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Introduction

There are many aspects of food and agricultural policy in Egypt that are advocated and implemented in the name of national food security. For example, the drive toward more self-sufficiency in basic food grains; the institution of strategic grain stocks; and, in part, the consumer subsidy policy for many basic food commodities are all conducted in the name of national food security. When attempting to clarify the objectives of the term "national food security" by asking responsible researchers and policymakers in Egypt, one is struck by the nebulous nature of the concept and by the inconsistent goals espoused by different parts of the national decision-making apparatus. For instance, it seems that the major concern of the Ministry of Supply is to maximize domestic procurement of basic food commodities for distribution to the consumers and that it is the major advocate of self-sufficiency policies. The Ministry of Defense, on the other hand, is concerned about the availability of basic foods in the case of a war type of emergency; it advocate the build up of strategic food reserves. The Ministry of Agriculture is naturally concerned about the welfare of the agricultural population, and it seems more eager to support policies that would increase the real incomes of farmers. The Ministry of Finance is more concerned about the availability of foreign exchange, and it seems to advocate a policy that would structure the agricultural production system along the lines of international comparative advantage.

Notably absent, although implicit in many of the discussions about food security in Egypt, is a realization of the constraints that the international markets for Egyptian-traded products place upon alternative agricultural production strategies. This is not to say, of course, that the international market is neglected in discussions of Egyptian food security. Goueli (1981), in fact, points out that the drive toward self-sufficiency in basic foods had its origins in the adverse prices of imported grains during 1973-74 and later. However, no one seems to have given an empirical illustration of alternative "self-sufficiency" or "food security" strategies so far as their consequence on the ability of Egypt to satisfy domestic food requirements is concerned. The purpose of this paper is to fill this gap.

We adopt the convention that national food security is best defined as the ability of a country to satisfy completely its domestic requirements for agricultural products while incurring the smallest possible foreign exchange expenditure and the smallest possible fluctuation in the agricultural balance of trade. This convention is translated into the optimization of a criterion, which is linear in the expected value and variance of the agricultural balance of trade, subject to various linear constraints on agricultural production activities. The optimizing model is then solved via quadratic programming. The results offer many insights into the most profitable direction Egypt should take in designing the agricultural crop pattern from a food security perspective.

Previous Literature

Most discussions have defined the term "food security" at the national level to mean the ability of a food deficit country to meet its yearly food consumption requirements [see, e.g., Siamwalla and Valdes (1980)] in the face of fluctuations in domestic grain supplies and international prices. Broadly speaking, this ability depends on the foreign exchange earning capacity of the country, the proportion of food imports to total export earnings, and the degree of fluctuation of food imports relative to fluctuations in net export earnings of the remaining sectors. Valdes and Konandreas (1981) have conducted an aggregate analysis of food insecurity in various developing countries using the above criteria and have shown that most of the variability in the food import bills of many countries is the result of variations in the quantities imported. In the case of Egypt, they find that 69 percent of the variability in the food import bill is accounted for by fluctuations in import volume and that only 31 percent is accounted for by random shifts in international price. They have also shown that, with few exceptions, the ratio of food imports to total export revenue is rather small for most developing countries.

Most of the remedies proposed for alleviating the food insecurity of developing countries have to do with national or international schemes of grain stockholding [see Reutlinger and Bigman (1981) and Tyers and Rachman (1981) for national stockholding simulations; see also Morrow (1981), Johnson (1981), Konandreas et al. (1978), and Sarris (1976) for international simulations] or with financial compensatory schemes [see Goreux (1981)].

The problem with international stabilization schemes via stockholding is that the wide consensus required for their implementation is usually not obtainable. Furthermore, these schemes have an impact on international prices without alleviating domestic structural problems which for many developing countries can be much more crucial for food security. National stockholding schemes usually neglect domestic interactions and substitutions in production and consumption among food products and, hence, tend to miscalculate the required levels of stocks.

The discussions on food security have centered on smoothing out fluctuations in food consumption and the attendant effects of alternative policies to do this, and very little attention has been paid to the structure of agricultural production. As will be seen in the sequel, however, the crop pattern has very serious implications for food security.

The Model

Assume that there are n agricultural products that are produced, consumed, and traded internationally by some country. Denote by S_{it} and D_{it} the domestic supply and demand, respectively, of product i in year t. Then, the quantity $S_{it} - D_{it}$ denotes the exported quantity of the product in year t in the absence of stock changes. If we denote by p_{it} the international price at the border of the country, the foreign exchange earnings of the country in year t from trade in agricultural products are given by the expression

$$F_t = \sum_{i=1}^{n} (S_{it} - D_{it})\, p_{it}. \tag{1}$$

The quantity F_t will be positive if the country experiences a surplus in the agricultural trade balance and negative if the country experiences a deficit. We will assume that domestic production and international prices are random, the randomness in domestic production arising out of the yearly variability in yield of agricultural products. It will also be assumed that

$$\text{Cov}\,(S_{it}, p_{jt}) = 0 \tag{2}$$

for all i, j = 1, . . . n. In other words, the international prices are not correlated with domestic yields. Domestic demand is assumed to be nonrandom. Denote by S_i and p_i the expected values of S_{it} and p_{it}. Also, define the matrices, B and C,

(3) $B = \{b_{ij}\}$ where $b_{ij} \equiv \text{Cov}(S_{it}, S_{jt})$ $\quad i, j = 1, \ldots, n$

(4) $C = \{c_{ij}\}$ where $c_{ij} \equiv \text{Cov}(p_{it}, p_{jt})$ $\quad i, j = 1, \ldots, n.$

Denote by x the column vector whose ith element is S_i, by p the column vector whose ith element is p_i, and by d the column vector whose ith element is D_i. (For economy of notation, we will drop the time subscript on the S_i, D_i, and F because the optimization will refer to one point in time only.) Then, the expected value and variance of F can be written as

(5) $$E(F) = x'p - d'p$$

(6) $$\text{Var}(F) = \text{tr}(BC) + x'Cx + p'Bp + d'Cd - 2x'Cd,$$

where a prime denotes the transposition of a vector or matrix and tr ( ) denotes the trace of a square matrix.

Food security policy will be assumed to maximize the objective function,

(7) $$W = E(F) - 1/2\, \Phi\, \text{Var}(F),$$

with respect to the production structure subject to several constraints on production. Implicit in this type of criterion is the assumption that the agricultural balance of trade is very important for food security. Furthermore, since agricultural trade is usually the most unstable component of the overall balance of trade, lowering its variance will contribute substantially toward a more stable overall trade balance. The parameter Φ denotes a national coefficient of aversion to international risks.

In the model we divide Egypt into three major geographical producing regions, namely, Lower, Middle, and Upper Egypt. Each of these regions produces several of the n products (but not necessarily all of them). For crop products, denote by A_i^k the area cultivated with product i in region k and by y_i^k the expected value of the yield; then, by definition, we have

$$(8) \qquad x_i = \sum_{k=1}^{3} A_i^k y_i^k.$$

Define the covariance matrix of yields by a symmetric matrix, R, defined as

$$(9) \qquad R = \begin{bmatrix} R^{11} & R^{12} & R^{13} \\ R^{21} & R^{22} & R^{23} \\ R^{31} & R^{32} & R^{33} \end{bmatrix}$$

where

$$(10) \qquad R^{kl} = \{r_{ij}^{kl}\} \text{ and } r_{ij}^{kl} = \mathrm{Cov}\,(y_i^k, y_j^l).$$

Then, the element, b_{ij}, of the covariance matrix, B, can be expressed as

$$(11) \qquad b_{ij} = \sum_{k=1}^{3} \sum_{l=1}^{3} A_i^k r_{ij}^{kl} A_j^l.$$

The largest number of activities in the model will be A_i^k (i.e., the areas cultivated to various crops). Agricultural products or activities that do not occupy land (such as animal products) can be modeled in a similar fashion:

$$x_i = X_i \cdot y_i, \tag{12}$$

where X_i is the production of the product and y_i is the "yield" of the product, which is assumed to be nonrandom and equal to one to conform to the structure of the problem. Animal products are an exception to this rule. In those cases, we take X_i to be the stock of animals (normalized to one in the base period); y_i is the base-year production of the product.

Domestic demand for product i will be composed of demand for food, animal feed, and industrial purposes,

$$D_i = f_i + e_i + u_i, \tag{13}$$

where

f_i = demand for food

e_i = demand for animal feed

u_i = demand for industrial processing.

Many of these components of demand will be zero depending on the product.

One of the major assumptions of the model is that the objective of food security policy is to keep the population fed adequately. This can be implemented in the model by fixing values for the quantities f_i so as to ensure a proper diet. Maximization of criterion (7) is then achieved while guaranteeing that f_i are always kept at their fixed values. The particular fixed values of f_i are not the concern of this paper. They depend on the domestic income distribution and prices (by the usual demand relationships) as well as on the welfare policies of the government. Once they are determined, however, maximization of equation (7) ensures that they are achieved with an agricultural production pattern that yields the best trade-off between expected value and variance of the agricultural trade balance.

From equations (6), (7), (11), (12), and (13), it is apparent that W will be a quadratic function of activities. The imposed constraints are all linear; hence, the resulting optimization is a quadratic programming problem.

Implementation

The model outlined above was implemented for the agricultural sector in Egypt; nineteen traded products were considered. Table 1 gives the products, the assumed fixed quantities of food, feed and industrial demand, the expected values of border prices, the standard deviations of those prices, and the domestic income elasticity of demand.

The fixed demand figures for 1980 were compiled from the U. S. Department of Agriculture Attache Report on the agricultural situation in Egypt (1982). The expected values and standard deviations (and the attendant correlation matrix of international prices on which the rest of the elements of matrix C depend) were computed by using United Nations, Food and Agriculture Organization data on Egyptian quantities and values of imports and exports. The border unit values were computed, and linear trends were fitted on the series. The expected values of prices are the trend values for 1980; the standard deviations and the correlation matrix were computed by using the residuals of the trend regression. The income elasticities of demand were computed by using the results of Von Braun (1981). These elasticities are used to update the fixed demand numbers of Table 1 when the analysis is carried for a future year. The zero income elasticity of soybeans does not mean that the demand

TABLE 1

Products, Demand Components (circa 1980), and Parameters in the Egyptian Agricultural Sector

Product	Assumed fixed quantities of demand for: Food (f_i)	Animal feed (e_i)	Industrial processing (u_i)	Expected value of international price at border (p_i)	Standard deviation (c_{ii})	Income elasticity
	1	2	3	4	5	6
	thousand metric tons			dollars (U. S.) per metric ton		
Barley	38.0	a/	b/	187	27	.097
Beans	294.5			185	71	.461
Groundnuts	45.8			975	135	.847
Lentils	89.5			206	79	.461
Maize	3,127.6	a/		155	30	.097
Winter onions	205.3			396	234	.484
Oranges	982.4			326	48	.906
Potatoes	1,288.3			241	37	.484
Rice (milled)	1,677.4			428	140	.005
Sesame	30.1			955	188	.847
Sorghum	245.6	a/		138	15	.097
Sugar (refined)	1,363.6			433	140	.510
Tomatoes	2,909.3			469	51	.484
Wheat	8,585.9	a/		190	39	.139
Vegetable oil	465.2			722	112	.455
Meat (total)	802.1			1,332	158	1.314
Cotton (lint)			343.8	3,047	372	.565
Flax (fiber)			24.9	761	119	.565
Soybeans		a/	a/	325	43	.000

a/ Relevant variable not taken as fixed but is an activity in the model.

b/ Blanks indicate not relevant, namely, are assumed equal to zero.

Sources:

Cols. 1-3: U. S. Department of Agriculture, Foreign Agricultural Service. Egypt: Annual Agricultural Situation Report--1981. Attache Report No. EG-2015, American Embassy, Cairo, Egypt, March, 1982.

Cols. 4 and 5: United Nations, Food and Agriculture Organization. Trade Yearbook, Rome, Italy, 1980.

Col. 6: J. Von Braun, "A Demand System for Egypt--Estimation, Results, and Scenario Analysis for Alternative Food Price Policies." Institute of Agricultural Economics, University of Gottingen, Germany, December 1981.

for soybeans does not increase. It is, rather, a numerical convention that has no effect as there are no fixed demand components for soybeans.

Table 2 summarizes the activities of the model, the expected yields in 1980, and the standard deviations of the yields computed from linear time trend regressions on time series data of regional yields. (The expected yields are the 1980 projections of these regressions.) The standard deviations are computed from the standard error of the regressions. The trend numbers are the estimated values of β in the equation,

$$y_t = \alpha + \beta t. \quad (14)$$

The correlation matrix of yields (not shown) was computed by using the residuals of the trend regressions.

The yield of the animal stock activities is basically the figure for total meat production in Egypt in 1980 (both red and white meat). The assumption in the sequel is that the composition of the animal stock does not change but that the whole population of animals can go up or down. The various constraint coefficients are computed accordingly.

For the linear constraints of the model, we have used as sources primarily the Water Master Plan LP model (Kutcher, 1980) and, to a lesser extent, the LP model developed by Von Braun (1980).

The constraints are of the following nature.

1. Monthly land constraints for each of the three regions.
2. Monthly labor constraints for each of the three regions.
3. Water availability (one constraint for all of Egypt).
4. Protein, starch, and roughage requirements for the animal stock for all of Egypt.

TABLE 2

Activity in Model, Expected Yield in 1980, Standard Deviation of Yield, and Linear Trend in the Egyptian Agricultural Sector

Product	Expected yield	Standard deviation of yield	Linear trend
	metric tons per feddan		
Lower Egypt			
Barley	1.160	.077	.005
Beans	.893	.122	.010
Long berseem	24.327	1.586	0.000
Short berseem	8.930	.582	0.000
Cotton (lint)	.427	.043	.007
Flax (fiber)	.450	.020	.005
Groundnuts	.818	.075	.001
Nili maize	1.384	.087	.021
Summer maize	2.092	.154	.029
Winter onions	6.506	.782	.072
Oranges	8.425	.921	.069
Nili potatoes	6.096	.856	0.000
Summer potatoes	7.480	.617	- .018
Rice (milled basis)	1.568	.077	.001
Sesame	.434	.034	.004
Sugarcane (refined basis)	2.428	.058	.018
Nili tomatoes	8.589	.248	.105
Summer tomatoes	7.630	.539	.016
Winter tomatoes	5.514	.711	.040
Wheat	1.644	.107	.026

(Continued on next page.)

Table 2--continued.

Product	Expected yield	Standard deviation of yield	Linear trend
	metric tons per feddan		
Middle Egypt			
Barley	1.482	.075	.016
Beans	1.150	.146	.013
Long berseem	23.406	.952	0.000
Short berseem	6.800	.277	0.000
Cotton (lint)	.318	.042	.001
Flax (fiber)	.448	.026	.002
Groundnuts	1.120	.069	.009
Nili maize	1.240	.077	.007
Summer maize	1.920	.241	.021
Winter onions	4.590	.561	- .053
Oranges	6.414	.830	.125
Nili potatoes	8.715	.386	.122
Summer potatoes	6.123	.554	.057
Rice (milled basis)	1.473	.098	.012
Sesame	.626	.031	.008
Sorghum	1.725	.093	.015
Sugarcane (refined basis)	3.119	.180	.021
Nili tomatoes	7.992	.445	.043
Summer tomatoes	7.298	.354	- .006
Winter tomatoes	4.353	.806	- .080
Wheat	1.583	.064	.018
Soybeans	1.498	.188	.069

(Continued on next page.)

Table 2--continued.

Product	Expected yield metric tons per feddan	Standard deviation of yield	Linear trend
Upper Egypt			
Barley	1.316	.044	.012
Beans	1.392	.099	.024
Long berseem	24.757	1.719	0.000
Short berseem	12.544	.871	0.000
Cotton (lint)	.407	.046	.005
Groundnuts	.577	.081	- .022
Lentils	.618	.109	0.000
Nili maize	1.191	.087	.007
Summer maize	1.890	.265	.013
Winter onions	11.433	.823	.129
Oranges	4.916	1.490	- .218
Sesame	.523	.074	.004
Sorghum	1.892	.135	.014
Sugarcane (refined basis)	2.458	.120	- .022
Nili tomatoes	7.587	.256	.067
Summer tomatoes	5.540	.387	- .040
Winter tomatoes	6.047	.484	- .004
Wheat	.423	.099	.014
All of Egypt			
Animal stock	459.000	0.000	0.000
Wheat for feed	1.000	0.000	0.000
Maize for feed	1.000	0.000	0.000
Barley for feed	1.000	0.000	0.000
Sorghum for feed	1.000	0.000	0.000
Soybeans for feed	1.000	0.000	0.000
Soybeans for crushing	1.000	0.000	0.000

5. Horsepower constraints (one for each of the three regions).
6. Rotational constraints for summer, winter, and Nili vegetables [from Von Braun (1980)].
7. Sugar-processing constraint.

In all, there are 87 linear constraints in the model.

The FORTRAN computer program was written to use a Harwell quadratic programming subroutine; it requires about 300 machine seconds of the IBM 4341 computer at the University of California, Berkeley.

Empirical Results

Table 3 summarizes the results for the optimal activity levels of four experiments run with the model and compares them with their actual 1979 levels. The experiments assume the following. Experiment 1 is a base case; it assumes that $\Phi = .01$. Experiment 2 is the same as Experiment 1 except that $\Phi = .001$. Experiment 3 is the same as the base case except that it assumes a 10 percent increase in the expected international price of oranges, sorghum, and sugar and a 10 percent decline in the expected international price of potatoes and groundnuts. Experiment 4 is an examination of the optimal crop pattern for 1985. It assumes that the per capita income will grow at 1 percent annually, population will grow at 2.3 percent annually, and mechanical tractor availability will grow at 2 percent annually.

From a comparison of the 1979 actual levels and the base case of Experiment 1, several interesting observations arise. First, the optimal crop pattern predicted by the model allocates substantially more cropland to wheat and rice (the main food crops) and substantially less land to cotton and berseem in almost all regions. This result supports the argument of those who

TABLE 3

Actual 1979 Level and Optimal Level of Activity Under Four Different Sets of Assumptions in the Egyptian Agricultural Sector

Product	1979 actual level of activity	Optimal level of activity[a]			
		Experiment 1[b]	Experiment 2[c]	Experiment 3[d]	Experiment 4[e]
	thousand metric tons				
Lower Egypt					
Barley	80	0.0	0.0	0.0	0.0
Beans	75	0.0	0.0	0.0	0.0
Long berseem	1,246	60.1	440.0	61.6	27.2
Short berseem	775	109.4	345.4	107.6	59.3
Cotton	827	343.2	818.8	343.2	343.2
Flax	65	0.0	0.0	0.0	0.0
Groundnuts	20	0.0	0.0	0.0	0.0
Nili maize	150	0.0	0.0	0.0	0.0
Summer maize	944	568.2	1,304.7	416.1	372.6
Winter onions	7	0.0	237.8	0.0	0.0
Oranges	134	0.0	0.0	42.3	41.8
Nili potatoes	47	0.0	0.0	0.0	0.0
Summer potatoes	56	381.0	0.0	280.3	226.4
Rice	1,019	1,490.2	194.1	1,659.6	1,617.0
Sesame	3	0.0	0.0	0.0	0.0
Sugarcane	10	0.0	0.0	0.0	0.0
Nili tomatoes	49	1,005.4	1,089.5	945.2	1,032.4
Summer tomatoes	94	86.9	511.8	131.8	227.2
Winter tomatoes	64	0.0	0.0	0.0	0.0
Wheat	803	2,375.4	1,396.8	2,394.3	2,390.5

(Continued on next page.)

Table 3--continued.

Product	1979 actual level of activity	Optimal level of activity[a]			
		Experiment 1[b]	Experiment 2[c]	Experiment 3[d]	Experiment 4[e]
	thousand metric tons				
Middle Egypt					
Barley	15	51.3	0.0	0.0	33.0
Beans	110	0.0	0.0	0.0	0.0
Long berseem	348	193.7	598.9	192.8	126.1
Short berseem	167	231.9	0.0	206.0	67.2
Cotton	222	42.4	42.4	42.4	42.4
Flax	3	0.0	0.0	0.0	0.0
Groundnuts	6	747.2	347.9	662.1	548.6
Nili maize	270	0.0	0.0	83.1	0.0
Summer maize	326	0.0	0.0	0.0	0.0
Winter onions	10	0.0	0.0	0.0	0.0
Oranges	14	0.0	0.0	0.0	0.0
Nili potatoes	25	144.1	0.0	130.7	285.4
Summer potatoes	13	149.4	0.0	149.4	129.4
Rice	17	0.0	0.0	0.0	0.0
Sesame	2	0.0	0.0	0.0	0.0
Sorghum	48	0.0	0.0	0.0	0.0
Sugarcane	38	0.0	0.0	0.0	112.5
Nili tomatoes	34	185.3	406.9	184.3	130.1
Summer tomatoes	15	0.0	149.4	0.0	20.0
Winter tomatoes	49	0.0	0.0	0.0	0.0
Wheat	227	313.7	114.2	392.9	365.8
Soybeans	100	0.0	0.0	0.0	0.0

(Continued on next page.)

Table 3--continued.

Product	1979 actual level of activity	Optimal level of activity[a]			
		Experiment 1[b]	Experiment 2[c]	Experiment 3[d]	Experiment 4[e]
	thousand metric tons				
Upper Egypt					
Barley	12	0.0	0.0	0.0	0.0
Beans	65	0.0	0.0	0.0	0.0
Long berseem	152	45.2	309.1	45.6	31.3
Short berseem	90	87.0	0.0	77.0	66.9
Cotton	147	142.7	77.0	126.2	181.7
Groundnuts	4	0.0	0.0	0.0	0.0
Lentils	22	0.0	0.0	0.0	0.0
Nili maize	52	0.0	0.0	0.0	0.0
Summer maize	143	605.9	0.0	584.7	600.6
Winter onions	7	71.3	38.5	63.1	90.8
Oranges	12	0.0	0.0	0.0	0.0
Sesame	32	0.0	0.0	0.0	0.0
Sorghum	345	0.0	0.0	0.0	0.0
Sugarcane	201	0.0	0.0	0.0	0.0
Nili tomatoes	5	20.9	381.8	48.4	21.3
Summer tomatoes	4	0.0	100.4	0.0	0.0
Winter tomatoes	15	0.0	0.0	0.0	0.0
Wheat	361	758.7	492.9	783.0	714.1

(Continued on next page.)

Table 3--continued.

Product	1979 actual level of activity	Optimal level of activity[a/]			
		Experiment 1[b/]	Experiment 2[c/]	Experiment 3[d/]	Experiment 4[e/]
	thousand metric tons				
All of Egypt					
Animal stock	1	1.1	1.18	1.11	1.11
Wheat for feed	40	0.0	0.00	0.00	0.00
Maize for feed	1,387	1,353.4	0.00	2,938.70	2,220.70
Barley for feed	74	0.0	0.00	0.00	0.00
Sorghum for feed	430	1,917.9	4,085.80	0.00	0.00
Soybeans for feed	31	0.0	0.00	0.00	0.00
Soybeans for crushing	93	207.9	0.00	350.70	0.00

a/ Units for activity level are thousand feddans for crop products, thousand metric tons for feeds (wheat, maize, barley, sorghum, soybeans, and soybeans for crushing), and no units for animal stock.

b/ Base case; assumes national coefficient of aversion to international risks (Φ) of .01.

c/ Same as (b) except that $\Phi = .001$.

d/ Same as (b) except that experiment assumes a 10 percent increase in expected international price of oranges, sorghum, and sugar and a 10 percent decline in expected international price of potatoes and groundnuts.

e/ Experiment is an examination of optimal crop pattern for 1985. Assumes that per capita annual growth will be 1 percent in income, 2.3 percent in population, and 2 percent in mechanical tractor availability.

advocate less reliance on the international market for the basic food grains. Maize is a very interesting case. The model allocates no cropland in any region to Nili maize. However, in the case of summer maize, the model allocates less land than is currently cultivated in Lower Egypt and Middle Egypt but substantially more land in Upper Egypt. Furthermore, the quantity of maize used for feed stays roughly the same. The model allocates no land to oranges--a rather surprising result--but substantially more total land to potatoes, winter onions, and tomatoes, especially Nili tomatoes.

Another surprising result is the increased level of animal stock that is predicted by the model. This is, in part, the result of the fact that international meat prices are high, but it is also a result of the rather tight constraints on horsepower requirements of the crop pattern (the stocks of tractors in the three regions are assumed to stay fixed at their 1980 levels). A rather interesting result, however, is that the model predicts a quite different structure for fulfilling the feeding requirements of animals. It allocates to animal feed much more sorghum (all imported) and much less berseem.

Of the constraints, several of those on land are binding--as expected. The slack values of the ones that are not binding are quite small. Almost all of the labor constraints, surprisingly, are not binding and have large slack values (an exception is labor in May in Lower Egypt). This suggests that agricultural labor is still in ample supply. The nutrient requirement constraints for animal feed and the horsepower requirement constraints of the crop pattern have the highest shadow prices. This suggests strongly that one of the ways food security can be increased is by greater use of mechanical cultivation techniques in order to alleviate the very tight horsepower constraints.

Using the 1979 levels of the activities, the expected level of F is equal to -$1,322 million (U. S.) while the standard deviation of F is $274 million (U. S.). At the optimum allocation of the base experiment, the expected level of F is $3,249 million (U. S.). The standard deviation of F declined in all experiments. The large, surprisingly positive expected level of F is due, in part, to the assumption implicit in the model that Egypt can import or export unlimited quantities of any agricultural product at unchanged international prices. This assumption that Egypt is a pricetaker is quite reasonable for the current trade position of the country, but it is not clear whether or not it will be reasonable for a substantially different crop pattern.

Before we analyze the other experiments, it is instructive to examine the first two columns of Table 4. Column 1 exhibits the expected level of the net exports of all products. (Note that, because the expected levels for 1980 are computed using the trend levels of yields, these levels will not be the same as the actual 1980 traded quantities.) Comparing columns 1 and 2 of the table, it can be seen that the optimizing model implies much higher net imports of maize, sugar, and sorghum and much lower imports of wheat and meat. The base solution (Experiment 1) also implies much higher levels of rice and vegetable exports but lower levels of cotton exports--in fact, cotton becoming an import.

The second experiment, which assumes much lower risk aversion on the part of policymakers in Egypt, is quite instructive. It suggests much higher levels of total area allocated to cotton and berseem and less area cultivated in wheat. It also suggests a smaller rice area and the shift of all maize

TABLE 4

Expected 1980 Level[a] and Optimal Levels of Activity[b] in Model of Net Exports of Agricultural Products in Egypt

Product	1980 expected level of activity	Optimal level of activity			
		Experiment 1[c]	Experiment 2[d]	Experiment 3[e]	Experiment 4[f]
	1	2	3	4	5
	thousand metric tons				
Barley	19.1	38.2	- 33.0	- 33.0	10.8
Beans	11.5	- 250.0	- 250.0	- 250.0	- 294.5
Groundnuts	- 12.5	758.5	332.9	667.8	568.6
Lentils	- 62.4	- 76.0	- 76.0	- 76.0	- 89.5
Maize	- 873.5	-1,878.5	- 210.6	-3,694.7	-3,433.7
Winter onions	- 7.8	586.5	1,680.9	498.8	833.4
Oranges	415.5	- 812.0	- 812.0	- 468.2	- 630.0
Potatoes	- 105.8	3,812.8	- 1,092.8	2,942.6	3,684.4
Rice (milled)	152.5	864.7	- 1,159.8	1,129.3	858.1
Sesame	- 6.6	- 25.0	- 25.0	- 25.0	- 30.1
Sorghum	59.2	-2,130.9	- 4,298.8	- 213.0	- 245.6
Sugar (refined)	- 496.5	-1,154.0	- 1,154.0	-1,154.0	-1,012.6
Tomatoes	- 270.4	7,773.4	17,627.4	7,823.3	9,038.7
Wheat	-5,455.9	-2,415.8	-4,522.1	-2,238.4	-3,060.5
Vegetable oil	- 248.8	- 307.4	- 303.5	- 283.9	- 405.3
Meat	- 188.0	- 141.9	- 105.2	- 138.4	- 294.0
Cotton (lint)	153.1	- 90.8	67.5	- 97.0	- 109.8
Flax (fiber)	7.6	- 21.0	- 21.0	- 21.0	- 24.9
Soybeans	- 15.6	- 207.9	0.0	- 350.7	0.0

a/ Not actual level.

b/ Net import if negative.

c/ Base case; assumes national coefficient of aversion to international risks (ϕ) of .01.

d/ Same as (c) except that ϕ = .001.

e/ Same as (c) except that experiment assumes a 10 percent increase in expected international price of oranges, sorghum, and sugar and a 10 percent decline in expected international price of potatoes and groundnuts.

f/ Experiment is an examination of optimal crop pattern for 1985. Assumes that per capita annual growth will be 1 percent in income, 2.3 percent in population, and 2 percent in mechanical tractor availability.

production to summer maize in Lower Egypt. It also suggests an 18 percent higher level of animal stocks than in the base case. The optimal expected value of F turns out to be very high--$5,995 million (U. S.)--while the standard deviation of F is higher than the base value, albeit still lower than the 1979 level. The results of this experiment strongly indicate that policies suggested when looking only at the mean levels of international prices [e.g., Cuddihy (1980)] while ignoring the risks involved can be quite misleading. A lower degree of risk aversion will make these policies attractive; but it must be realized that they imply large fluctuations in foreign exchange earnings and, hence, lower ability to satisfy consistently the domestic food requirements. However, this is precisely what food security is all about.

Examining Table 4, it can be seen that Experiment 2 allocates land so as to maximize production and export of profitable cash crops such as cotton and vegetables. The implied expected imports of maize are much lower than in the base case or those the current actual crop pattern implies.

Experiment 3 is designed to test if some seemingly abnormal results are due to the assumption about international prices. Although five prices were changed, significant change from the base solution is observed only in the case of sorghum, which is drastically diminished in production and imports and is substituted largely by maize. The optimal expected value of F is $2,979 million (U. S.), which is quite close to the optimal figure for the base value. Apart from the sorghum-maize substitution, in this solution there does not appear to be much difference from the base case.

The final experiment (Experiment 4) is an attempt to predict how the future food requirements of Egypt can best be met. Since food demand changes over time because of income and population changes, the goals of food security also change. Implicit in the solution reported here is the assumption that income distribution does not change in the medium run. Demand is, of course, not the only variable that changes in the model. The expected levels are assumed to change according to past trends. However, the expected values of international prices are assumed to remain at their 1980 expected levels.

The results suggest no serious change in crop pattern except that more area is allocated to sugarcane in Middle Egypt. The only other significant result is the switch from large sorghum imports to more maize imports for feed compared to the base case. The expected optimal value of F increases to a surprising $3,451 million (U. S.) compared to $3,249 million (U. S.) in the base case. The reason for this seemingly unreasonable result is that the trends in the yields of many products are favorable and will more than make up for the increased demand for food.

Conclusions

The empirical results, although still tentative pending further experimentation and tuning of the model, are fairly suggestive. They indicate that the drive in Egypt toward more self-reliance in staple food grains, such as wheat, at the expense of seemingly more profitable cash crops, such as cotton, is justified when one considers the domestic and international risks. All solutions indicate that more of the profitable vegetable crops should be produced and marketed abroad. The model also suggests an increase in the stock of animals to satisfy both the high levels of domestic meat demand and the large horsepower requirements of the crop pattern. However, the model strongly suggests a very low reliance on berseem as a feed and a much higher reliance on imported sorghum and maize.

Also, the results are, of course, conditional because of imperfections in the model. Optimizing models of this type, unlike linear programming models designed to replicate in the base solution the existing situation, cannot be calibrated easily. The attitude taken here is that, by adopting the constraints of well-tested linear programming models and putting much effort into the careful specification of the objective function, errors of misspecification are minimized.

The model is very flexible and can be adapted to answer several questions. It is large but it is still manageable. It is hoped that future experimentation with it will increase its reliability and its effective use as a tool for designing food security policies in Egypt.

Footnotes

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