Duloy, J. H.

ABSTRACT

AGRICULTURE AND THE ENERGY CRISIS: A CASE STUDY IN MEXICO

A general equilibrium model of Mexican agriculture is solved to evaluate the impacts on the sector of higher costs of agrochemicals and machinery operations and higher world market prices. It is found that agricultural production declines and aggregate sector incomes increase, but that the sector income distribution becomes more skewed and consumer welfare declines.

Key words: agriculture, energy, Mexico, general equilibrium, income distribution, linear programming.

Contributed paper, AAEA meetings, Aug. 1974, College Station, Texas

Revised
August, 1974

AGRICULTURE AND THE ENERGY CRISIS: A CASE STUDY IN MEXICO

J.H. Duloy, P.B.R. Hazell, and R.D. Norton

In recent years, the world has experienced substantial price increases for virtually all primary commodities. Agricultural producers in particular have confronted a drastically changed situation. On the cost side, the increases in world oil prices have raised the costs of agrochemicals, by as much as three-fold, and the higher fuel prices have affected the costs of operating agricultural machinery. On the output side, many world market prices are now much higher than two years ago, and relative prices have also changed markedly, so that farmers may be revising their patterns of crop diversification.

In developing economies, where agriculture typically accounts for a larger share of national product, these impacts may be quite significant. In particular, substantial changes can be expected not only in farm production and prices, but also in domestic food consumption, international agricultural trade, rural employment, and the levels and distribution of farm income. It is difficult to anticipate what these effects will be, not only in their numerical magnitudes but even, in many cases, in the directions of change involved. Historical experience provides little guidance because similar magnitudes of oil price increases

---

* The authors are members of the Development Research Center of the World Bank, Washington, D.C. The World Bank does not necessarily concur with the views expressed in this paper. Computational assistance was provided by Malathi Parthasarathy and Maria de Castro Silva. The authors are grateful to Bela Balassa for helpful criticisms of an earlier draft.

have not been experienced before. The only rigorous and consistent way to attack the problem is through a general equilibrium analysis, which would allow full account to be taken of the many interactions involved among relevant economic variables, particularly on the market side. We have undertaken such an analysis for Mexico utilizing an existing and currently operational model of the agricultural sector.

Our results show that in the aggregate real agricultural sector incomes may actually increase as a result of the oil cost increases, but that the income distribution within the sector is likely to become more unequal. It is the nonagricultural part of the economy which will suffer most of the burden of change through substantial increases in food prices. Farm incomes tend to increase for two reasons: because the export prices are higher and because, with relatively inelastic demand schedules, reduced supplies on the domestic market generate higher farm incomes. These two effects more than offset the higher costs of production. Rural employment also will increase somewhat owing to labor-capital substitution caused by the increases in the costs of operating agricultural machinery.

Description of the Model

The existing agricultural model for Mexico, called Chac,[1] is a linear programming model which encompasses the supply, domestic and imported, and all demands - domestic and export - for 33 short cycle crops. It does not include livestock, forestry or long cycle crops. On the domestic supply side, the model is built up from regional sub-models, which are linked through a national market structure and by some common resource constraints. Chac is a static equilibrium model and provides a perfect competition solution for all product markets, treating both prices and quantities as endogenous variables.[2] Price-responsive demand structures are included, and the objective function which guarantees the competitive equilibrium is the sum over all markets of producer and consumer surpluses. For this study, a version of Chac was used which is specified at predicted 1976 levels of technology, market demand schedules and resource constraints, but with all monetary values expressed in 1968 prices. The 1976 technology levels were predicted by extrapolation of past trends on yields per hectare and input use, but there are technological alternatives which permit substitution on the input side. Market demand schedules were shifted forward in time in accordance with expected growth rates of population and per capita income.

Inclusion of the demand structure permits analysis of both aggregate and relative price changes in domestic product markets, as consequences of the exogenous changes in input costs and export prices. The demand structure comprises a set of linear domestic demand functions for 16 commodity groups (see Table 2). These groups are assumed to be demand independent, but linear substitution is allowed among products within each group at rates fixed by 1968 relative prices. Export and import possibilities are also allowed at fixed world prices, but are constrained by quotas and other marketing restrictions where relevant.

The production set of this version of Chac comprises nineteen regional submodels representing a total of 5.1 million farms. Each submodel is constructed with one to four "representative farms," so that overall Chac is based on twenty-nine representative farms.[3] The farms are thought to be sufficiently homogeneous within each group that this procedure is unlikely to lead to any serious aggregation bias problems. The existing results on model validation indeed show little evidence of aggregation bias [1, 5].

Model activities provide for the production of relevant crops in each region with a choice of up to three mechanization levels (involving alternative mixes of mules, labor and machines) and up to four planting dates per crop in each location. Crop intensity in water, fertilizer, and other inputs also varies across representative farms, as a reflection of basic differences in soils and climate, so that via spatial rearrangement of cropping patterns further input substitution is possible in the aggregate. There are, in all, more than 2300 alternative production activities. For corn, for example, the implicit supply function is quite complex, inasmuch as it is based on the more than 200 points represented by production activities. It also responds to variations in the prices of other crops which compete for the same resources in each locality.

Sets of labor activities provide flexibility in selecting seasonal combinations of family and hired day labor. Family labor is charged a reservation wage which has been estimated for Mexico at 30% to 50% of the market wage for hired labor [4]. Purchasing activities provide for perfectly elastic supplies of short-term credit, fertilizers, improved seeds, and the services of draft animals and machinery. Irrigation water is both priced and bounded at levels of physical availability, so that in most cases the economic rent accruing to the use of water in the model exceeds its administered price. Land constraints are monthly for each submodel.

Chac has already been used to estimate capital-labor substitution parameters [2]. The numerical specifications of alternative degrees of mechanization in the model are grounded in detailed studies of farm-level data, and this combined with the scope for shifts in cropping patterns probably makes it a relatively good instrument for analyzing factor substitution. However, it is less well suited for studying the impacts of fertilization pricing. In irrigated submodels, the model contains just one fertilization level per crop and per representative farm - the observed base-year level. In the non-irrigated submodels, there are two fertilization alternatives per crop.[4] Hence the response to variations in the fertilizer cost is largely confined to changing the crop mix.[5]

Some other limitations of Chac for this analysis are as follows:

a) Since Chac is a static equilibrium model, it only predicts the new equilibrium levels of production and prices which would eventually be achieved for a specified set of values of the exogenous variables. It does not therefore enable predictions for specific calendar years, nor say anything about temporary market disequilibria that are bound to arise as farmers seek to adjust to new relative price and cost ratios. Nevertheless, comparison of alternative potential equilibrium states is helpful for policy formation.

b) The model was initially tested and verified for reliability at 1968 price and cost ratios. It is certain that the reliability of the results will decrease the more radical the changes in price and cost ratios from 1968 levels.

c) Chac encompasses only the annual cropping part of Mexican agriculture.[6]

These limitations arise because the model was built for rather different purposes than the present need, and they could be overcome only through a considerable effort to collect new information and restructure the model. Any method of analysis must be based on simplifying assumptions, no matter how formal or informal the technique, and the assumptions behind Chac do not seem too unreasonable given the comprehensiveness of the model (and the speed with which results can be obtained by using it!). The major advantage offered by Chac is that, it incorporates relative price movements and the response of production to those movements in its simulation of sector reactions to exogenous changes.

Experimental Assumptions about the Exogenous Variables

The model was first solved with predicted 1976 levels of technology, resource constraints, and demand schedules, with all monetary values expressed in 1968 prices. This yielded a base solution, case A in the tables, from which to measure changes. Five experimental solutions were then defined to capture various aspects of the energy crisis. The first three, cases B, C, and D, represent different assumptions about the degree of increase in exogenous costs and export prices, as compared to 1968 relative prices.

The cost changes reflect in part three different levels of fuel cost increases but also increases in the non-fuel component of agrochemical and machinery inputs. The export price increases reflect the cutbacks in world production associated with the fertilizer and machinery cost increases, but no changes were made in the relative prices[7] of vegetable exports from Mexico to the U.S.A. Import prices were also increased at rates comparable to the export price increases, thus implying the same percentage price differentials, but increasing absolute differentials to reflect greater transportation costs. Constraints on export activities were maintained at predicted 1976 levels for solutions B and C, but in solution D it was assumed that world trade deficits would allow unlimited export possibilities for wheat, rice, maize, sorghum a and cotton fiber and seed, and that Mexican sugar export quotas would be increased by 25%.

On the import side, in cases A, B and C, the model allows the possibility of unlimited imports of some crops but restricts the imports of a few key crops in which the Mexican government wishes to maintain self-sufficiency.[8] However, in case D it was felt that the contraction of domestic supply may be so strong as to render autarkic policies untenable, so the import bounds were removed for that case, with the resultant importation of some basic foods, as discussed below.

So defined, cases B, C and D represent alternative possible sets of external circumstances which Mexican agriculture may have to face as a result of the world energy crisis. For estimating the total impact of the crisis, it is useful to group the exogenous changes in this way. However, to better understand the role of each variable, it is useful to define additional cases which focus on the exogenous changes one by one. Case E includes only the increased costs of agrochemicals and machinery operation, without any changes in export or import prices. Case F is identical with D except that autarkic import policies are retained; it was defined to explore the quantitative impact of restrictive import policies. Thus, while cases B, C, and D are designed to represent possible states of the world, cases E and F are artificial examples to help identify more precisely the contributions of particular factors.

Table 1: ASSUMPTIONS DEFINING ALTERNATIVE SOLUTIONS OF CHAC

(prices expressed as indexes; 1968 level = 100)

	Solution					
	A	B	C	D	E	F
Agrochemical costs	100	150	225	300	300	300
Variable machinery costs	100	125	160	200	200	200
Export price for:						
Sugar	100	200	250	250	100	250
Wheat	100	100	150	200	100	200
Rice	100	100	125	150	100	150
Maize	100	100	125	150	100	150
Sorghum	100	100	125	150	100	150
Cotton Fiber	100	130	170	200	100	200
Cotton Seed	100	100	100	200	100	200
Key imports bounded?	Yes	Yes	Yes	No	Yes	Yes
Export bounds loosened?	No	No	No	Yes	No	Yes

The results of these solutions are presented in the following sections, first at the national level and then at the regional level. The numerical results should not be taken too literally, but the basic qualitative outcomes and the orders of magnitudes appear to be plausible.

Results at the National Level

The results at the national level are summarized in Tables 2 through 5. As Table 2 shows, there is a very definite substitution of labor (and draft animal power) for machinery as fuel costs increase. Employment is always higher than in the base solution, and in cases D and F the increment over the base solution is about 330,000 man-years of employment each year. Given that the typical job in Mexican agriculture does not imply full time work,[9] this represents between 600,000 and 700,000 additional jobs per year.

As expected, use of agrochemicals (fertilizers plus pesticides) is cut back in the world of the energy crisis, by as much as 22% when costs increase but export prices are unchanged, and by 12% when the export prices increase along with costs.

The sector's nominal income rises progressively with the cost increases, to a point where it is 50% higher in case D than in case A. There are two reasons for this. First, the exogenous increases in export prices and sales prospects lead to important increases in revenue. Exports account for 17% of total sector revenue in solution A, and for 20%, 22%, and 42% in solutions B, C and D, respectively. Second, the cost increases affect sector production levels negatively which, given, the generally inelastic demand structure facing agriculture, gives rise to increases in producers' net revenue. A comparison of solutions D and E shows that the output-and-price effect increases sector income by 13% and the exports by another 37%[10].

The importance of the relatively inelastic domestic demand structure is illustrated by case E, which contains the cost increases but for purposes of illustration assumes no export/import price increases. In that case, a quantum index of production falls by slightly more than 4% but the price index increases by 39%. (Owing to index number problems, the domestic demand structures are not quite as inelastic as these figures imply.) The net impact of these changes is a 25% increase in the sector's gross revenue and a 13% increase in nominal net incomes. The higher domestic prices also induce somewhat of a diversion of products away from export markets in case E, but in the other cases the higher export prices induce a diversion in the opposite direction.

The output-and-price effects increase disproportionately as the costs increase - as the sector's adjustment possibilities diminish. The initial cost increases (solution B) are largely countered by substitution of labor and mules for machinery, and by switching to crops which require less fertilizer. However, with the larger cost increases in solutions C and D, and with more limited additional adjustment possibilities, production for the domestic market is also cut back, effectively forcing domestic prices to sufficient levels to cover costs.

The changes in production in percentage terms are not as great as the changes in prices and sector incomes. However, as shown later in table 4 the production levels change more for some individual crops. In the aggregate, there are two opposing effects on production: the disincentive of cost increases, and the incentive of higher export prices. A comparison of cases C and D in table 2 shows that it is hard to predict a priori which effect will dominate.

The group which suffers most from the energy crisis is the consumers. Low income farmers lose ground in relative terms, as is discussed in the succeeding section on regional results, but consumers are made worse off in absolute terms. They consume less and that which they consume is more expensive. As costs and export prices increase (solutions B, C, D) consumer welfare declines by 2%, 9%, and 16%, respectively, as measured by

Table 2: NATIONAL EFFECTS

	Base Solution Levels	Percentage Changes from Base Levels				
	A	B	C	D	E	F
Sector Income (Ten Million Pesos)	2060	+ 1	+23	+50	+13	+61
Sector Gross Revenue+ (Ten Million Pesos)	2994	+ 4	+18	+27	+25	+32
Sector Production Index	100	-1.1	-5.2	-5.1	-4.2	-2.4
Machinery Use (Thousand Months)	1061	-10	-41	-55	-64	-47
Mule Use (Thousand Months)	8276	+11	+54	+74	+83	+69
Chemical Use (Ten Million Pesos)	3707	- 5	-13	-12	-22	- 8
Employment (Thousand Man Years)	2349	+ 2	+ 7	+14	+12	+14
Index of Consumer Welfare	100	- 2	- 9	-16	-13	-19
Value of Exports (Ten Million Pesos)	507	+23	+53	+214	-25	+192
Price Index for Sector Output	100	+12	+26	+60	+39	+67
Domestic Consumption* by the Demand Groups (thou. tons):						
1 Wheat/Maize	9374	- 1	- 4	- 6	- 6	- 7
2 Chillies	287	0	- 2	+ 6	+13	- 6
3 Sugar Cane	29632	0	0	- 5	0	- 8
4 Beans/Rice/Potatoes/Chickpeas	3177	0	- 4	- 8	- 8	- 8
5 Tomatoes	866	0	0	- 9	0	- 9
6 Onions/Garlic	257	0	- 3	- 3	- 3	- 3
7 Cucumbers	38	0	0	0	0	0
8 Sweet potatoes	183	0	- 4	- 8	- 8	- 8
9 Lima Beans	62	0	- 5	- 5	-10	-10
10 Forage Crops	24392	0	- 9	-13	-13	-18
11 Malt Barley	330	0	- 1	- 2	- 2	- 3
12 Cotton Fiber	319	- 4	- 8	-39	- 9	-39
13 Oil Seeds	2881	- 4	-11	-13	-13	-13
14 Peanuts	111	0	0	+ 2	+ 2	0
15 Fruits	1995	0	0	0	0	0

+ Gross revenue is calculated at endogenous prices; therefore it is not a quantum index of production.

* Consumption = Domestic production + imports - exports.

the sum of consumer surplus over all markets. With solution D cost levels but without the expanded exports (solution E), consumers are somewhat better off: losing 13% instead of 16% in welfare terms.

Farm household food consumption is also included in the total domestic consumption - Chac does not deduct family food requirements from total production but essentially values them at market prices - hence farmers also lose as consumers, and this loss is to be offset against the gain in nominal sector income. Farm consumption actually accounts for about 40% of the national consumption of food products, and after allowing for foreign trade and non-food consumption, the actual values of farm food consumption in solutions A, B, C and D are 995, 996, 1105 and 1002 ten million pesos respectively. The total farm expenditure on foods is thus seen to remain virtually constant, the quantity consumed being reduced to offset price increases. As a more direct measure of producers' welfare, we have calculated the sum of producers' surplus plus 40% of consumers' surplus over all markets. Taking solution A as the base, this measure of producers' welfare changes by -1%, +2% and +8% in solutions B, C and D respectively.

These results suggest that in aggregate, the farmers of Mexico will actually gain from substantial increases in the costs of agrochemicals and machinery operations. They will gain substantially in terms of nominal farms incomes, but much less so in terms of overall welfare. Other rural families will also gain through increases employment opportunities as labor is substituted for machinery. The real brunt of the adjustment burden is borne by the non-agricultural sector through increased food prices and reduced consumption levels. As the lower part of Table 2 shows, in quantity terms consumption of virtually all commodity groups is reduced in case D as compared with case A.

Solution F is effectively a test of the self-sufficiency policy for basic foods. Recall that it is identical to solution D except that F retains the import restrictions. Under this assumption, farmers are made even better off and consumers even worse off. Allowing imports has the effect of placing a price ceiling on domestic markets, and hence farmers gain at the expense of consumers when this ceiling is removed. As Table 3 shows, the principal commodity to be imported under a freer trade policy is corn; this is consistent with the comparative advantage calculations worked out for all crops in [5]. Essentially, imported corn replaces that amount which is cultivated under irrigation. Within Mexico, the comparative advantage in corn production lies with non-irrigated areas.[11]

Tables 4 and 5 illustrate some of the production and price effects for individual crops. Given the generally price-inelastic nature of demand, the price responses tend to be proportionately greater than the quantity responses. Solution D shows a significant substitution of wheat for corn (Table 4) when import possibilities are opened up. The reasons for the producers' gains and consumers' losses in aggregate terms can be seen quite concretely in the simulated market price reactions (Table 5). In solution D, beans are up 46% in price, corn up 40%, tomatoes up 15%, and wheat up 98%, all relative to the general price index.[12]

Table 3: EFFECT ON EXPORTS AND IMPORTS FOR IMPORTANT CROPS
(Levels traded in thousand tons)

Crop/Variable	Solution					
	A	B	C	D	E	F
EXPORTS						
Beans	90	90	0	0	0	0
Cantaloupes	149	149	149	149	149	149
Chillies	69	69	69	0	4	51
Cotton Fiber	452	452	452	860	398	859
Sorghum	201	0	0	503	0	0
Strawberries	81	81	81	81	81	81
Sugar	8030	8030	8030	9997	0	9997
Wheat	0	0	250	1591	0	1071
Tomatoes	417	417	417	417	417	417
Safflower/Sesame/Linseed	85	85	85	85	37	85
Total Value of Exports (ten million pesos)	507	628	777	1593	381	1481
IMPORTS						
Maize	6	6	6	2048	6	6
Rice	0	2	0	0	2	0
Soybeans	0	7	27	27	27	27
Oats	0	0	0	3	3	3
Total Value of Imports (ten million pesos)	0.6	2.6	7.4	297	5.1	5.2

Table 4: EFFECTS ON NATIONAL PRODUCTION LEVELS FOR SELECTED CROPS

(quantity indexes)

Crop	Solution					
	A	B	C	D	E	F
Corn	100	99	94	68	91	86
Wheat	100	98	102	133	94	119
Beans	100	100	90	86	86	86
Sugar cane	100	100	100	101	79	99
Cotton (raw)	100	97	96	137	89	137
Sorghum	100	95	86	113	82	93
Tomatoes	100	100	100	94	100	94
Rice	100	99.7	96	92	91	92
Chillies (green and dry)	100	100	98	87	96	86
Safflower	100	100.4	99	92	104	88
Cantaloupe	100	100	100	100	100	100
Onions	100	103	100	98	98	98
Chickpeas	100	100	92	186	88	169

Table 5: EFFECTS ON DOMESTIC PRICE LEVELS, SELECTED CROPS
(Indexes)

	Solution					
Crop	A	B	C	D	E	F
Corn	100	112	131	140	148	158
Wheat	100	115	134	198	154	198
Beans	100	116	127	146	143	148
Sugarcane	100	107	118	133	113	146
Cotton (raw)	100	113	124	243	138	243
Sorghum	100	110	130	153	145	155
Tomatoes	100	100	100	115	100	115
Rice	100	112	127	133	144	149
Chillies (green)	100	100	100	100	100	100
Safflower	100	116	122	128	128	127
Cantaloupe	100	115	137	156	157	170
Onions	100	116	140	149	149	149
Chickpeas	100	97	78	130	86	117

We turn now to examine some of the distributional effects of the gains in the agricultural sector as portrayed in the model results at the regional levels.

Regional Results

Of the nineteen submodels in Chac, five have been selected to illustrate the regional impacts of the energy crisis. Each is representative of a certain type of agriculture in Mexico: two represent irrigated zones, two represent temperate rainfed areas, and one represents tropical agriculture. Table 6 shows some salient details of solution D for all five submodels, and Tables 7 through 11 give more information on each submodel.

The submodels were selected for their diversity. With an average annual net income per farm of 27,447 pesos, the farmers of the Rio Yaqui district are among the top five percent in the Mexican rural income distribution. At the other extreme, the rainfed farms in the states of Mexico and Tlaxcala belong to the lowest twenty-five percent: their average annual farm income is 1,139 pesos. The tropical farms in the states of Tabasco and Veracruz are not much better off.[13] The irrigated farms in El Bajio are more productive per hectare than those in Rio Yaqui, but they are sufficiently smaller in size that their farm income levels are lower. The non-irrigated part of El Bajio is one of the more productive rainfed zones in the country.

Table 6 makes it clear that the richer farmers gain more from the energy crisis. The rainfed El Bajio farms and the tropical farms gain absolutely, but at a lesser rate, and the poorest rainfed farms actually slip in absolute terms. These income distribution effects are accentuated even more if allowance is made for the increased cost of family food consumption.

The main reason for these disparities in impact is that the farmers with irrigation have a more diversified portfolio of crops and hence are more able to take advantage of shifting relative prices by altering their cropping pattern. In Rio Yaqui, for example, in comparing solution D with solution A the following cropping pattern shifts occurred in response to the corresponding relative price changes:

Crop	% change in hectares harvested	% change in market price
Wheat	+93	+46
Cotton	+ 8	+143
Corn	-100	+40
Barley	-100	+37

While the prices of all crops increased, the crop mix shifted strongly toward those which went up most. In the El Bajio irrigated zone, the same sort of phenomenon occurred over a somewhat different set of crops. Command of water implies greater flexibility in production choices, and this flexibility is important for successful adaptation to changed circumstances.

Among other things, the regional tabulations also show that general results at the sector level do not always hold in the case of each region. While employment is higher in case D than case A in the aggregate, it is lower in Rio Yaqui, owing to the shift out of a more labor intensive crop (corn) into a more capital intensive crop (wheat). As another example, fertilizer use actually goes up as the cost rises in the El Bajio rainfed submodels. (Table 9). This is entirely attributable to a shift into a relatively fertilizer intensive crop, beans. In this case, interregional comparative advantage on the output side, in the face of shifting relative crop prices, outweighed considerations of higher input costs. In the Tlaxcala-Mexico submodel, the mule-machinery

Table 6: BASIC REGIONAL RESULTS, SOLUTIONS A AND D

Variable	Submodel: Irrigated El Bajío	Irrigated Río Yaqui	Non-Irrigated El Bajío	Non-Irrigated Tlaxcala -Mexico	Non-Irrigated Tropical
Solution A net income/ farm (pesos)	17,455	27,447	3,878	1,139	1,967
Solution D % change relative to solution A, for:					
income	+70	+94	+60	-24	+38
employment	+ 6	-33	0	- 7	+ 2
mule use	+486	0	0	+78	+ 1
machinery use	-100	+ 9	- 2	-96	0
chemical use	- 8	+ 3	+ 2	-61	-12

Notes on submodel coverage:

The submodels are defined fully in Bassoco and Rendón [3]. definitions are summarized here and reference is made to their submodel numbering system [3, pp.344-345].

(1) El Bajío irrigated: submodel No. 10, official irrigation districts of Alto Río Lerma and La Begoña, lying mostly in the state of Guanajuato, in the central plateau.

(2) Río Yaqui: submodel No. 1, official irrigation district of the same name in the state of Sonora, northwestern Mexico.

(3) El Bajío non-irrigated: submodels Nos. 8 and 9, the area surrounding the irrigation districts of Alto Río Lerma and La Begoña.

(4) Tlaxcala-Mexico: submodel No. 14, the rainfed areas lying at more than 2000 meters of elevation and receiving 600-800 mm. of annual rainfall (includes small portions of Hidalgo and some other states).

(5) Tropical: submodel No. 18, the lands lying at less than 500 meters elevation and receiving more than 1500 mm. of annual rainfall - mostly the states of Tabasco and Veracruz.

shift is evidence of a shift toward more labor-intensive techniques, but there is also a reduction of output caused by higher production costs. The output effect more than offsets the substitution effect, so that the net change in employment is negative.

In the tropical submodel, there is an improvement in income levels, although not as strongly as in the irrigated submodels. In spite of the expanded sugar quota of case D, total sugar production declines because (a) the reduction in domestic sales has a pronounced effect and (b) the sugar producers of other tropical zones appear to capture more of the increment in the quota due to interregional comparative advantage. Employment moves irregularly over cases B, C, D, and E, as a function of irregular shifts among crops of differing labor intensities.

We do not suggest that these regional results be taken literally - Chac is probably more reliable at the aggregate level than at the local level - but they do seem persuasive for Mexican agriculture on two points: the widening of income disparities as a consequence of the energy crisis, and the impossibility of applying sector-wide generalizations to specific localities.

To conclude on an appropriately speculative note, we would like to point out some likely implications of the regional results for the Tlaxcala-Mexico submodel. The average farm size there permits marginal amounts of crop sales after satisfying family consumption requirements, but on the whole these farmers operate on extremely thin profit margins. Many of them earn the bulk of their income by seasonal migration to Mexico City to work as laborers and street vendors. Permanent out-migration to the city is also higher in this zone than in any other. The submodel results suggest that the increased costs of production stemming from the energy crisis, however small in absolute value, are likely to significantly reduce their income from cultivation. Hence it is quite likely that their tendency to migrate in search of work, both seasonally and permanently, will be noticeably reinforced. A by-product of the energy crisis therefore may be a further swelling of the population in the low-income, migrant sections of Mexico City.

Table 7: EFFECTS ON AVERAGE IRRIGATED FARM IN EL BAJIO (CENTRAL PLATEAU)

Variable	Value in Base Solution	Percentage Changes from Base Solution			
	A	B	C	D	E
Net Farm Income (Pesos)	17,455	+12	+ 17	+ 70	+ 26
Total Employment (Man Years)	1.9	0	+ 13	+ 6	+ 12
Mule Use (Days)	35	+ 4	+434	+486	+486
Machinery Use (Days)	11	- 1	- 76	-100	- 89
Chemical Use (Pesos)	415	0	- 3	- 8	- 4
Alfalfa (ha)	1.48	0	0	0	0
Garlic (ha)	0.08	0	- 13	- 13	- 13
Onions (ha)	0.10	0	0	0	0
Barley (ha)	0.92	0	- 70	+ 23	- 52
Green Chillies (ha)	0.04	0	0	0	-100
Lima Beans (ha)	1.30	0	- 48	-100	- 64
Tomatoes (ha)	0.33	0	0	0	0
Corn (ha)	5.03	0	+ 13	- 4	+ 10
Total Crops (ha)†	9.28	0	- 7	- 14	- 9

Number of Farms: 23,687.

Hectares per Farm: 7.9

† Includes double cropping.

Table 8: EFFECTS ON AVERAGE IRRIGATED FARM IN RIO YAQUI DISTRICT (STATE OF SONORA)

Variable	Value in Base Solution	Percentage Changes from Base Solution			
	A	B	C	D	E
Net Farm Income (Pesos)	27,447	+ 8	+ 12	+ 94	+ 9
Total Employment (Man Years)	2.1	+ 8	+ 11	- 33	+ 23
Mule Use (Days)	0	0	0	0	*
Machinery Use (Days)	52	- 2	- 4	+ 9	- 18
Chemical Use (Pesos)	1,030	0	- 1	+ 3	- 4
Cotton (ha)	2.55	+ 7	+ 4	+ 8	- 7
Barley (ha)	0.04	-100	-100	-100	-100
Corn (ha)	6.56	+ 18	+ 27	-100	+ 27
Wheat (ha)	6.73	- 20	- 28	+ 93	- 31
Total Crops (ha) †	15.90	0	- 1	- 1	0

Number of Farms: 13,049

Hectares per Farm: 15.7

* Absolute level under solution E: 78 days.

† Includes double cropping.

Table 9: EFFECTS ON AVERAGE RAINFED FARM IN EL BAJIO (CENTRAL PLATEAU)

Variable	Value in Base Solution	Percentage Changes from Base Solution			
	A	B	C	D	E
Net Farm Income (pesos)	3,878	+10	+16	+60	+40
Total Employment (man years)	1.1	+ 1	+ 7	0	+ 7
Mule Use (days)	46	- 1	+ 9	0	+17
Machinery Use (days)	7	+ 3	-44	- 2	-44
Chemical Use (pesos)	116	+47	+63	+ 2	+59
Beans (ha.)	3.61	+46	+62	+ 2	+59
Chickpeas (ha.)	3.61	+ 3	-44	- 2	-44
Corn (ha.)	5.16	-33	-44	- 2	-41
Total Crops (ha.)†	12.38	+ 1	-13	0	-13

Number of Farms: 41,432

Hectares per Farm: 8.8

† Includes double cropping.

Table 10: EFFECTS ON AVERAGE RAINFED FARM IN THE STATES OF TLAXCALA AND MEXICO (CENTRAL PLATEAU)

Variable	Value in Base Solution	Percentage Changes from Base Solution			
	A	B	C	D	E
Net Farm Income (pesos)	1,139	- 6	- 1	-24	- 1
Total Employment (man years)	0.5	-10	- 4	- 7	+ 8
Mule Use (days)	45	+13	+21	+78	+107
Machinery Use (days)	7	-36	-51	-96	-95
Chemical Use (pesos)	130	-46	-47	-61	-55
Corn (ha.)	4.17	-16	-17	-41	-30
Potatoes (ha.)	0.22	-100	-100	-100	-100
Total Crops (ha.)	4.39	-20	-21	-42	-33

Number of Farms: 261,593

Hectares per Farm: 4.45

Table 11: EFFECTS ON AVERAGE TROPICAL FARM IN THE STATES OF TABASCO AND VERACRUZ

Variable	Value in Base Solution	Percentage Changes from Base Solution			
	A	B	C	D	E
Net Farm Income (Pesos)	1,967	+11	+22	+38	+ 27
Total Employment (Man Years)	0.2	0	- 6	+ 2	- 16
Mule Use (Days)	16	0	+13	+ 1	+ 38
Machinery (Days)	-	0	0	0	0
Chemical Use (Pesos)	8	- 1	-20	-12	- 61
Rice (ha)	0.44	+ 1	-16	+21	- 37
Sugar (ha)	0.38	- 1	-20	-12	- 61
Corn (ha)	0.18	- 2	+82	-26	+223
Total Crops (ha.)	1.00	0	0	0	0

Number of Farms: 364,892

Hectares per Farm: 1.0

Footnotes

1 Chac, named after the Mayan rain god, was constructed jointly by the Development Research Center and the Secretaría de la Presidencia, Mexico. A complete description of the model can be found in Duloy and Norton [4] and Bassoco and Rendón [3]. Chac is now actively used in the formation of current agricultural policy in Mexico; an illustrative set of the planning results is presented in Bassoco and Norton [2].

2 In the Mexican planning version of the model [2], the perfect competition assumption is modified for subsistence producing areas, where a flexible minimum consumption constraint is introduced which permits satisfaction of basic consumption needs either through own production or through purchase from the market. If the latter course is followed, a penalty is paid which reflects commercial margins, market imperfections, and seasonal price fluctuations.

3 Again, the operational Mexican version differs slightly, having twenty submodels and thirty-one representative farms. The difference arises from a farm size disaggregation for one region in the Mexican version.

4 It was hoped to include in Chac more points on fertilizer response functions, but sheer lack of information at the field level prevented doing so.

5 Changes in the cropping patterns at the submodel level do not necessarily imply changes in the aggregate, for compensating spatial shifts can occur. Fertilization rates do differ by location for the same crop, so that such compensating spatial shifts could be a plausible response to fertilizer price changes.

6 More precisely, it covers the 31 major annual crops plus sugar cane and alfalfa.

7 Throughout the text, the phrase "real prices" means relative prices expressed in the framework of 1968 prices. Thus, in the first round of changes, it is assumed that prices of fertilizer, fuel, and some exports went up relative to the overall Mexican price index, but that vegetable export prices did not. Of course, the model is used to estimate real changes in other prices in the 2nd through nth rounds.

8 Throughout the late 1950's and 1960's, Mexico successfully maintained a "no-import policy" for agricultural goods, but production difficulties made necessary substantial imports of corn, wheat and sorghum in 1970-73. The policy makers are attempting to stimulate production

of these crops enough to be able to return to the historical pattern of self-sufficiency, so cases A through C are based on the assumption that those attempts will be successful.

9 Farmers without irrigation normally spend less than six months a year in their fields, and landless laborers may work as little as one or two months of the year. See [2] and [5] for estimates of the seasonal employment curves in Mexican agriculture. Estimates of sector-wide capital-labor substitution elasticities are also given in [2].

10 The two effects may not be strictly additive, as the sentence in the text implies.

11 Table 3 shows an extreme result in solution E: the elimination of sugar exports. This is the case where chemical and variable machinery costs are up three-fold and two-fold respectively, but export prices are unchanged. In this situation, evidently sugar producers are caught in a cost-price squeeze and, in Chac, opt to supply only the domestic market, where prices are rising. Of course this model result should only be taken as indicative of a direction of change, but it does suggest that higher world or quota sugar prices are quite important to Mexican sugar producers given the energy crisis. The result may not be so far-fetched in light of the difficulties in the Mexican sugar industry in the past two years; the President himself has called for replacement of outmodeled processing machinery and for other measures to improve labor productivity in the industry.

12 Of course, agricultural price increases of these magnitudes would be likely to fan general inflation, so that ultimately these prices would not be so high relative to the overall price index. However, to analyze that sequence of reactions in a problem of the theory of inflation and beyond the scope of this exercise. Although the relative price increases reported here may be diluted by general inflation, it is useful to analyze them if only to understand the magnitude of one of the principal causes of general inflation.

13 In the case of the tropics, these figures give a somewhat misleading picture of the farm operation, for the typical farm there includes substantial amounts of livestock and/or tree crops, and Chac includes neither. Elsewhere in the country, the farms tend to be more clearly differentiated into either livestock ranches or annual-crop farms with only marginal amounts of livestock and tree crops.