6].

† This is basically an agronomic specification of supply conditions. Heady and various associates were pioneers in developing this kind of supply treatment; see, for example, Heady, Randhawa, and Skold [11].

draft animal services, short-term credit, and miscellaneous cost items. Land, labor, and water are treated on a monthly basis. For the treatment of labor, as explained below, the twenty submodels are grouped into four major regions.

(c) *Interdependence in demand.* As noted previously, price-elastic demand functions are incorporated in CHAC and, when projections are made, income elasticities of demand are used to make appropriate shifts of the static demand functions. This structure permits varying crop portions in aggregate production, with corresponding variations in relative prices. This amounts to indirect substitution in demand. To permit direct substitution, crop groups are specified within which limited substitution may take place at a constant marginal rate of substitution. For lack of more precise information, export demands are typically specified as perfectly elastic up to a bound. The interdependence both in supply and demand is an important aspect of the agricultural sector, and capturing it in the model has helped considerably as regards the realism of the model's results.

(d) *Simulating market equilibria.* The incorporation of demand structures permits specification of alternative market forms, e.g., competitive or monopolistic or a quasi-monopolistic supply-control regime. For the bulk of the CHAC solutions, the competitive market form was assumed since, with a few possible exceptions in the fruits and vegetables, no producer or association of producers can influence the market price through production decisions. The optimization feature of the model is not used in a normative sense, to maximize some goal set, but rather in a descriptive sense, to simulate the behavior of the competitive market. This is achieved by maximization of the sum of the Marshallian surpluses for each product's market.* Qualifications to the purely competitive assumption are made for the case of some of the producers in non-irrigated areas, where participation in the market is not as widespread. These are discussed below.

(e) *Elements of dualism.* Dualistic concepts are contained in CHAC in the technology sets and in the parameters of market participation. One explanation for the lower elasticities of crop supply which are often obtained for more traditional farmers is simply that these farmers have few alternative crops to consider in making their planting decisions. Farmers who have access to irrigation water, and who have enough land to be able to afford to take some risks, can contemplate a wide variety of grains, vegetables, oilseeds, fruits, and other crops which are nearly equal in profitability per hectare. A small shift in relative crop prices is therefore more likely to induce him to change his cropping pattern than it would in the case of the farmer who has a smaller array of choices.† In CHAC, the non-irrigated areas have fewer alternative crops and technologies than the irrigated areas do. The second way in which traditional farmers are differentiated in the model is in the specification of home consumption constraints. Many producers tend to satisfy their families' consumption needs in the basic food crop (corn) before marketing it or producing another crop. Several possible explanations, not all of them strictly economic, can be adduced for this behavior, but for the

* For a full exposition of the CHAC demand structures and their properties, see Duloy and Norton [7].

† This holds true as long as resource endowments are fixed in each case. As mentioned below, some solutions of CHAC have underscored the importance of idle, marginal lands in non-irrigated zones. Price increases may bring these lands under cultivation and therefore show a rather high supply elasticity for non-irrigated areas.

model the following simple assumption sufficed to explain the observed behavior. If a farmer meets his family's food requirements through market purchase of corn the year round, the average price per kilo he pays will be higher than the price he could get for his own corn crop at harvest time. This price differential arises from both the normal buying-selling margin—perhaps exaggerated by market imperfections—and seasonal price movements. For the model, it was assumed that this differential is paid when a farmer does not devote enough of his land to corn to meet consumption needs. In the solutions, the differential proved sufficient to enforce production for own consumption—allowing crop diversification only after family consumption needs were satisfied.

(f) *Labor supply functions.* Labor in CHAC is specified in three basic categories: farmers and family workers, day laborers, and machinery operators. The stock of farmers is divided into twenty parts, one corresponding to each spatial submodel on the production side. Farmers with irrigation are assumed not to migrate or work on other farms in the short run, but farmers without irrigation are assumed to be available for hire as day laborers in slack months.* The pool of day laborers is divided into four regional components, and interregional migration may occur in the model if the day laborers in a given region are fully employed in at least one month. Thus hiring of day laborers and farmers in non-irrigated areas is specified on a monthly basis. Hiring of farmers in irrigation submodels is stated in annual terms: a farmer makes a commitment (to himself) to see his farm through the crop year. Machinery operators are assumed to be freely available at their going wage, and thus no quantity restriction is imposed. In practice, they form a tiny fraction of labor force and lack of their availability has not been cited as an obstacle to agricultural undertakings in Mexico.

Day labor wages are set at the going market levels for each of the four regions; the northwest has a wage nearly twice that of the south—a reflection of the slow pace at which interregional wage differentials adjust. The labor of farmers is priced at a monthly "reservation wage" which is greater than zero but less than the day labor wage. In narrow terms, the reservation wage may be regarded as the measure of the disutility of work; in other terms it is the minimum productivity at which farmers will undertake additional tasks on their farms. It is sometimes observed that farmers will not adopt new techniques which promise minimal additional returns per unit of additional work. In other words, at a zero wage the labor supply function is zero. Time is simply too valuable (for noneconomic activities also) to waste it in unproductive labor. On the other hand, farmers clearly undertake some low productivity tasks on their farms, secure in the knowledge that their annual income will flow in at a higher rate. Over the course of a year, they gain not only the sum of monthly "reservation wages," but also the economic rents which accrue to their land, water, and labor and management skills. In fact, in CHAC, the reservation wage payments typically amount to one-third to one-fifth of a farmer's total income.

* This assumption follows from the less-intense cycle of work observed on rainfed farms—where the most labor-intensive crops are not feasible, nor is double-cropping. Obviously there are exceptions: small-scale farmers with irrigation may be found who work off the farm seasonally, and large-scale rainfed farmers may stick to their farms the entire year, but on the whole the assumption describes the actual degrees of labor mobility.

The empirical question confronted was the appropriate level of the reservation wage. Simulations were made with the model (and also with submodels solved in isolation) under varying reservation wage rates to see which figure gave the more appropriate cropping patterns and labor hire patterns. For irrigated areas, the answer fell consistently in the neighborhood of 40 to 50 percent of the day labor wage; and values in the ranges 0-30 percent and 60-100 percent gave quite distorted results. For non-irrigated areas, the appropriate value appeared to be somewhat lower, around 30-40 percent of the market wage. Values in these ranges were therefore adopted for the planning solutions.

(g) *Comparative statics*. CHAC is an annual model which may be solved for any given cropping cycle. Validation runs were made for the base year of 1968,* with the resource endowments of that year entered as constraints. Subsequently, solutions were made for 1976 under alternative assumptions on the following parameters:

- (i) the rate of expansion of arable land, irrigation supplies, and the labor force;
- (ii) the rate of change of yields per hectare for all crops;
- (iii) the rates of GNP growth (which determine the degree of shift in the demand functions);
- (iv) the rate of change of upper *bounds* on crop exports (which is not the same as export *levels* in the solution), to reflect changing world market circumstances.

For each 1976 solution, 1968-1976 annual rates of change were calculated and are reported below. These solutions constitute the bulk of the planning runs, for they permit assessment of the sensitivity over time of several variables (including employment and the income distribution) with respect to policies which would be designed to influence the above parameters. A number of other solutions were carried out to explore the static behavior of the model for the year 1968. In particular, a series of capital-labor substitution isoquants and response surfaces were traced out by varying relative factor prices and making appropriate assumptions about constancy of output or other variables. These "static" experiments of course are also useful for planning employment-oriented policies.

4. BASIC MACROECONOMIC RESULTS

In the preceding discussion of the comparative static procedures, it was noted that four kinds of exogenous information define the solution. In terms of numbers, the following assumptions were made to establish the "basic case" for 1976:

- (i) The endowments of cultivable land and irrigation supplies increase by 2 percent per year from 1968 to 1976. This implies a corresponding 2 percent annual increase in the number of farm families;†
- (ii) Real GNP increases at 8 percent per year, as does disposable income:

* For stochastic parameters such as yields and prices, three-year averages for the years 1967-1969 were used.

† With a continuation of historical rates of urban-rural migration, assumption (i) would imply that the absolute number of landless laborers neither increases nor decreases.

- (iii) Crop yields and the upper limits on exports by crop were increased in accordance with the judgements of specialists.

These sets of assumptions defined the solutions for 1976 which are discussed in the remainder of this section. The macroeconomic results shown in Table 1 demonstrate, first of all, that the difference between 7 and 8 percent GNP growth is important for the agricultural sector. To avoid increased imports,* sector production grows at 4.7 percent in the one case and 5.4 percent in the other. Even with this increase in sector production, production is not keeping up with demand increases, as may be seen by the projected increases of agricultural prices relative to the economy-wide price level: 1.5 percent per year in the case of 7 percent GNP growth and 2.0 percent per year in the case of 8 percent GNP growth. These rates of relative price increase constitute one of the measures of sufficiency of the agricultural sector development program, in the context of an economy-wide program. As noted above, they are based on certain rates of increase of cultivable land, irrigation water, and per hectare yields, which in turn are determined in part by the magnitude and composition of the public investment program in agriculture. The implication of these results is clear: the assumed rates of expansion of the agricultural resource base are not sufficient to meet expanding needs for agricultural products.†

While the rates of relative price change are useful indicators, care must be taken in interpreting the CHAC prices at the overall sectoral level. They reflect changes in agricultural prices *relative* to the rest of the economy's prices, but agricultural prices are one of the main determinants of the economy-wide price level and the second-round effects are not included in the analysis. Hence there is a lack of closure in CHAC which cannot be overcome without enlarging it to be an economy-wide model. Nevertheless, it is possible to use CHAC prices in the following two ways:

- (a) The overall sector price index may be compared from one solution to another, to see how inflationary each alternative program is, *relative to the other programs*.
- (b) The individual commodity prices in each CHAC solution may be examined to see which commodities are likely to be most (or least) stable in price.

Another interesting aspect of the macroeconomic results concerns employment. Measured in total man-years, it increases at 1.0 to 2.5 percent per year in the various solutions. Given that the sector labor force increases at more than 3.0 percent, this implies continuing rural-urban migration at a significant rate. Comparing these employment growth rates with the production growth rates, it is seen that the "employment elasticity‡ of agriculture output" is about 0.40 (from 0.38 to 0.46 in the four solutions).

In terms of man-years instead of elasticities, a 4.7 percent growth rate of agricultural production creates about 55,000 man-years of employment per year

* By assumption, import levels were held constant in 1968 and 1976. Solutions could be designed which permit changes in the import structure.

† In fact, as of this writing, the public investment programs in Mexico are expanding the agricultural resource base at a slightly more rapid rate.

‡ Defined as the annual percentage change in employment divided by the annual percentage change in sector output, in a given solution.

TABLE 1
CHAC: PRINCIPAL MACROECONOMIC RESULTS
(Millions of 1968 pesos)

	1968	1976			
		7% GNP Growth	8% GNP Growth	7% GNP Growth, Slower Tech. Change	7% GNP Growth, Higher Export
Objective function	66,822	97,589	102,934	96,349	97,952
Producers' income	12,250	17,891	18,295	18,295	17,706
Sectoral income	13,491	19,857	20,640	19,698	20,510
Value of production	25,692	37,110	39,065	37,071	37,958
Total employment, man years	2,016	2,350	2,451	2,334	2,357
Income per man-year	6,693	8,451	8,422	8,441	8,701
Exports	3,479	5,152	5,152	5,036	6,036
Price index	100.0	112.8	117.0	121.5	120.5
		Annual Rates of Change (%)			
Objective function		4.9	5.6	4.7	4.9
Producers' income		4.9	5.2	5.0	4.7
Sectoral income		5.0	5.7	4.9	5.4
Value of production		4.7	5.4	4.7	5.0
Total employment		1.9	2.5	1.8	2.0
Income per man-year		3.0	2.9	3.0	3.4
Exports		5.0	5.0	4.7	7.1
Price index		1.5	2.0	2.5	2.4

and a 5.4 percent growth rate creates about 73,000 man-years,* given present relative prices of capital and labor. Increasing the export growth rate (in varying proportions by crop) from 5.0 to 7.1 percent overall, adds about 3,000 man-years per year.

In terms of jobs, the results are different, for the sector labor force is a mixture of day laborers who may work as little as one month per year and farmers who may work as much as twelve months per year. The impact on jobs of various types is best seen through the changes in the monthly patterns of employment, and that is shown in Section 7 below.

5. MEASURING THE AGGREGATE SECTOR SUPPLY FUNCTION

The aggregate supply response of a sector may be measured in several ways. First of all, there is the simple "elasticity" of sector production with respect to GNP.† The results of Table 1 show that this elasticity is of the order of 0.67 to 0.71 for annual GNP growth in range of 7 to 8 percent. The higher elasticity value

*For these calculations, it is assumed (a) that the sector labor force is roughly 7,000,000 now and (b) that the average laborer in the sector, including those who work full-time, part-time, and not at all, works about 5 months of the year.

†The elasticity is measured here as the percentage change in sector production divided by the percentage change in GNP. It should be pointed out that the values might be different outside the 7-8 percent range of GNP growth.

applies for the case of accelerated export growth. This, however, is not the same concept as a supply elasticity, for it measures the aggregate response of the moving supply-demand equilibria for all crops in the sector.

A version of the aggregate supply elasticity can be measured from these results, however. Figure 1 illustrates the procedure for the case of a single crop. The curve D^{68} is the price-elastic demand curve for the base year, 1968, and the curves D^{76-1} and D^{76-2} are the corresponding curves for 1976, under 7 and 8 percent annual GNP growth respectively. In CHAC, they have been shifted by an amount determined by both the rate of GNP growth and the magnitude of the income elasticities of demand. Hence the amount of shift is different for each commodity. The implicit supply curve in CHAC (which is nonlinear, as shown) is represented by S^{68} for year 1968 and by S^{76} for the year 1976. It may be seen from the figure that the arc elasticity of supply between points a and b is readily calculated *ex post* as follows:

$$(1) \quad \epsilon = \frac{(q_2 - q_1)/(q_2 + q_1)}{(p_2 - p_1)/(p_2 + p_1)}$$

Since the model provides both price and quantity estimates for all crops, the calculation of ϵ is a straightforward matter, using the production and price indices of Table 1. The 7 and 8 percent growth cases for 1976 are used because they jointly identify different points on the same short-run supply curve. Thus, for example, it is not possible to utilize pairs of points defined by the cases of faster and slower technological change, for they define different supply functions.

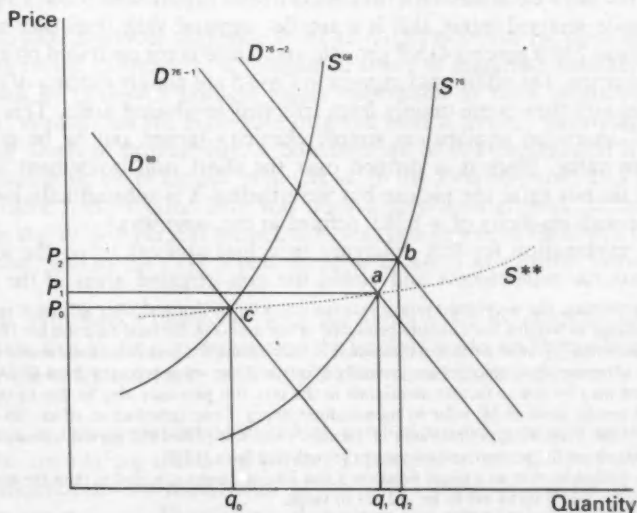


Figure 1 Procedure for measuring the sector supply function

Taking the 7 and 8 percent growth cases, then, the calculations yielded an aggregate supply elasticity of 1.383.* How is this figure to be interpreted? First of all, in one sense it represents a long-term supply elasticity, since it refers to behavior between two *equilibrium* points, after all adjustment processes have worked themselves out. However, in another respect it is a short-run concept, for it does not allow investment in expansion of the sector's resource base (land, water). That expansion is taken care of in the *shift* of supply function from S^{68} to S^{76} . Hence we may call the CHAC elasticity an "equilibrium short-run elasticity."

Second, as noted before, it refers only to the supply of short-cycle crops. It is clear that the number would be smaller (a) if it treated perennial crops, and (b) if it were a purely short-run (non-equilibrium) elasticity concept. Looked at in this light, the magnitude seems reasonable in light of existing international studies.†

Alternatively, it is possible to redefine the supply function as a "long-run equilibrium supply function" which includes the effects of fixed investments and yield changes over time. This would be curve S^{**} in Figure 1 which passes through points *c* and *a*. Using the same measurement rule, this long-run arc elasticity (between points *c* and *a*) is calculated at the value +3.030.‡ It may be asked what is the contribution of technological progress (change in yields per hectare) to this value? Here it is necessary to explicitly treat the cases of different rates of technological progress. With a slower rate of progress, the long-run equilibrium arc elasticity is computed as +1.865 (Cases 4 and 1 in Table 1). In other words, reducing the rate of per hectare yield increase from about 2 percent per year (averaged over all crops) to about 1 percent per year reduces the supply elasticity by nearly 40 percent. This underlines the importance for the sector's responsiveness of the public sector programs aimed at achieving higher yields in actual practice.

Although the effect on total production was quite small, it was interesting to make the same calculation for the case of higher export sales (Case 5 vs. Case 2). In aggregate sectoral terms, this is a smaller demand shift than that caused by moving from 7 to 8 percent GNP growth, and it also is concentrated on a different bundle of crops. The additional exports in Case 5 are mainly exports of fruits and vegetables and they come mainly from irrigated producing areas. This "export-oriented" short-run equilibrium supply elasticity turned out to be quite low: +0.342 in value. Since it is defined over the short run, investment and yield increases do not enter the picture but nevertheless it is substantially lower than the sector-wide elasticity of +1.383, defined in the same way.§

The explanation for this difference in values appears to be the following. Given resource endowments and yields, the non-irrigated areas of the republic

* For reference, the weighted-average income elasticity of demand over all crops in CHAC is +0.545, utilizing as weights the quantity produced in the model in the base solution for 1968.

† See Behrman [4] for an extensive discussion of both estimation procedures and numerical results. Purely short-run supply elasticities are typically about half the value reported from CHAC. Part of the difference may be due to factors mentioned in the text, but part may also be due to the fact that most of the results cited in [4] refer to monoculture zones. Crop substitution effects do contribute somewhat to the overall supply response in Mexico. Over the 1930-1960 period, substitution alone accounted for about 0.5 percent annual output growth (see Solis [13]).

‡ If one wishes to view as a single function a line joining points *c*, *a*, and *b*, then the arc elasticity between points *c* and *b* turns out to be +2.631 in value.

§ These elasticities refer to the *aggregate bundle* of crops produced in irrigated and non-irrigated areas. For individual crops, the elasticities tend to be higher in irrigated areas because of the crop substitution possibilities. (See Section 3 above.)

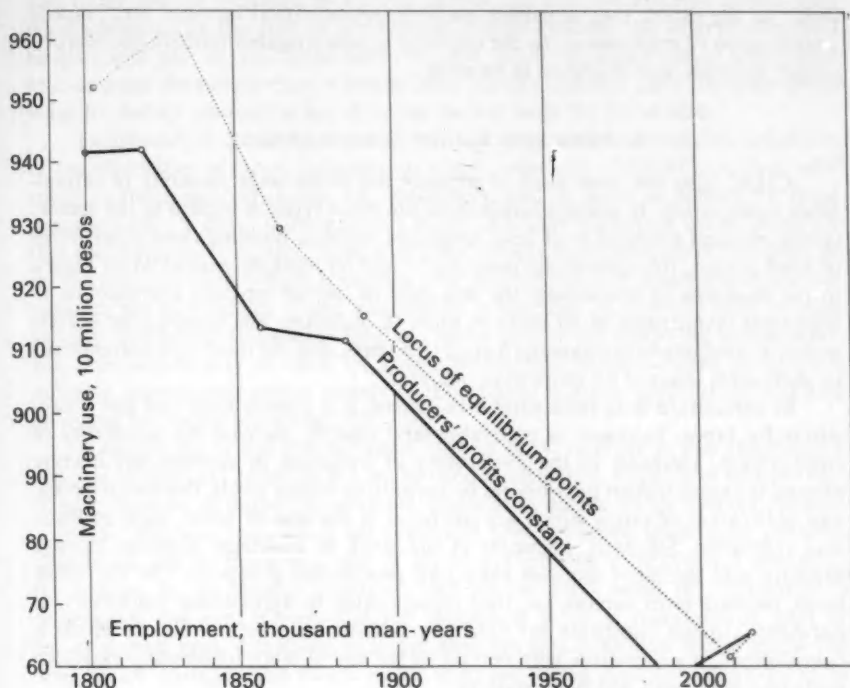


Figure 2 CHAC: Sector Isoquants for Capital and Labor

appear to have a greater aggregate (over all crops) potential for price responsiveness, due to the existence of a substantial stock of marginal, uncultivated land which will be gradually brought under cultivation as price incentives rise. In contrast, virtually all the cultivable irrigated land is already cultivated,* due to its higher levels of profitability. A confirmation of this explanation is provided by an interesting set of figures from CHAC in the 1968 solution: 29.3 percent of the available non-irrigated land was uncultivated even at peak periods of field labor. In the 1976-7 percent growth solution, this degree of slack was reduced to 8.3 percent, and in the 1976-8 percent growth case it was further reduced to 0.2 percent.

This explanation coincides with the observation of students of Mexican agriculture that in the post-war period the terms of trade, and hence the incentives to cultivate marginal land, have steadily worsened from the sector's viewpoint [14, p. 40].

Thus, at this particular point in Mexican history, price incentives should have powerful stimulating effects on private expansion of the cultivated land. This result underscores the importance of the Plan's prescriptions for utilization of price incentive tools. The obverse deduction for practical programs may also

*Except for areas affected by land tenure disputes and other problems which are not responsive to price inducements.

hold: to the extent that imperfect markets, sociocultural barriers, etc., impede transmission of price signals to the majority of non-irrigated farmers, the sector's supply response may continue to be weak.

6. MEASURING FACTOR SUBSTITUTABILITY

CHAC also has been used to estimate the sector-wide elasticity of capital-labor substitution. In general terms there are three types of capital in the sector: (a) the physical availability of land, irrigation systems, buildings and other forms of fixed capital; (b) agricultural machinery; and (c) working capital. With regard to the financing of investment, the first type of capital typically corresponds to long-term investments of 10 years or more in duration. The second type corresponds to medium-term financing from 2 to 5 years, and the third type corresponds to short-term loans of no more than one year.

In agriculture long-term capital in general is a complement and not a substitute for labor. Increases in cultivable land directly increase the possibility of employment. Increases in the availability of irrigation in supplies per hectare expand the employment possibilities by permitting higher yields, double cropping, and cultivation of crops which are intensive in the use of labor, such as fruits and vegetables. Similarly, increases in the stock of buildings augment storage capacity and therefore increase sales and production prospects. On the other hand, medium-term capital, i.e., that incorporated in agricultural machinery, is normally a direct substitute for field labor. Short-term capital can be either a complement or a substitute with respect to the use of labor, depending upon the particular field tasks which it supports.

In most econometric studies of factor substitution, the first two types of capital are lumped together, and sometimes all three classes are grouped. Thus both positive and negative substitution effects are aggregated and the sign that dominates, and by how much, depends on: (a) the strength of the two opposing effects, and (b) the relative weights of the different classes of capital within the total capital stock of the sector. For example, Behrman in his estimates of capital-labor substitution for Chile [3] used time-series data which group together several forms of capital. In his study, the value of all of the sectoral elasticities of substitution estimated is less in unity, and for the agricultural sector the value is 0.31.

Estimations with CHAC refer solely to the second type of capital, i.e., machinery, and therefore they measure solely the substitution effect without any admixture of effects of the opposite sign. Therefore it could be expected that the elasticities of substitution measured with CHAC would be of higher absolute value, and in fact they are: they range from around 1.0 to more than 3.0, in accordance with the different isoquant definitions which are presented below. Given that the financing of investment in machinery is generally of a different term than investment in land and other long-term works, the conceptual separation of types of capital for the elasticity calculations is consistent with a distinction between different instruments of policy.

The experiments with the model were carried out by specifying proportional salary increases for all types of labor as a means of inducing movement along the isoquant. The total cost of labor, which includes the farmers' returns to their land

and water, always increases by a lower proportion than the nominal salary. This occurs because as the cost of production (which includes the salary) increases, farmers lose part of their fixed factor returns. Also, the higher salary levels tend to encourage the substitution of family labor for day laborers, since the reservation wage for family laborers is less than the market wage for hired labor.

To summarize the foregoing, it is worth noting two important characteristics of the elasticities of factor substitution which come out of CHAC: (a) they refer solely to medium-term capital, i.e., machinery, and (b) labor as defined for these measurements is not a homogeneous factor. Another important characteristic is that the isoquant is derived from a sectoral production function, or envelope of production functions, which is defined over multiple factors. Land and irrigation supplies are two factors whose availability is specified in monthly form in each locality. The actual amounts of land and water used in the model are endogenous, but their availability is fixed. In formal terms, this multiple-factor production function corresponds rather closely to the process analysis model described and analyzed by Georgescu-Roegen [9], [10].

A fourth important characteristic of the CHAC estimate is that the model's sectoral production function is a multi-product function. Because of this characteristic, in order to define the isoquant, users must decide which concept remains constant. The solutions which are presented here are based upon three different definitions: (a) the economic rent of producers (profits) is maintained constant; (b) nothing is maintained constant; and (c) the total value of production is maintained constant. Given that the income of labor is composed in part of the economic rent, it is to be expected that the first definition would allow the least factor mobility and hence would give the lowest elasticity of substitution between factors, and that is exactly what occurs. This definition is the iso-profit curve. The second definition does not give an isoquant but rather locus of general equilibrium points associated with changes in factor prices. Although this is not an isoquant, it is perhaps more interesting from the viewpoint of the decision makers, because it constitutes a complete estimate of the set of multi-market reactions to hypothetical changes in prices. It is a type of response surface. Among other things it is interesting to see how closely the response surface approximates the isoquant. The third definition given above is very close to that of the isoquant itself because, as will be explained below, it ensures that production, measured by a quantum index, is maintained approximately constant. Results under the three definitions are presented as Cases I, II, and III, respectively, in Table 2 below. Cases I and II are also shown in Figure 2.

It should also be mentioned that the production function of CHAC is specified with respect to the flows of various current inputs which are used in the production process. These inputs have a price in the model but they are not restricted in any way in the versions used for these solutions.

Regarding results, then, the sectoral elasticity of factor substitution, measured as an arc elasticity over the longest arc, has a value of 0.956 when producers' profits are held constant, a value of 1.395 in the case of unrestricted equilibrium points, and a value of 3.341 along the isoquant.

Comparing Cases I and II first, the locus of equilibrium points shows a greater degree of factor substitutability than the iso-profit curve. In other words,

TABLE 2
ELASTICITIES OF FACTOR SUBSTITUTIONS

Case 1: Iso-Profits Curve	Segment of the Curve					
	0	1	2	3	4	5
X: Value of production	2311.5	2342.6	2374.3	2403.6	2439.3	2478.9
P: Producers' profits	927.71	925.71	927.71	927.71	927.71	927.71
W: Wage payments	512.40	554.01	558.67	595.31	621.72	653.38
Y: Total labor income	1440.11	1481.72	1486.38	1523.02	1549.43	1581.09
E: Employment	2015.59	1988.64	1884.04	1856.56	1818.29	1799.33
Y/E: Income per man-year	0.7145	0.7451	0.7889	0.8203	0.8521	0.8787
K: Use of machinery	865.55	858.04	911.67	913.58	942.16	941.64
R: Rate of interest	0.12	0.12	0.12	0.12	0.12	0.12
K/E	0.4294	0.4315	0.4839	0.4921	0.5182	0.5233
(Y/E) ÷ R	5.9542	6.2092	6.5742	6.8358	7.1008	7.3225
Elasticity (a)		+0.116	+2.008	+0.430	+1.359	+0.319
Elasticity (b)		+0.116	+1.206	+0.987	+1.067	+0.956
Case II: Locus of Market Equilibria						
X	2311.5	2276.9	2356.4	2391.2	2390.7	2403.7
P	927.71	847.80	902.90	901.21	856.27	840.25
W	512.40	560.96	560.24	596.75	623.18	653.58
Y	1440.11	1408.76	1463.14	1497.96	1479.45	1493.83
E	2015.59	2009.31	1890.18	1863.54	1829.00	1802.30
Y/E	0.7145	0.7011	0.7741	0.8038	0.8089	0.8288
K	865.55	861.72	915.60	929.55	963.01	952.29
R	0.12	0.12	0.12	0.12	0.12	0.12
K/E	0.4294	0.4289	0.4844	0.4988	0.5265	0.5284
(Y/E) ÷ R	5.9542	5.8425	6.4508	6.6983	6.7408	6.9067
Elasticity (a)		+0.062	+1.228	+0.778	+8.543	+0.149
Elasticity (b)		+0.062	+1.504	+1.272	+1.639	+1.395
Case III: Value of Production Constant						
X	2311.5	2311.5	2311.5	2311.5	2311.5	2311.5
P	927.71	880.55	853.36	807.48	767.59	729.15
W	512.40	561.36	560.92	600.12	622.51	653.70
Y	1440.11	1441.91	1414.28	1407.60	1390.10	1382.85
E	2015.59	2010.58	1894.16	1873.75	1832.14	1810.25
Y/E	0.7145	0.7172	0.7467	0.7512	0.7587	0.7639
K	865.55	863.27	919.96	942.59	975.57	972.61
R	0.12	0.12	0.12	0.12	0.12	0.12
K/E	0.42943	0.42936	0.4857	0.5031	0.5325	0.5373
(Y/E) ÷ R	5.9542	5.9767	6.2225	6.2600	6.3225	6.3658
Elasticity (a)		-0.043	+3.053	+5.857	+5.710	+1.314
Elasticity (b)		-0.043	+2.792	+3.157	+3.573	+3.341

Notes:

1. The value of production is defined at endogenous prices. The units are tens of millions of 1968 prices.
2. Producers' profits are the sum of economic rents which accrue to land, water, and family labor. The units are the same as above.

3. Wage payments include both wages paid to day laborers and "payments" of the reservation wage to the farmer and family laborers. The units are the same as above.
4. Total labor income is the sum of producers' profits and wage payments.
5. Employment is measured in man-years and includes employment of both hired labor and family labor.
6. The use of agricultural machinery is measured as the flow of machinery services in units of ten million pesos.
7. Elasticity (a) is the arc elasticity measured between contiguous endpoints of the linear segments of the curve. For example, in Case II its value is +2.005 from the end of Segment 1 to the end of Segment 2. Elasticity (b) is always measured from Segment 0 to the end of the segment indicated. Thus, the longest arc is that from Segment 0 to Segment 5, and it has an elasticity of +0.956 in Case I and +1.395 in Case II. "Segment 0" is not a segment but rather a point which corresponds to the base solution.
8. The elasticity is always measured as the percentage change in factor proportions divided by the percentage change in the ratio of factor prices. See Ferguson [8] regarding methods for calculating elasticities along an isoquant of piece-wise linear segments.

the iso-profit curve underestimates the degree of factor response in the sector as a whole; this is the relevant point for the formulation of agriculture policy. Secondly, both curves have elasticities which vary substantially over the different segments, and in some cases they are not even convex. This behavior was foreseen by Georgescu-Roegen [9]. The non-convexity rises from the fact that CHAC is a model with multiple products and multiple factors and the "isoquants" are projections of a multi-dimensional hyperplane onto Euclidean 2-space. The following question arises from these results: if in fact the process analysis production model is a reasonable representation of reality, how useful are substitution parameters which are estimated by (a) imposing on the data a production model which includes the implicit assumption of constant elasticities of substitution; and (b) utilizing a production function of two factors and one product?

Another interesting aspect of the capital-labor substitution results is that the iso-profit curve gives levels of net labor income which are always higher than those of the response surface. Correspondingly, the levels of employment are always lower along the iso-profit curve than along the response surface. The reason for this can be seen clearly in Table 2. In the first place, with profits held constant, the producers' economic rents are not permitted to fall as nominal salaries rise. And the only way that profits can be maintained constant while production costs are increasing (through the salary increases) is through sufficient rises in product prices. Therefore, and secondly, the physical levels of production are lower in the iso-profits case than in the response surface case. Given that agricultural products in the aggregate have a price elasticity of demand less than unity (in absolute value), the reduced levels of production tend to raise producers' profits slightly so that the higher costs of production are exactly compensated. This chain of reactions is thus reflected in a lower production index for the iso-profit curve, in comparison with the response surface, and a higher value for production at endogenous prices for the iso-profit curve.

In sum, it can be seen that imposing constant producers' profits on the model stimulates a series of compensating changes in production levels and in product prices. These changes are completely different than in the case of the unrestricted market response surface. In the latter case the value of production rises neither

as rapidly nor as uniformly as salaries are raised. Due to these production effects, the iso-profits curve not only underestimates the elasticity of substitution, but it also underestimates absolute level of utilization of capital and labor in all segments, in comparison with the response surface curve.

Although it may be preferable to use the response surface instead of the iso-profit curve for policy purposes, it must be recognized that neither of these concepts permits the measurement of a pure substitution effect. Both Case I and Case II include output effects* as well as substitution effects. For this reason, in order to isolate the substitution effect alone, CHAC was formulated for a third set of results by maintaining the value of production at endogenous prices constant. These results are presented as Case III.

Case III by definition does not permit the physical levels of production to fall as factor costs increase. Although this case has been generated with CHAC holding constant the value of production, that procedure implies that the quantum index of sectoral production also must remain approximately constant† (permitting compensating changes among individual products) given that the average price elasticity of demand for agricultural products is not equal to unity. Therefore Case III gives physical levels of production which are higher, and higher levels of utilization for both factors, than in either Case I or II.

As anticipated, the pure elasticity of substitution in this case is significantly higher than in Cases I and II. Though this measure is simpler conceptually than either of the other two, in order to calculate it it has been necessary to impose restrictions on the market response in the model and these restrictions have forced the aggregate value of production to differ significantly from its full equilibrium level along the unrestricted response surface. For this reason, Case II is likely to be more useful for policy purposes. If the response surface of Case II is the relevant concept for program formulation purposes, then using the isoquant results would appear to be misleading since they overestimate more than two-fold the percentage response of employment with respect to changes in labor income levels.

As a final point of interest, Table 3 shows the "income elasticity of employment" for all segments of the curves in all three cases. This concept is measured as a percentage response in all types of employment divided by percentage change in total labor income (salaries plus producers profits). As the table shows there is a substantial variation along the course of each isoquant and among definitions of the isoquant. Once again Case III, where production is held constant, shows the greater degree of response. The limiting value of elasticity is -1.606 in Case III, while it is -0.754 in Case II, and -0.550 in Case I.

As a curiosity, it may be pointed out that in one segment of Case II the sign of the income elasticity of employment is positive, that is, both employment and total income per man-year fall. This is attributable to the complex structure of labor income determination in the model. When the salary alone is taken into

* Over some segments, the fall in physical production is also accompanied by a fall in value of production because a few of the crops face demand curves which are relatively elastic with respect to price, and in some segments of the isoquants these products are the ones which register greater movement.

† The quantum index of production will not be exactly constant owing to index number problems.

TABLE 3
ELASTICITIES OF EMPLOYMENT WITH RESPECT TO TOTAL LABOR INCOME

		Segment of the Curve				
		1	2	3	4	5
Case I	(a)	-0.321	-0.946	-0.376	-0.548	-0.342
	(b)	-0.321	-0.682	-0.596	-0.586	-0.550
Case II	(a)	+0.165	-0.617	-0.377	-2.958	-0.605
	(b)	+0.165	-0.802	-0.666	-0.783	-0.754
Case III	(a)	-0.660	-1.480	-0.1803	-0.2260	-1.760
	(b)	-0.660	-1.409	-1.456	-1.589	-1.606

Notes:

1. The three cases defined as in Table 2.
2. The elasticity is defined as the percentage change in employment divided by the percentage change in total labor income (variables *E* and *Y* in Table 2).
3. As before, elasticity (a) refers solely to the arc of one segment, while elasticity (b) refers to the arc which reaches from Segment 0 to the end of the indicated segment. The elasticities are always calculated about the mid-point of the arc.

account (and not producers' profits) the data in Table 2 show that the salary elasticity of employment for this segment has the usual sign and its value is -0.033 .

7. INCOME DISTRIBUTION AND DERIVED DEMAND FOR INPUTS

(a) *Income distribution*

In a model like CHAC, there are basically two ways of specifying an income distribution: (a) by including various farm size classes, and (b) by specifying various producing areas. The latter can be delineated, of course, to capture important distinctions such as that between dryland and irrigated farming. In CHAC, farm size classes are incorporated only for one submodel (El Bajío), and the pattern of income over those size classes was reported earlier [2]. Hence for the sectoral distributional measures, the regional income results are reported here.

Of course, using average regional income levels as points on an income distribution suffers the well-known disadvantage that each point represents a group whose range of individual income levels may overlap the income ranges of other groups. Nevertheless, the regional measure is of some interest, in part because many kinds of policies may be pursued on a regional basis. To conform to widely accepted regional designations in Mexico, the CHAC results for the submodels were aggregated to a basis of seven regions: five representing irrigated agriculture and two representing non-irrigated agriculture. Table 4 shows the CHAC net producer income* results for the seven regions, for the year 1968. It should be borne in mind that the coverage of the model excludes farms which are primarily dedicated to tree crops and livestock. Nevertheless, the typical annual-crop

* Net producer income is calculated as gross sales at endogenous prices less the value of purchased inputs. Here the services of day laborers are regarded as purchased inputs.

farmer earns a small amount of supplementary income from fruit trees and small-scale livestock. CHAC does not include these sources of supplementary income, and to that extent it understates farm income levels.

Table 4 shows a wide divergence in farm incomes. At one extreme, the rainfed farms constitute 51.2 percent of the population (as defined here) and yet earn

TABLE 4
CHAC ESTIMATE OF THE AGRICULTURAL INCOME DISTRIBUTION, 1968

Region	Annual Net Income per Farm (pesos)	Number of Farms	Cumulative Percentage of Net Income	Cumulative Percentage of Farms	Average Farm Size (hectares)	Net Income per Hectare
Dryland	1,393	1,579,174	17.2	51.2	3.5	398
Tropical	3,886	792,217	41.3	76.9	2.9	1,340
North	5,270	81,882	44.7	79.6	2.1	2,510
Center	8,825	407,665	72.9	92.8	2.4	3,677
South	9,806	47,541	76.6	94.3	3.0	3,269
Northeast	10,530	40,396	79.9	95.6	6.5	1,620
Northwest	19,220	133,299	100.0	100.0	8.4	2,280
Non-irrigated total	2,226	2,371,391	41.3	76.9	3.3	675
Irrigated total	10,527	710,783	100.0	100.0	3.7	2,845
TOTAL	4,140	3,082,174			3.4	1,218

Note: Dryland and tropical are both non-irrigated regions; the rest are irrigated.

TABLE 5
EMPLOYMENT AND PRODUCTION BY REGION IN CHAC

Region	Employment			Value of Production		
	Per Hectare Cultivated ^a	Per Farm ^b	Per Unit of Water ^c	Per Hectare Cultivated ^d	Per Farm ^e	Per Unit of Water ^f
<i>Irrigated:</i>						
Northwest	2.08	16.95	1.69	5,143	41,904	4,171
North	2.07	10.50	2.48	4,120	8,524	2,009
Northeast	3.36	21.78	2.50	3,615	23,467	2,694
Center	4.52	11.06	7.90	4,652	11,383	8,129
South	7.06	21.46	5.89	6,402	19,436	5,341
<i>Dryland</i>	1.11	3.88	—	1,377	4,826	—
<i>Tropical</i>	1.65	4.77	—	2,609	7,527	—
<i>Total Irrigated</i>	3.58	13.41	3.42	4,811	18,003	4,600
<i>Non-Irrigated</i>	1.26	4.18	—	1,737	5,729	—
TOTAL	1.85	6.31	3.42	2,517	8,559	4,600

^aMan-months/hectare

^bMan-months/farm

^cMan-months/10 thousand m³

^dGross value in pesos/hectare

^eGross value in pesos/farm

^fGross value in pesos/10 thousand m³

only 17.2 percent of the income. At the other extreme, irrigated farms in the northwest represent 4.4 percent of the population and earn 20.1 percent of the total income. The average farmer with irrigated land in the northwest earns 13.8 times as much as his dryland counterpart. Yet less than half of the difference is accounted for by higher productivity per unit of land: the northwest irrigated farms produce 5.7 times the income per hectare of rainfed farms. On the other hand, the northwestern irrigated farms are more than twice as large.

In terms of productivity per hectare, the central plateau irrigated farms are the most efficient: 3,677 pesos/ha. vs. 2,280 pesos/ha. in the northwest. The irrigated farms in the south and the north are also more productive per hectare than those in the northwest. Part of the explanation for this is found in the cropping patterns: the central plateau produces proportionally more high-value fruits and vegetables than any other part of the country. The south has tobacco and the north has cotton.

But it is also true that the central plateau farmer uses fewer purchased inputs and relies more on his own labor and hence has a higher ratio of net income to gross income. Having smaller farms makes it economic to use much less machinery and hired labor. From Tables 4 and 5, the ratios of net to gross income for the regions are as follows:

Dryland	0.29	South	0.50
Tropical	0.52	Northeast	0.45
North	0.62	Northwest	0.46
Center	0.78		

Relative to non-irrigated agriculture, irrigated agriculture as a whole generates 4.7 times as much net income per farm, 4.2 times as much net income per hectare, and 2.8 times as much employment per hectare. These figures reveal that a man-year generates 1.5 times as much net income with irrigation vs. without. The employment comparison is striking for policy purposes. Adding water enhances enormously the employment absorption capacity of agriculture, even though the typical irrigated farm also is more intensive in machinery use than the typical non-irrigated farm. The additional sources of employment under irrigation are higher yields (higher harvest labor requirements), double cropping, and the ability to grow labor-intensive fruits and vegetables which need controlled water. The typical fruit/vegetable crop in Mexico needs four times as much labor per hectare as the typical grain crop (e.g., corn, wheat).

In every respect—production, income, and employment—irrigation is clearly the factor of primordial importance in Mexico. The uneven distribution of water over farms is clearly the major determinant of the skewness of the sector income distribution. Figure 3 shows the Lorenz curves for the sector's income distribution, for both 1968 and 1976 under 8 percent growth. The curves are very similar except that the lowest income groups appear to gain somewhat over time. In numbers, the temporal farmers receive 17.2 percent of total producers' income in 1968, 18.5 percent in 1976 under 7 percent growth, and 19.2 percent in 1976 under 8 percent growth. In all cases, they represent 51 percent of the farms.

Clearly, higher growth makes the sector income distribution somewhat more uniform. The reason for this is the same as the reason for the higher aggregate

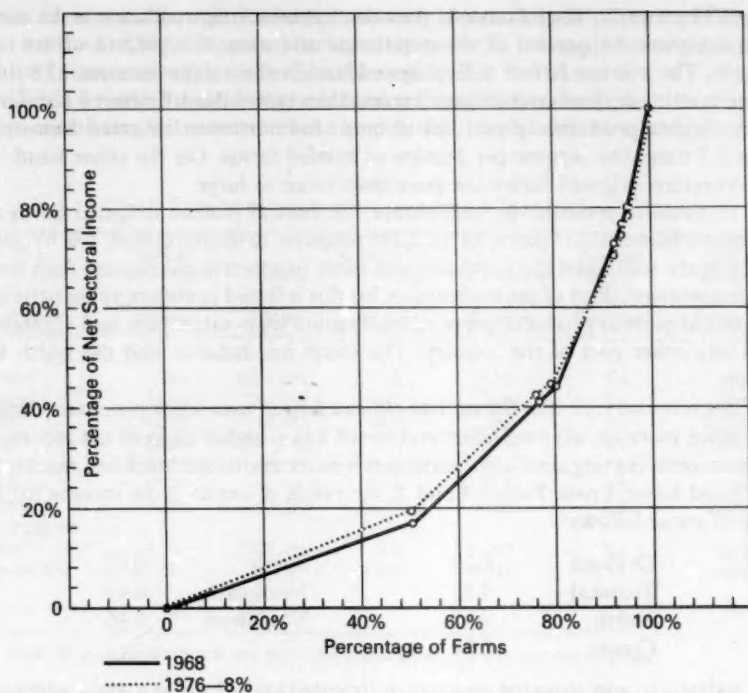


Figure 3 CHAC, Lorenz curves for the sectoral income distribution

supply elasticity in non-irrigated areas: the non-irrigated farmers have more idle, marginal land, and hence they respond more to price incentives. Higher growth means more favorable terms of trade and hence induces the non-irrigated farmers to put a higher proportion of their land under cultivation. The consequence is an improved income position for them. Conversely, slow growth brings about an increasing skewness in the income distribution, in the Mexican context.

These results are of course conditional with respect to the hypotheses established regarding rates of increase of yields and the agricultural resource base in each region. To present the problem of income distribution in its simplest profile, we have used the income results from the same solutions reported earlier, which contain the assumption of equal rates of yield and resource increase for both irrigated and non-irrigated agriculture. Unfortunately, the historical time series evidence on this is not very reliable, but it does seem to indicate roughly equal rates of technological progress and resource expansion in both regimes of agriculture.

To pursue the matter further, it would be interesting to alter these assumptions for additional CHAC solutions, i.e., what would be the impact on the income distribution of a research and extension program which favored non-irrigated areas?

(b) Seasonal employment patterns

As was mentioned in the earlier section on macro-economic results, it is difficult to evaluate the rate of employment increase in the sector only in terms of total man-years of employment. Seasonality is the essence of the agricultural employment problem.

Figure 4 shows sectoral employment by month, for the three solutions for 1968, 1976 at 7 percent, and 1976 at 8 percent. The first characteristic which stands out is that employment is highly seasonal in the sector. In the peak month there are about five times as many jobs as in the least busy month. Each of these seasonal curves is of course an aggregate of the corresponding curves for irrigated, dryland and tropical farming. Both irrigated and tropical farming generate fairly smooth seasonal demands for labor, i.e., for dryland areas alone the seasonality is even more marked than in Figure 4.

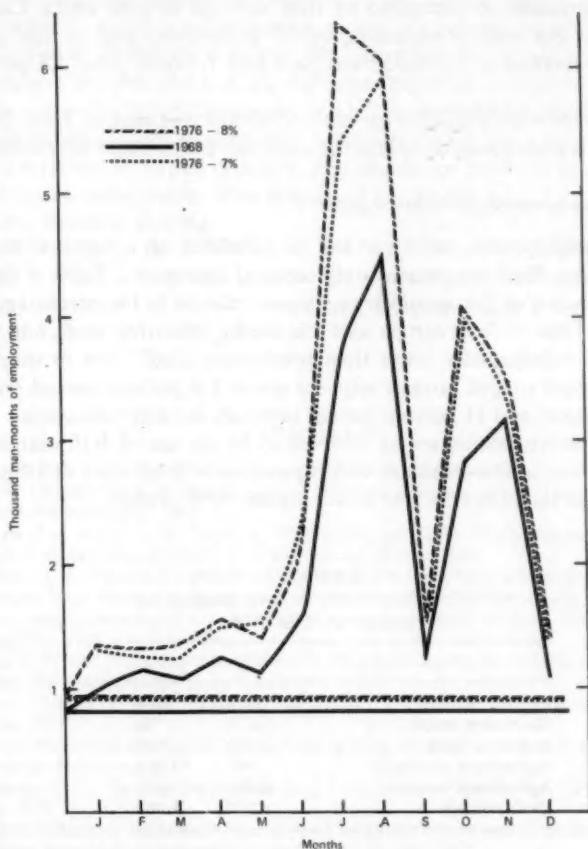


Figure 4 CHAC, seasonal employment

A comparison of the three curves shown in the graph reveals that the increased demands for employment do not occur uniformly over seasons. Rather, employment is increasing more rapidly in the peak months than in the base months: the degree of seasonal variation is becoming more pronounced. This of course is an inevitable consequence of a trend pointed out earlier: the area cultivated is expanding most rapidly in dryland regions, as greater price incentives bring more marginal lands under the plow. While expansion of area cultivated is one of the sectoral policy aims, the increasing seasonality of employment is an unfortunate by-product.

In figures, the following comparisons may be made. As shown in Table 1, total sectoral employment measured in man-years grows by 2.5 percent per year when GNP grows by 8 percent per year. However, "steady" employment, as measured by the man-years worked in jobs which last 10, 11, or 12 months per year, is growing at only 2.0 percent per year in that case. In contrast, highly seasonal employment, as measured by time devoted to jobs which last only 1, 2, or 3 months per year, is increasing by 3.5 percent per year in that case. The lowest rate of increase is registered for the 6 and 7-month jobs: 1.6 percent per year.

Similar results are available for each submodel and region. Here the aim is simply to offer a numerical example of the seasonal results which flow from CHAC.

(c) *Derived demands for other inputs*

As with employment, input use can be tabulated on a regional basis from CHAC solutions. Here we present only sectoral aggregates. Table 6 shows the percentage response of the use of various inputs relative to the percentage change in production, 1968-1976. It can be seen that credit, improved seeds, and fertilizer demands grow substantially faster than production itself.* Put in other terms, 5.0 percent annual output growth requires about 8.0 percent annual credit and fertilizer expansion, and 11 percent annual increases in improved seeds.

Labor-intensive techniques, as represented by the use of draft animals, grow more rapidly than capital-intensive techniques (machinery) when GNP growth is at 7 percent, and the reverse is true under higher GNP growth.

TABLE 6
CHAC: INPUT ELASTICITIES WITH RESPECT TO
PRODUCTION, 1968-1976

	7%	8%
Sectoral income	1.063	1.056
Short-term credit	1.829	1.796
Improved seeds	2.319	2.185
Agricultural chemicals	1.765	1.740
Agricultural machinery	0.894	1.000
Draft animals	1.297	0.981

* It is worth re-emphasizing at this point that CHAC is a cross-section model, and it does not include historical estimates of the relationships in Table 6.

As a final note, it is interesting to see how the marginal productivity of irrigation water responds to GNP growth: under 7 percent growth, when agricultural prices increase 1.5 percent in relative terms, the value of water grows by 1.8 percent per year. However, under 8 percent growth, with price increasing at 2.0 percent, the value of water goes up even faster, by 3.0 percent per year. These kinds of calculations are relevant to benefit-cost evaluations of irrigation projects.

8. CONCLUDING REMARKS

This paper has presented a few of the principal numerical results from CHAC which were used in the process of agricultural policy planning in Mexico. The exposition shows how a single sectoral model can shed some light on a rather wide variety of issues of concern to agricultural policy makers. An earlier set of results, focusing on yet other issues, are reported in [6]. Taken together, these papers illustrate ways in which a programming model can be used to address questions related to growth, distribution, supply responsiveness, factor use, and output mix, and to address policies which might influence behavior in these areas. Although CHAC is a constrained optimization model in the mathematical sense, it is a descriptive model as regards economic behavior. Policy goals are not maximized directly, but rather the model is used to simulate sector behavior under alternative values of policy instruments. This feature of the model helps to make it a more useful aid to decision making.

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