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1. Introduction

Over the last decade, "food security" has become a catch phrase in the name of which food and agriculture policies in many developing countries, as well as calls for various international agreements, are justified. Food security at the national level can be broadly defined as the ability of a country to meet consistently and without excessive expenditures its yearly domestic food requirements [Siamwalla and Valdes (1980)]. As such, it involves insurance against certain risks. There are two sets of relatively independent risks that are inherent in discussions of this problem. First is the set of risks associated with the international market. Such risks include fluctuations of prices of imports and exportables, embargoes, foreign exchange fluctuations, etc., and are usually beyond the control of any one country. Second is the set of risks that is generated domestically in any country. Such risks include mainly the various environmental factors that give rise to fluctuations in the production of agricultural products.

The discussions about food security in the mid-1970s were influenced to a large extent by the events of 1973-74 that led to the so-called world food crisis. Hence, emphasis was placed on international cooperation and agreements designed to diminish the excessive fluctuations in the international prices of grains and assure world availabilities of supplies via buffer stocks [Reutlinger (1982)]. Such an approach, however, was predestined to have no success because, as has been shown both theoretically [Hueth and Schmitz (1972)] and empirically [Johnson (1981); Konandreas, Huddleston, and Ramangkura (1978); Morrow (1981); Sarris (1976)], international grain price stabilization via buffer stocks is expensive to achieve and influences adversely several of the participating countries. International buffer stock schemes are very unlikely to be agreed upon even if compensation is paid to the losers because the uncertainty surrounding the estimated costs and benefits is very high.

In the heated political and economic discussions about food security, it has been overlooked that food security for an individual country can be substantially improved, even within unstable international markets, if the country via internal reallocation of resources alters its exposure to international risk. It is this idea that provides the motivation for this paper.

There have been some discussions of national schemes to improve food security [Reutlinger and Bigman (1981), Tyers and Rachman (1981)]. All of them, however, focus on the operation of a national grain buffer stock scheme, an institution that will alleviate the symptoms but will not change the internal causes of food insecurity.

The analysis of this paper uses a static resource allocation model of the agricultural sector coupled with an objective function that is designed to capture food security considerations in order to determine, in a normative planning context, an allocation of agricultural production that substantially improves national exposure to international risk. The resulting quadratic programming problem provides an empirical application of the theory of international trade under uncertainty [Brainard and Cooper (1968), Anderson and Riley (1976), Rothenberg and Smith (1971)].

The methodology is applied to Egypt, a country which has elevated food security to the status of the main objective of national food and agriculture policy. Underneath the rhetoric, however, there is considerable variance within the Egyptian government and among intellectuals about the specific goals and policies that food security implies. One ministry advocates self-sufficiency in basic grains as the main objective of food security; another is concerned about war emergency reserves; a third advocates policies to increase real farmer income; and still another is concerned about availability and fluctuations in foreign exchange outlays for food and feed imports.

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 as 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.

Section 2 of the paper exhibits the theoretical background of the approach; section 3 discusses the implementation of the model to the agricultural sector in Egypt; section 4 summarizes the empirical specification of the model; section 5 presents the results of the analysis for the base year 1980; section 6 presents the results of five-year projections from 1980 under alternative assumptions; and the final section summarizes the main findings.

2. A theoretical model of food security

In this section, the theory of trade under uncertainty will be adapted to the food security problem at hand in order to provide the background of the approach and the objective function to be optimized.

Consider a country that produces two classes of goods, namely, agricultural and nonagricultural ones. Denote by x_a the production vector of the goods produced in the agricultural sector, by x_n the composite good of the nonagricultural sector, by c_a the vectors of agricultural goods consumed domestically, and by c_n the consumption of the nonagricultural composite good. Let p_a, p_n denote the corresponding international prices of these goods which are assumed not to be influenced by the country's trade (in other words, we make a small country assumption). Following earlier literature on trade under uncertainty (Brainard and Cooper, Anderson and Riley, Rothenberg and Smith), consider a two-period decision problem for the country. In the second period, the country is facing a standard deterministic static consumption optimization problem of the following form

$$\max U(c_a, c_n), \qquad \text{subject to}$$
$$p_a c_a + p_n c_n = p_a x_a + p_n x_n, \tag{1}$$

where U is the country's welfare function.

In eq. (1), the prices--p_a, p_n--and the production quantities--x_a, x_n--are assumed known. A solution of eq. (1) yields the optimum consumption quantities--c_a^o, c_n^o--as functions of the remaining variables. Substitution of these in U yields the indirect utility function

$$U\left[c_a^o(p_a, p_n; x_a, x_n), c_n^o(p_a, p_n; x_a, x_n)\right] \equiv V(p_a, p_n; x_a, x_n). \tag{2}$$

In the first period, the precise values of p_a, p_n, x_a, and x_n are not known; only a joint probability distribution of them is known. Hence, the optimization problem is of the form

$$\max E\, V(p_a, p_n; x_a, x_n), \quad \text{subject to}$$

$$T(\bar{x}_a, \bar{x}_n) \leq 0, \tag{3}$$

where an overbar denotes expected value, and the inequality in eq. (3) is a compact notation for the technical production constraints facing the country. The expectation in eq. (3) is taken over the joint probability distribution of all stochastic variables.

The above general welfare optimization problem under conditions of international price and domestic production uncertainty is now adapted to the problem of food security as follows. First, it will be assumed that nonagricultural production and prices are fixed exogenously. This is done in order to focus on agricultural production although more general models are possible. Assume furthermore, for simplicity, that $p_n = 1$.

Food security is assumed to imply a fixed consumption bundle, c_a^*, for the policymakers. The particular value of this vector could be obtained by detailed analysis of consumption patterns among different income classes, coupled with government evaluation of the needs of the population, and government consumer price policies. In this paper, no particular attention is paid to the methods that can be used in evaluating c_a^*. It is assumed, however, that, whatever value of c_a^* is deemed most appropriate, it will always be achieved either through domestic production or trade.

Based on the above assumption, eqs. (1) and (3) can be combined as follows

$$W^o = \max E\left[W\left(p_a x_a - p_a c_a^*\right)\right], \quad \text{subject to}$$

$$\tilde{T}(\bar{x}_a) \leq 0, \tag{4}$$

where

$$W\left(p_a x_a - p_a c_a^*\right) \equiv U\left(c_a^*, p_a x_a - p_a c_a^* + x_n^*\right)$$

$$\tilde{T}(\bar{x}_a) \equiv T\left(\bar{x}_a, x_n^*\right). \tag{5}$$

Notice that the expression within the parentheses of W are equal to the net export receipts of the agricultural sector which we will denote by F. In order to make the model empirically operational, a particular form of W is needed. In this paper, an exponential utility is assumed and, under the assumption of normal distributions for the random variables, the objective becomes equivalent to maximization of a linear function of the expected value and the variance of F as follows

$$W^o = \max[E(F) - \frac{1}{2}\phi \operatorname{var}(F)], \qquad \text{subject to}$$

$$\tilde{T}(\bar{x}_a) \leq 0. \tag{6}$$

The parameter, ϕ, is the well-known coefficient of absolute risk aversion of the country's welfare. A model such as the one in eq. (6) will be applied to the Egyptian food security problem.

3. The empirical model

Assume that there are n agricultural products that are produced and consumed by a country, m of which (the first m by convention) are traded internationally. Denote by S_i and D_i the domestic supply and demand of product i. In the absence of stock changes, $S_i - D_i$ denotes the exported quantity of the product. If the international price at the border of the m traded products is p_i (assumed exogenous), then

$$F = \sum_{i=1}^{m} (S_i - D_i)\, p_i. \qquad (7)$$

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

$$\text{cov}(S_i, p_j) = 0 \qquad i, j = 1, \ldots, m. \qquad (8)$$

In other words, the international prices are not correlated with domestic yields. Domestic demand for all products, as already discussed, is assumed fixed.

Denote by $\overline{S}_i$ and $\overline{p}_i$ the expected values of S_i and $p_i (i = 1, \ldots, m)$. Also, define the matrices B and C as follows

$$B = \{b_{ij}\} \text{ where } b_{ij} \equiv \text{cov}(S_i, S_j) \qquad i, j = 1, \ldots, m \qquad (9)$$

$$C = \{c_{ij}\} \text{ where } c_{ij} \equiv \text{cov}(p_i, p_j) \qquad i, j = 1, \ldots, m. \qquad (10)$$

Denote by $\overline{x}$ the column vector whose ith element is $\overline{S}_i$, by $\overline{p}$ the column vector whose ith element is $\overline{p}_i$, and by d the column vector whose ith element is D_i. (For economy of notation, the subscript, a, in x, p, and d will be dropped with the understanding that all products and prices refer to the agricultural sector.) Then, the expected value and variance of F can be written as

$$E(F) = x'p - d'p \qquad (11)$$

$$\text{var}(F) = \text{tr}(BC) + x'Cx + p'Bp + d'Cd - 2\, x'Cd, \qquad (12)$$

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

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 $\bar{y}_i^k$ the expected value of the yield; then, by definition, we have

$$\bar{S}_i = \sum_{k=1}^{3} A_i^k \bar{y}_i^k. \tag{13}$$

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

$$R = \begin{bmatrix} R^{11} & R^{12} & R^{13} \\ R^{21} & R^{22} & R^{23} \\ R^{31} & R^{32} & R^{33} \end{bmatrix} \tag{14}$$

where

$$R^{kl} = \left\{r_{ij}^{kl}\right\} \text{ and } r_{ij}^{kl} = \text{cov}\left(y_i^k, y_j^l\right). \tag{15}$$

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

$$b_{ij} = \sum_{k=1}^{3} \sum_{l=1}^{3} A_i^k r_{ij}^{kl} A_j^l. \tag{16}$$

The largest number of activities in the model will be the 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

$$S_i = X_i \cdot y_i, \tag{17}$$

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 (such as meat) 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,

$$D_i = f_i + e_i + u_i, \tag{18}$$

where

f_i = demand for food

e_i = demand for animal feed

and

u_i = demand for industrial processing.

Many of these components of demand will be defined as nonexistent depending on the product.

The food security objective is implemented by fixing the f_i for the various food categories. In addition, for certain products which are used for industrial purposes and whose by-products are used indirectly for d (e.g., cotton and flax), we postulate a fixed industrial demand.

From equations (11), (12), (16), (17), and (18), it is apparent that the objective function which was defined in eq. (6) is a quadratic function of the activities. The imposed technical constraints on the activities are all linear. Hence, the resulting optimization is a quadratic programming problem.

It should be noted that the model outlined here is a strictly normative one; and, hence, it is not meant to simulate the current agricultural production pattern as is done with traditional positive price equilibrium linear programming models of the agricultural sector. This poses a fundamental question about how is one to believe that the constraint set is the right one given that detailed calibration is not feasible. This problem was solved, on the one hand, by adopting as the constraint set an intersection of sets defined by linear constraints in well-tested and calibrated positive agricultural sector models of Egypt. The necessity of using more than one constraint set arises from the fact that the activities of the particular model used here do not correspond exactly with any of the activity sets used in previous programming models. On the other hand, much experimentation, sensitivity analysis, and discussions with experts were conducted in order to obtain a feeling about how the model behaves and, hence, a judgment about the appropriate constraints and their level. It is, nevertheless, readily acknowledged that the building of such models is still an art without prescribed rules; and, hence, results must be interpreted with care.

4. Model implementation

In this section, we discuss how 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 were assumed to be those actually prevailing in 1980 and were compiled from the U. S. Department of Agriculture Attache Report

Table 1

Products, demand components (circa 1980), and parameters in the Egyptian agricultural sector.[a]

Product	Assumed fixed quantities of demand for: Food (f_i)[b]	Animal feed (e_i)	Industrial processing (u_i)	Expected values of international price at border ($\bar{p}_i$)	Standard deviation (c_{ii})	Income elasticity
	1	2	3	4	5	6
	thousand metric tons			dollars (U. S.) per metric ton		
Barley	33	--[c]	d	187	27	.097
Beans	250			185	71	.461
Groundnuts	38			975	135	.847
Lentils	76			206	79	.461
Maize	2,713	--		155	30	.097
Winter onions	174			396	234	.484
Oranges	812			326	48	.906
Potatoes	1,092			241	37	.484
Rice (milled)	1,463			428	140	.005
Sesame	25			955	188	.847
Sorghum	213	--		138	15	.097
Sugar (refined)	1,154			433	140	.510
Tomatoes	2,466			469	51	.484
Wheat	7,429	--		190	39	.139
Vegetable oil	395			722	112	.455
Meat (total)	647			1,332	158	1.314
Cotton (lint)			209	3,047	372	.565
Flax (fiber)			21	761	119	.565
Soybeans		--	--	325	43	.000

[a]Sources: Cols. 1-3: U. S. Department of Agriculture, Foreign Agricultural Service (1982); Cols. 4 and 5: computed from data in United Nations, Food and Agriculture Organization (1980); Col. 6: computed from Von Braun (1981).

[b]Notation corresponds to the one in the text.

[c]Dashes indicate relevant variable not taken as fixed but is an activity in the model.

[d]Blanks indicate not relevant, namely, are not included in the model either as fixed or as activities.

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 and, hence, do not correspond to actual average border prices 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 for soybeans does not increase. It is, rather, a numerical convention that has no effect as there are no fixed demand components for soybeans.

Appendix table 1 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 fitted values of these regressions and, hence, do not correspond to actual 1980 yields. This is done because we are interested in the expected values of yields and not the realizations in any one year. The standard deviations are computed from the standard error of the regressions. The trend numbers are the estimated values of β in the equations of the form

$$y_t = \alpha + \beta t. \qquad (19)$$

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. It is assumed that the area devoted to products not included in the model stays unchanged.
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.
5. Horsepower constraints, namely, availability of traction power from draft animals and tractors (one for each of the three regions).
6. Rotational land-use constraints for summer, winter, and Nili vegetables in all regions (from Von Braun).
7. Sugar-processing constraint.

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

The FORTRAN computer program was written to use the Minos nonlinear programming system that was developed at Stanford University; it requires about 40 machine seconds of the IBM 4341 computer at the University of California, Berkeley.

5. Empirical results for the base period

The first question which we address has to do with the efficiency of the current Egyptian agricultural production pattern. Fig. 1 exhibits a mean-standard deviation efficiency frontier[1] (ϕ_1 ϕ_{11}) generated by the model by optimizing the production pattern for various values of the risk aversion parameter ϕ. It should be noted that ϕ was varied over more than six orders of magnitude in the various experiments to the point that further increase or decrease did not change the values of the mean and standard deviation of net agricultural foreign exchange earnings. Accordingly, points ϕ_1 and ϕ_{11} on the figure represent the end points of the frontier (ϕ_1 = .0001, ϕ_{11} = 100).

Point A represents the mean-standard deviation combination of net agricultural foreign exchange earnings that is afforded by the current (circa 1980) production pattern in Egypt. The actual figures for point A are \$-1,322 million (U. S.) for the expected foreign exchange earnings and \$325 million (U. S.) for the standard deviation. In other words, the current production structure in Egypt can afford food security in the sense defined earlier (namely, assured availability of a fixed food consumption basket) with an agricultural trade balance which, on average, is in substantial debit (roughly 10 percent of Egyptian GNP) and fluctuates very widely. To obtain an idea of how suboptimal the current situation is, consider points C and D. Point C is quite close to the edge of the frontier, namely, point ϕ_{11} which represents an expected value of \$-1,143 million (U. S.) and a standard deviation of only \$92.7 million (U. S.) (it corresponds to a very high value of ϕ) while point D corresponds to an expected value of foreign exchange earnings of \$3,850 million (U. S.) at the same standard deviation as the current situation.

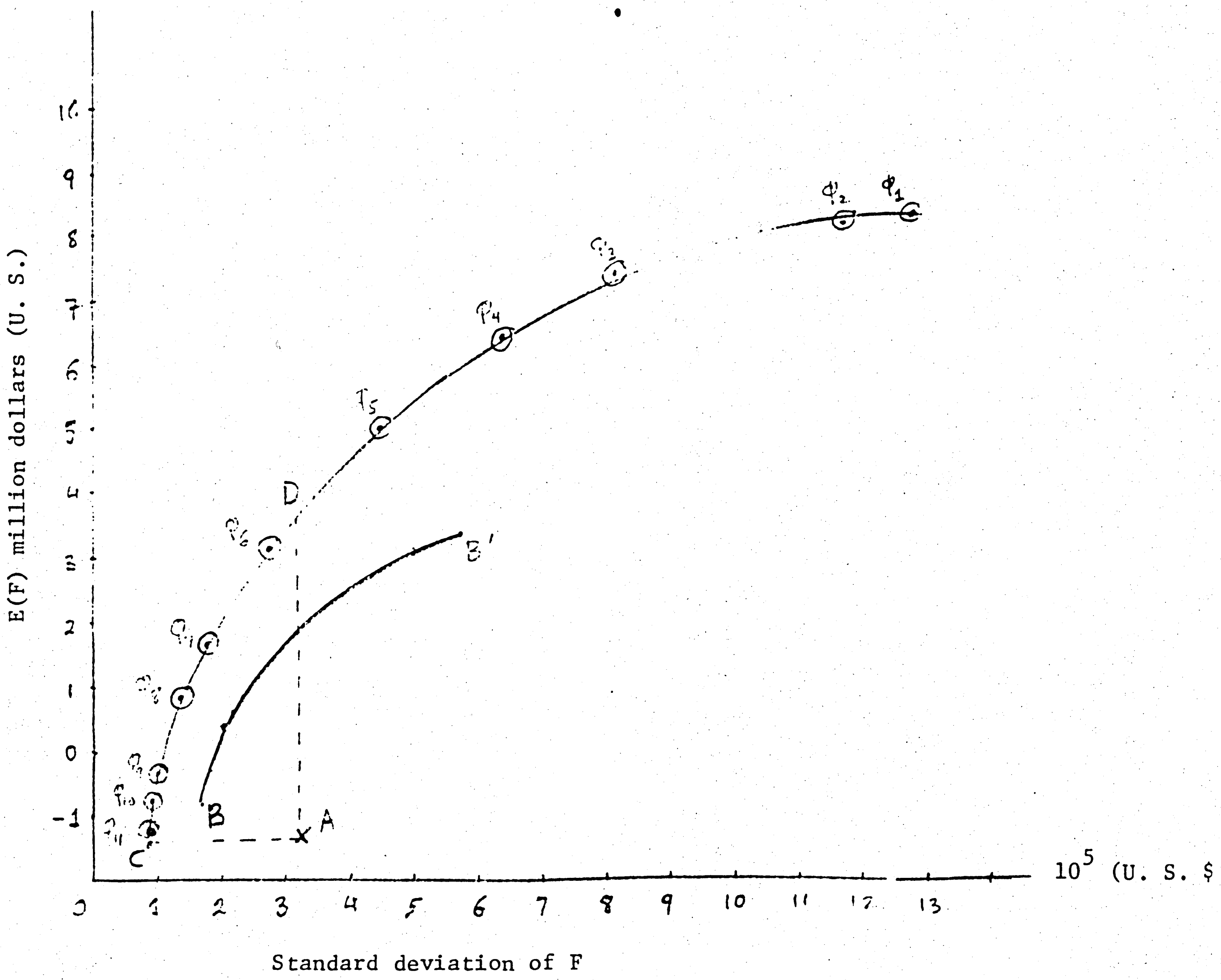

Fig. 1. Frontiers of expected value vs. standard deviation of Egyptian agricultural foreign exchange net export earnings.

The points on the efficiency frontier were derived on the assumption that no area controls are in effect. This, however, does not mean that, even under the current area controls, the production pattern is mean-variance optimum. Schedule BB' is the locus of optimum mean-standard deviation. Agricultural foreign net export receipt points are derived under the additional constraints that the cultivated areas for beans, cotton, flax, groundnuts, rice, sesame, sugarcane, winter onions, lentils, maize, and wheat in each of the three regions are larger than the areas allotted by the government.[2] It is quite obvious, since BB' is uniformly below $\phi_1 \phi_{11}$, that, even with the current controls, the Egyptian agricultural production structure could be improved considerably without sacrificing food security.

Given the conclusion we reached above, the next question of substantial interest to Egyptian policymakers is how to improve efficiency within the food security policy objective defined earlier, namely, which products should be increased in crop area. Table 2 presents the results of a series of experiments which are designed to illustrate the evolution of the optimum crop areas (and quantities) of various activities (aggregated at the national level for ease of exposition) under no government controls for different levels of national aversion to foreign exchange risk.

The table is very revealing because it exhibits some very interesting optimum patterns of production. In cotton, for example, the optimum cultivated area constantly declines from a value much higher than current levels at very low levels of risk aversion to values less than half the current levels for high degrees of risk aversion. It is quite clear then that arguments such as those presented by Cuddihy (1980), namely, that cotton area in Egypt should be expanded because it is profitable to do so, can be reversed if Egyptians' aversion to risk is reasonably high. On the other hand, exactly the opposite

Table 2

1980 optimum uncontrolled national agricultural production patterns for various values of the national risk aversion parameter, ϕ.[a,b]

Product	1980 production pattern	ϕ_1 .0001[c]	ϕ_2 .001	ϕ_3 .005	ϕ_4 .01	ϕ_5 .02	ϕ_6 .05	ϕ_7 .1	ϕ_8 .2	ϕ_9 .5	ϕ_{10} 1.0	ϕ_{11} 100.0[d]
		thousand feddans										
Barley	107	0	0	0	107.4	0	0	0	0	0	0	0
Beans	250	0	0	0	0	77.3	0	0	0	0	0	0
Cotton	1,196	1,515.4	1,386.6	1,107.7	896.2	786.2	666.8	594.1	530.4	495.9	490.2	481.3
Flax	68	0	0	148.2	670.1	888.0	1,019.2	1,221.6	1,356.0	438.7	300.9	223.1
Groundnuts	30	0	211.5	1,148.6	1,916.2	2,095.5	1,829.6	1,057.2	591.8	472.7	370.0	288.4
Nili maize	472	0	0	0	0	0	77.0	154.6	136.6	686.4	728.2	854.4
Summer maize	1,413	796.7	635.0	471.3	150.2	106.2	393.6	820.2	1,157.1	1,143.4	1,213.5	1,202.2
Winter onions	24	481.3	500.5	396.1	255.3	200.3	140.6	104.2	72.4	55.1	52.4	47.8
Oranges	160	0	247.4	627.8	362.5	285.0	205.0	166.2	134.0	117.3	107.2	86.9
Nili potatoes	72	0	0	307.6	452.9	273.2	5.1	135.1	121.2	111.9	109.6	102.0
Summer potatoes	69	0	0	0	0	118.1	238.2	76.8	76.1	0	0	0
Rice	1,036	0	0	75.9	242.9	556.9	1,068.3	1,469.2	1,677.8	1,559.0	1,626.4	1,684.9
Sesame	37	0	0	0	0	0	0	0	122.8	25.8	0	32.7
Sugarcane	249	0	0	0	121.9	299.4	311.5	311.5	311.5	311.5	311.5	311.5
Nili tomatoes	88	2,388.2	2,209.6	1,464.3	1,198.8	877.5	711.6	632.2	645.2	437.8	407.5	367.8
Summer tomatoes	113	852.6	852.6	679.8	661.2	543.1	339.8	149.4	121.1	50.4	14.3	0
Winter tomatoes	128	83.6	0	0	0	0	0	0	0	0	0	0
Wheat	1,391	0	0	287.1	248.4	456.3	1,129.6	1,427.1	1,495.3	3,274.5	3,360.5	3,359.6
Sorghum	393	0	0	0	0	0	56.3	40.5	0	0	0	0
Soybeans	100	0	0	0	0	0	0	0	0	0	0	0
Lentils	22	0	0	0	0	0	0	0	0	0	0	0
Long berseem	1,746	1,950.9	1,987.6	1,919.8	1,893.6	1,548.9	1,006.8	1,127.2	1,088.1	342.7	369.1	406.3
Short berseem	1,032	314.8	312.7	119.1	87.0	539.4	1,143.8	615.1	504.8	60.0	456.4	449.9
Animal stock (no units)	1	.943	.932	.913	.861	.831	.901	1.012	1.038	1.141	1.218	1.247

(Continued on next page.)

Table 2--continued.

Product	1980 production pattern	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ_5	ϕ_6	ϕ_7	ϕ_8	ϕ_9	ϕ_{10}	ϕ_{11}
		Values of ϕ										
		.0001[c]	.001	.005	.01	.02	.05	.1	.2	.5	1.0	100.0[d]
	thousand metric tons											
Wheat for feed	40	0	0	0	0	0	0	0	0	0	0	0
Maize for feed	1,387	0	0	1,409.2	313.9	0	0	0	0	0	0	0
Barley for feed	74	0	0	0	0	0	0	0	0	0	0	0
Sorghum for feed	430	1,613.9	1,457.7	0	0	0	0	0	0	2,256.5	2,794.6	3,616.9
Soybeans for feed	31	0	0	0	0	0	0	0	0	0	0	0
Soybeans for crushing	93	0	0	0	497.3	108.8	1,161.0	1,268.2	1,305.5	1,272.9	1,221.4	1,251.8

[a]Source: Computed.

[b]The points, ϕ_i (i = 1, 11), correspond to the points on the frontier in fig. 1.

[c]The pattern for values of ϕ = less than .0001 (including ϕ = 0, namely, a pure linear programming expected value maximization problem) is identical to the pattern exhibited for ϕ = .0001.

[d]The pattern for values of ϕ (larger than 100.0) does not change significantly.

is true about wheat. Low degrees of risk aversion imply that very little, if any, agricultural land of Egypt should be devoted to wheat. Otherwise, aversion to international risks implies quite the opposite; in fact, a doubling of the wheat area is projected by the model as optimum at not too high values of ϕ.

The optimal pattern of production for maize (summer and nili) and rice--two of the major staple products in Egypt--are similar to wheat; that is, at low degrees of risk aversion, only small areas are shown to be optimal. At high levels of risk aversion, however, both products are seen to be quite attractive. The same seems to be true of sugarcane as well, although the constraint imposed from the current capacity of sugar refineries limits the maximum area that can be devoted to sugarcane.[3]

Another major item of debate among Egyptian policymakers is the degree to which the country should push the production of fruits and vegetables for export. In the model used here, there are three vegetables (onions, potatoes, and tomatoes) and one fruit (oranges). The optimum pattern of production for all of these is quite apparent from table 2. At low degrees of risk aversion, substantially more agricultural area should be allocated to these products. At high levels of risk aversion, however, the optimum levels of area that should be allocated to these products decline dramatically and, in several cases, to levels below their current values.

Two products hitherto neglected, namely, flax and groundnuts, seem to offer a very good potential at medium and high degrees of risk aversion. Their attractiveness is not a chance consequence of particular values for their international prices and yield levels. Several sensitivity experiments were carried out in which their international prices, as well as domestic yields, were diminished; and the standard deviation of their world prices and domestic yields were increased by as much as 20 percent. The model still points toward a high level of cultivated area for them. Part of the explanation for the attractiveness of flax is that, other than the fiber, it yields an oilseed which can be used to satisfy part of the country's substantial vegetable oil consumption requirements.

A constraint that could apply to flax and groundnuts (and, of course, other products) is the limits of foreign markets to absorb Egypt's exportable surplus. This could easily be incorporated in the model if we knew the limits or even the foreign demand curve facing Egypt. Barring this knowledge, however, we are content to indicate that the possibilities of these two products should be examined more carefully by Egyptian policymakers.

An interesting set of results pertains to the animal-feed grain complex. At low levels of risk aversion, the model points toward a small decline in the animal population. At higher levels of ϕ, however, this is reversed, and the model points to the fact that a 10-20 percent increase in Egypt's animal stock is optimum. Interestingly enough, this increase is not accompanied by an attendant increase in the area of long berseem which currently provides the major feed in Egypt. Furthermore, soybeans is not projected to be optimum in the crop pattern. Instead, imported sorghum seems to be suggested by the model as a reasonable feed in addition to the by-products of wheat, maize, and rice where increased production yields increased levels of feed by-products.

Finally, there are several food products which do not seem to be optimal at almost any level of risk. Barley, beans, sesame, and lentils are prominent among these products. The food consumption requirements are satisfied through imports.

As far as regional allocation of the crop areas is concerned, we exhibit in appendix table 2 the optimal regional allocation of the areas for crops for the cases where $\phi = .01$, .1, and .5 which have been exhibited in summary in table 2. It is clear from that table in the appendix that the optimal regional allocation also depends on the degree of risk aversion of the country as a whole. For instance, the case of oranges and nili tomatoes is quite interesting. Although the optimal total area of these two products declines as the country becomes more risk averse, the decline is seen to occur only in Lower Egypt; while, to the contrary, the optimal area in Middle and Upper Egypt is seen to increase. The regional specialization results from the different average yields of the products achieved in these three regions as well as the structure of the covariance matrix of the yield fluctuations.

As expected, as far as the constraints are concerned, the land constraints are binding in several months of the year. The labor constraints do not seem to be binding except in one or two months under optimal allocations in all risk situations. This conclusion holds even if we decrease the labor availability by as much as 20 percent. This result is somewhat surprising and might seem to contradict some casual observations that point to a recent scarcity of agricultural labor. This issue is important and well beyond the purpose of this paper; hence, we do not go much beyond this observation.

The water constraint does not seem to be binding either at the current crop pattern or at any optimum pattern at various values of ϕ. It is, however, very nearly binding. Finally, the horsepower constraints seem to be binding--in particular, in Middle and Upper Egypt--while there seems to be an abundance of tractor power in Lower Egypt. This points to the fact that a redistribution of tractors toward Middle and Upper Egypt might be advantageous in the short and medium run. An experiment in which 100,000 tractor horsepower from Lower Egypt was redistributed equally between Middle and Upper Egypt leads (for ϕ = .1) to an optimal production pattern that implies an increase in the expected value of net export earnings of 6.1 percent and only a 1.1 percent rise in the standard deviation of export earnings.

A controversial subject in Egyptian agricultural policy has been the topic of land reclamation. We simulate this possibility by increasing the availability of land successively in Lower, Middle, and Upper Egypt. Fig. 2 illustrates the effect on the optimal expected value of net foreign exchange receipts of increasing land availability in the three regions. The experiments leading to these curves assumed a fixed value of ϕ (= .1). In the various exercises the standard deviation did not vary much; hence, we display only the expected value.

In this figure, it is surprising to observe that expanding the agricultural land of Middle Egypt seems to lead, under optimum production conditions, to higher expected returns than expanding agricultural land in Lower and Upper Egypt. The marginal increase (starting from the present situation) in optimum expected net foreign exchange earnings, adding 100,000 feddans, is $150 million (U. S.); if the addition is in Middle Egypt, $127 million (U. S.); and only $37 million (U. S.) if it is in Upper Egypt. This result, of course, assumes that Egypt begins from an optimum base production pattern--something which, as was seen earlier, is far from the current facts.

Finally, the issue of food self-sufficiency was analyzed as follows. The model was first simulated with an additional constraint that domestic wheat production has to be larger than food demand. A second experiment imposed the constraints that self-sufficiency is achieved in the production of rice,

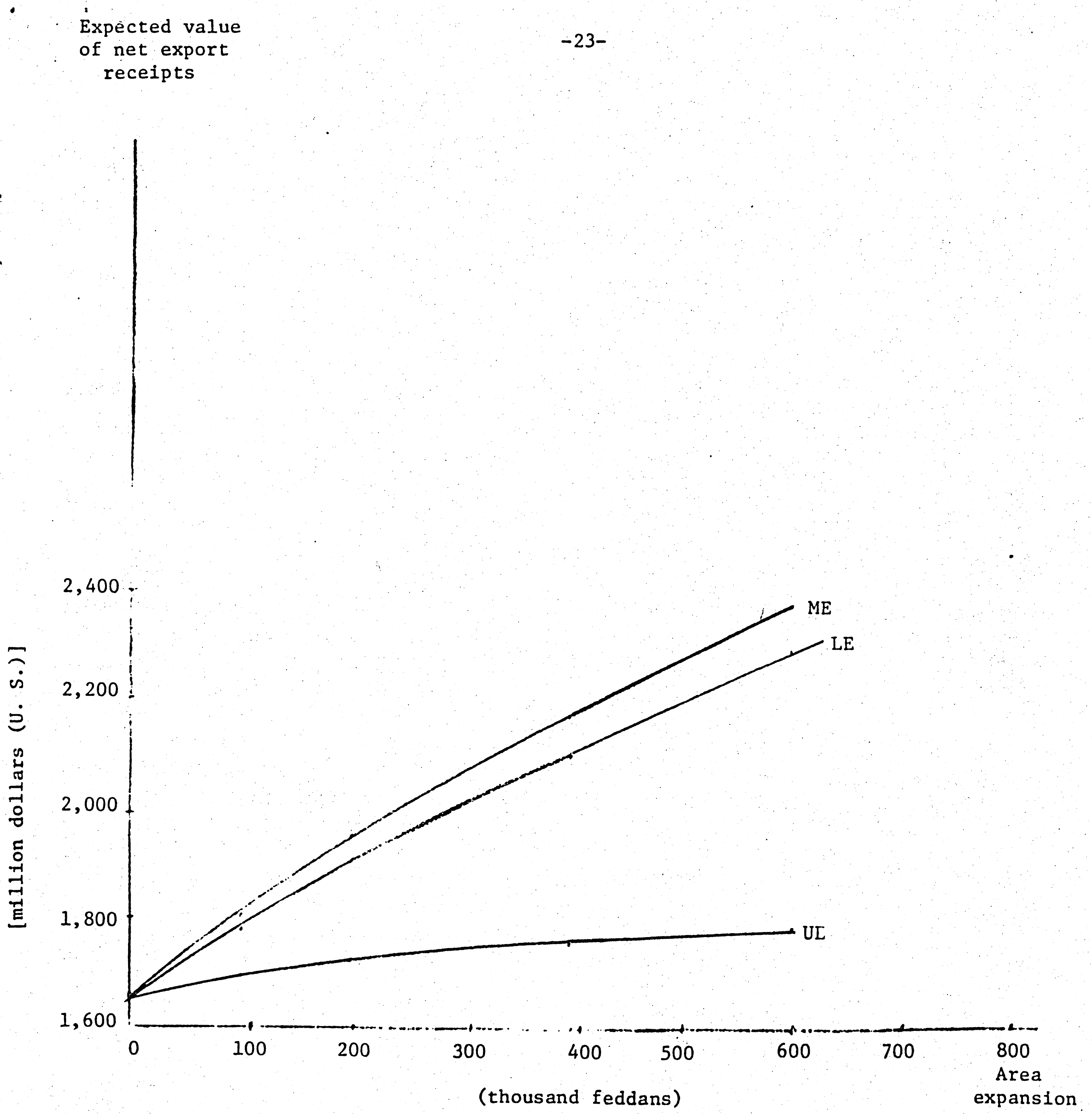

Fig. 2. Effects on the expected value of net agricultural export receipts from agricultural area expansion in Lower, Middle, and Upper Egypt (LE, ME, UE, respectively).

beans, sugarcane, maize, and vegetable oil but not wheat. Both experiments gave infeasible solutions. The conclusion is that the goal of self-sufficiency in basic foods in Egyptian agriculture at current levels of yields is infeasible with mere redistribution of available resources.

6. Future projections

Because of growing income and population growth, Egypt's policymakers are increasingly worried about the possibility of providing in the future adequate nutrition for its people at reasonable cost. The model outlined earlier provides a powerful tool by which various possibilities could be considered. Having shown earlier the trade-offs that different values of ϕ imply, we adopt here a value of ϕ equal to .1.

All simulations pertain to a five-year projection from the base year (namely, to 1985). The food security assumption made is that the projected demands for various commodities, based on various income growth rates assumed and the income elasticities of demand exhibited in table 1, will always be satisfied either by domestic production or trade. Table 3 gives the results of various experiments. Experiments A and B assume no new reclaimed areas--just different rates of income growth and mechanization. In B, even with more tractors available than in A, the optimum expected net foreign exchange earnings from agriculture is reduced to a third of its base optimum, and this happens with a reasonable 5.3 percent projected annual total income growth. This, of course, occurs because the demand for food under the given assumptions grows much faster than yields. In terms of crop patterns, the optimum in both cases A and B indicates a substantial expansion of the wheat, rice, and maize areas from the base optimum along with reduction of the area of many cash crops, notably long berseem.

Table 3

1980 actual base and optimal production patterns and 1985 optimal production patterns (ϕ = .1) under various assumptions.[a,b]

Product	Actual value in base (1980)	Optimal value in base (1980)	Optimal production patterns, 1985 — Under experiment A	B	C	D	E	F	G
	thousand feddans								
Barley	107.0	0	0	0	0	0	0	0	0
Beans	250.0	0	0	0	0	0	0	0	0
Cotton	1,196.0	594.1	573.1	574.0	623.9	634.4	648.0	651.1	645.4
Flax	68.0	1,221.6	1,034.4	1,002.3	2,421.8	2,238.5	2,245.0	2,500.1	2,723.3
Groundnuts	30.0	1,057.2	747.6	653.7	947.7	1,491.4	1,502.3	1,437.7	1,226.0
Nili maize	472.0	154.6	437.0	468.8	305.2	203.8	199.0	112.8	4.9
Summer maize	1,413.0	820.2	790.3	786.7	1,112.3	1,433.0	1,091.6	1,128.1	1,605.1
Winter onions	24.0	104.2	93.7	94.2	119.2	124.4	131.2	132.7	120.7
Oranges	160.0	166.2	223.9	268.3	173.1	137.3	127.1	121.5	124.1
Nili potatoes	72.0	135.1	105.2	94.3	195.8	142.5	151.7	152.5	148.5
Summer potatoes	69.0	76.8	139.8	167.1	0	0	0	0	0
Rice	1,036.0	1,469.2	1,735.0	1,832.4	1,590.0	1,239.3	1,238.4	1,249.2	1,443.9
Sesame	37.0	0	0	0	114.9	1.1	103.9	159.0	0
Sugarcane	249.0	311.5	332.3	316.9	347.7	347.7	347.7	347.7	347.7
Nili tomatoes	88.0	632.2	571.8	548.9	720.2	800.6	813.2	824.1	826.0
Summer tomatoes	113.0	149.4	149.4	150.4	228.4	287.0	256.4	259.1	248.6
Winter tomatoes	128.0	0	0	0	0	0	0	0	0
Wheat	1,391.0	1,427.1	2,182.8	2,253.9	2,024.8	1,732.1	2,197.7	2,140.7	1,335.3
Sorghum	393.0	40.5	0	0	0	0	0	0	81.3
Soybeans	100.0	0	0	0	0	0	0	0	0
Lentils	22.0	0	0	0	0	0	0	0	0
Long berseem	1,746.0	1,127.2	344.5	280.4	284.7	806.1	681.9	604.4	1,487.0
Short berseem	1,032.0	615.1	741.1	690.6	637.7	693.3	654.1	633.1	693.7
Animal stock (no unit)	1.0	1.012	.981	.968	.939	1.102	1.115	1.047	1.285

(Continued on next page.)

Table 3--continued.

Product	Actual value in base (1980)	Optimal value in base (1980)	Optimal production patterns, 1985 — Under experiment A	B	C	D	E	F	G
	thousand metric tons								
Wheat for feed	40.0	0	0	0	0	0	0	0	0
Maize for feed	1,387.0	0	0	0	0	0	0	0	0
Barley for feed	74.0	0	0	0	0	333.1	722.1	516.4	0
Sorghum for feed	430.0	0	0	0	0	0	0	0	0
Soybeans for feed	31.0	0	0	0	0	0	0	0	0
Soybeans for crushing	93.0	1,268.2	1,451.3	1,478.6	1,915.4	2,177.1	2,063.7	2,159.2	2,081.0
	million dollars (U. S.)								
Expected value of net for exchange earnings	-1,322.0	1,651.4	922.3	568.0	1,781.2	2,312.0	2,362.7	2,444.0	2,506.7
Standard deviation of net for exchange earnings	325.1	175.7	183.1	190.9	199.4	206.9	208.3	208.5	201.5

[a]Source: Computed.

[b]A: This experiment assumes 1 percent growth rate of per capita income (GRPCY), 2.3 percent yearly growth of population (GRPOP), and 2 percent yearly growth in the availability of tractor power (GRTRA) in all three regions.

B: Assumes GRPCY = 3 percent, GRPOP = 2.3 percent, and GRTRA = 5 percent.

C: Assumes GRPCY = 3 percent, GRPOP = 2.3 percent, and GRTRA = 5 percent; in addition, agricultural area expansion in Lower Egypt is 1 million feddans.

D: Assumes GRPCY = 3 percent, GRPOP = 2.3 percent, and GRTRA = 5 percent; in addition, agricultural area expansion in Lower Egypt is 1 million feddans and in Middle Egypt is 500,000 feddans.

E: Assumes GRPCY = 3 percent, GRPOP = 2.3 percent, and GRTRA = 5 percent; in addition, agricultural expansion in Lower Egypt is 1 million feddans, in Middle Egypt is 500,000 feddans, and in Upper Egypt is 500,000 feddan.

F: Same as E above; in addition, 100,000 horsepower of tractor traction power is transferred from Lower Egypt and distributed equally between Middle and Upper Egypt.

G: Same as E above; in addition, the national water availability is increased by 10 percent.

Experiments C, D, and E assume the same income and mechanization growth as B but increase the availability of newly reclaimed land. It can be seen that the model indicates that major expansion from the results of B should occur in the cash crops and notably flax and groundnuts as well as in the animal stock.

When the agricultural area is expanded, the horsepower constraints in Middle and Upper Egypt, as well as the water constraint, become strongly binding. In experiment F, we simulate a redistribution of tractor horsepower from Lower to Middle and Upper Egypt under the assumption of 2 million feddans of new agricultural land. This is presumed to increase efficiency and, as can be seen from table 3, the gain in expected net foreign exchange earnings over the situation in E is about $80 million (U. S.). In experiment G, we assume that water availability is increased by 10 percent combined with a 2 million feddan land increase. The water increase could probably be achieved through better management practices and less waste. Such an assumption leads to an increase in expected net foreign exchange earnings from the situation in E but through substantial restructuring of the crop pattern. By comparing columns E and G, we note in G a substantial increase in the area of flax, summer maize, rice, and long berseem as well as a 15 percent increase in animal stock. At the same time, there are substantial declines in the areas of groundnuts and wheat.

Table 4 indicates the expected net exports of the various products in the base year (actual and optimum) as well as the optimal projected net exports corresponding to experiments B and E. The changes in the optimum pattern of trade between the base period and the five-year projection under no land expansion (experiment B) are, in some cases, large in magnitude. In other words, the products that are exported remain the same although their optimal traded magnitudes change. However, when the agricultural land area is

Table 4

Expected net exports of traded products: base year (1980) and projected (1985).[a,b]

Product	Actual value in base (1980)[c]	Optimal value in base (1980)	Optimal, 1985 Under experiment B[d]	E[d]
	million metric tons			
Barley	19.1	- 33.0	- 37.5	- 759.6
Beans	11.5	- 250.0	- 299.9	- 299.9
Groundnuts	- 12.5	965.1	650.4	1,484.4
Lentils	- 62.4	- 76.0	- 91.2	- 91.2
Maize	- 873.5	- 956.8	- 918.8	- 560.5
Onions	- 7.8	587.8	558.7	729.6
Oranges	415.5	464.7	1,024.1	9.8
Potatoes	- 105.8	548.6	749.2	- 10.8
Rice	152.5	832.0	1,231.0	300.2
Sesame	- 6.6	- 25.0	- 31.7	12.9
Sorghum	59.2	- 139.9	- 242.1	- 242.1
Sugar	- 496.5	- 347.3	- 611.8	- 556.3
Tomatoes	- 270.4	3,439.8	2,523.6	5,008.2
Wheat	-5,455.9	-5,387.3	-4,919.4	-5,200.7
Vegetable oil	- 248.8	183.5	103.4	532.1
Meat	- 188.0	- 182.7	- 436.1	- 368.4
Cotton	153.1	- 64.8	- 117.7	- 86.1
Flax	7.6	497.6	420.8	974.2
Soybean	- 15.6	-1,268.2	-1,478.6	-2,063.7

[a]Value of ϕ assumed throughout to be equal to .1.

[b]Sources: Computed.

[c]Base figures are not equal to the actual traded quantities because losses and stock changes have been neglected and the expected values of yields rather than actual 1980 yields are considered.

[d]B: Assumes GRPCY = 3 percent, GRPOP = 2.3 percent, and GRTRA = 5 percent.

E: Assumes GPRCY = 3 percent, GRPOP = 2.3 percent, GRTRA = 5 percent; in addition, agricultural area expansion in Lower Egypt is 1 million feddans, Middle Egypt is 500,000 feddans, and Upper Egypt is 500,000 feddans.

expanded, the optimum pattern of trade changes quite drastically. The country is then projected to become a much larger importer of barley and soybeans, and the exports of oranges and potatoes decrease to quantities close to zero while those of rice fall substantially. On the other hand, the country is projected to become a much larger exporter of groundnuts, flax, tomatoes, and vegetable oil while, at the same time, it is projected to decrease considerably its imports of maize.

7. Summary and conclusions

The empirical results have shown that the model offers wide-ranging possibilities for agricultural sector planning under uncertainty within the physical and social constraints of the country. The major result of the empirical analysis seems to indicate crops to be socially profitable at low levels of risk aversion, mainly the cash crops in the case of Egypt, become quite unattractive and give place to subsistence crops at high levels of national risk aversion. This conclusion casts grave doubts on the recommendations about production patterns of many analysts who use deterministic techniques such as domestic resource cost computations. These techniques might be better applicable to situations (e.g., some industrial products) where international and domestic price and production fluctuations are not a serious consideration. In the case of Egypt, for instance, Cuddihy's analysis concluded that expansion of cotton and the contraction of wheat areas was recommended. As was seen, however, if one considers risk aversion, this result is exactly reversed.

It must be emphasized that results such as the ones above are by no means to be expected in every country. Situations in different geographical zones and production systems will in general yield quite different patterns of domestic yield variability, with different conclusions at the same degree of national risk aversion.

It might be argued that in the case of Egypt we have not captured all the relevant constraints. The addition of further restrictions will in general shrink the set of feasible solutions with an attendant inward shift of the mean-standard deviation frontiers of fig. 1. However, the current degree of inefficiency of the Egyptian crop patterns seems to be such as to justify considerable effort at restructuring the current production allocation.

Notably absent from the model of this paper have been considerations of farmer behavior. The analysis has been strictly restricted to what is possible and optimum from a national viewpoint. This raises the issue of whether or not what seems to be optimum from a national viewpoint can indeed be achieved within the Egyptian agrarian system. It is, of course, always possible in a mainly centrally planned agricultural system like the one in Egypt to impose area controls to achieve the planned objectives. The difficulty in past Egyptian farm policy is that the price policy that has accompanied the area controls was inconsistent with the area allotments. In other words the government might impose a large area for cultivation of a particular crop but not give to the farmer a price that makes it attractive for him to comply. The result in Egypt has been a massive evasion of area controls. The design of appropriate price policies to achieve the optimum crop pattern is the next step in this analysis but is outside the scope of this paper.

The methodology and empirical illustration of this paper have hopefully shown that domestic reallocation of resources, something that does not necessitate international cooperation, can yield substantial improvements in food security for developing countries. Indeed, these improvements are orders of magnitude above what can be expected through national or international buffer stocks. This conclusion will hopefully contribute toward shifting the emphasis of discussions about food security away from the issue of buffer stocks. This is not to say that food reserves building does not have a role to play in national and international food security policies. It, rather, indicates that, before scarce monetary resources are put into an expensive buffer stock program, some serious thought should be given to whether or not these resources can be better utilized in domestic resource reallocation and yield improvement.

Appendix Table 1

Activity in model; base year (1980) value; and expected value, standard deviation, and linear trend of yield in Egyptian agricultural sector.[a]

Product	Base year (1980) value	Yield		
		Expected value	Standard deviation	Linear trend
	thousand feddans[b]		metric tons per feddan	
Lower Egypt				
Barley	80	1.160	.077	.005
Beans	75	.893	.122	.010
Long berseem	1,246	24.327	1.586	.000
Short berseem	775	8.930	.582	.000
Cotton (lint)	827	.427	.043	.007
Flax (fiber)	65	.450	.020	.005
Groundnuts	20	.818	.075	.001
Nili maize	150	1.384	.087	.021
Summer maize	944	2.092	.154	.029
Winter onions	7	6.506	.782	.072
Oranges	134	8.425	.921	.069
Nili potatoes	47	6.096	.856	.000
Summer potatoes	56	7.480	.617	-.018
Rice[c]	1,019	1.568	.077	.001
Sesame	3	.434	.034	.004
Sugarcane[d]	10	2.428	.058	.018
Nili tomatoes	49	8.589	.248	.105
Summer tomatoes	94	7.630	.539	.016
Winter tomatoes	64	5.514	.711	.040
Wheat	803	1.644	.107	.026

(Continued on next page.)

Appendix Table 1--continued.

Product	Base year (1980) value	Yield: Expected value	Yield: Standard deviation	Yield: Linear trend
	thousand feddans[b]	metric tons per feddan		
Middle Egypt				
Barley	15	1.482	.075	.016
Beans	110	1.150	.146	.013
Long berseem	348	23.406	.952	.000
Short berseem	167	6.800	.277	.000
Cotton (lint)	222	.318	.042	.001
Flax (fiber)	3	.448	.026	.002
Groundnuts	6	1.120	.069	.009
Nili maize	270	1.240	.077	.007
Summer maize	326	1.920	.241	.021
Winter onions	10	4.590	.561	-.053
Oranges	14	6.414	.830	.125
Nili potatoes	25	8.715	.386	.122
Summer potatoes	13	6.123	.554	.057
Rice[c]	17	1.473	.098	.012
Sesame	2	.626	.031	.008
Sorghum	48	1.725	.093	.015
Sugarcane[d]	38	3.119	.180	.021
Nili tomatoes	34	7.992	.445	.043
Summer tomatoes	15	7.298	.354	-.006
Winter tomatoes	49	4.353	.806	-.080
Wheat	227	1.583	.064	.018
Soybeans	100	1.498	.188	.069

(Continued on next page.)

Appendix Table 1--continued.

Product	Base year (1980) value	Yield: Expected value	Yield: Standard deviation	Yield: Linear trend
	thousand feddans[b]	metric tons per feddan		
Upper Egypt				
Barley	12	1.316	.044	.012
Beans	65	1.392	.099	.024
Long berseem	152	24.757	1.719	.000
Short berseem	190	12.544	.871	.000
Cotton (lint)	147	.407	.046	.005
Groundnuts	4	.577	.081	-.022
Lentils	22	.618	.109	.000
Nili maize	52	1.191	.087	.007
Summer maize	143	1.890	.265	.013
Winter onions	7	11.433	.823	.129
Oranges	12	4.916	1.490	-.218
Sesame	32	.523	.074	.004
Sorghum	345	1.892	.135	.014
Sugarcane[d]	201	2.458	.120	.022
Nili tomatoes	5	7.587	.256	.067
Summer tomatoes	4	5.540	.387	-.040
Winter tomatoes	15	6.047	.484	-.004
Wheat	361	.423	.099	.014

(Continued on next page.)

Appendix Table 1--continued.

Product	Base year (1980) value	Yield: Expected value	Yield: Standard deviation	Yield: Linear trend
	thousand metric tons	metric tons per feddan		
All of Egypt				
Animal stock[e]	1	459.000	.000	.000
Wheat for feed	40	1.000	.000	.000
Maize for feed	1,387	1.000	.000	.000
Barley for feed	74	1.000	.000	.000
Sorghum for feed	450	1.000	.000	.000
Soybeans for feed	31	1.000	.000	.000
Soybeans for crushing	93	1.000	.000	.000

[a]Source: Computed.

[b]One feddan is 1.038 acres or .42 hectare.

[c]Milled basis.

[d]Yield on refined sugar basis.

[e]Base year value normalized to one.

Appendix Table 2

Actual and optimal regional allocation of crop area for 1980 for ϕ = .01, .1, and 0.5.[a]

Crop	Actual area, 1980	Optimal allocation ϕ = .01	ϕ = .1	ϕ = .5
	thousand feddans			
Lower Egypt				
Barley	80	107.4	0	0
Beans	75	0	0	0
Cotton	827	486.3	495.6	440.7
Flax	65	670.1	876.6	124.3
Groundnuts	20	1,038.2	305.1	0
Nili maize	150	0	154.6	637.5
Summer maize	944	150.2	710.6	705.8
Winter onion	7	71.6	76.2	48.7
Oranges	134	362.5	139.8	73.5
Nili potatoes	47	0	10.8	0
Summer potatoes	56	0	76.8	0
Rice	1,019	242.9	1,469.2	1,391.7
Sesame	3	0	0	25.8
Sugarcane	10	0	0	0
Nili tomatoes	49	1,127.0	121.2	0
Summer tomatoes	94	511.8	0	0
Winter tomatoes	64	0	0	0
Wheat	803	0	634.5	2,315.6
Sorghum	b			
Soybeans				
Lentils				
Long berseem	1,246	1,143.2	1,054.8	342.7
Short berseem	775	0	515.4	410.8

(Continued on next page.)

Appendix Table 2--continued.

Crop	Actual area, 1980	Optimal allocation		
		ϕ = .01	ϕ = .1	ϕ = .5
	thousand feddans			
Middle Egypt				
Barley	15	0	0	0
Beans	110	0	0	0
Cotton	222	42.4	42.4	42.4
Flax	3	0	345.0	314.4
Groundnuts	6	488.6	622.3	472.7
Nili maize	270	0	0	0
Summer maize	326	0	0	0
Winter onion	10	0	0	0
Oranges	14	0	13.7	32.7
Nili potatoes	25	452.9	124.3	111.9
Summer potatoes	13	0	0	0
Rice	17	0	0	167.3
Sesame	2	0	0	0
Sugarcane	38	121.9	0	0
Nili tomatoes	34	13.1	316.3	292.0
Summer tomatoes	15	149.4	149.4	0
Winter tomatoes	49	0	0	0
Wheat	227	248.4	266.8	369.0
Sorghum	48	0	0	0
Soybeans	100	0	0	0
Lentils				
Long berseem	348	283.7	0	0
Short berseem	167	0	54.0	0

(Continued on next page.)

Appendix Table 2--continued.

Crop	Actual area, 1980	Optimal allocation		
		ϕ = .01	ϕ = .1	ϕ = .5
	thousand feddans			
Upper Egypt				
Barley	12	0	0	0
Beans	65	0	0	0
Cotton	147	367.5	56.1	12.8
Flax				
Groundnuts	4	389.4	129.8	0
Nili maize	52	0	0	48.9
Summer maize	143	0	109.6	437.6
Winter onion	7	183.8	28.0	6.4
Oranges	12	0	12.7	11.1
Nili potatoes				
Summer potatoes				
Rice				
Sesame	32	0	0	0
Sugarcane	201	0	311.5	311.5
Nili tomatoes	5	58.7	194.7	145.8
Summer tomatoes	4	0	0	50.4
Winter tomatoes	15	0	0	0
Wheat	361	0	525.8	589.9
Sorghum	345	0	40.5	0
Soybeans				
Lentils	22	0	0	0
Long berseem	152	466.7	72.4	0
Short berseem	90	87.0	45..7	60.0

[a]Source: Computed.

[b]Blanks indicate that the crop is not produced in this region and is not included as an activity.

Footnotes

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[1]We prefer to plot mean-standard deviation rather than mean-variance frontiers because we believe they are more convenient for illustrative purposes. Of course, the former frontier is a monotonic positive transformation of the latter; hence, the conclusions of the analysis, irrespective of which frontier one chooses to work with, are the same.

[2]In Egypt the government controls directly the crop pattern via regional area allotments to various crops. Actual cultivated areas deviate somewhat from the allotments because farmers on many instances prefer to risk being caught and fined for not conforming in order to get higher returns from cultivation of uncontrolled higher valued crops.

[3]If the sugar refining capacity is increased, the optimal area of sugarcane increases at higher levels of risk aversion.

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