TMD DISCUSSION PAPER NO. 1

LAND, WATER, AND AGRICULTURE IN EGYPT: THE ECONOMYWIDE IMPACT OF POLICY REFORM

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TMD Discussion Papers contain preliminary material and research results, and are circulated prior to a full peer review in order to stimulate discussion and critical comment. It is expected that most Discussion Papers will eventually be published in some other form, and that their content may also be revised. Funding for the present paper was provided by the U.S. Agency for International Development in connection with the IFPRI Project on Maintaining Food Security in Egypt (USAID Grant No. 263-0225-6-00-3102). Views expressed in the paper are solely those of the authors and do not necessarily reflect official views or statements of policy of the U.S. Agency for International Development.

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ABSTRACT

The tax and subsidy system in Egypt in 1986-88 was very distorted, involving large, sectorally variegated, output taxes and subsidies. In agriculture, there were also major input subsidies and no charges for water. In this paper, an 11-sector, computable general equilibrium (CGE) model is used to capture this mix of policies, focusing on land and water use in agriculture and on the links between agriculture and the rest of the economy. The model combines an optimizing, programming model of land and water use in agriculture with a simulation model of the non-agricultural sectors. Empirical results indicate that policies in 1986–88 were biased against agriculture and led to a water-conserving structure of agricultural production. Had Egypt introduced markets for water in 1986–88, the equilibrium market price would have been close to zero — land, not water, was the binding constraint. Policy reform increases both aggregate welfare and the demand for water. Water demand is inelastic and policy reform on the output side would strain the existing system of water distribution, since water would become much more valuable than land to agricultural producers. Given the initial policy bias against agriculture, policy reform would favor rural employment and lead to reduced pressure for rural-urban migration.

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1. INTRODUCTION

Egypt is currently engaged in major macroeconomic and market reforms, comparable to those undertaken in the early 1980s by Turkey and in the mid-1980s by Mexico. Egypt is an economy in which agriculture comprises 18 percent of GDP and about 40 percent of total employment (in 1991). Egypt is unique among developing countries in its almost complete dependence on irrigation; its dependence on water from a single source, the Nile river; and its limited capacity to expand the arable land base. The current reform efforts seek to put the Egyptian economy on a new growth path. Further growth in GDP and population, however, will strain Egypt's essentially fixed agricultural resource base. This study seeks to determine the magnitude of these strains and suggest appropriate policies for achieving optimal land and water use in the reform environment.

EGYPT IN A COMPARATIVE FRAMEWORK

Tables 1 and 2 present selected data on Egypt and a number of comparator developing countries. Egypt's levels of per capita income, population, and aggregate GDP make it comparable to the smaller Asian, Latin American, and African economies. There is a clear correlation between increasing income level and shrinking share of agriculture in GDP, and this correlation is evident in Table 1. In the early stages of development, agriculture plays a major role in providing food, employment, and foreign exchange. With growth and industrialization, this role is reduced as resources are transferred to the nonagricultural sectors and the center of gravity of the economy shifts to urban areas. Egypt's share of urban population and the ratio of exports to GDP are higher than those of the smaller African and Asian economies. Its trade share and degree of urbanization make it comparable to Colombia, Turkey, and Mexico, all of which, however, have significantly higher levels of per capita GNP.

Table 2 provides information on comparative performance over time. In the 1980s, Egypt's growth performance was very good, comparable to the more successful developing countries. Major factors behind this success were high growth rates in both agriculture and industry, expanding trade, and a population growth rate significantly lower than that of the poorer countries.

Historically, Egypt's economy has been characterized by a dominant public sector, a centralized planning system, and a highly distorted incentive system that includes a multitude of foreign exchange rates, trade controls, and, in agriculture, extensive direct controls.[1] Large fiscal and current-account deficits were financed largely by foreign aid debt accumulation.[2]

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[1] For a description and analysis of economic reform in Egypt between 1974-91, see Lofgren (1993a).

[2] World Bank (1993) estimates an outstanding debt of $51.1 billion in 1990.

Table 1--Comparative indicators, 1991

Countries	GNP/capita (US$/year) (1)	Population (million) (2)	Urban Total Pop (percent) (3)	GDP (billion US $) (4)	Agric/GDP (percent) (5)	Exports/GDP (percent) (6)
Tanzania	100	25	34	2	61	20
Kenya	340	25	24	7	27	27
Nigeria	340	99	36	34	37	36
Egypt	610	53	47	30	18	30
Philippines	730	63	43	45	21	30
Morocco	1030	26	49	27	19	22
Colombia	1260	33	71	42	17	21
Thailand	1570	58	23	93	12	38
Turkey	1780	57	63	96	18	20
Mexico	3030	83	73	282	9	10

Source: World Development Report (1993)

Table 2--Average annual growth rate, 1980-91, in percent

Countries	GDP (1)	Agriculture (2)	Industry (3)	Exports (4)	Imports (5)	Population (6)
Tanzania	2.9	4.4	-2.4	-1.9	2.8	3.0
Kenya	4.2	3.2	4.0	2.9	1.0	3.8
Nigeria	1.9	3.5	-0.4	1.2	-14.3	3.0
Egypt	4.8	2.4	4.2	2.8	-2.3	2.5
Philippines	1.1	1.1	-0.5	3.3	3.0	2.4
Morocco	4.2	6.8	3.0	5.9	3.8	2.6
Colombia	3.7	3.2	4.8	12.0	-1.7	2.0
Thailand	7.9	3.8	9.6	14.4	11.1	1.9
Turkey	5.0	3.0	6.0	7.2	7.4	2.3
Mexico	1.2	0.5	1.3	3.5	2.2	2.0

Source: World Development Report (1993)

Table 3 provides data on the sectoral structure of production, trade, resource use, taxes, and subsidies in 1987. The distorted incentive system is clearly evident, with high and sectorally variegated taxes, subsidies, and tariffs. The importance of trade is also clearly evident, with many sectors having large trade shares.

Starting in 1991, Egypt embarked on a fundamental reform associated with a World Bank/IMF structural adjustment program. The basic goal was to improve efficiency by lowering price distortions and relying on market forces to determine resource allocation. Two important components of the reform are domestic price liberalization in the agricultural, manufacturing, and energy sectors; and foreign trade liberalization through reduction of tariff and non-tariff barriers to both imports and exports (El-Laithy 1994, pp3–4).

Significant changes have occurred in the Egyptian economy between the 1970s and the late 1980s. In the early 1970s, agriculture contributed about 28 percent of total GDP and employed about 53 percent of the work force. Toward the end of the 1980s, agriculture's contribution to GDP declined to 18 percent and its share of total employment dropped by nearly one third. There has been a significant shift from an agricultural to a more diversified economy. Oil became a major source of foreign exchange and the share of agricultural exports in total exports declined from 61 percent in 1970–74 to 21 percent in 1985–89. The massive inflow of foreign exchange from oil exports, Suez canal receipts, worker's remittances, tourism receipts, and foreign aid propelled Egypt's rapid growth in the 1970s and early 1980s. The sharp decline in oil prices reduced oil revenue and also affected workers' remittances, leading to decreased real GDP growth. The growth rate of GDP fell from an average of over nine percent a year in the late 1970s to less than three percent a year during the period 1986–89 (Goueli and El-Miniawy 1993).

EGYPTIAN AGRICULTURE

Agriculture in Egypt is unique because it is almost entirely dependent on irrigation, and has only one main source of water, the Nile River. At 0.13 feddan per capita, Egypt's area of cultivable land is among the lowest in the world.[3] The potential for increasing the cultivable land base is limited because of both the continuing loss of agricultural lands to urbanization, and the constraint on water available for irrigated agriculture.[4] With rapid population growth in the past 40 years, fixed agricultural land is required to supply food for a growing population and is threatened by urban expansion Adams (1985), Gardner and Parker (1985), and Ikram (1980). In Egypt, "any future growth in agricultural production will need to come from more efficient utilization of the existing land and water resources of the country (World Bank 1993:6).

Agricultural land in Egypt has been used intensively and has been highly productive. Currently, cotton, wheat, rice, maize, and berseem together account for 80 percent of the cropped area. Wheat is a principal winter crop, cotton and rice are important summer cash crops, while maize is a major subsistence crop. Sugar

[3] A feddan is an Egyptian unit of land area equal to 1.037 acres or 0.420 hectares.

[4] The availability of reliable water supply from the High Aswan Dam is governed by the existing water sharing agreement with Sudan [World Bank (1993)]. All the land suitable for the production of most crops was brought into production and attempts to reclaim desert land have been largely high-cost, low-productivity operations [Antle, (1993, p.173)].

production is geared toward helping meet the rising local demand resulting from a growing population (Ward 1993). Major shifts in cropping patterns took place from 1970 to 1990.[5] The structure of production and resource use in 1987 is given in Table 3. Most important was the significant decline (8 percent) in area devoted to cotton and the increase in area devoted to fruits, winter vegetables, and summer vegetables (by 165 percent, 94 percent, and 32 percent, respectively) (Goueli and El-Miniawy 1993). Sugar cane yields have recently increased after decades of decline (Gardner and Parker 1985, 1993).

The policy environment surrounding Egyptian agriculture consists of sector-specific intervention and macroeconomic and trade policies that affect agricultural prices through their effects on the real exchange rate. Sector-specific intervention may take the form of:(1) delivery quotas for certain crops; (2) fixed producer/procurement prices for food and export crops; and (3) agricultural input subsidies, both explicit and through pricing of some inputs below marginal cost, e.g. water (Dethier 1989a, pp.46–48). Table 4 shows sector-specific policies for five major agricultural crops that prevailed in 1985.

In 1986, the Agricultural Policy Reform Program began the dismantling of the distortions in the sector. By December 1992, area and production quotas and marketing restrictions on all crops had been eliminated, except for cotton and sugarcane. The exchange rate subsidy for imported inputs was eliminated in 1991 and all other input subsidies have been reduced. The plan to totally eliminate input subsidies in sugarcane and cotton markets by 1993 is yet to be implemented (Goueli and Miniawy 1993, p.101).

Until 1991, Egypt had a multiple exchange rate system. Agricultural exports and imports were valued at an official exchange rate that artificially cheapened wheat imports and hurt producers of export crops (e.g., cotton, rice, and vegetables) as well as producers of major import competing crops (cereals other than wheat). The implicit taxation on cotton (and, to a lesser extent, on wheat and other crops) from the overvalued exchange rate added to the taxation caused by sector-specific policies.[6] As a result of this pattern of taxation, farmers have moved away from cotton to less-regulated crops, such as vegetables and fruits. The Egyptian government devalued the Egyptian pound in 1979 and 1987 to reduce the overvaluation of the official exchange rate (Goueli and Miniawy 1993).

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[5] Egyptian agriculture joined the "Green Revolution" of the 1960s and 1970s by adopting improved varieties of rice and increasing the use of nitrogenous fertilizers. Insecticides were used to deal with pest problems, especially in cotton.

[6] Bautista and Gehlhar (1994) provided the evidence by estimating the overvaluation of the exchange rate used for agriculture.

Table 3. Sectoral information in the base model, 1987

Sector	Share of water use	Share of land use	Water intensity	Water use per value added	Sectoral Taxes/subsidies	Tariffs	Employment share	GDP share	Export/ Output	Import/ Supply
	------ percent ------		---- cu m/ Fed ----		------ ad valorem rate ------		------	percent ------		
Cotton	9.0	8.2	3.2	2.0	-15.0	-67.7	6.2	4.5	5.0	0.0
Veg	16.5	14.8	3.3	2.4	0.0	0.0	7.3	6.1	3.2	0.0
Rice	25.5	8.6	8.8	8.2	-32.0	-25.0	4.9	2.7	1.1	0.0
Sugar	9.2	2.3	12.0	9.9	-13.0	-57.6	1.2	0.8	0.0	25.5
Grains	34.5	54.2	1.9	2.5	-19.1	-17.9	16.2	12.0	0.0	13.1
Otheg	5.3	12.0	1.3	2.0	0.0	0.0	1.8	2.3	0.8	0.0
Oil	0.0	0.0	0.0	0.0	-10.4	5.0	0.9	5.7	49.7	14.7
Ind	0.0	0.0	0.0	0.0	5.3	22.0	11.0	20.3	3.9	26.8
Svc	0.0	0.0	0.0	0.0	-3.5	0.0	47.2	39.5	12.7	6.4
Elect	0.0	0.0	0.0	0.0	-3.5	0.0	0.8	1.4	0.0	0.0
Cons	0.0	0.0	0.0	0.0	-0.7	0.0	2.5	4.8	0.0	0.0
Total/ Average	100.0	100.0	5.1	4.5	-8.4	-12.8	100.0	100.0	6.9	7.9

Sources: World Bank (1993) for first four columns.
Wenner, M. et al. (forthcoming) for indirect taxes, tariffs and export subsidies for agricultural sectors.
Lofgren (1993d) for other data.

Table 4. Agricultural Policies Specific to Five Major Crops

Crops	Exportable or Importable	Policy
Cotton	Main export	Fixed producer price
Wheat	Main import	Procurement quota
Rice	Exportable	Procurement quota
Maize	Importable	None
Sugarcane	Importable	Fixed producer price

Source: Dethier (1989), p.48

2. THE EGYPTIAN LAND-WATER ECONOMYWIDE CGE MODEL

The Egyptian model is an economywide, computable general equilibrium (CGE) model that disaggregates the agricultural sector and provides special treatment of land and water. This land/water or LW-CGE model is in the tradition of trade-focused CGE models that have been applied to a number of developing countries to explore issues of structural adjustment.[7] It also draws from earlier CGE models of Egypt, especially those focused on agriculture, and on an earlier regional agricultural model of the San Joaquin Valley in California that focused on water use.[8]

EARLIER CGE MODELS OF EGYPT

Egypt has had extensive experience with Social Accounting Matrices (SAMs) and CGE models. Two recent surveys by El-laithy (1994) and Lofgren (1993b) show that since 1976, a number of Egyptian SAMs and CGE models have been developed for wide ranging purposes, including policy formulation and assessment in the Ministry of Agriculture. An Egyptian SAM for 1975 was developed by Taylor (1979) and a 1976 SAM by Mohie El-Din (1978).[9] Since then, more detailed SAMs have been developed for six different years, the most recent of which is the 1986/87 CAPMAS SAM [Eckaus, et al. (1981), Choucri and Lahiri (1983), Khorshid (1984), Dethier (1985), CAPMAS (1988; 1991) and Khorshid (1992)]. CGE models based on these SAMs have focused on a variety of policy issues and have included a variety of theoretical specifications: static and dynamic, neoclassical and structuralist. [Mohie El-Din (1978), Taylor (1979), Eckaus, et al. (1979), Choucri and Lahiri (1983), Khorshid (1984), Dethier (1985), Ahmed et al. (1985), Kheir-el-din and El-laithy (1990), Khorshid (1992), and Lofgren (1993)].

The successful operation of the MISR1 model, using a 1980/81 SAM, was the first time a CGE model was constructed and used for policy analysis exclusively by Egyptians (El-laithy 1994, p.13). The MISR1 model was updated by Kheir-El-Din and El-laithy into MISR3, using a 1983/84 SAM, to assess the impacts of changes in government expenditures, taxation, and remittances on the performance of the Egyptian economy in the short and medium term.

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[7] See Robinson (1989) for a survey of CGE models in developing countries. Devarajan, Lewis, and Robinson (1990) describe the structure and properties of these trade-focused CGE models.

[8] For surveys, see El-laithy (1994) and Lofgren (1993b). Dethier (1989) provides an early agriculture-focused CGE model of Egypt, while Lofgren (1993c) discusses agricultural sector models and presents a quadratic programming model of agriculture in a particular region that endogenizes prices. The San Joaquin Valley model is described in Berck, Robinson, and Goldman (1991).

[9] Under the Development Research and Technological Planning Center (DRPTC), Cairo University, Egypt.

Although some CGE models have focused on agriculture (Dethier 1979 and Lofgren 1993c), the two reviews do not mention any study of the agricultural sector with enough disaggregation to enable analysis of other important agricultural crops, such as rice, maize, sugar, and other agriculture. Neither has there been any study that specifically addressed impacts of macroeconomic and sectoral reforms on land and water allocation in the agricultural sector.

As Egypt continues to pursue policy reforms and a structural adjustment program, and population growth continues to exert pressure on the use of available agricultural land, there is an increasing urgency to address the issue of the efficiency of land and water allocation. A CGE model provides a useful framework in which to analyze the economywide impacts of major policy reforms and explore appropriate policies for achieving more efficient or optimal land and water use in the new policy environment.

TECHNOLOGY, MARKETS, AND WELFARE

The LW-CGE model combines an activity-analysis, programming representation of agricultural technology (including inequality constraints) with a standard, neoclassical representation of the technology of the non-agricultural sectors. Appendix 1 documents the computer program used to implement the model.[10] Appendix 2 describes the data base. While the programming specification of the agricultural sectors in this version is quite simple, the model is capable of being linked to more elaborate agricultural sector models in the future.[11] There are six agricultural sectors (cotton, fruits and vegetables, rice, sugar, grains, and other), each using land, water, capital, labor, and intermediate inputs. There are five non-agricultural sectors (oil, industry, services, electricity, and construction), each using capital, labor, and intermediate inputs.

Figure 1 shows the nested structure of the sectoral production functions. At the top level, sectoral output is a linear function of real value added and intermediate inputs. Intermediate inputs are demanded with fixed input-output coefficients. Real value added is a constant elasticity of substitution (CES) function of labor, capital, and (in the agricultural sectors) a land/water aggregate. The land/water aggregate, in turn, is a linear aggregation of water (H2O, in cubic meters) and raw land (FED, or feddan).

While this nested structure provides some flexibility in specifying production technology, it still represents an over-simple specification of agricultural technology. For example, the model specifies a single land type which can be freely allocated across different crops. Similarly, capital and labor are assumed to be freely allocable across agricultural sectors and there is no consideration of livestock. Even with relatively low substitution elasticities and many fixed-coefficients, this specification probably overstates the flexibility of the agricultural sector with regard to changing the cropping pattern and moving around factors of production. The LW-CGE model should be seen as a stylized

[10] The model is implemented in the GAMS modelling language. See Brooke, Kendrick, and Meeraus (1988).

[11] Our intent is eventually to link the CGE model with a detailed programming model of Egyptian agriculture developed by Hazell *et al.* (1994).

empirical model which incorporates important general-equilibrium effects, but which needs to be complemented with more detailed analysis of agricultural subsectors.

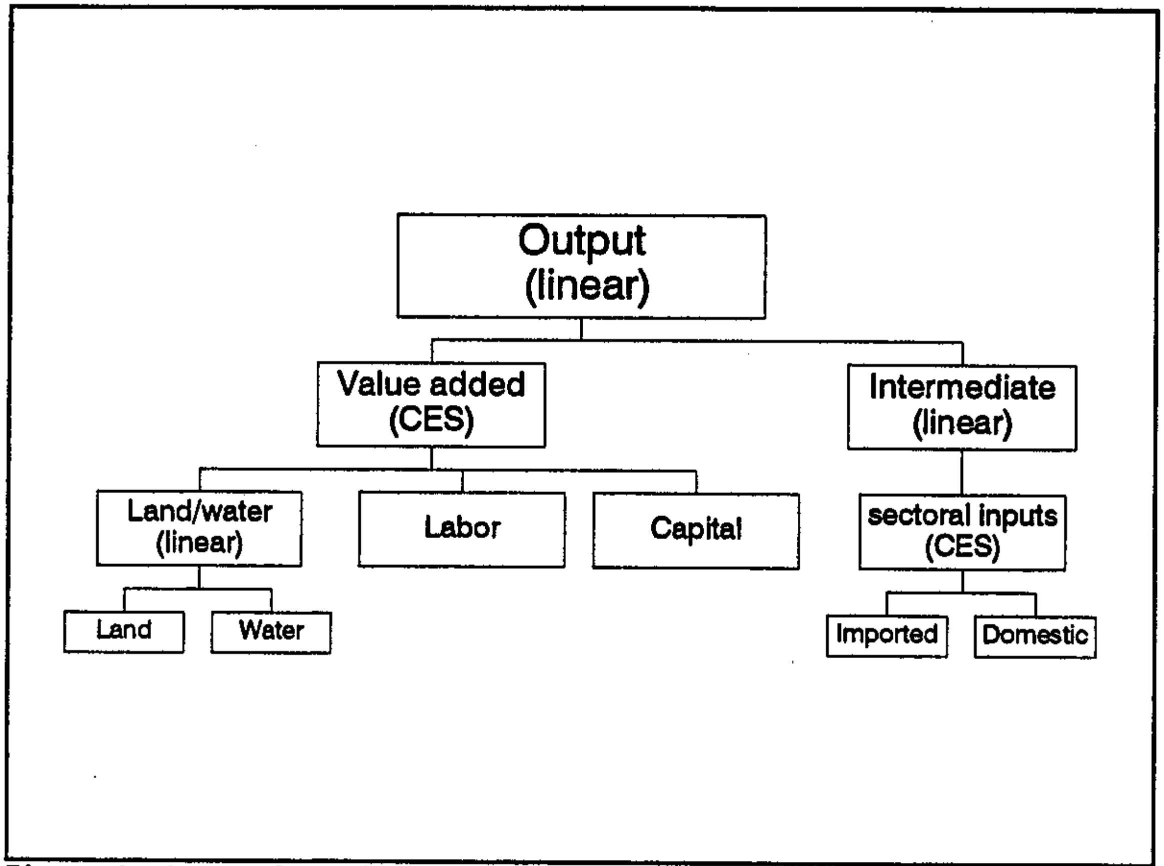

Figure 1: Sectoral production functions

Table 5 provides a listing of the equations of a simplified version of the LW-CGE model. The full model is presented in Appendix 1. This simplified presentation focuses on the production technology and ignores international trade, income distribution, and macro aggregates such as savings, investment, the balance of trade, and the government deficit. Equations 1 to 5 give the production structure, following the nesting in Figure 1. Equations 6 to 13 define cost prices and the various first-order conditions for profit maximization. Equations 14 and 15 map from factor income to product demand, while equations 16 to 20 provide market clearing conditions. Finally, equations 21 to 26 bring together a number of revenue-expenditure identities arising from the homogeneity of the various underlying functions. These identities are implied by the other equations, given homogeneity, and are hence not independent equations. The model has ($13 \cdot i + i \cdot j + 5$) endogenous variables and, assuming all constraints are binding, ($13 \cdot i + i \cdot j + 6$) equations. The model, however, satisfies Walras' Law and therefore has only ($13 \cdot i + i \cdot j + 5$) independent equations.

Table 5: Equations of a Simplified LW-CGE Model

	Production	
1.	$X_i = \mathrm{LIN}_i(V_i, INT_i)$	Linear production function.
2.	$V_i = \mathrm{CES}_i(K_i, L_i, LND_i)$	CES value added function.
3.	$X_{ij} = \mathrm{LIN}_{ij}(INT_j)$	Intermediate inputs.
4.	$FED_i = \mathrm{LIN}_i(LND_i)$	Land input.
5.	$H2O_i = \mathrm{LIN}_i(LND_i)$	Water input.
	Prices and Factor Demand	
6.	$(1 - t_i^X) \cdot P_i^X = \mathrm{LIN}_i(P_i^V, P_i^{INT})$	Output cost price.
7.	$P_i^{INT} = \mathrm{LIN}_i(P_{ji}; j)$	Intermediate input cost price.
8.	$P_i^V = \mathrm{CES}_i(W^K, W^L, W_i^{LND})$	Value added cost price.
9.	$W_i^{LND} = \mathrm{LIN}_i(W^{FED}, W^{H2O})$	Land/water cost price.
10.	$W_i^{LND} = \dfrac{\partial V_i}{\partial LND_i} P_i^V$	Demand for land/water.
11.	$W^K = \dfrac{\partial V_i}{\partial K_i} P_i^V$	Demand for capital.
12.	$W^L = \dfrac{\partial V_i}{\partial L_i} P_i^V$	Demand for labor.
13.	$\bar{P} = \prod_i (P_i^X)^{\beta_i}$	Numeraire cost of living index.
	Income and Final Demand	
14.	$Y = \sum_i \left(P_i^V \cdot V_i + t_i^X \cdot P_i^X \cdot X_i\right)$	Aggregate income.
15.	$P_i^X \cdot C_i = \beta_i \cdot Y$	Consumption demand.
	Supply-Demand Balances	
16.	$X_i = C_i + \sum_j X_{ij}$	Product supply-demand.
17.	$\overline{FED} \geq \sum_i FED_i$	Land supply-demand.
18.	$\overline{H2O} \geq \sum_i H2O_i$	Water supply-demand.
19.	$\bar{L} = \sum_i L_i$	Labor supply-demand.
20.	$\bar{K} = \sum_i K_i$	Capital supply-demand.

Identities

21.	$(1 - t_i^X) \cdot P_i^X \cdot X_i = P_i^V \cdot V_i + P_i^{INT} \cdot INT_i$	Sales/income.
22.	$P_i^V \cdot V_i = W^K \cdot K_i + W^L \cdot L_i + W_i^{LND} \cdot LND_i$	Value-added/factor payments.
23.	$P_i^{INT} \cdot INT_i = \sum_j P_{ji}^X \cdot X_{ji}$	Intermediate input expenditure.
24.	$W_i^{LND} \cdot LND_i = W^{FED} \cdot FED_i + W^{H2O} \cdot H2O_i$	Land/water payments.
25.	$\sum_i P_i^X \cdot C_i = Y$	Income/expenditure.
26.	$Y = W^K \cdot \bar{K} + W^L \cdot \bar{L} + \sum_i W_i^{LND} \cdot LND_i + \sum_i t_i^X \cdot P_i^X$	Income/factor payments.

Variables and Parameters

Variables

X_i	Output
V_i	Real value added
INT_i	Aggregate intermediate input use
K_i	Capital input
L_i	Labor input
LND_i	Aggregate land/water input
X_{ji}	Intermediate input from sector j to sector i
FED_i	Land subfactor input into land/water aggregate
$H2O_i$	Water subfactor input into land/water aggregate
P_i^X	Output market price
P_i^V	Value added price
P_i^{INT}	Aggregate intermediate input price
W^K	Rental rate of capital
W^L	Wage of labor
W_i^{LND}	Rental rate of sectoral land/water aggregate
W^{FED}	Rental rate of land subfactor
W^{H2O}	Price of water subfactor
Y	Aggregate income
C_i	Consumption demand

In total, there are 13•i + i•j + 5 variables.

Parameters

t_i^X	Indirect tax rate (or subsidy, if negative)
β_i	Consumption expenditure shares
$\overline{FED}$	Aggregate supply of land subfactor
$\overline{H2O}$	Aggregate supply of water subfactor
$\bar{L}$	Aggregate supply of labor
$\bar{K}$	Aggregate supply of capital

Notation

LIN	Linear function
CES	Constant elasticity of substitution function

Except for the land/water aggregate (LND), the model has a standard neoclassical specification. The CES functions for real value added yield well-behaved first-order conditions for profit maximization (equations 10 - 12), conditions which will generally yield a solution with all factor prices strictly positive. The land/water aggregate, however, is a linear function of water and land (H2O and FED), with separate supply constraints (equations 17 and 18). Given that there are six agricultural sectors with quite different water and land coefficients, it is certainly possible to have both constraints binding. If either the water or land constraint is especially binding, however, it is also possible that the constraint on the other will not be binding. For example, the water constraint might be so binding that it is impossible to find a crop mix that utilizes all the land, and the land constraint equation will then be satisfied as a strict inequality. If the land or water constraint is not binding (equations 17 and 18), the corresponding market price of land or water (W^{fed} and W^{H2O} in equation 9) should be zero in equilibrium. The solution prices in the CGE model should display the same kind of complementary slackness as the shadow price system in a programming model.

A neoclassical CGE simulation model will generally have a unique solution that satisfies all the non-linear first-order conditions with all prices strictly positive and all constraints satisfied as equalities. No maximand is needed, since the model includes explicit supply and demand equations for all goods and factors. In the LW-CGE model, the first-order conditions for the land and water constraints are summarized in the linear cost functions in equation 9. There is a problem, however, in that there is an infinite number of solutions that satisfy the cost function (equation 9) and the two inequality constraints (equations 17 and 18). Without an explicit maximand, there is nothing in the cost equations that prevents the model economy from operating within the production possibility frontier for agriculture. In the usual CGE simulation model, this possibility is eliminated by expressing the resource constraints as strict equalities.

Given the inequalities for the land and water constraints, the LW-CGE model requires an explicit maximand to ensure that there is a solution in which at least one of the constraints is binding — that the economy operates on the production possibility frontier for agriculture. The addition of a maximand completes the programming model specification of the use of land and water in the agricultural sectors. A zero price for either land or water is perfectly acceptable, although both cannot be zero since equation 10 will not allow a zero rent (W^{LND}) for the land/water aggregate at the level of the CES value added function — land and water together are required always. In the programming specification, at least one of the constraints will always be binding, generating a strictly positive rent for the land/water aggregate.

Since the CGE model is designed to simulate the operation of a market economy, it is important to specify a maximand that generates a solution that can be seen as simulating a market outcome. However, we explicitly specify in equation 9 that the price of the land/water aggregate must equal the cost of the water and land used — a condition that is true in a competitive equilibrium in which there are no excess profits. In general, any solution that is on the production possibility frontier and satisfies equation 9 with non-negative prices can be seen as a market outcome. Factor wages would equal marginal revenue products for land and water in all agricultural sectors, which characterize a profit-maximizing market equilibrium.[12]

Given that the LW-CGE model has a single consumer, there are strong arguments for choosing consumer welfare as the maximand. In a competitive economy, maximizing consumer welfare will generate a profit-maximizing market equilibrium.[13] In addition, the various supply-demand balance constraints will then have shadow prices that measure the welfare gains from relaxing the constraints. If there are distortions in the market price system —for example from sectoral tariffs, taxes, and subsidies— the differences between the market prices and shadow prices measure the welfare costs associated with the distortions.

In this model, we have chosen as numeraire (Equation 13) the cost of living index associated with the utility function that underlies the expenditure functions (Equation 15). In this case, the variable Y, which measures aggregate income and expenditure, is a direct measure of utility. Given the numeraire, it corresponds to expenditure in the indirect utility function. Changes in Y are a direct measure of "equivalent variation," which is a standard measure of welfare change.[14] In addition, for this choice of maximand, if there are no distortions in the model economy, the shadow prices associated with the supply-demand balance equations should exactly equal the endogenous market-clearing prices at the simulated market equilibrium.

FACTOR MARKETS, PRICES, AND DISTORTIONS

While the LW-CGE model solves for market rental rates for land and water (FED and H2O) at the bottom of the production nest, it is not necessary to interpret these rates as occurring in an actual market. In fact, Egypt does not charge for water use, so there is currently no market for water.[15] However, we do assume that, at the next level, the

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[12] There are issues of degeneracy and tie breaking that might arise theoretically, but are not serious in our application. In effect, the model is a market simulation model with a "regime switch" when one of the constraints is not binding. With equality constraints, the model would want to subsidize the use of the redundant factor to maintain the strict equality constraint, in effect generating a negative price. We do not allow this possibility and, instead, switch regimes at that point, dropping the constraint and setting the corresponding factor price to zero. For a market equilibrium, we require that the market price be zero when the constraint is satisfied by a strict inequality.

[13] In some agricultural sector models, the maximand is the sum of consumer and producer surplus, given linear approximations to supply and demand curves, which approximates aggregate welfare and so generates a solution whose shadow prices can be viewed as market prices. These models do not include first-order conditions explicitly, and so do not simulate market solutions directly. See, for example, Hazell and Norton (1986). In this case, the choice of maximand is crucial. In a non-linear model, there is no reason not to choose aggregate welfare as the maximand, and so avoid any approximation errors.

[14] See Shoven and Whalley (1992), pp. 123–128, for a discussion of different welfare measures and their use in CGE models.

[15] The model ignores non-agricultural uses of water and also assumes that there are no distribution costs. Water is a necessary, costless, input to agriculture whose aggregate supply is fixed.

solution rental rate for the land/water aggregate does reflect a market valuation. In effect, we are assuming that, when a farmer uses land to grow a particular crop, he is entitled to the needed water, and the market return to his land reflects that entitlement.

The model separately prices land and water and so decomposes the rental value of the land/water aggregate into components reflecting pure land rent and the value of the water entitlement. The model solution generates information about the counter-factual "what if" question: If Egypt were to institute a market for water and charge for water used in agriculture, what would be the market-clearing price? It is also interesting to compare the simulated market price of water with its shadow price. While they will be equal if there are no market distortions, in fact the Egyptian economy is characterized by a variety of distortions. The difference between the shadow and simulated market prices of water indicate the difference between the social value of water at the margin and the demand price for water in the distorted market environment.

Given that Egypt does not charge for agricultural use of water, it is also interesting to explore the implications for water demand of different policy reform scenarios in an environment in which water is free. That is, instead of assuming a binding water constraint and letting the model generate a scarcity value for water under different policy scenarios, we can alternatively set the price of water to zero and let the model solve for the demand for water. In some empirical experiments reported below, we explore the implications of using constrained-water and unconstrained-water variants of the model.

The simplified model presented in Table 5 includes only one tax variable, a sectoral ad valorem indirect tax rate. This rate can be negative, reflecting a sectoral production subsidy. The indirect tax/subsidy puts a wedge between the sectoral price paid by demanders (P^X) and the price received by producers (Equation 6). The resulting tax revenue (or subsidy cost) is simply transferred in a lump sum to (or from) consumers (Equation 14). The full model includes an additional distorting tax instrument: ad valorem sectoral tariffs on imports. Indirect taxes, subsidies, and tariffs differ widely across sectors in Egypt, and hence significantly distort producer and consumer incentives relative to what would occur in an undistorted competitive market solution.

The simplified model has only one labor type. In the full model, the labor market is segmented, separating rural and urban labor. Rural labor works only in the six agricultural sectors, while urban labor works in all non-agricultural sectors. The wages in the two labor markets are determined through separate supply-demand equations. In effect, the value-added production function (Equation 2) includes two labor categories, but each sector only hires one type of labor.[16] Similarly, we add an additional first-order condition (Equation 12), with an agricultural wage applying to the agricultural sectors and an urban wage applying to the non-agricultural sectors.

In some experiments, we link the two labor markets by adding a migration equation. With migration, labor moves between the two labor markets to maintain a fixed relative wage between agricultural and non-agricultural labor. In the model with migration, social welfare can be increased by any changes which cause labor to move out of low-wage (and hence low-productivity) agricultural sectors into higher-wage industrial and service sectors. In the migration version of the model, the shadow price system will

[16] In this specification, "rural" is equivalent to "agricultural" and "urban" is equivalent to "non-agricultural."

reflect the fact that labor has a higher productivity in the non-agricultural sectors, leading to a deviation between shadow and market wages, even if there are no other distortions in the system.

Both the migration and non-migration variants of the model assume that the entire labor supply is employed. Both models are neoclassical in the sense that there is no overt unemployment. Underemployment is indicated by a low market wage. In addition, the model does not include any adjustment costs or transitory unemployment. All the experiments reported below should be viewed as comparative static experiments, assuming enough time has passed for the various factor and product markets to adjust, achieving a new equilibrium.

Even the full model has a number of very strong simplifying assumptions. Water is assumed to be costless to distribute and can be freely allocated to different crops. We do not consider any losses in water distribution, so the water usage numbers reflect "consumptive use" rather than supply. Non-agricultural water use is not modelled at all. Land is also assumed to be freely allocable across different crops. There is no differentiation of land by quality, no explicit representation of multiple cropping, and no regional differentiation. All these simplifications can be relaxed in a more elaborate model of Egyptian agriculture, which is one of our future research goals.

International Trade and Macro Closure

The simplified model does not include international trade, aggregate investment, or government demand. The full model includes all three. The trade specification follows closely the standard treatment in trade-focused CGE models.[17] Imports and domestically produced goods with the same sectoral classification are assumed to be imperfect substitutes in use, with a constant elasticity of substitution. What is demanded is a composite good, which is a CES aggregation of imports and domestically produced goods. Exports are also differentiated from goods sold on the domestic market. Sectoral output is "transformed" between export and domestic markets according to a constant elasticity of transformation (CET) function. The resulting model incorporates a great deal of product differentiation and also a degree of realistic insulation of domestic prices from changes in world prices.

Egypt is assumed to be a small country, so that world prices of its exports and imports are not affected by the volume of trade. The model includes the balance of trade, which is assumed fixed. The model solves endogenously for an exchange rate that equilibrates the demands for domestic and traded goods, given the fixed balance of trade. The equilibrating variable is the real exchange rate, which is the relative price of tradables (both exports and imports) and domestically produced goods sold on the domestic market.

Given the balance of trade, real government expenditure, and real investment, some macro mechanism is required in the model to generate adequate government revenue and aggregate savings to finance the three deficits (the balance of trade, government deficit, and savings-investment gap). The macro closure of the model is

[17] See Devarajan, Lewis, and Robinson (1994) for a detailed discussion of the treatment of trade in CGE models.

very simple. The balance of trade is fixed exogenously in terms of world prices, although its value in domestic prices depends on the exchange rate, which is determined endogenously. The balance of trade in domestic currency is assumed to be financed from (or, if negative, be a source of) aggregate savings. Government tax rates are all set exogenously, so that government revenue is determined endogenously. The government deficit (or surplus) is assumed to be a drain on (or addition to) aggregate savings. The equilibrating macro variable is the aggregate private savings rate, which is assumed to adjust to achieve savings-investment balance. The macro mechanisms by which this equilibrium savings rate might be achieved are not explicitly modelled.[18]

Given the macro closure, with fixed aggregate real investment and real government expenditure on goods and services, any change in sectoral taxes, subsidies, or tariffs will be offset by a lump-sum transfer to or from households. Policy reform experiments, in which distorting ad valorem taxes, subsidies, and tariffs are eliminated, yield gains in allocative efficiency. Since these taxes and subsidies are implicitly replaced by efficient lump-sum taxes or transfers, the model does not consider efficiency costs of alternatives to ad valorem taxes and subsidies. The results should be viewed as providing an upper-bound estimate of the efficiency gains from policy reform.

[18] This macro closure is called "Johansen closure" after Lief Johansen, who used it in the first CGE model of Norway. For a discussion of different macro closure rules, see Robinson (1989, 1991).

3. EMPIRICAL RESULTS

We ran three different series of experiments with the LW-CGE model to explore a variety of issues regarding the impact of reforms on Egyptian agriculture. In the first series, we explore the impact of removing agricultural taxes and subsidies sector by sector, with no policy changes elsewhere in the economy. The intent is to provide partial-equilibrium measures of the responsiveness of individual sectors to removal of taxes or subsidies. In the second series of experiments, we explore the general-equilibrium impact of eliminating distortions due to the tax, subsidy, and tariff system, both agricultural and non-agricultural. The focus is on the welfare and structural implications of major, pervasive, reform of Egyptian industrial and agricultural policy. In the final series, we estimate the demand curve for water by agriculture. In these experiments, we progressively reduce the aggregate supply of water and trace out the impact on the price of water and the structure of agricultural production and water use. In all three sets of experiments, we explore the implications of using different model variants: migration versus no migration and constrained water versus unconstrained water.

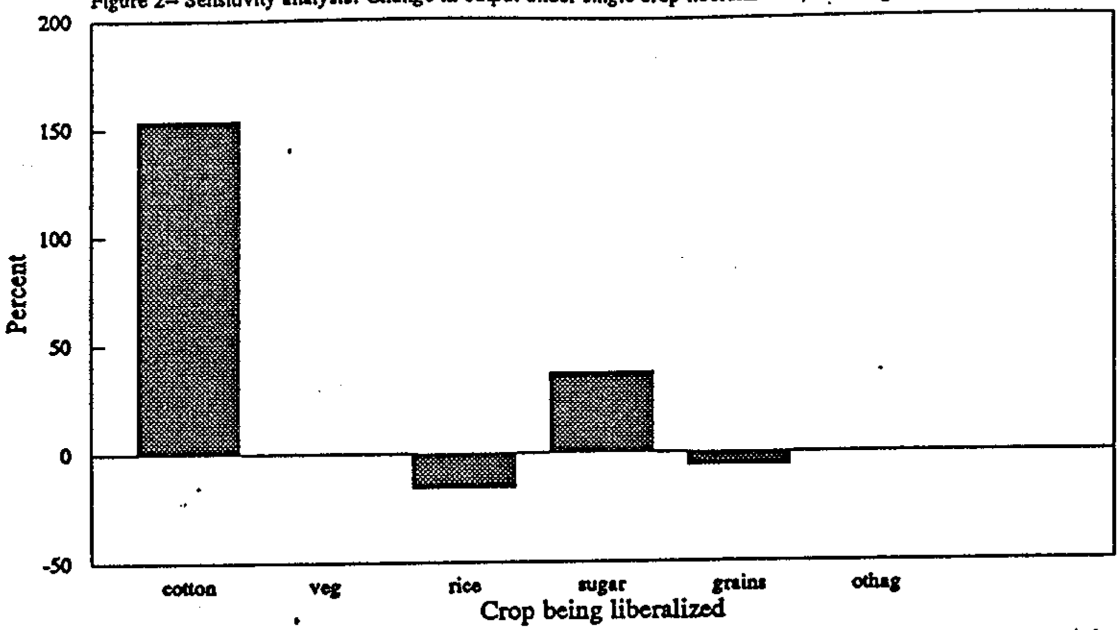
SINGLE-SECTOR POLICY EXPERIMENTS

In the single-sector reform experiments, we eliminate, sector by sector, the sectoral indirect tax or subsidy and the import tariff (Table 3). The sectoral output results are given in Figure 2. The general-equilibrium effects of these single-sector experiments are very small and are not reported. It also did not matter greatly what model variant we used —with or without migration, and with or without the water constraint binding (constrained or unconstrained water). In Figure 2, we report results from the model variant with migration and unconstrained water.

As expected, the quantitative effect of removing sectoral import protection and taxes or subsidies depends on the initial levels of protection and tax/subsidy. The sectors which are taxed, cotton and sugar, increase output by 153 and 37 percent, respectively, while output of grains and rice, both with net subsidies and high tariffs, decline under sectoral policy reform (by 6 and 16 percent, respectively). Two sectors, other agriculture and fruits and vegetables, have no sectoral taxes/subsidies or import protection, and so sectoral policy reform has no effect on them.

The results of these experiments indicate the direction of sectoral impact that one would expect from general policy reform. With more widespread changes, however, general-equilibrium effects become much more significant. Also, the results become more sensitive to the different behavioral specifications under the alternative model variants.

Figure 2-- Sensitivity analysis: Change in output under single crop liberalization, with migration, constrained water



POLICY REFORM EXPERIMENTS

In this series of experiments, we explore the implications of removing all policies which distort sectoral production and demand incentives. The experiments are described in Table 6. The first experiment removes all non-agricultural indirect taxes/subsidies and tariffs in the non-agricultural sectors. It represents industrial reform alone. The remaining five experiments progressively eliminate indirect taxes/subsidies in the agricultural sectors, in equal steps of 20 percent each. The experiments are run under all model variants: migration and no migration, constrained water and unconstrained water.

Table 6. Description of Policy Reform Experiments

Experiment	Description
Exp 1	Reduce indirect taxes/subsidies and tariffs to zero in all non-agricultural sectors.
Exp 2	Exp 1 plus reduce indirect taxes/subsidies and tariffs in agricultural sectors by 20%.
Exp 3	Exp 1 plus reduce indirect taxes/subsidies and tariffs in agricultural sectors by 40%.
Exp 4	Exp 1 plus reduce indirect taxes/subsidies and tariffs in agricultural sectors by 60%.
Exp 5	Exp 1 plus reduce indirect taxes/subsidies and tariffs in agricultural sectors by 80%.
Exp 6	Exp 1 plus reduce indirect taxes/subsidies and tariffs in agricultural sectors by 100%.

The results for a number of economywide variables under the four model variants are given in Tables 7 and 8. Note first the impact of policy reform on aggregate welfare. As discussed above, the change in aggregate consumption measures the increase in welfare as the equivalent variation (presented as a ratio to the base level of welfare) due to the experiment. In the Egyptian case, there are significant gains from policy reform. Complete removal of distorting policies increases aggregate welfare by 4.8–5.9 percent (constrained and unconstrained water) in the no-migration variant and by 3.6–3.7 percent in the migration variant. Allowing migration into agriculture, the lower productivity sector, reduces overall welfare when there is policy reform. Removal of non-agricultural distortions alone (experiment 1) increases welfare by 1.9–3.3 percent, depending on model variant. These are large gains, especially considering that they only include static efficiency gains, and indicate the large potential benefits arising from policy reform in Egypt.

Table 7. Macro results, Policy Liberalization Experiments, Migration Model

Variable	Base	Policy Liberalization Experiments: constrained water EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	unconstrained water EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
	Value	Ratio to base						Ratio to base					
1.GDP (billion LE)	42.209	1.005	1.014	1.023	1.029	1.033	1.033	1.005	1.014	1.023	1.030	1.033	1.033
2. Consumption	25.932	1.006	1.020	1.032	1.039	1.041	1.036	1.006	1.020	1.032	1.040	1.041	1.037
3. Exports	0.27	1.004	1.719	2.863	4.352	5.937	7.437	1.004	1.719	2.878	4.400	6.037	7.604
4. Imports	1.268	1.002	1.050	1.203	1.471	1.816	2.195	1.002	1.054	1.215	1.498	1.870	2.284
5. Agric VA Terms of Trade	100.000	0.972	0.992	1.027	1.074	1.122	1.165	0.972	0.992	1.026	1.072	1.119	1.162
6. Exch. Rate	1.000	1.027	0.988	0.938	0.880	0.823	0.772	1.027	0.988	0.938	0.880	0.823	0.771
7. Rural wage	1.096	1.040	1.036	1.037	1.041	1.047	1.050	1.040	1.036	1.037	1.042	1.047	1.052
8. Urban wage	2.362	1.039	1.036	1.037	1.041	1.046	1.050	1.039	1.037	1.038	1.042	1.047	1.052
9. Land /Water Aggregate Rent Index	1.000	1.025	1.019	1.013	0.997	0.975	0.950	1.025	1.019	1.006	0.991	0.962	0.931
10. Profit Index													
a. rural	1.000	1.034	1.062	1.12	1.205	1.301	1.391	1.034	1.062	1.12	1.207	1.304	1.398
b. urban	1.000	1.152	1.117	1.071	1.021	0.973	0.933	1.152	1.117	1.072	1.021	0.974	0.933
11. Rural- urban migration		Value						Value					
a. million people	0.000	0.01	-0.044	-0.142	-0.276	-0.416	-0.544	0.01	-0.044	-0.142	-0.276	-0.419	-0.549
b. percent share of rural labor force	0.000	-0.216	0.859	3.023	5.694	8.348	10.651	-0.216	0.953	3.019	5.707	8.395	10.74
12. Land Rent (LE/Fed)													
a. Shadow	0.259	0.211	0.214	0.208	0.200	0.199	0.206	290.000	0.246	0.252	0.254	0.254	0.256
b. Market	0.317	0.325	0.313	0.299	0.279	0.254	0.226	0.317	0.325	0.323	0.319	0.314	0.305
13. Water Prices (LE/100 cu m)													
a. Shadow	1.120	1.235	1.347	1.672	1.979	2.082	1.962	0.000	0.000	0.000	0.000	0.000	0.000
b. Market	0.000	0.012	0.350	0.740	1.246	1.865	2.551	0.000	0.000	0.000	0.000	0.000	0.000
14. Quantity of water demand (bn cu m)	0.356	0.356	0.356	0.356	0.356	0.356	0.356	0.357	0.357	0.36	0.364	0.368	0.372

Notes:
(1) For description of experiments, see table 6.
(2) Changes in aggregate consumption represent changes in welfare (equivalent variation) relative to base value.
(3) All macro aggregates and wages are in real terms.
(4) Agric VA (Value Added) Terms of Trade is VA /unit output in agriculture divided by VA/unit output in nonagriculture.
VA terms of trade includes inidrect taxes and subsidies per unit of output.
(5) Exchange rate is LE/unit of foreign exchange rate. A rise implies depreciation.

Table 8. Macro results, Policy Liberalization Experiments, No Migration Model

Variable	Base	Constrained water EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	Unconstrained water EXP1	EXP2	EXP3	EXP4	EXP5	EXP6
	Value	Ratio to base						Ratio to base					
1.GDP (billion LE)	42.209	1.005	1.015	1.026	1.036	1.043	1.048	1.005	1.016	1.026	1.036	1.043	1.048
2. Consumption	25.932	1.006	1.022	1.037	1.050	1.057	1.059	1.006	1.016	1.026	1.036	1.043	1.048
3. Exports	0.27	1.007	1.685	2.693	3.926	5.200	6.415	1.007	1.685	2.711	3.970	5.293	6.552
4. Imports	1.268	0.998	1.063	1.233	1.501	1.832	2.188	0.999	1.067	1.245	1.528	1.882	2.267
5. Agric VA Terms of Trade	100.000	0.970	1.002	1.056	1.126	1.203	1.279	0.970	1.002	1.054	1.124	1.200	1.276
6. Exch. Rate	1.000	1.027	0.989	0.943	0.894	0.847	0.806	1.027	0.989	0.943	0.894	0.847	0.806
7. Rural wage	1.096	1.035	1.060	1.109	1.174	1.246	1.316	1.035	1.060	1.109	1.175	1.249	1.320
8. Urban wage	2.362	1.041	1.028	1.011	0.992	0.971	0.950	1.041	1.028	1.012	0.992	0.972	0.951
9. Land/water aggregate rent index	1.000	1.028	1.019	1.003	0.984	0.959	0.931	1.028	1.016	1.000	0.978	0.946	0.912
10. Profit index													
a. rural	1.000	1.034	1.060	1.108	1.174	1.246	1.315	1.034	1.060	1.108	1.175	1.248	1.320
b. urban	1.278	1.151	1.121	1.084	1.046	1.010	0.977	1.151	1.121	1.085	1.046	1.011	0.978
		Value						Value					
11.Rural -urban migration													
a. million people	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
b. percent share of rural labor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12. Land Rent (Le/Fed)													
a. Shadow	0.259	0.259	0.257	0.246	0.233	0.226	0.223	0.292	0.293	0.292	0.29	0.289	0.289
b. Market	0.317	0.325	0.312	0.296	0.276	0.251	0.223	0.326	0.322	0.317	0.31	0.3	0.289
13. Water Prices (LE/100 cu m)													
a. Shadow	1.12	1.153	1.284	1.666	2.077	2.342	2.425	0.000	0.000	0.000	0.000	0.000	0.000
b. Market	0	0.01	0.356	0.748	1.231	1.801	2.425	0.000	0.000	0.000	0.000	0.000	0.000
14. Quantity of water demand (bn cu m)	0.356	0.356	0.356	0.356	0.356	0.356	0.356	0.357	0.36	0.364	0.368	0.372	0.377

Notes:
(1) For description of experiments, see table 6.
(2) Changes in aggregate consumption represent changes in welfare (equivalent variation) relative to base value.
(3) All macro aggregates and wages are in real terms.
(4) Agric VA (Value Added) Terms of Trade is VA /unit output in agriculture divided by VA/unit output in nonagriculture. VA terms of trade includes inidrect taxes and subsidies per unit of output.
(5) Exchange rate is LE/unit of foreign exchange rate. A rise implies depreciation.

Policy regimes in many developing countries discriminate against agriculture.[19] Indeed in Egypt, we find that is the case. Consider the value-added terms of trade, which measures the ratio of value added (including ad valorem taxes and subsidies) per unit of output in agriculture to that in the non-agricultural sectors. This ratio falls in experiment 1, in which non-agricultural taxes, subsidies, and tariffs are eliminated, which indicates that these policies, on net, tax the non-agricultural sectors. In experiments 2–6, the terms-of-trade ratio increases, indicating that the agricultural policies provide a large net tax to agriculture. The policy bias against agriculture is also indicated by the fact that all the policy reform experiments lead to a flow of resources into agriculture and/or an increase in returns to factors of production in agriculture.

In general, an important impact of import protection policies is to appreciate the market exchange rate, providing an incentive bias against exports and in favor of import substitution. In Egypt, 1986–88, there were significant export taxes on major agricultural sectors. The bias against exports is explicit and sector specific. In the aggregate, export taxation leads to an undervaluation of the real exchange rate. In the case of Egypt, when all distortions are removed, there is an appreciation of the equilibrium real exchange rate by 20–23 percent (Tables 7 and 8), which reflects the empirical importance of export taxes in agriculture compared to protection in the non-agricultural sectors.

It is often argued that, in addition to import protection, many developing countries maintain an overvalued exchange rate by relying on an unsustainable level of foreign borrowing, leading to an additional source of incentive bias against exports (Krueger 1992) and (Schiff and Valdés 1992). We explore the impact of this effect by doing some sensitivity experiments, whose results are not tabulated, in which we reduce the deficit in the balance of trade. Starting from the policy-distorted base, reducing the trade deficit to zero leads to about a 20 percent real depreciation. Whether such an overvaluation discriminates against agriculture depends on its role in trade relative to that of the non-agricultural sectors. The over-valuation of the exchange rate hurts tradables relative to non-tradables, and the net effect on a given sector depends on its extent of "tradability" relative to the rest of the economy. Although there is significant depreciation when the trade deficit is eliminated, the impact on agriculture is very small. The share of agriculture in GDP actually declines very slightly, indicating that the overvalued exchange rate regime favors agriculture slightly.

The gap between the welfare gains in the migration and no-migration model variants indicates the importance of structural change. With complete policy reform, the final equilibrium results in about 11 percent of the non-agricultural labor force moving to work in agricultural sectors, where they are less productive — earnings are 2.2 times higher in the non-agricultural sectors. These comparative-static results can be interpreted as indicating that policy reform would significantly lessen rural-urban migration pressure. The comparative static experiment says nothing about the adjustment process and how long it might take, but does indicate the strong pressure for structural change in factor markets that will accompany policy reform.

[19] See, for example, Bautista and Valdés (1993) for a comparative study of policy regimes in a variety of developing countries, which documents that a policy bias against agriculture is common.

Figure 3 plots the impact of policy reform on rural and urban wages. Without migration, urban wages fall while rural wages rise, and the rural-urban gap falls from 2.2 to 1.56 and 1.55 (under the constrained and unconstrained water variants of the model). Given the prevalence of rural poverty, this trend would improve the distribution of income. With migration, the rural-urban gap stays constant (by assumption). Agricultural and non-agricultural wages rise under non-agricultural policy liberalization (Experiment 1 in Figure 3 and Tables 7-8), and continue to rise slightly under agricultural policy liberalization (even as non-agricultural labor moves into the agricultural labor market).

Figure 4 shows the return to the land/water aggregate, which falls monotonically as agricultural policy distortions are eliminated. The return to the land/water aggregate falls by around 5-7 percent with the complete elimination of the policy bias. As the policy bias against agriculture is eliminated, changes in the return to the land/water aggregate come from changes in the intensity of factor demand, or Stolper-Samuelson effects.[20] The elimination of distortions leads farmers to switch into crops that are more capital and/or labor intensive, and less land/water intensive (e.g., cotton).

While there is a shift away from land/water intensive crops, there is also a shift toward more water-intensive versus land-intensive crops (e.g., sugar and cotton versus grains). The net effect is a dramatic change in the relative returns to the underlying subfactors, land and water. Figures 5 and 6 show the market and shadow prices of water and land with policy liberalization under the migration and no-migration model variants. At the base solution, the market price of water is almost zero, while that of land is quite high. With complete liberalization, the market price of water rises while that of land falls.

The shadow price of water, however, is significantly positive in the base solution, while the shadow price of land is much lower than the market price. The implication of these results is that the existing set of Egyptian policies biases production in favor of agricultural sectors which are less water intensive. While water is clearly valuable, with a high shadow price, if Egypt were to introduce a water market with the existing set of output tax and subsidy policies, the market-clearing price would be near zero! Alternatively, given the existing tax and subsidy system, farmers have no incentive to cheat in order to acquire additional water. Water demand equals supply, even when the water is provided free.

With policy liberalization, however, the market price of water rises steeply. The shadow price, however, rises only slightly, indicating that the social value of water changes little. As theory predicts, the market price exactly equals the shadow price when all distortions are eliminated in the no-migration model variant (Figure 5b). The implication of this steep rise in the market price is that policy liberalization will create significant strains on the existing system of water allocation. In an undistorted market, farmers will value water highly. With policy reform, any water distribution system that relies on quantitative allocations at zero cost to the recipients will engender enormous incentives for cheating and corruption.

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[20] The Stolper-Samuelson Theorem states that an increase in the relative price of one commodity raises the real return of the factor used intensively in producing that commodity and lowers the real return of the other factor [Jones and Neary (1984)].

Figure 3. Real Wages, Urban and Rural , Policy Liberalization Experiments

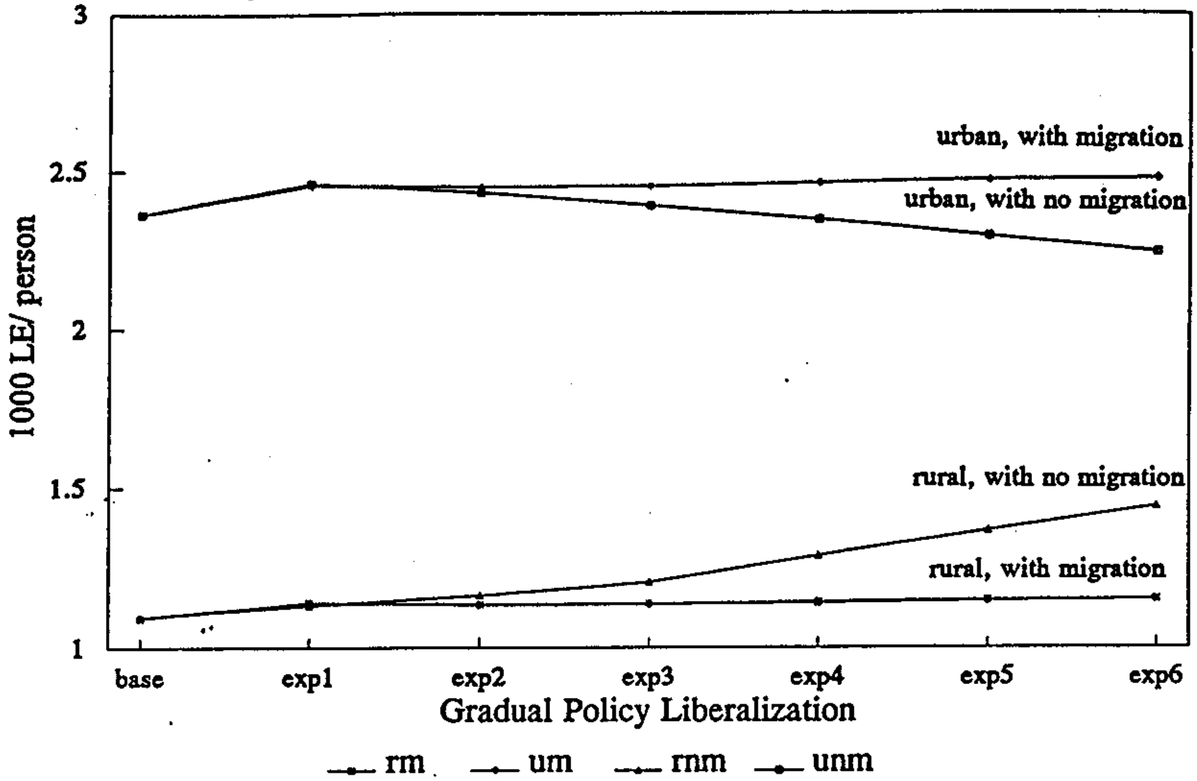


Figure 4. Rental value of Land/Water Aggregate, Policy Liberalization Experiments

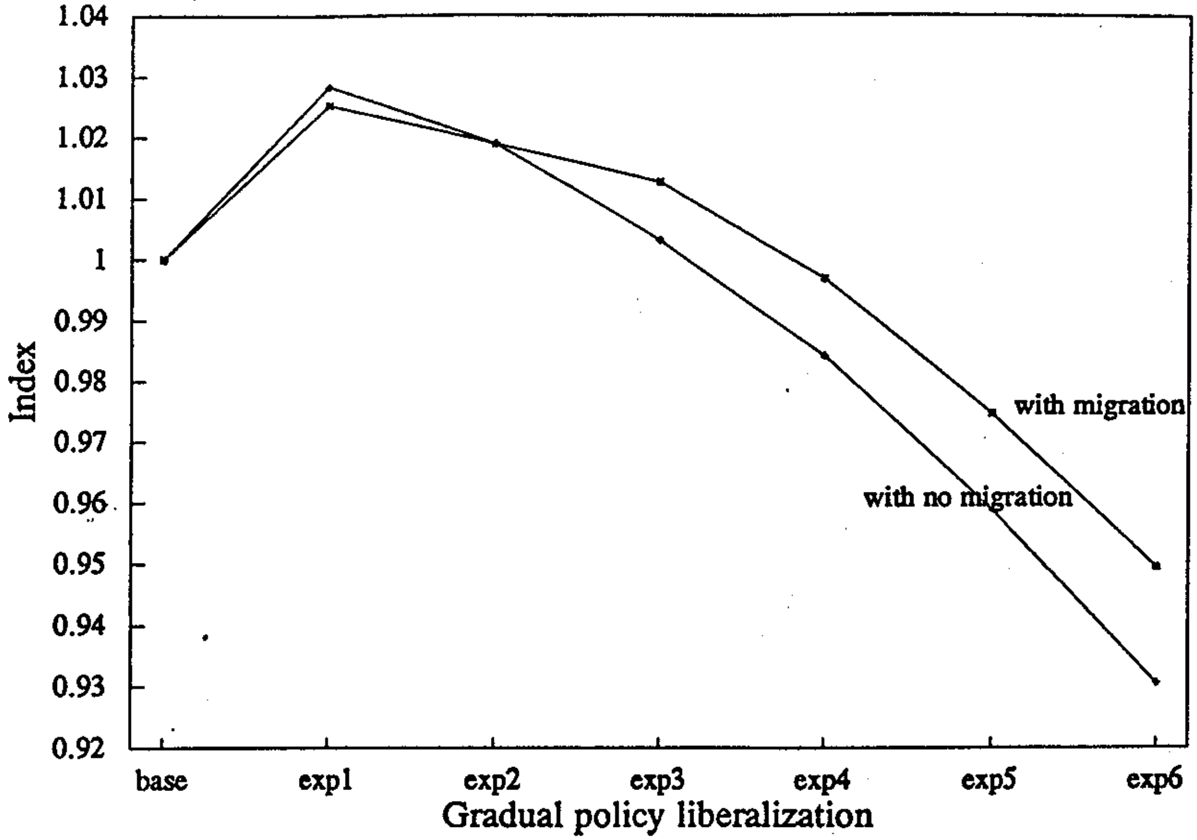


Figure 5a. Full Policy Liberalization: Market and Shadow Prices of Water, With Migration

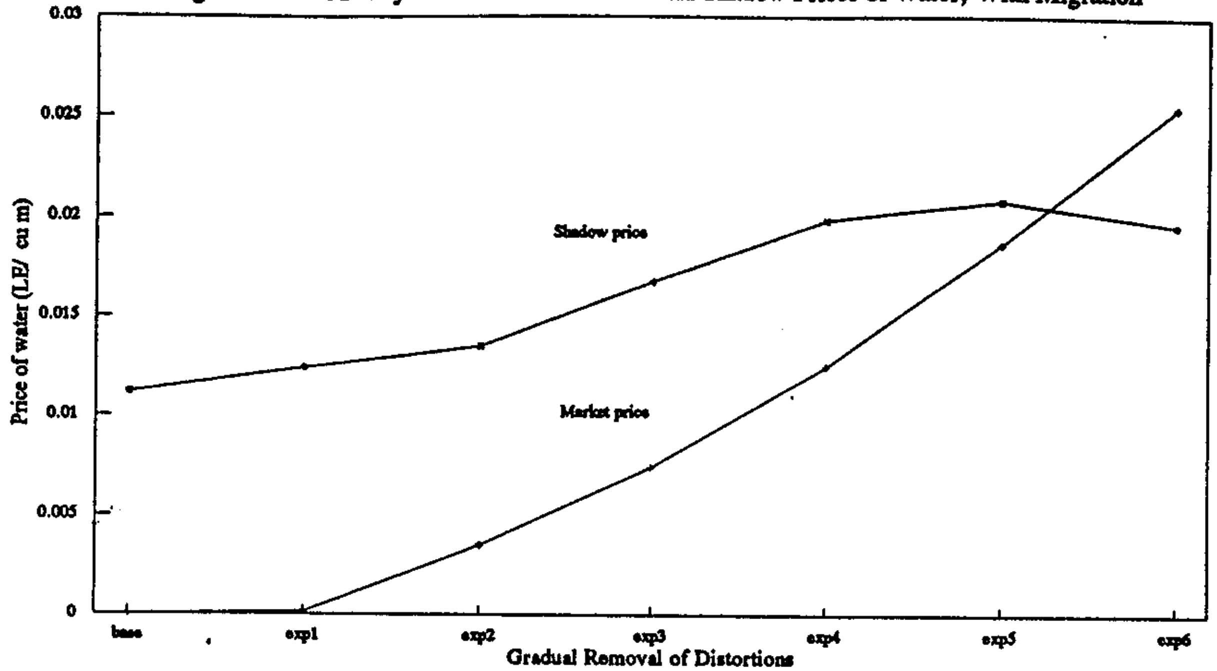


Figure 5b. Full Policy Liberalization: Market and Shadow Prices of Water, With No Migration

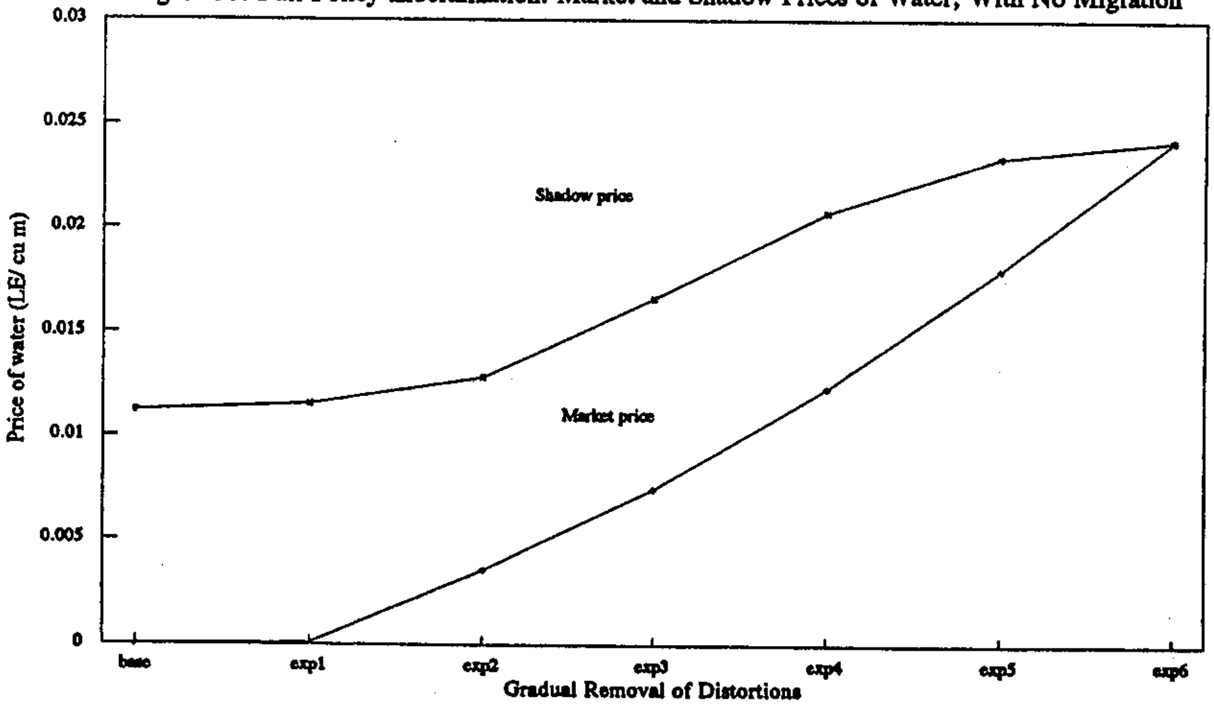


Figure 6a. Full Policy Liberalization: Market and Shadow Prices of Land, With Migration

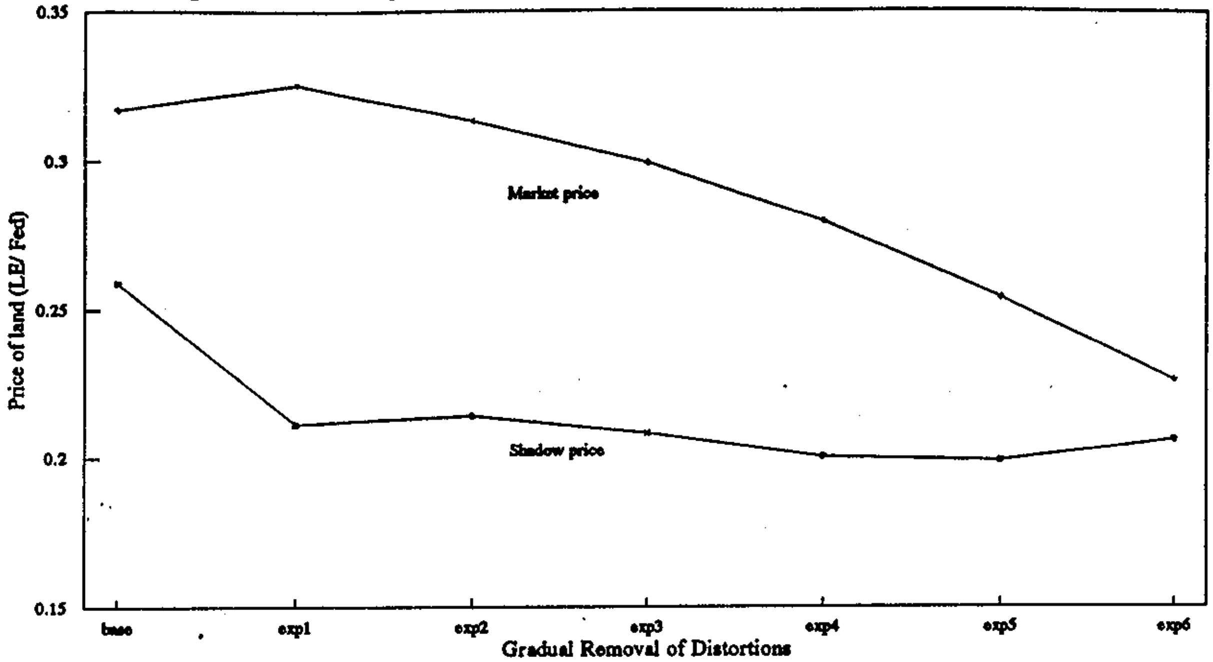
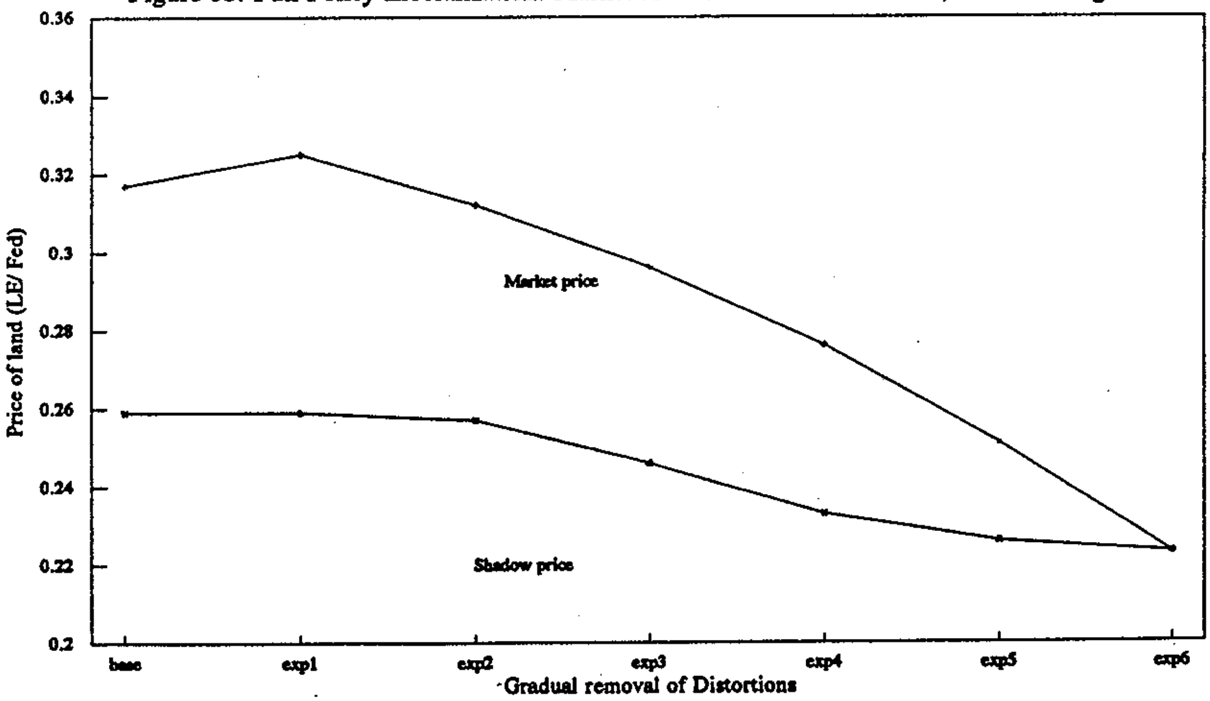


Figure 6b. Full Policy Liberalization: Market and Shadow Prices of Land, With No Migration



The market for raw land, with no associated water rights, appears to be the inverse of the water market. The market land rent starts high in the base and falls dramatically with policy liberalization. As with water, the shadow price changes much less. Again, as theory predicts, the market rent equals the shadow rent with full policy liberalization under the no-migration model variant (Figure 6b).

These results indicate that under the existing policy regime, the value of the land/water aggregate is almost entirely attributable to land. The fact that water is distributed free causes little strain, since land ownership — for which the market is well developed — is the binding constraint. Of course, the fact that land ownership and the decision to produce a given crop permit access to adequate water is very important. At the margin, however, the water supply is adequate to meet the demand, given the policy regime and resulting pattern of crops.

With policy liberalization, the pattern of crop production changes dramatically. Figure 7 shows the changes in sectoral output within agriculture for complete liberalization under the four model variants. Production of grains, rice, and fruits and vegetables, which are subsidized, fall significantly (10–40 percent). Cotton production, which is currently taxed, rises significantly. Other agriculture and sugar both expand under policy liberalization. They gain from the general-equilibrium spillover effects from policy changes in the other agricultural sectors.

The net effect of these changes in cropping pattern is to increase the demand for water. In the experiments in which water is assumed to remain free (the unconstrained water model variant), the aggregate demand for water increases by 4.2 percent (Table 7). With water constraints, the market price of water rises dramatically.

Demand Curve for Water

To explore the importance of water availability to Egyptian agriculture, we did a series of experiments to trace out the demand curve for water. In this series of five experiments, we started either from the base run with existing policies or from the fully liberalized run and progressively lowered the aggregate supply of water in 5 percent steps, stopping when the aggregate water supply was reduced by 25 percent. The results are presented in Table 9 and Figures 8 to 12.

Figures 8 and 9 show the demand curve for water under alternative model variants and starting from policy-distorted or liberalized bases, plotting the solution market and shadow prices against aggregate water demand.[21] These are general-equilibrium demand curves in that, as the aggregate supply of water is changed, the economy is allowed to adjust fully, with changes in supply, demand, and prices across all sectors and factors. The market and shadow demand curves are quite steep, with an arc price elasticity that is reduced, the existing system of taxes and subsidies in the policy-distorted base leads to a cropping pattern that seeks to maintain production in high water-using sectors, generating an inelastic demand for water.

As the aggregate water supply is reduced, the land constraint ceases to be binding and land is taken out of production. When the land constraint ceases to be binding, both

[21] Note that the total demand for water shown in Figures 8 and 9 represents "consumptive use" in agriculture and does not account for any distributional losses or non-agricultural use.

Figure 7a: Change in crop output under full policy liberalization, with migration

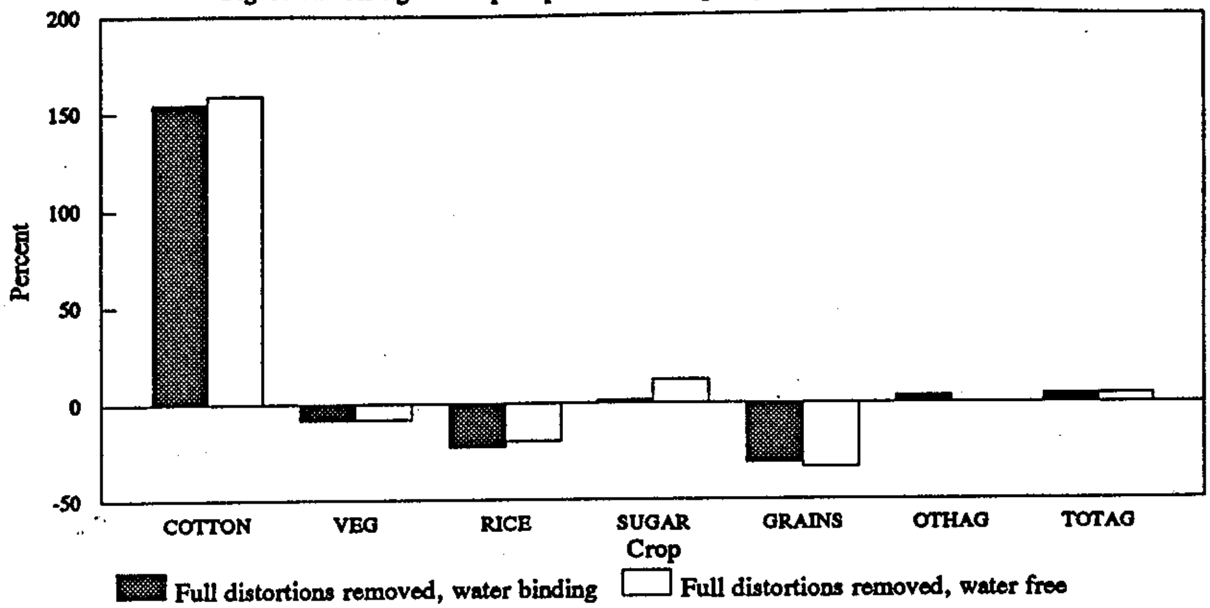


Figure 7b: Change in crop output under full policy liberalization, without migration

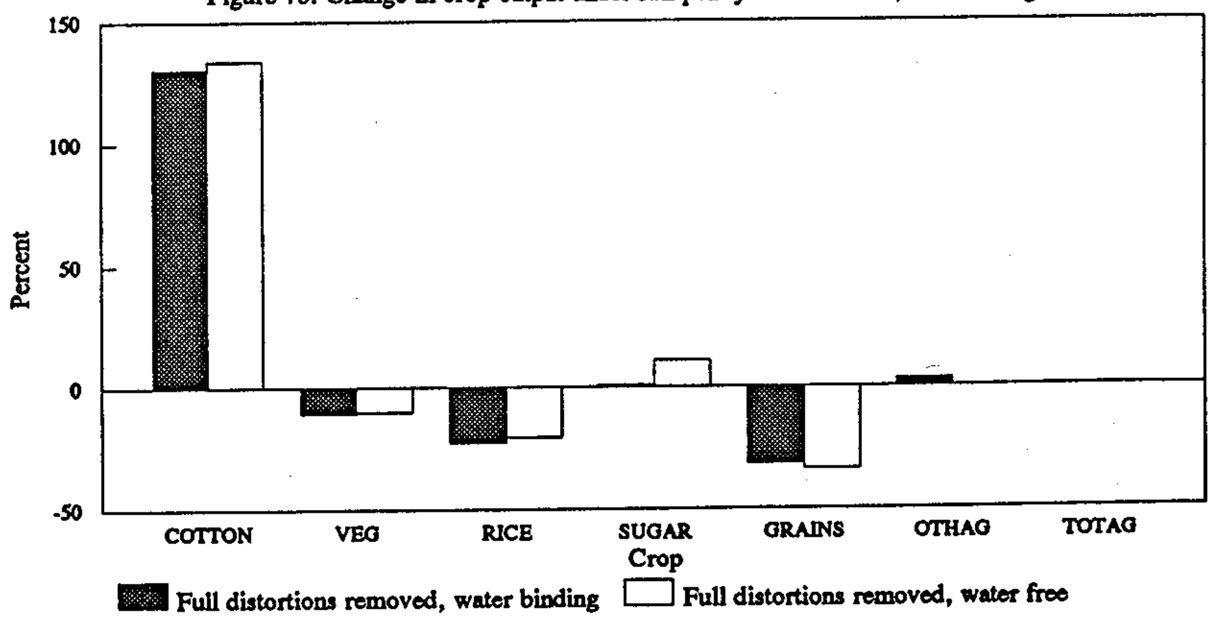


Table 9. Macro results from experiment on agricultural water supply reduction, with and without migration

Variable	Base	EXPERIMENTS: with migration — Reduce water supply by: 5%	10%	15%	20%	25%	without migration — Reduce water supply by: 5%	10%	15%	20%	25%
	Value	Ratio to base					Ratio to base				
1.GDP (billion LE)	44.217	0.999	0.997	0.993	0.989	0.983	0.999	0.997	0.992	0.987	0.981
2. Consumption	27.457	0.998	0.993	0.985	0.977	0.967	0.997	0.992	0.984	0.974	0.964
3. Exports	1.732	0.966	0.914	0.894	0.880	0.865	0.969	0.924	0.911	0.906	0.900
4. Imports	2.774	0.957	0.906	0.917	0.944	0.975	0.957	0.906	0.916	0.973	1.008
5. Agric VA Terms of Trade	100.000	1.005	1.015	1.035	1.060	1.089	1.004	1.009	1.026	1.046	1.069
6. Exch. Rate	1.002	1.002	1.006	1.007	1.009	1.009	1.001	1.004	1.004	1.002	1.001
7. Rural wage	1.442	0.996	0.988	0.976	0.962	0.947	0.991	0.974	0.951	0.926	0.898
8. Urban wage	2.244	0.996	0.987	0.975	0.962	0.947	0.997	0.993	0.986	0.977	0.967
9. Land /Water Aggregate Rent Index	1.000	1.034	1.088	1.214	1.369	1.556	1.034	1.092	1.220	1.380	1.569
10. Profit Index											
a. rural	1.000	0.990	0.970	0.944	0.916	0.884	0.991	0.973	0.951	0.926	0.899
b. urban	1.000	0.998	0.998	0.994	0.989	0.984	0.998	0.994	0.988	0.982	0.974
11. Rural- urban migration		Value					Value				
a. million people	0.000	0.011	0.034	0.061	0.09	0.124	0.000	0.000	0.000	0.000	0.000
b. percent share of rural labor force	0.000	0.251	0.751	1.351	2.017	2.796	0.000	0.000	0.000	0.000	0.000
12. Land Rent (LE/Fed)											
a. Shadow	0.223	0.135	0.031	0.000	0.000	0.000	0.140	0.024	0.000	0.000	0.000
b. Market	0.223	0.140	0.025	0.000	0.000	0.000	0.140	0.024	0.000	0.000	0.000
13. Water Prices (LE/100 cu m)											
a. Shadow	2.425	5.144	9.871	12.417	13.993	15.850	5.880	11.230	13.673	15.447	17.549
b. Market	2.425	5.873	11.190	13.619	15.356	17.408	5.880	11.230	13.673	15.447	17.549
14. Quantity of water demand (bn cu m)	0.356	0.339	0.321	0.303	0.285	0.267	0.339	0.321	0.303	0.285	0.267
15. Quantity of land demand (bn LE)	12.098	12.098	12.098	11.526	10.83	10.134	12.098	12.098	11.523	10.826	10.128

Notes:
(1) For description of experiments, see table 6.
(2) Changes in aggregate consumption represent changes in welfare (equivalent variation) relative to base value.
(3) All macro aggregates and wages are in real terms.
(4) Agric VA (Value Added) Terms of Trade is VA /unit output in agriculture divided by VA/unit output in nonagriculture. VA terms of trade includes inidrect taxes and subsidies per unit of output.
(5) Exchange rate is LE/unit of foreign exchange rate. A rise implies depreciation.

Figure 8a– Private and social demand for water, with migration, using liberalized and distorted base

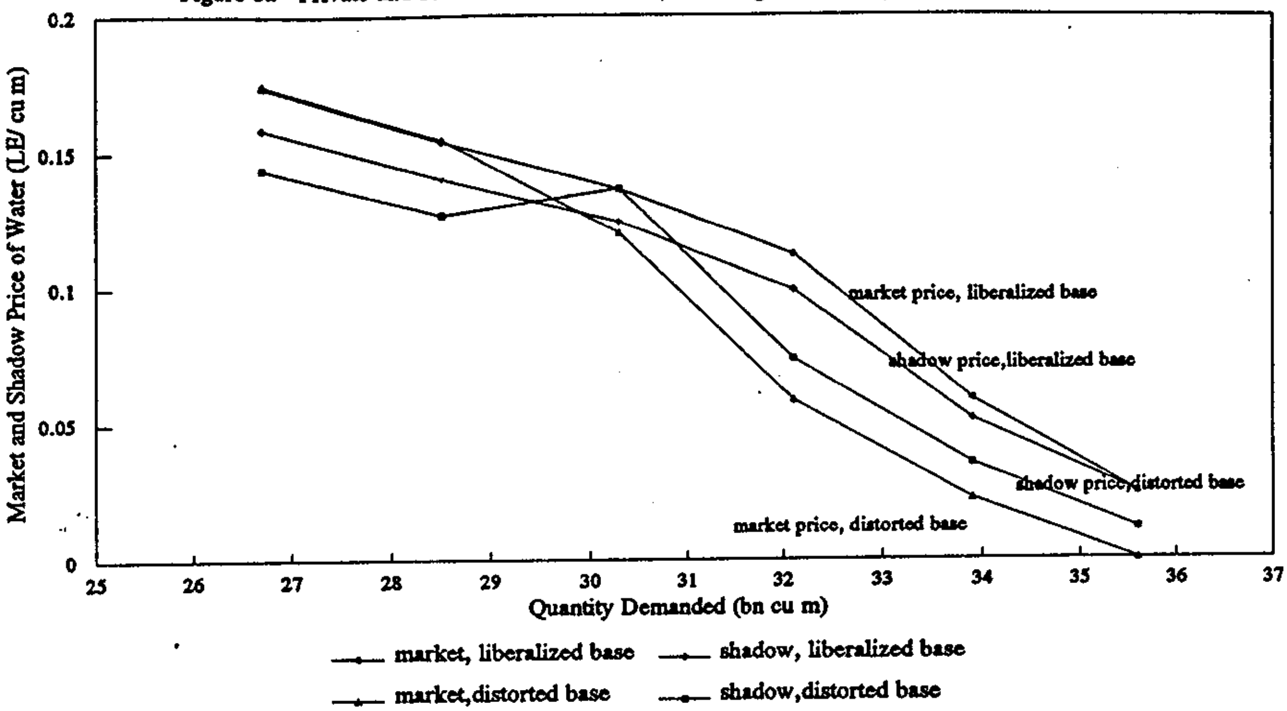


Figure 8b– Private and social demand for water, with no migration, using liberalized and distorted base

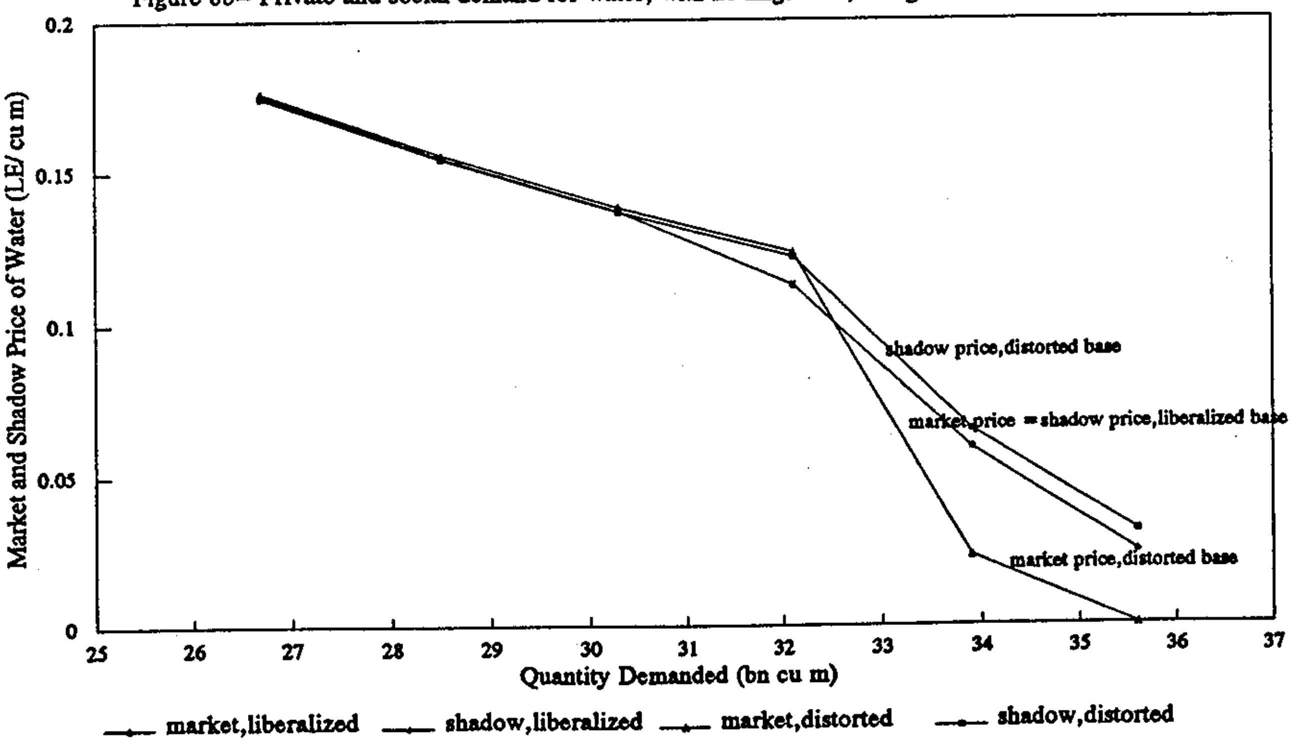


Figure 9. Aggregate land and water use, water reduction scenario, with migration, using distorted and liberalized base

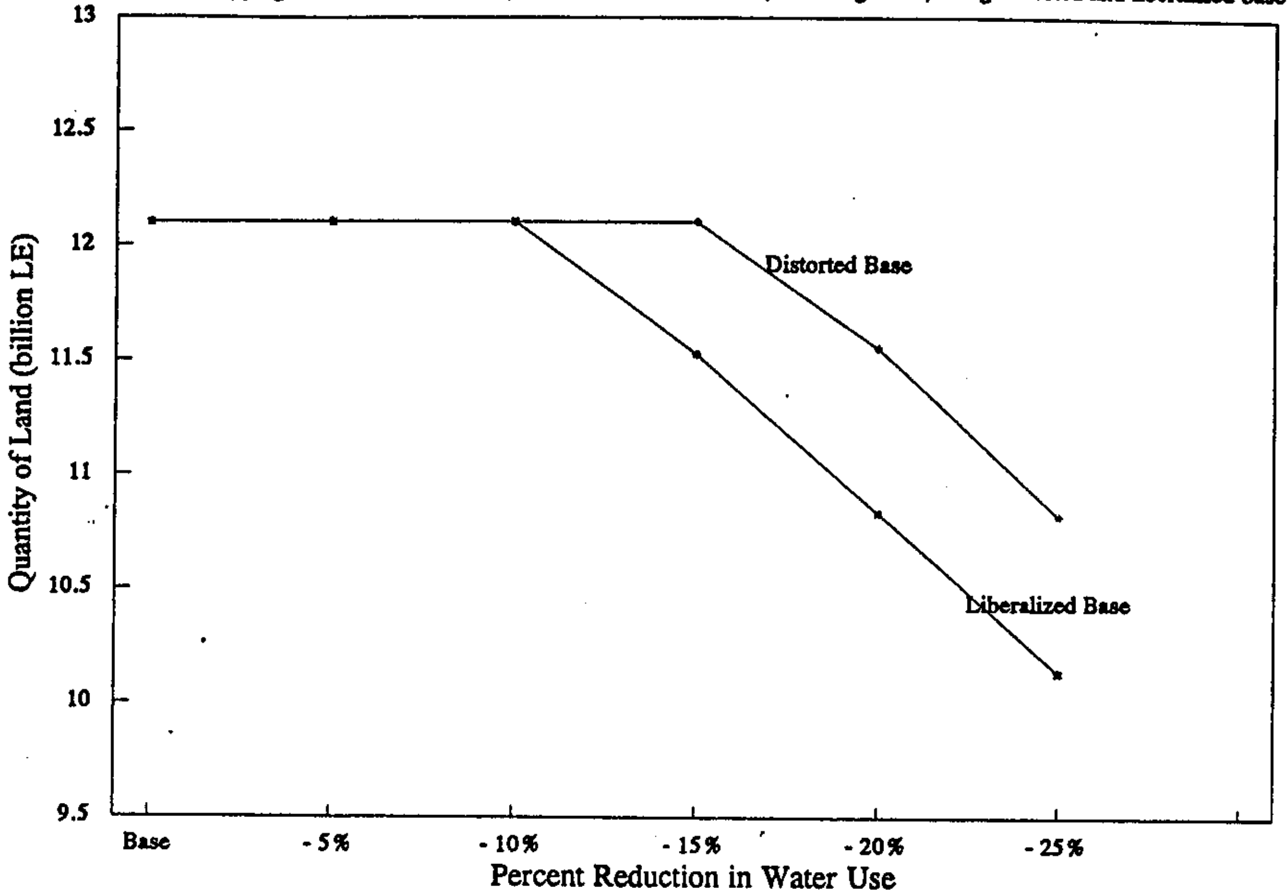


Figure 10a– Sectoral water use from gradual reduction of water supply, with migration, liberalized base

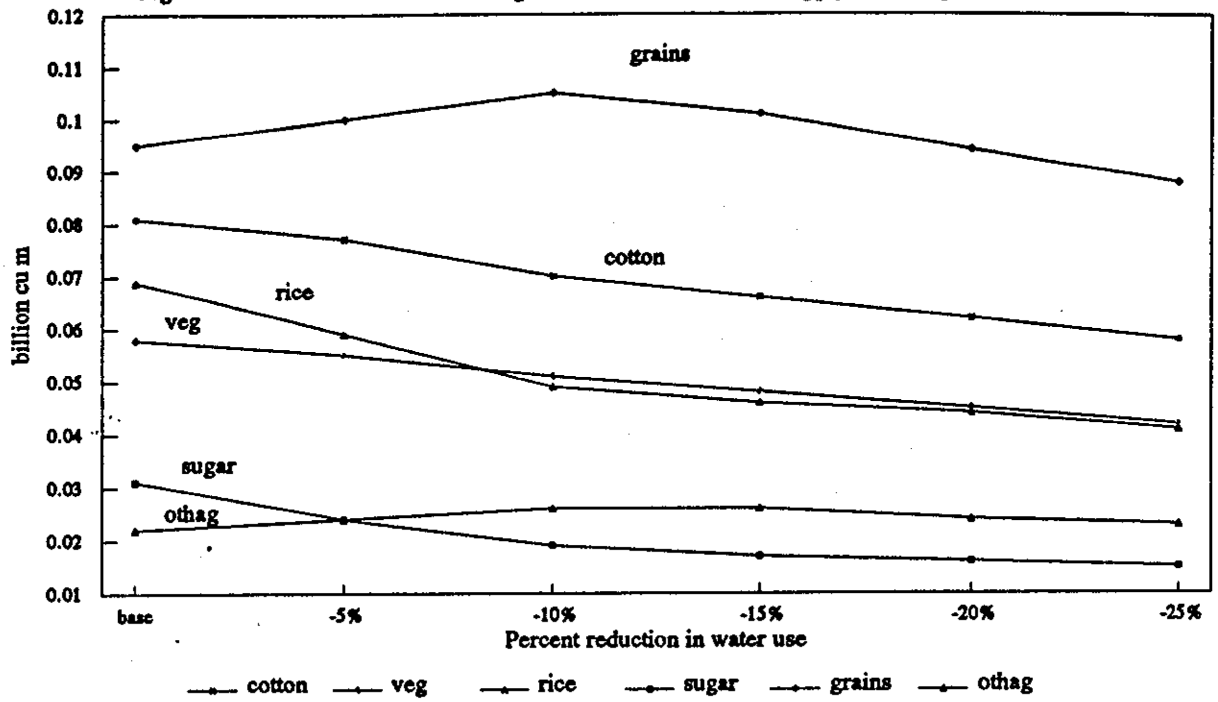


Figure 10b– Sectoral land use from gradual reduction of water supply, with migration, liberalized base

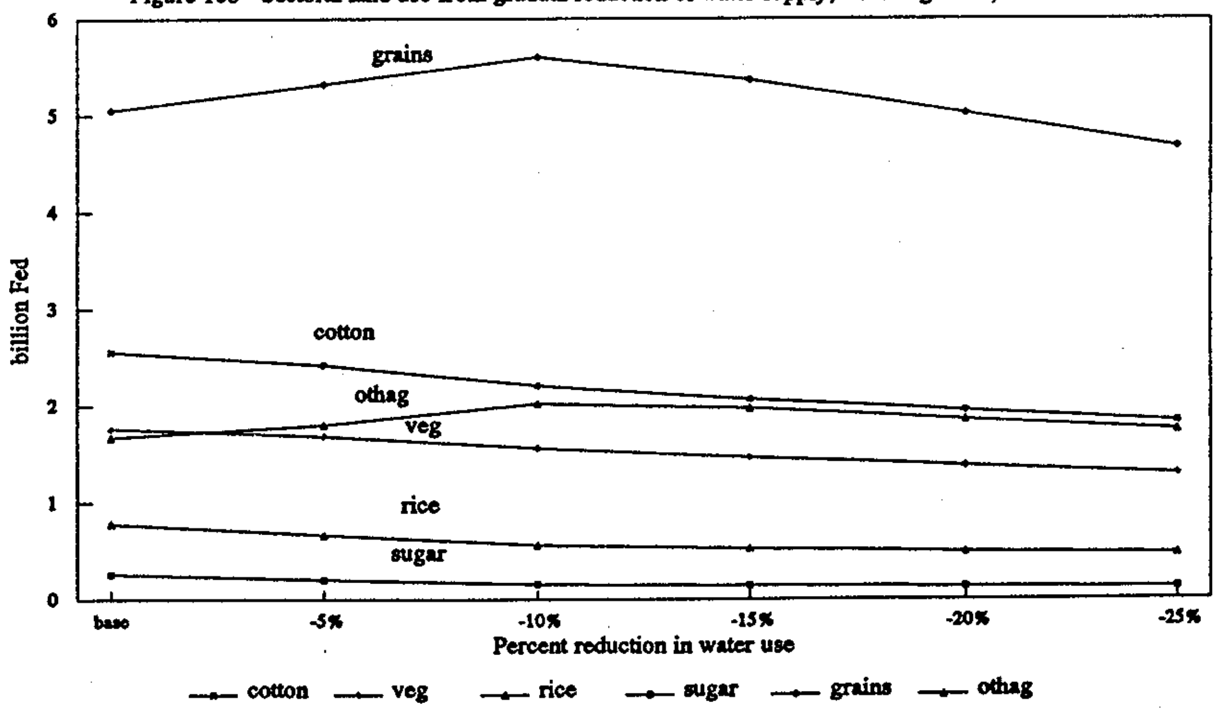


Figure 11a-- Change in output from 25% water supply reduction, with and without migration, using liberalized base

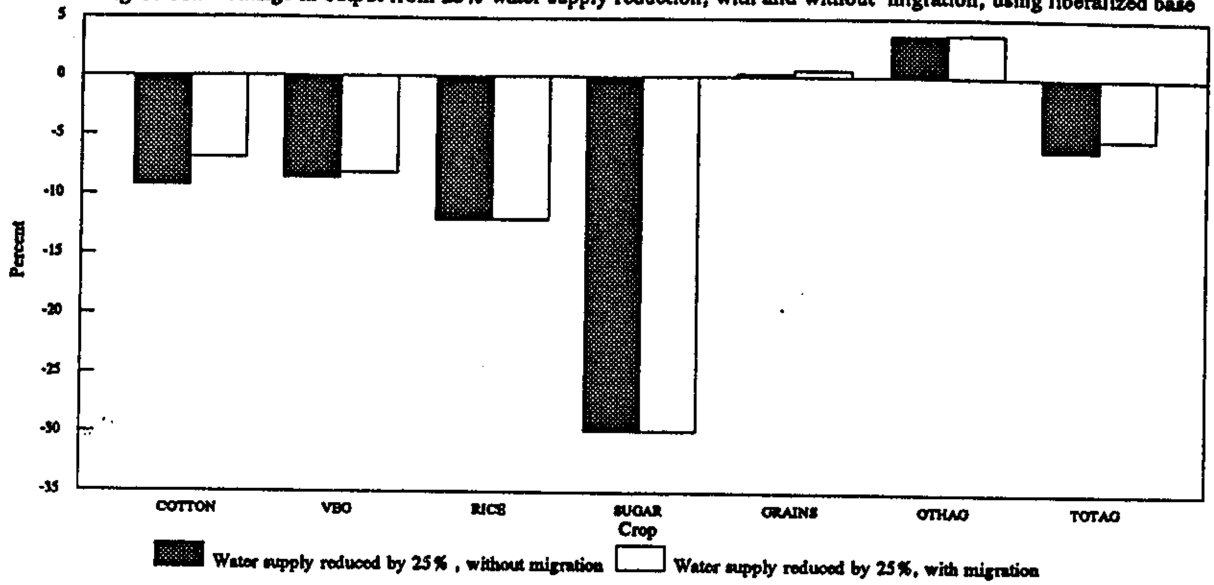


Figure 11b-- Change in output from 25% water supply reduction, with and without migration, using distorted base

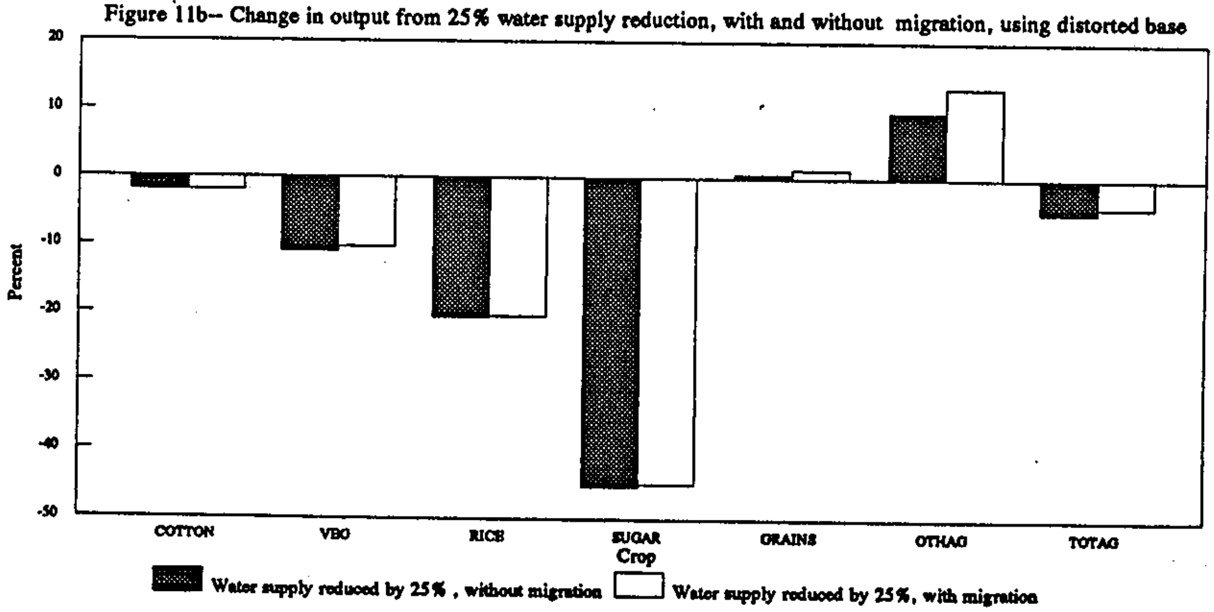
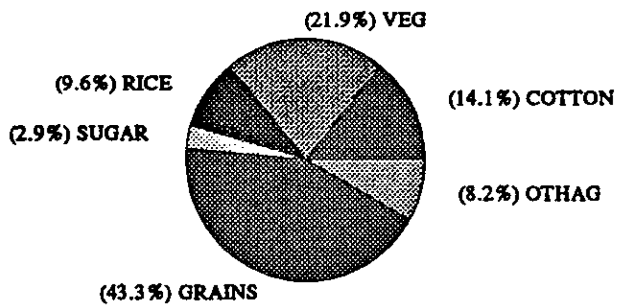
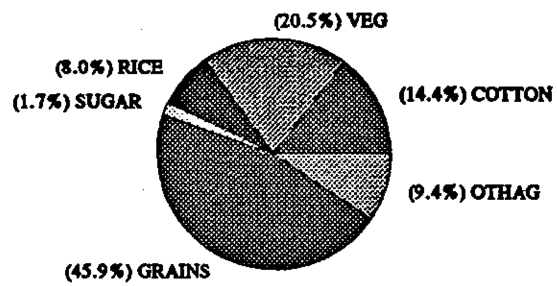


Figure 12a--Structure of production, distorted base, no migration



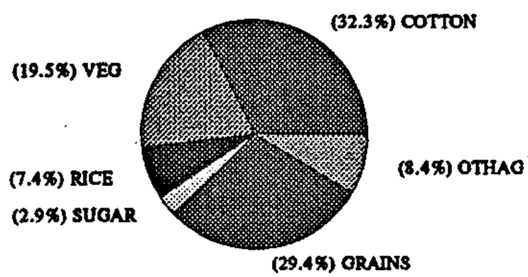
Real total agricultural output in base year prices = 17.14 billion LE

Figure 12b--Structure of production, 25% water reduced
Distorted base



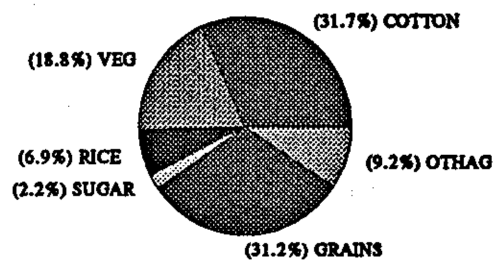
Real total agricultural output in base year prices = 16.38 billion LE

Figure 12c--Structure of production, liberalized base, no migration



Real total agricultural output in base year prices = 17.19 billion LE

Figure 12d--Structure of production, 25% water reduced
Liberalized base



Real total agricultural output in base year prices = 16.31 billion LE the market and shadow prices go to zero. Figure 9 shows the relationship between aggregate water and land use as the supply of water is reduced from either a distorted or liberalized base, under the migration model variant. After a 15 percent reduction in aggregate water supply, land starts to be taken out of production under the policy-distorted base (and after 10 percent reduction under the liberalized base). With a 25 percent reduction in water use, there is a 14 percent reduction in land use. As the land constraint ceases to bind, the value of the land/water aggregate depends solely on the fact that land use carries with it the right to use water — all the value is attributable to water.

Figure 10 indicates the change in water and land use by crop as the aggregate water supply is reduced, and Figure 11 shows the change in production with a 25 percent reduction using liberalized and policy-distorted base. At first, the high water-using sectors, rice and sugar, cut back and grain output increases. Beyond a 10 percent reduction in total water supply, grains become the major adjusting sector. At the end, with a 25 percent reduction in water use, grain production ends up near its initial value, and the major adjustment comes from reductions in sugar, rice, vegetables, and cotton.

Although changes in output seem large for some crops, the structure of agricultural production in Egypt is less affected by reducing water availability than by policy reform. Figure 12 shows the structure of agricultural production with and without policy reform and with a 25 percent reduction in total water use. Reading from left to right indicates the effect of reducing water use, while reading down indicates the effect of policy reform. Starting from a policy-distorted base, Figures 12b and d are not remarkably different from Figures 12a and c. Reading down, however, there are much more dramatic changes in production: Figures 12c and d compared to Figures 12a and b.

4. CONCLUSIONS

There are a number of conclusions that can be drawn from the results of the experiments done with the Egyptian LW-CGE model. First, in 1986–88, the existing tax and subsidy system in Egypt was very distorted and there were significant potential gains from policy reform. Second, the distortions led to a water-conserving structure of agricultural production. Under the 1986–88 policy regime land, not water, was the binding constraint to farmers. Currently, farmers are not charged for water and receive adequate supplies given their cropping pattern. The model results indicate that, given the system of output taxes and subsidies in 1986–88, this situation is essentially an equilibrium — even if Egypt had introduced markets for water, the equilibrium market price would have been close to zero.

Third, elimination of distorting ad valorem taxes and subsidies increases the demand for water and greatly increases the market price of water that would prevail if there were an open water market. The analysis of the demand curve for water also demonstrates this result —water demand appears to be quite inelastic. In this environment, policy reform on the output side would greatly strain the existing system of water distribution, since water would become much more valuable than land to agricultural producers. Similarly, if it is necessary to reduce water consumption or to manage water distribution in an environment in which agriculture is growing but the water supply remains fixed, then the model results indicate that the value of water to farmers will increase greatly. If there is to be successful reform of distorting policies on the output side, or if Egypt must deal with increasing water scarcity, then it is necessary to devise a means to ensure the efficient allocation of water in an environment in which it's potential market value is great. Any administrative allocation system will therefore have to operate in an environment in which there are significant incentives for cheating and corruption.

Finally, the results indicate that, while there are significant welfare gains from policy liberalization, there is also a great deal of structural adjustment that must occur. Reform will lead to major changes in the structure of agricultural production. Removing the bias against agriculture inherent in the 1986–88 policy regime would, however, significantly lessen the pressure for rural-urban migration. While the model results indicate the size of the required adjustment, the comparative-static nature of the analysis prevents any analysis of the time period over which the adjustments might occur, and what might be the costs of adjustment over that period. Considering the size of the required structural changes, adjustment costs will be significant. Further analysis and policy attention are required to manage the adjustment process efficiently in order to achieve the welfare gains with a minimum of economic and social disruption.

APPENDIX 1: THE EGYPT LW-CGE MODEL

Introduction

This appendix presents the equations of the Egypt land/water, LW-CGE model in the format of the software in which the program was written, GAMS. GAMS stands for "General Algebraic Modeling System" and the software is described in Brooke, Kendrick, and Meeraus (1988). For ease of exposition, only the sets, parameters, variables, and equations are presented. Data, parameter intitialization, and table printing code is omitted.

GAMS statements are case insensitive. However, we use a few notation conventions to improve readibility:

(1) variables are all in upper case;
(2) variable names with a suffix 0 represent base-year values and are specified as parameters in the model;
(3) parameters are all in lower case; and
(4) sets are all in lower case.

In the GAMS language:

Parameters are treated as constants in the model and are defined in separate "PARAMETER" statements.
"SUM" is the summation operator, sigma.
"PROD" is the product operator, pi.
"LOG" is the natural logarithm operator.
"$" introduces a conditional "if" statement.
The suffix .FX indicates a fixed variable.
The suffix .L indicates the level or solution value of a variable.
The suffix .LO indicates the lower bound of a variable.
The suffix .UP indicates the upper bound of a variable.
As asterisk (*) in column one indicates a comment. Some alternative treatments are shown commented out.
A subset is denoted by the subset name followed by the name of the larger set in parentheses. In statements, the subset name is used by itself.
A semicolon (;) terminates a GAMS statement.
Items between slashes ("/") are data.

```
*EGYPT 1987 LW-CGE model.
*Water version with subfactors.
*Programmed by Sherman Robinson, Jan-Mar 1994.
*Starts from USDA/ERS GDP CGE Model, Version of April 1990.
*Programmed by: Sherman Robinson, Kenneth Hanson, and Maureen Kilkenny.

*###################### SET DECLARATION #############################

SETS

 i          Sectors of production
                 / cotton       cotton
                   veg          fruits and vegetables
                   rice         rice
                   sugar        sugar cane
                   grains       food and feedgrains
                   othag        other agriculture
                   oil          oil and products
                   ind          industry
                   svc          services
                   elect        electricity
                   cons         construction
                            /
  im(i)     Import sectors
  imn(i)    Non-import sectors
  ie(i)     Export sectors
  ien(i)    Non-export sectors
  ied(i)    Sectors with export demand from rest of world
                 /cotton, veg, rice, sugar, grains, othag /
  iedn(i)   Not ied
 ;
  ALIAS(i,j) ;

* Defined subsets
  iedn(i)      = not ied(i) ;

* Factors and groupings
SETS
 f    FACTORS OF PRODUCTION     /capital
                                 rurlab
                                 urblab
                                 land
                                   /

 ff1(f)  Factors without subfactors
                                /capital
                                 rurlab
                                 urblab/

 ff2(f)  Factors with subfactors
                                /land /

 la(f)   labor categories      /rurlab
                                urblab /

 sff     Subfactors            /fed       land in feddan
                                h2o       water in m 3
                               /

 ;
 ALIAS(la,lb) ;
 ALIAS(iff,f) ;
```

```
SETS
  imigru(la,lb) Labor mobility map  /urblab.rurlab /
  rmig(la)      mobile labor factors
  hh            Households          / urban, rural /
  ins           institutions        / privcrp, pubcrp /
 ;

 ALIAS(hh,hhh) ;


*######################### PARAMETER DECLARATION ######################

 PARAMETERS
 depr(i)         depreciation rates
 sdepr(ins)      shares of depreciation by institution
 dstr(i)         ratio of inventory investment to gross output
 esr(ins)        enterprise savings rate
 etr(ins)        enterprise tax rate
 gles(i)         government consumption shares
 htax(hh)        household tax rate
 itax(i)         indirect tax rates
 kish(i)         shares of investment by sector of destination
 rhsh(hh)        household remittance share
 rhoc(i)         armington function exponent
 rhop(i)         ces production function parameter
 sigmap(i)       ces substitution elasticity
 rhoe(i)         export demand price elasticity
 rhot(i)         cet function exponent
 sstr            social security tax rate
 te(i)           export subsidy rates
 tm(i)           tariff rates on imports
 thsh(hh)        household shares of government transfers
 sfctr(f)        share of factor income distributed to households
 cles(i,hh)      household consumption shares
 imat(i,j)       capital composition matrix
 io(i,j)         input-output coefficients
 sintyh(ins,hh)   household distribution of institutional income
 hhfcty(f,hh)    mapping from factors to households directly
 sinst(f,ins)    mapping from factor income to institutions
 pwm(i)          world market price of imports (in dollars)
 pwse(i)         world price of export substitutes
 ac(i)           armington function shift parameter
 ad(i)           cobb douglas shift parameter
 ad2(i)          ces shift parameter
 alpha(i,f)      factor share parameter cobb douglas function
 alpha2(i,f)     factor share parameter ces function
 at(i)           cet function shift parameter
 delta(i)        armington function share parameter
 econst(i)       export demand constant
 gamma(i)        cet function share parameter
 pwts(i)         price index weights
 pwtc(i)         consumer price index weights
 qd(i)           dummy variable for computing ad(i)
 rmd(i)          ratio of imports to domestic sales
 sumsh           sum of share correction parameter
 sumhhsh(hh)     sum of share for hh cles
 sumimsh(i)      sum of share for imat
 tereal(i)       real export subsidy rate in 1982 dollars
 tmreal(i)       real tariff rate in 1982 dollars
         ;
```

```
*##########################################################################

 VARIABLES

*#################### VARIABLE DECLARATION ###########################

*## PRICE BLOCK
   EXR          exchange rate
   P(i)         price of composite goods
   PD(i)        domestic prices
   PE(i)        domestic price of export
   PINDEX       gdp deflator
   PINDCON      consumer price index
   PK(i)        price of capital goods by sector of destination
   PM(i)        domestic price of imports
   PVA(i)       value added price
   PWE(i)       world price of exports
   PX(i)        average output price

*## PRODUCTION BLOCK
   E(i)         exports                                        (87 bil le)
   M(i)         imports                                        (87 bil le)
   X(i)         composite goods supply                         (87 bil le)
   XD(i)        domestic output                                (87 bil le)
   XXD(i)       domestic sales                                 (87 bil le)

*## FACTOR BLOCK
   FS(f)        factor supply
   SUBFS(sff)   subfactor supply
   FDSC(i,f)    factor demand by sector
   SUBF(i,sff)  subfactor demand
   WF(f)        average factor price
   WFSUB(sff)   subfactor price
   WFDIST(i,f)  factor market distortion variable
   YFCTR(f)     factor income                                  (bil le)
   YFCTRH(f)    Factor income distributed to households

*## MIGRATION BLOCK
   AVWF(iff)       average wage with current weights
   WGDFL(la,lb)    wage differentials
   MIGRU(la)       labor migration flows

*## INCOME AND EXPENDITURE BLOCK
   CD(i)        final demand for private consumption           (87 bil le)
   DEPRECIA     total depreciation expenditure                 (bil le)
   DEPREC(ins)  depreciation charges by institution
   DK(i)        volume of investment by sector of destination (87 bil le)
   DST(i)       inventory investment by sector                 (87 bil le)
   ENTSAV       enterprise savings                             (bil le)
   ENTSAV2(ins)  savings by institution
   ENTTAX       enterprise tax revenue                         (bil le)
   FBOR         net foreign borrowing                          (bil le)
   FSAV         net foreign savings                            (bil le)
   FXDINV       fixed capital investment                       (bil le)
   GD(i)        final demand for government consumption       (87 bil le)
   GDTOT        total volume of government consumption         (87 bil le)
   GENT2(ins)   payments from govt to ent                      (bil le)
   GENT         total payments from govt to ent
   GOVSAV       government savings                             (bil le)
   GR           government revenue                             (bil le)
   HHSAV        total household savings                        (bil le)
   HHT          household transfers                            (bil le)
   ID(i)        final demand for productive investment         (87 bil le)
   INDTAX       indirect tax revenue                           (bil le)
```

```
   INT(i)          intermediates uses                                    (87 bil le)
   INVEST          total investment                                      (bil le)
   MPS(hh)         marginal propensity to save by household type
   NETSUB          export duty revenue                                   (bil le)
   REMIT           net remittances from abroad                           (bil le)
   SAVINGS         total savings                                         (bil le)
   SSTAX           social security tax revenue                           (bil le)
   TARIFF          tariff revenue                                        (bil le)
   TOTHHTAX        household tax revenue                                 (bil le)
   YH(hh)          household income                                      (bil le)
   YINST(ins)      institutional income                                  (bil le)
   YINSTH(ins)     institutional income to households

*## GDP AND WELFARE CALCULATIONS
   RGDP            real gdp                                              (87 bil le)
   GDPVA           value added in market prices gdp                      (bil le)
   WALRAS1         walras law for savings investment
   OBJECT          objective function variable
   YLAND           land income
   TCON            total nominal consumption
      ;

*##########################################################################

 EQUATIONS

*#################### EQUATION DECLARATION ###########################

*## PRICE BLOCK
   PMDEF(i)            definition of domestic import prices
   PEDEF(i)            definition of domestic export prices
   ABSORPTION(i)       value of domestic sales
   SALES(i)            value of domestic output
   ACTP(i)             definition of activity prices
   PKDEF(i)            definition of capital goods price
   WSUBFEQ(i)          factor price definition with subfactors
   PINDEXDEF           definition of general price level
   PINDCONDEF          definition of consumer price index
*## PRODUCTION BLOCK
   ACTIVITY(i)         production function
   PROFITMAX(i,f)      first order conditions for profit maximum
   SUBFEQ(i,sff)       subfactor demand
   INTEQ(i)            total intermediate uses
   CET(i)              cet function
   CET2(i)             domestic sales for nontraded sectors
   ESUPPLY(i)          export supply
   EDEMAND(i)          export demand functions
   ARMINGTON(i)        composite good aggregation function
   ARMINGTON2(i)       composite good agg. For nontraded sectors
   COSTMIN(i)          f.o.c. For cost minimization of composite good
*## INCOME BLOCK
   YFCTREQ(f)          factor income
   YLANDEQ             land income
   YFCTRHEQ(f)         factor income to households
   YINSTEQ             institutional income
   YINSTHEQ(ins)       institutional income to households
   GENTEQ              govt transfers to enterprises
   HHY(hh)             household income
   TARIFFDEF           tariff revenue
   INDTAXDEF           indirect taxes on domestic production
   NETSUBDEF           export subsidies
   TAXSS               social security tax
   ETAX                enterprise tax
   HHTAXDEF            total household taxes collected by govt.
   DEPREQ              depreciation expenditure
```

```
   DEPREQ2(ins)       depreciation by institution
   ESAVE              enterprise savings
   ESAVE2(ins)        savings by institution
   HHSAVEQ            household savings
   GREQ               government revenue
   TOTSAV             total savings
*## EXPENDITURE BLOCK
   CDEQ(i)            private consumption behavior
   GDEQI(i)           govt consumption of commodities
   GRUSE              government savings
   DSteQ(i)           inventory investment
   FIXEDINV           fixed investment net of inventory
   PRODINV(i)         investment by sector of destination
*  IEQ(i)             investment by sector of origin
*## MIGRATION EQUATIONS
   WAGE1(iff)         average wages
   WGEQRU(la,lb)      wage equilibrium
   MIGFLOW(la)        migration equations
   NETMIGRU           net migration constraint
*## MARKET CLEARING
   EQUIL(i)           goods market equilibrium
   FMEQUIL(f)         factor market equilibrium
   SUBFEQUIL(sff)     subfactor market equilibrium
   CAEQ               current account balance (bill dollars)
   WALRAS             savings investment equilibrium
   OBJECTIVE          objective function
   TCONEQ             aggregate consumption

*## GROSS NATIONAL PRODUCT
   GDPY               total value added including indtax
   GDPR               real gdp
        ;


*######################## EQUATION ASSIGNMENT  #######################

*## PRICE BLOCK

 PMDEF(im)..       PM(im)  =E= pwm(im)*EXR*(1 + tm(im)) ;

 PEDEF(ie)..       PE(ie)  =E= PWE(ie)*(1 + te(ie))*EXR ;

 ABSORPTION(i).. P(i)*X(i)    =E= PD(i)*XXD(i) + (PM(i)*M(i))$im(i) ;

 SALES(i)..        PX(i)*XD(i) =E= PD(i)*XXD(i) + (PE(i)*E(i))$ie(i) ;

 ACTP(i)..         PVA(i) =E= PX(i)*(1.0-itax(i)) - SUM(j,io(j,i)*P(j)) ;

 PKDEF(i)..        PK(i)    =E= SUM(J, P(j)*imat(j,i)) ;

 WSUBFEQ(i)..      WF("land")*WFDIST(i,"land") =E=
                     SUM(sff, alphaf(i,sff)*WFSUB(sff)) ;

 PINDEXDEF..       PINDEX  =E= GDPVA/RGDP ;

 PINDCONDEF..      PINDCON =E= PROD(i$pwtc(i), P(i)**pwtc(i)) ;

*## PRODUCTION BLOCK

*Cobb Douglas production function
* ACTIVITY(i)..    XD(i)    =E= AD(i)*PROD(f$alpha(i,f),
*                                FDSC(i,f)**alpha(i,f)) ;
*
* PROFITMAX(i,f)$wfdist0(i,f)..  WF(f)*WFDIST(i,f)*FDSC(i,f) =E=
*                                             XD(i)*PVA(i)*alpha(i,f) ;
```

```
*CES Production Function
 ACTIVITY(i)..          XD(i)  =E= AD2(i)*( SUM(iff$FDSC0(i,iff),
              alpha2(i,iff)*FDSC(i,iff)**(-rhop(i)))   )**(-1/rhop(i)) ;

 PROFITMAX(i,iff)$WFDIST0(i,iff)..  WF(iff)*WFDIST(i,iff)  =E=
                   pva(i)*AD2(i)
                   *( SUM(f$FDSC0(i,f), alpha2(i,f)*FDSC(i,f)
                   **(-rhop(i)))   )**((-1/rhop(i)) - 1)
                   *alpha2(i,iff)*FDSC(i,iff)**(-rhop(i)-1);

 SUBFEQ(i,sff).. SUBF(i,sff)  =E= alphaf(i,sff)*fdsc(i,"land") ;

 INTEQ(i)..        INT(i)   =E= SUM(j, io(i,j)*XD(j));

 CET(ie)..         XD(ie)   =E= at(ie)*(gamma(ie)*E(ie)**RHOT(ie) +
                     (1-gamma(ie))*XXD(ie)**RHOT(ie))**(1/RHOT(ie)) ;

 CET2(ien)..       XD(ien) =E= XXD(ien) ;

 ESUPPLY(ie)..     E(ie)    =E= XXD(ie)*(PE(ie)/PD(ie)*(1 - gamma(ie))
                           /gamma(ie))**(1/(RHOT(ie)-1)) ;

 EDEMAND(ied)..    E(ied)   =E= econst(ied)*((PWE(ied)/pwse(ied))
                                              **(-rhoe(ied))) ;

 ARMINGTON(im)..    X(im)   =E= AC(im)*(delta(im)*M(im)**(-rhoc(im)) +
                    (1 - delta(im))*XXD(im)**(-rhoc(im)))**(-1/rhoc(im)) ;

 ARMINGTON2(imn)..   X(imn)  =E= XXD(imn) ;

 COSTMIN(im)..     M(im)/XXD(im)  =E=  (PD(im)/PM(im)*delta(im)/
                                    (1 - delta(im)))**(1/(1 + rhoc(im))) ;

*## INCOME BLOCK

 YFCTREQ(f)..      YFCTR(f)  =E= SUM(i, WF(f)*WFDIST(i,f)*FDSC(i,f));

 YLANDEQ..         YLAND     =E= SUM((i,sff), wfsub0(sff)*SUBF(i,sff)) ;

 YFCTRHEQ(f)..     YFCTRH(f)  =E= sfctr(f)*yfctr(f) ;

 YINSTEQ(ins).. YINST(ins)   =E=   SUM(f, sinst(f,ins)*(YFCTR(f) - YFCTRH(f)))
                                 + GENT2(ins) ;

 YINSTHEQ(ins).. YINSTH(ins) =E= YINST(ins) - ENTSAV2(ins)
                           - ETR(ins)*(YINST(ins) - DEPREC(ins)) ;

 GENTEQ..          GENT     =E= SUM(ins, GENT2(ins)) ;

 HHY(hh)..         YH(hh)  =E= SUM(ins, SINTYH(ins,hh)*YINSTH(ins))
                            + SUM(f, hhfcty(f,hh)*yfctrh(f))
                            + REMIT*RHSH(hh)*EXR + HHT*thsh(hh) ;

 TARIFFDEF..       TARIFF =E= SUM(im, tm(im)*M(im)*pwm(im))*EXR ;

 INDTAXDEF..       INDTAX =E= SUM(i, itax(i)*PX(i)*XD(i)) ;

 NETSUBDEF..       NETSUB =E= SUM(ie, te(ie)*E(ie)*PWE(ie))*EXR ;

 TAXSS..           SSTAX   =E= SSTR*YFCTR("rurlab")+sstr*YFCTR("urblab") ;

 ETAX..            ENTTAX =E= SUM(ins, ETR(ins)*(YINST(ins) - DEPREC(ins))) ;

 HHTAXDEF..        TOTHHTAX =E= SUM(hh, htax(hh)*YH(hh)) ;
```

```
DEPREQ..          DEPRECIA =E= SUM(i, DEPR(i)*PK(i)*FDSC(I,"capital")) ;

DEPREQ2(ins)..    DEPREC(ins) =E=  sdepr(ins)*deprecia ;

ESAVE2(ins)..     ENTSAV2(ins) =E=  esr(ins)*(YINST(ins)
                     - etr(ins)*(YINST(ins) - DEPREC(ins)) - DEPREC(ins))
                     + DEPREC(ins)  ;

ESAVE..          ENTSAV  =E=  SUM(ins, ENTSAV2(ins)) ;

HHSAVEQ..        HHSAV  =E= SUM(hh, MPS(hh)*YH(hh)*(1 - htax(hh))) ;

GREQ..           GR      =E= TARIFF - NETSUB + INDTAX +TOTHHTAX +
                                         SSTAX + ENTTAX + FBOR*EXR ;

TOTSAV..     SAVINGS =E= HHSAV + GOVSAV + DEPRECIA + FSAV*EXR + ENTSAV ;

*## EXPENDITURE BLOCK

CDEQ(i)..       P(i)*CD(i) =E= SUM(hh, cles(i,hh)*(1-MPS(hh))*YH(hh)
                                         *(1-htax(hh))) ;

GDEQI(i)..      GD(i)   =E= gles(i)*GDTOT ;

GRUSE..         GR      =E= SUM(i, P(i)*GD(i)) + GOVSAV + GENT + HHT ;

DSTEQ(i)..      DST(i) =E= dstr(i)*XD(i) ;

FIXEDINV..      FXDINV =E= INVEST - SUM(i, DST(i)*P(i)) ;

PRODINV(i)..    PK(i)*DK(i) =E= kish(i)*FXDINV ;

* IEQ(i)..      ID(i)   =E= SUM(J, imat(i,j)*DK(j));

*## Migration equations

WAGE1(iff)..    AVWF(iff) =E= SUM(i, wfdist(i,iff)*wf(iff)
                                *fdsc(i,iff))/SUM(j, fdsc(j,iff)) ;

wgeqru(la,lb)$imigru(la,lb)..  AVWF(la) =E=  WGDFL(la,lb)*AVWF(lb) ;

MIGFLOW(la)..  FS(la) =E= FS0(la) + MIGRU(la) ;

NETMIGRU..      SUM(la, MIGRU(la)) =E=  0 ;


*## MARKET CLEARING

EQUIL(i)..      X(i)    =E= INT(i) + CD(i) + GD(i) + ID(i) + DST(i) ;

FMEQUIL(f)..    SUM(i, FDSC(i,f)) =E= FS(f) ;

SUBFEQUIL(sff).. SUM(i, SUBF(i,sff)) =L= SUBFS(sff) ;
*SUBFEQUIL(sff).. SUM(i, SUBF(i,sff)) =E= SUBFS(sff) ;

CAEQ..          SUM(im, pwm(im)*M(im)) =E= SUM(ie, PWE(ie)*E(ie))
                                 +  FSAV + REMIT + FBOR ;

WALRAS..        SAVINGS =E= INVEST + walras1 ;
```

```
*## GROSS NATIONAL PRODUCT

 GDPY..       GDPVA =E= SUM(i,PVA(i)*XD(i)) + INDTAX + TARIFF - NETSUB ;

 GDPR..       RGDP =E= SUM(i,CD(i) + DST(i) + ID(i) + GD(i))
                  + SUM(ie,(1.0 - teREAL(ie)) * E(ie) )
                  - SUM(im,(1.0 - tmREAL(im)) * M(im) ) ;

 OBJECTIVE..   OBJECT  =E=  WALRAS1*WALRAS1 ;

 TCONEQ..      TCON    =E= SUM(i, P(i)*CD(i)) ;


*########################### MODEL CLOSURE ##############################

*## FOREIGN EXCHANGE MARKET CLOSURE
* In this version, the balance of trade (current account balance) is
* fixed exogenously and the exchange rate is the equilibrating variable.

*   EXR.FX      = EXR.L ;
    FSAV.FX     = FSAV.L ;
    REMIT.FX    = REMIT.L ;
    FBOR.FX     = FBOR.L ;

*## INVESTMENT-SAVINGS CLOSURE
* This version specifies Johansen Closure.  Real investment demand
* by sector is fixed id.fx(i).  We then drop the aggregate investment
* equation, ieq(i), and the urban savings rate adjusts.

*    MPS.FX(hh)        = MPS.L(hh) ;
     MPS.FX("rural")  = mps.l("rural") ;
     ID.FX(i)         = ID.L(i) ;
*    INVEST.FX        = INVEST.L ;

*## EXOGENOUS GOVT EXPENDITURE
*## AND GOVT CLOSURE RULE
* Real government spending (GDTOT) is fixed exogenously.  The government
* deficit (GOVSAV) is determined residually.

    GDTOT.FX         = GDTOT.L ;
    GENT2.FX(ins)    = GENT2.L(ins) ;
    HHT.FX           = HHT.L ;
*   GOVSAV.FX        = GOVSAV.L ;

*## FACTOR MARKET CLOSURE
* In this version, all factors, including capital, are mobile.
* Commented equations allow a version with fixed wage for labor.
* The model then determines aggregate employment.

    FS.FX(f)         = FS.L(f) ;
    WFDIST.FX(i,f)   = wfdist0(i,f) ;

*SR Fix wage and cut loose aggregate employment
*   WF.FX("rurlab") = WF.L("rurlab") ;
*   WF.FX("urblab") = WF.L("urblab") ;
*   FS.LO("rurlab") = -inf ;
*   FS.LO("urblab") = -inf ;
*   FS.UP("rurlab") = +inf ;
*   FS.UP("urblab") = +inf ;

*SR fix sectoral capital stocks
*    FDSC.FX(i,"capital")    =  FDSC.L(i,"capital") ;
*    WFDIST.LO(i,"capital") = 0 ;
*    WFDIST.UP(i,"capital") = +inf ;
```

```
*   WF.FX("capital")        = 1.0 ;
*   FS.LO("capital")        = 0 ;
*   FS.UP("capital")        = +inf ;

*SR Subfactor market closure
*disconnect land sector at aggregate level
   WFDIST.LO(i,ff2)        = 0 ;
   WFDIST.UP(i,ff2)        = +inf ;
   WF.FX(ff2)              = WF.L(ff2) ;
   FS.LO(ff2)              = -inf ;
   FS.UP(ff2)              = +inf ;

*  WFSUB.FX("h2o")         = 0.0 ;
*  WFSUB.FX("fed")         = 1.0 ;

   SUBFS.FX(sff)           = SUBFS.L(sff) ;
*  SUBFS.FX("fed")         = SUBFS.L("fed") ;
*  SUBFS.FX("h2o")         = subfs.l("h2o") ;

*SR turn model into standard land constrained model
*  WFSUB.FX("h2o")         = 0.0 ;
*  subfs.lo("h2o")         = -inf ;
*  subfs.up("h2o")         = +inf ;

*  WFSUB.FX("fed")         = 1.10 ;
*  wfsub.lo("fed")         = 0.0 ;
*  wfsub.lo(sff)           = 0.0 ;

*## MIGRATION CLOSURE

* Turn migration of factors on/off:
* To turn off labor migrations: MIGRU fixed, free up WGDFL

 migru.fx(la)                   = 0.0 ;
 WGDFL.LO(la,lb)$imigru(la,lb) = -inf ;
 WGDFL.UP(la,lb)$imigru(la,lb) = +inf ;

*  To turn on across category labor migrations: release MIGRU, fix WGDFL
*  Also free up FS of migrating categories.

* migru.lo(la)$rmig(la)   = -inf ;
* migru.up(la)$rmig(la)   = +inf ;
* FS.LO(la)$rmig(la)      = 0.0  ;
* FS.UP(la)$rmig(la)      = +inf ;
* WGDFL.FX(la,lb)$imigru(la,lb) = WGDFL.L(la,lb) ;

*## NUMERAIRE PRICE INDEX

*  PINDEX.FX     = PINDEX.L ;
   PINDCON.FX    = PINDCON.L ;

*#### ADDITIONAL RESTRICTIONS CORRESPONDING TO EQUATIONS
*# PMDEF, PEDEF, EDEMAND, ESUPPLY, COSTMIN, AND PROFITMAX
*# FOR NON-TRADED SECTORS AND SECTORS WITH FIXED WORLD EXPORT PRICES

 PM.FX(imn)     = PM0(imn) ;
 PE.FX(ien)     = PE0(ien) ;
 PWE.FX(iedn) = PWE.L(iedn) ;
 E.FX(ien)      = 0;
 M.FX(imn)      = 0;
 FDSC.FX(i,f)$(wfdist0(i,f) EQ 0) = 0 ;

*########################### END OF MODEL ############################
```

APPENDIX 2: DATA FOR THE EGYPTIAN LW-CGE MODEL

The data for the Egyptian LW-CGE model consists of the Social Accounting Matrix (SAM) and other data such as water-use coefficients and trade (Table 3 in the text). We started from a 1987 SAM developed by Lofgren (1993d) who, in turn, used the CAPMAS 1987/1986 SAM. Lofgren's SAM includes accounts for six activities and six commodities (one for each of the six production sectors), six institutions (urban and rural households, private and public companies, government, and the rest of the world), three factors (labor, capital, and land), and a separate tax and tariff account.

Activity accounts show the producing sectors. Revenues come from export subsidies, exports, and sales to the domestic market, while payments are for factors, intermediate inputs, and net indirect taxes.

We expanded Lofgren's SAM by disaggregating the agricultural sector into six subsectors and labor into rural and urban. Disaggregation was based on several criteria: cotton is an important export crop; grains represent staple food; and, for their high water requirements, sugar, rice, and fruits and vegetables. For each crop, additional data required and their sources are: value added and trade data (exports and imports) [World Bank (1993)].

Data on value added for each crop were initially obtained from the World Bank (1993) and then adjusted to match the total for the agricultural sector in Lofgren's SAM. Agricultural taxes and subsidies are included in value added at market prices. The data on tariffs, and taxes and subsidies for the agricultural sectors come from Wenner, M. et al. (forthcoming), who present data on producer and consumer subsidy equivalents (PSEs and CSEs) for Egypt. Table A2.1 shows the database for the 1986-88 tariffs and sectoral subsidies/taxes used in the model and Table 3 in the text.

The share of value added attributable to land was estimated by assuming a uniform land rent, and then multiplying by cropped area for each sector. The remaining sectoral value added was divided evenly between capital and labor. The value of gross output for each crop was estimated by assuming that all crops had the same ratio of intermediate input demand to gross output as did total agriculture in Lofgren's SAM. In effect, we assume that all crops have the same intermediate input technology, and that there are no intersectoral flows among the agricultural sectors.

Intermediate demand for agriculture by the non-agricultural sectors was disaggregated assuming the same shares as agricultural gross output. Final demand components for each crop (consumption by households, government, and investment) were reconciled to the aggregate data in Lofgren's SAM. We assumed that rural and urban households have the same average expenditure shares. In the model, we aggregate them for the purpose of computing welfare measures. Table A2.2 shows the aggregate SAM in the base solution.

Table A2-2: Aggregate SAM, Egypt 1987 (Billion LE)

			Expenditures:						
Receipts:	Commodity	Activity	Value added	Enterprises	Households	Govt.	Capital acct	World	Total
Commodity		27.8		0.0	25.9	8.4	11.7		73.8
Activity	63.2					-0.3		6.0	68.8
Value added		42.6							42.6
Enterprises			12.0	0.0	0.0	-1.3	0.0	0.0	10.7
Households			30.6	3.1	0.0	0.0	0.0	3.3	37.1
Government	0.8	-1.6	0.0	2.3	5.0	0.0	0.0	0.4	7.0
Capital account				5.3	6.2	0.2	0.0	0.0	11.7
World	9.7			0.0	0.0	0.0	0.0	0.0	9.8
Total	73.8	68.8	42.6	10.7	37.1	7.0	11.7	9.8	

Notes: Cells without entries indicate no transaction possible.

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