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TIGER OR TURTLE? EXPLORING ALTERNATIVE FUTURES FOR EGYPT TO 2020

Hans Löfgren
Sherman Robinson
David Nygaard

Trade and Macroeconomics Division

International Food Policy Research Institute
1200 Seventeenth Street, N.W.
Washington, D.C. 20036-3006 U.S.A.

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Hans Löfgren
Sherman Robinson
David Nygaard

Trade and Macroeconomics Division
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Washington, D.C.

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ABSTRACT

A dynamic computable general equilibrium (CGE) model is used to explore alternative scenarios for 1990-2020 in areas critical for Egypt's economy — productivity growth, investment, foreign trade, and water. The model is formulated as a mixed-complementarity problem, has a detailed treatment of agriculture, assumes competitive markets and determines efficient water allocation. A "Turtle" scenario extrapolates Egypt's recent poor productivity and low investment, while a "Tiger" scenario assumes East Asian performance. For the Turtle scenario, incomes are stagnant and a crisis emerges in the labor market. With rapid growth in export demand, investment and productivity, the "Tiger" scenario generates almost tripled per-capita incomes and full employment. Sensitivity analysis for the Tiger scenario suggests that growth in export demand is important, while tariff removal with no other policy changes has little effect. Increasing water scarcity hurts agriculture and labor absorption, but has little effect on overall growth.

NON-TECHNICAL SUMMARY

Over the last few years, Egypt's government has managed to stabilize the macro economy. Now, the key challenges facing economic policymakers are to raise real incomes and reduce unemployment given continued macro stability. In this paper, a simulation model is used to explore the impact of alternative scenarios for the period 1990-2020 in areas critical for long-run economic performance—productivity growth, investment, foreign trade, and agricultural water scarcity. The model belongs to the class of dynamic computable general equilibrium (CGE) models and has a detailed treatment of the agricultural sector. It is assumed that Egypt's economy will be market-oriented and competitive; that there will be mechanisms in place for achieving an efficient allocation of water in agriculture; and that growth will occur in an environment of general macroeconomic balance.

We consider two broad scenarios: the "Turtle," which extrapolates on the basis of the productivity growth and investment levels characteristic of Egypt's recent past; and the "Tiger," which combines key aspects of successful East Asian economic performance with Egyptian resource constraints and production structure. The results for the Turtle scenario are grim. Per-capita income remains roughly the same in 2020 as today. As the country's labor force grows dramatically, the labor market moves toward a crisis, with some unsustainable combination of increasing unemployment and falling real wages. On the other hand, the "Tiger" scenarios, which assume that Egypt achieves rates of investment and productivity growth typical of South Korea and other high-performance East Asian economies, are more encouraging. When combined with rapid growth in export demand, per-capita household income almost triples, while full employment is also achieved.

Sensitivity analysis of the results for the Tiger scenario suggests that export-demand growth and balanced rapid productivity growth (not excluding agriculture) are of crucial importance. While having a positive effect, the removal of distorting import tariffs alone is of minor importance. Increasing water scarcity has a strong negative impact on agricultural performance and labor absorption without, however, significantly reducing growth in aggregate output and income. The unemployment rate is the aggregate indicator that is most sensitive to changes in economic performance, assuming downward rigidity of real wages.

The broader policy implications from this analysis are clear. Egypt should attach top priority to measures that promise to raise balanced long-run, productivity growth (covering both agriculture and other sectors); encourage high investment rates; and seek foreign trade agreements that give access to export markets while lowering import tariffs in return. The gains from increased exports far outweigh the costs of structural adjustments required from opening domestic markets. In searching for a successful Egyptian development strategy, it is potentially fruitful to learn from South Korea and other successful East Asian economies.

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1. Introduction

In the 1980s and early 1990s, the Egyptian economy suffered from slow growth in both GDP and productivity, declining real wages, growing unemployment, and falling household incomes. This discouraging performance was combined with chronic macroeconomic imbalances manifested in large budget deficits and high inflation rates. The simultaneous occurrence of a foreign exchange crisis and high levels of food imports in the late 1980s suggested that the country's food security was at risk. Over the last couple of years, the situation has improved in important respects, primarily as a result of a program for macroeconomic stabilization: the current account is in surplus, inflation has declined, and the budget deficit has been brought under control. However, economywide growth is still low and incomes are stagnant; Egypt has yet to emerge as a Middle East tiger. As Egypt approaches the turn of the millennium, the key challenges facing economic policymakers include raising real incomes and reducing unemployment given manageable internal and external macro imbalances.

Egypt's success in meeting these challenges will clearly depend on a wide range of factors. This paper is focused on three critical areas —productivity growth, investment, foreign trade, and agricultural water scarcity. In order to simulate the effects of alternative scenarios over the period 1990 to 2020, a dynamic computable general equilibrium (CGE) model of the Egyptian economy was developed. The different scenarios were defined drawing on Egyptian and South Korean data, the latter proxy for successful East Asian economies that provides some indication of potential achievement. Section 2 presents the model structure and the data base. In Section 3, we define the alternative scenarios and analyze the results. Section 4 wraps up the paper with a brief discussion of the main findings.

2. The CGE Model: Structure and Data Sources

Our dynamic CGE model of Egypt, called AGRO-CGE, starts from the static Egyptian Land-Water (ELW) model of Robinson and Gehlhar (1995). These models are in the tradition of trade-focused CGE models of developing countries described in Dervis, de Melo, and Robinson (1982). Both the ELW and AGRO-CGE models draw on earlier models of Egypt, including Löfgren (1995a; 1995b).[1] Among the distinguishing features of the ELW model is an activity-analysis representation of agricultural resource (water and land) technology, including inequality supply-demand constraints. Compared to earlier CGE models of Egypt, the representation of the agricultural sector in the ELW model is relatively detailed.[2]

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[1]For surveys of earlier CGE models of Egypt, see El-Laithy (1994) and Löfgren (1994b).

[2]Dethier (1985) is an early agriculture-focused CGE model of Egypt. Hazell *et al.* (1995) use a detailed, partial-equilibrium, programming model of the Egyptian agricultural sector, extended in Löfgren (1995b) for analysis of water policy. Löfgren (1995a) is a CGE model

The AGRO-CGE model extends the ELW model in a number of ways: (1) the data base is now updated from 1986/87 to 1989/90 and disaggregated to match the detailed treatment of the agricultural sector; (2) the treatment of the agricultural sector has been disaggregated to capture seasonality in land use and links between crop and livestock activities; and (3) the model is now dynamic (using a multi-period recursive formulation). Conceptually, the model can be divided into two modules: a static, within-period, module —the core, one-period CGE model— and a dynamic, between-period, module where parameters and exogenous variables of the core CGE model are updated over time. Appendix 1 presents a simplified version of the equations of the static module, with a focus on the activity-analysis features of the model. The discussion here uses no equations.

The Static Module

Table 1 shows the disaggregation of factors, institutions, and activities in the model. The treatment of institutions is quite aggregate. Among the factors, labor and capital are used by all sectors, whiles water, summer-land, and winter-land are used only by agricultural crop activities. Given the long-run nature of the analysis, it is assumed that all factors are sectorally mobile. For capital, the model solves endogenously for the intersectoral allocation that equates the rental rate across sectors and fully employs the aggregate capital stock. In the labor market, however, we allow for unemployment. The labor supply function is assumed to be infinitely elastic at the 1990 real wage until aggregate employment reaches 95% of the labor force (a 5% unemployment rate), at which point the supply curve becomes vertical. For water and the two land types, a similar dual regime is specified. If there is excess supply, the price is zero. When the resource is scarce, a flexible price adjusts to clear the market.[3] Like capital rent, the water price is uniform across all sectors. However, for land and labor, the price (the rent or the wage) is differentiated across the demanding sectors on the basis of fixed ratios (calculated from base-year data). This is a reflection of real-world phenomena that are not modeled explicitly. Proportional variations in each of these differentiated sectoral prices clear the markets when the relevant demand-supply balances are binding.

The model includes 22 activities and 22 commodities, with 13 agricultural sectors in both. This relatively fine disaggregation of agricultural commodities and activities is unique to CGE models of Egypt. The crop activities are differentiated according to period of land occupation into winter crops, summer crops, and perennial crops. With a few important exceptions, there is a one-to-one mapping between activities and commodities. The exceptions are the two berseem (clover) activities, which produce the same commodity (berseem), and a crop fodder commodity which is

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adapted to the structure of Egypt's economy. The representation of agriculture in the AGRO-CGE model is in the tradition of Hazell *et al.*, although less detailed.

[3]Compared to labor, the difference is that, for these agriculture-specific resources, the supply curve is horizontal at a price of zero whenever demand is less than the fixed quantity supplied.

Table 1. Disaggregation of factors, institutions, and activities

Set	Elements
Institutions	1. Households 2. Enterprises 3. Government 4. Rest of the world
Factors of production	1. Capital 2. Labor 3. Water 4. Summer-land 5. Winter-land
Activities (22 sectors)	
Crop Agriculture (12)	Winter crops Short Berseem, Long Berseem, Wheat, Winter Vegetables, Other Winter Crops Summer crops Cotton, Maize, Rice, Summer Vegetables, Other Summer Crops Perennial crops Fruit, Sugarcane
Other activities (10)	Livestock, Oil (Crude Oil and Natural Gas), Food Processing, Cotton Ginning, Textiles, Other Industry, Electricity, Construction, Government Labor Services, Other Services

also the second output (byproduct) of five crop activities: maize, rice, wheat, other summer crops, and other winter crops. Among the commodities, all except berseem, (raw) cotton, crop fodder, and government labor services have both exports and imports.

The production technologies are summarized in Figure 1. Producers are assumed to maximize profits given their technology, specified by a nested CES value-added function, and fixed (Leontief) intermediate input coefficients. The arguments of the value-added functions are labor, capital and, for the crop sectors, a land/water aggregate. The latter is made up of land and water in fixed proportions. Thus, for crops, substitutability is possible between land, capital and the land/water aggregate on the level of the value-added functions; there is no substitutability between land and water. Two major agronomic area constraints are captured: the area of short berseem is constrained to equal the cotton area, and the cotton area is limited to one third of the land not covered by perennial crops. For the oil activity (crude oil and natural gas), it would be erroneous to assume that output levels and factor use can vary in response to profitability

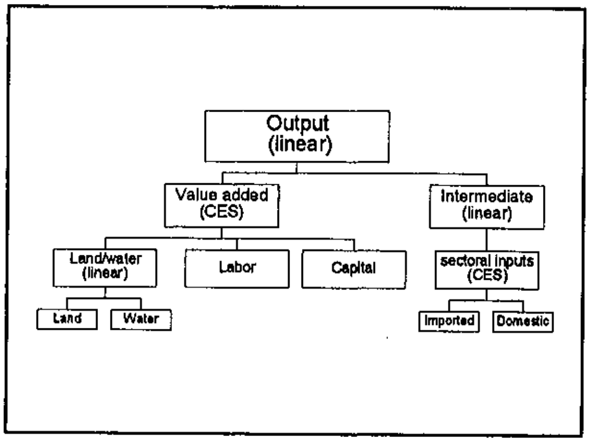

Figure 1: Sectoral Production Technology

considerations in a manner which parallels other sectors. Instead, the quantities of output and factor use for the oil activity are fixed at the 1990 level. In the absence of a more detailed treatment of this activity —its behavioral rules and sustainable productive capacity (most importantly determined by the levels of petroleum and gas reserves)— such an assumption is an appropriate simplification of a more complex reality. Finally, the output of the activity for government labor services is in effect fixed —the government, the sole demander, demands a fixed quantity of the non-traded commodity produced by this activity.

There is one exception to the assumption of fixed intermediate input coefficients: the intermediate (feed) input coefficients of the livestock activity are flexible in the context of livestock producer minimization of feed costs subject to a limited degree of substitutability between different feeds (given by a CES function) and a fixed *aggregate* feed requirement per unit of the livestock activity. The livestock sector is treated differently given the crucial importance of links between crop and livestock activities in Egypt's agriculture, as crop activities supply the livestock activity with the bulk of its intermediate feed inputs.

Domestic factor incomes are split among the domestic institutions (government, enterprises, and households) in fixed shares. The fact that, if water is scarce, its income (like land incomes) accrues to the household, is compatible with the assumption that proprietary rights to water have been assigned to the current users.[4] In addition to factor incomes, government revenue consists of transfers from the rest of the world (fixed in foreign currency) and taxes —direct taxes from households and enterprises, indirect taxes from domestic activities, and import tariffs. All taxes are *ad valorem*. Transfers from the government and aggregate government consumption are fixed shares of nominal GDP. After having paid for a fixed quantity of labor, the government consumes remaining commodities in fixed value shares. Enterprise income (from factors and government transfers) is distributed to households after subtracting taxes, savings, and transfers to the rest of the world (fixed in foreign currency). In addition to factor income and payments from enterprises, households receive transfers (labor remittances) from the rest of the world (fixed in foreign currency). Total household income is used to pay taxes, save (according to an exogenous saving propensity), and consume. Sectoral consumption demand is determined by a linear expenditure system, expressed in per-capita form.

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[4]For a survey of issues related to water markets in LDCs, see Rosegrant and Binswanger (1994).

The rest of the world supplies imports and demands exports. Import prices are exogenous in foreign currency (an infinite price-elasticity of supply). Exports are demanded according to constant-elasticity demand curves, the price-elasticities of which are high but less than infinite. The treatment of oil exports deviates from this pattern: Egypt, being a small supplier of this highly homogeneous commodity, is facing an infinitely elastic demand at the exogenous world price. The Armington assumption is used to model the choice between imports and domestic output, which are assumed to be imperfect substitutes. More specifically, to the extent that a commodity is imported, all domestic demands —household and government consumption, investment demand, and intermediate demands— are for the same composite commodity, with the mix between imports and domestic output determined by the assumption that domestic demanders minimize cost subject to imperfect substitutability, captured by a CES aggregation function. Similarly, the allocation of domestic output between exports and domestic sales is determined on the assumption that domestic producers maximize profits subject to imperfect transformability between these two alternatives, expressed by a constant-elasticity-of-transformation (CET) function. These assumptions —imperfect substitutability and transformability — grant the domestic price system a certain degree of independence from international prices and dampen export and import responses to changes in the producer environment. Domestic prices of domestic outputs and composite commodities are all flexible, performing the task of clearing relevant markets in a competitive setting where both suppliers and demanders are price-takers.

The macro system constraints (or macro closures) determine the manner in which the accounts for the government, the rest of the world, and savings-investment are brought into balance. Government savings are fixed; the government adjusts the direct tax rates of enterprises and households proportionally to generate the desired savings level. Foreign savings are also fixed (but in foreign currency), leaving the task of generating balance for the rest-of-the-world account (*i.e.* equality between Egypt's foreign currency earnings and outlays) to a flexible real exchange rate. On the spending side of the savings-investment balance, aggregate investment is a fixed share of real GDP. On the savings side, the enterprise savings rate is assumed to be flexible, varying to generate a level of total savings needed to finance aggregate investment.[5]

The primary data sources for the disaggregated model SAM (a 56x56 matrix) are: CAP-MAS' SAM and input-output tables for 1989/90 (CAPMAS 1995; 1994); USAID and Ministry of Agriculture data on agricultural crops (USAID 1992); and FAO data on agricultural trade. Compared to the CAPMAS SAM, the disaggregated model SAM is rearranged and has a more aggregate representation of non-agricultural sectors (9 sectors instead of 14), but provides a considerably more detailed view of agriculture (13 sectors instead of 2). A macro version of the model SAM —identical to the disaggregated SAM except for the aggregated depiction of activities and commodities— is shown in Table 2. A variety of sources were used for estimates of elasticities for the Armington, CET, CES (production), LES (household consumption), and

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[5]Savings from the other sources —government, households, and the rest of the world— are not free to equilibrate aggregate savings-investment. Government and rest-of-the-world savings are exogenous while household savings are a fixed share of income.

export-demand functions. (The values used are given in Table A2.1 in the Appendix.) Sectoral wage and land rent differentials were derived from CAPMAS (1993) and USAID (1992). On the basis of SAM data, and independent estimates of the capital stock (£Ebn113.3) and depreciation (£Ebn4.48), rates of depreciation (4.0%) and net profitability (36.5%) were calculated (World Bank.1994, Annex B, Table 42; CAPMAS 1995, p. 75). Sectoral capital stocks were derived on the assumption of equal sectoral depreciation and gross profit rates.

The Dynamic Module

The within-period, static model is solved for 1990 (the base year), 1993, 1995, and every five years thereafter until 2020. Between the static-model solutions, selected parameters are updated in the dynamic (between-period) module, either using lagged endogenous variables (from solutions in previous periods) or exogenously (on the basis of trends). Parameters for the capital stock and consumer demand equations are changed endogenously. The capital stock is updated given previous investment and depreciation, extrapolating for the inter-period years. Simulated per-capita incomes and budget shares enter the functions for updating the parameters of the LES consumer demand functions.[6] The parameters for population, labor force, and total factor productivity by activity are updated exogenously.

Approach to Model Solution

CGE models are typically formulated and solved as systems of simultaneous equations exclusively made up of strict equalities. To permit the inclusion of inequality constraints for resources generating the desired dual-price regime, the ELW model was solved as an optimization problem, maximizing an objective function, subject to a set of constraints, made up of a mixture of strict equalities and inequalities. The AGRO-CGE model deals with this phenomenon in a different manner: it is formulated as a mixed complementarity problem (MCP), consisting of a set of simultaneous equations (once again a mix of strict equalities and inequalities), but without an objective function. The inequalities, which are linked to bounded (price) variables, apply to labor, land and water. The GAMS modeling software is used both to generate the disaggregated SAM and to implement the model. The model is solved with PATH and MILES, two solvers for mixed complementarity problems.[7]

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[6]More specifically, simulated values for per-capita consumption, commodity prices, and real per-capita income enter the relationships from which the LES parameters are derived. The Frisch parameter is adjusted on the basis of changes in simulated per-capita income, drawing on a function estimated by Lluch, Powell and Williams (1977, p. 248): $F = -36X^{-0.36}$ where F = Frisch parameter, X = per-capita income.

[7]For GAMS, see Brooke *et al.* (1988). Rutherford (1995) provides more information on PATH and MILES.

Table 2. Macro SAM for Egypt, 1989/90 (billion 1989/90 £E)

	Act.	Comm.	Factors			Institutions				Savings	Taxes/Subsidies/Tariff			
	1.	2.	3a.	3b.	3c.	4a.	4b.	4c.	4d.	5.	6a.	6b.	6c.	6d.
1. Activity		106.6							14.5					
2. Commodity	52.8					54.2		4.9		24.7				
3. Factors														
3a. Labor	17.9							7.2	8.3					
3b.Capital	39.8													
3c.Land	8.0													
4. Institutions														
4a Households			33.5	19.8	8.0		4.6	-1.2	1.0					
4b.Enterprises				19.8				1.4						
4c.Government				0.0					2.0		4.3	-1.9	4.2	2.9
4d.Rest of World		27.2					2.5							
5. Savings						10.4	11.3	-0.9	3.9					
6. Taxes/Subs/Tariffs														
6a.Ind.Taxes	4.3													
6b.Subsidies	-1.9													
6c.Dir.Taxes						1.1	3.1							
6d.Tariffs		2.9												
7. Total	121.0	136.6	33.5	39.8	8.0	65.7	21.4	11.5	29.7	24.7	4.3	-1.9	4.2	2.9

Note: Only column totals are shown; for each account, the row total is identical to the column total.

3. Simulations

The model is used to simulate the Egyptian economy for the period 1990-2020. The simulations are divided into three categories exploring, respectively, the effects on economic performance of alternative scenarios for productivity growth and investment rates, foreign trade and agricultural water supplies.

The basic assumptions for the dynamic (30-year) simulations are presented in Table 3. The values for transfers from the rest of the world and the current-account deficit for 1993 and onward reflect a judgement about what is considered reasonable and sustainable in light of recent improvements in Egypt's current account balance.[8] They imply that Egypt's trade deficit remains unchanged in absolute real terms but, as the economy grows, will decline relative to the overall size of the economy. The annual growth rate for export demand is at the level of Egypt's export growth for the period 1983-1994 (World Bank 1995, pp. 256-257). Future changes in the supply of two key agricultural resources, land and water, are difficult to predict. With regard to land, reclamation of less fertile lands and the transfer of older, more fertile lands to non-agricultural uses represent two opposing forces. For water, contradictory forces are also at work: increased efficiency and improved exploitation may raise the supply while growing demands from upstream Nile countries and non-agricultural sectors domestically may force the agricultural sector to manage with less.[9] Here, it is assumed that water availability declines gradually between 1990 and 2020, reaching a supply in 2020 that is 20% less than in 1990.[10] For agricultural land, there is no supply change: in "efficiency" units, land reclamation is assumed to equal loss of lands to non-agricultural uses.

Scenarios for Productivity Growth and Investment

The specific assumptions underlying the three scenarios that are simulated are presented in Table 4. On the pessimistic side, the "Turtle" extrapolates the relatively dilatory economic

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[8]The current account was in deficit between 1974 and 1990, when it moved into surplus. Since 1992, the surpluses have declined gradually from a high of $2.8bn. (EIU 1995, pp. 3 and 9). We simply assume a zero deficit throughout the period 1993-2020.

[9]For discussions of the different factors involved, see Abu-Zeid (1993) and World Bank (1993a, pp. 23-29). The basic scenarios of this paper have been formulated in the spirit of Richards (1995): Egypt's agriculture is or is about to become supply-constrained for water as total supply is unlikely to increase significantly at the same time as non-agricultural water demands are likely to grow.

[10] The impact of declines in water supplies are indistinguishable from the impact of lower rates of productivity growth for water. The sensitivity of the results to alternative cuts in agricultural water supply (or productivity) is analyzed later.

Table 3. General assumptions for simulations 1990-2020

Item	1990 value	1993-2020 projection
Population size (mn.)	56.3	+1.65% per year
Labor force (mn.)	15.5	+2.62% per year
Labor force participation rate (%)	27.5	gradual increase to 37.2% in 2020
Export demand	—	+6% per year
Transfers from RoW to household (1990 £Ebn)	9.3	12.5
Transfers from RoW to government (1990 £Ebn)	2.0	2.7
Current-Account Deficit (1990 £Ebn)	3.9	0
Current Government Savings (1990 £Ebn)	-0.9	0
Agricultural land (mn. feddans)	6.1	no change
Agricultural water supply (bn m^3)	32.9	gradual decline to 80% of base supply in 2020

Sources: World Bank (1994b, p. 210) and UN projections.
Note: In 2020, the size of the population and the labor force are 92.0 and 33.6 million, respectively. Water quantities are measured in terms of consumptive use (after deducting losses in the distribution system). For 1990, it is assumed that the water supply very marginally exceeded recorded water use, 32.9bn m^3 (World Bank 1993a, p. 24).

Table 4. Assumptions for alternative productivity and investment scenarios

Item	Turtle	Tiger	Urban Tiger
Investment share of GDP (%)	20.0	25.0	25.0
Factor Productivity Growth (%/year)	0.32	2.5	Agriculture : 0.32 Other sectors: 2.5
Incremental Capital-Output Ratio	4.8	4.0	4.0

Sources: World Bank (1993c, pp. 42 and 56; 1993b, p. 45; 1994a, Annex B, Table 42); authors' calculations. Note: For 1990, the investment share implicit in CAPMAS' SAM, 21.6%, is used. A slightly lower value is used for later periods in the turtle scenario in light of an observed decline in the GDP investment share in the early 1990s.

performance of the 1980s and early 1990s, a period characterized by unfavorable external conditions and stagnant domestic policies. The more optimistic "Tiger" scenario postulates a decisive break from the past, incorporating investment rates and productivity growth —but not export growth— typical of successful East Asian economies. The third scenario, labeled the "Urban Tiger", explores the consequences of low agricultural productivity growth in a setting with high aggregate investment rates and rapid productivity growth for the rest of the economy.

Table 5 shows selected results for these three scenarios, compared with data for 1990 when relevant.[11] The message of the Turtle scenario is strong —extrapolation on the basis of the investment and productivity performance of the 1980s produces a very discouraging outcome. Per-capita GDP and household consumption decline and an unsustainable level of unemployment emerges in the labor market. In face of a growing budget share for foodstuffs, the food trade deficit increases.

In reality, one would expect that the dramatic increase in unemployment for the Turtle scenario would be tempered by a decline in real wages. To test the sensitivity of these results to the current assumption of a downwardly rigid real wage, the Turtle scenario was repeated with a flexible market-clearing wage at the 1990 unemployment rate throughout the period 1990-2020. The general trend was similar. The main difference is that the increase in unemployment was replaced by a decline in real wages, by 3.2%per year, signaling a dramatically different impact on income distribution. With a steady unemployment rate and declining wages, output growth was stronger —GDP at factor cost grew by 1.5% per year— and the small fall in household consumption was replaced by a minor increase (the index for household per capita income ended up at 104.7 in 2020, from a base of 100 in 1990). Nevertheless, the over-all results are quite insensitive to the assumption about the labor market.

[11]Tables A2.1-3 in Appendix 2 present cropping patterns and resource prices for the different scenarios.

Table 5. Results for alternative productivity and investment scenarios

	Value: 1990	2020 value or 1990-2020 growth rate: Turtle	Tiger	Urban Tiger
GDP per capita at market prices (% growth/year)	—	-0.63	3.10	2.38
Household per capita consumption (index 1990=100)	100.0	98.9	194.0	157.8
Unemployment (%)	20.0	55.7	18.5	31.1
Imports (% of Nominal GDP)	34.7	35.8	55.0	57.5
Exports (% of Nominal GDP)	18.5	26.3	49.0	50.6
Trade deficit (% of Nominal GDP)				
Total	16.3	9.6	6.0	6.9
Food & agriculture	10.2	13.6	11.8	17.2
Other	6.1	-4.1	-5.7	-10.2
Exchange rate (£E/$; index 1990=100)	100.0	86.1	127.9	113.3
Wheat self-sufficiency rate (%)	44.6	24.5	40.8	11.3
Food self-sufficiency rate (%)	79.3	73.5	76.0	71.2
GDP at factor cost (% growth/year)				
Total	—	1.06	5.09	4.46
Agriculture	—	0.37	3.33	1.45
Non-Agriculture	—	1.30	5.61	5.18
Share of agriculture in real GDP at factor cost (%)	29.1	23.7	17.4	12.0

Note: Units are indicated in the first column. "1990" column refers to base year values; a dash (—) indicates "not applicable" (for rows indicating % growth/year 1990-2020).

The outcome for the Tiger scenario dramatically illustrates the impact of achieving higher levels of investment and productivity growth over a 30-year period. GDP per capita grows at more than 3% a year, per-capita real household consumption is almost doubled, and the unemployment rate now declines slightly. The trade deficit, which is fixed in foreign currency, represents 16% of GDP in 1990 but, as GDP grows rapidly, it falls to 6% in 2020. Disaggregating the trade deficit, by the year 2020 there is an increase in the food deficit and a shift to a surplus in non-food items, a highly plausible tendency for a land- and water-constrained economy. While the real exchange rate appreciates for the slow-growth Turtle scenario, it now depreciates. This reflects that, with relatively rapid growth in output and demand (including import demand), depreciation is needed to encourage exports and discourage imports sufficiently to generate the fixed aggregate trade deficit.

The GDP share of agriculture declines strongly for the Tiger scenario and, to a lesser extent, also for the Turtle scenario, as growth in agriculture is much lower than growth in the rest of the economy. This trend, typical of growing economies, reflects the inverse relationship between growing income and the share spent on food, as well as the constraining impact on agriculture in Egypt of fixed or declining levels of scarce, sector-specific resources. Another structural change shown in Table 5 that is particularly strong for the Tiger scenario revolves around Egypt's economic relationship with the outside world: in the context of a liberal trading environment and a declining trade deficit (as share of GDP), the GDP export and import shares, which were substantial already in 1990, expand dramatically.

The third scenario, the "Urban Tiger", was formulated to gauge the importance of the agricultural sector in the (Tiger) context of rapid growth and a diminishing agricultural share in GDP. It differs from the basic Tiger scenario in that, for the agricultural sectors, the optimistic assumption of annual total factor productivity growth at a rate of 2.5% is replaced by the Turtle rate of 0.32% (Table 4). Compared to the Tiger scenario, performance deteriorates (Table 5) —aggregate growth is significantly lower, agricultural growth falls by more than 50%, and unemployment in 2020 is much higher than in 1990. In the food and agricultural area, Egypt is becoming more heavily reliant on the outside world; in particular, there is a dramatic fall in the rate of wheat self-sufficiency which probably would be considered unacceptable to Egyptian policy makers. The overall implication is that the performance of the agricultural sector will remain crucial also in the next century, even if non-agricultural growth is fairly rapid. Hence, it is important to nurture supporting activities (such as agricultural research and extension services) while preserving existing agricultural resources from environmental degradation and other sources of productivity losses.

Sensitivity Analysis: Foreign Trade

The above scenarios assumed that import tariff rates remained at the levels of 1990[12] whereas export demand grows at an annual rate of 6%. We will here assess the effects of tariff cuts and more successful penetration of export markets in the context of the Tiger scenario. For tariff cuts, the first scenario assumes the removal of all agricultural tariffs, and the second the removal of tariffs across all sectors. In both cases, the relevant tariff rates are set at zero starting

[12]For import tariffs, aggregate figures in CAPMAS' SAM implied higher rates for individual commodities than suggested by available disaggregated information (American Embassy 1992, p. 41). Drawing on this information, this inconsistency was overcome by assuming a uniform low tariff for staple crops (primarily grains, set at 8%), and a uniform high tariff for other crops (primarily vegetables and fruits, calibrated to 77%). The results presented in the paper do not seem to be sensitive to the specific levels of these two uniform rates.

from 1993. For export demand, we test the impact of doubling the annual growth rate to 12%, close to South Korea's record for the period 1973-1993 (World Bank 1995, pp. 396-397)

Table 6 shows results for these three scenarios compared to the basic Tiger scenario and 1990 data. For both tariff cut scenarios, the aggregate impact is positive but very minor: the indicators for per-capita GDP growth, household consumption, and unemployment all show some small improvement. The positive effects are slightly stronger for the scenario with full tariff removal. In reality, tariff cuts may boost productivity growth by increasing the exposure of domestic producers to international competition; however, such potential effects are not captured in the current model. Given the closure rule for the government account, the tariff cuts lead to a shortfall in government revenue that is made up for by an increase in direct tax rates. Compared to the basic Tiger scenario, the direct tax rates are 8% higher for the agricultural tariff cut and 72% higher for the economywide tariff cut.[13] For both scenarios, there is some additional depreciation, strengthening the competitiveness of tradables sufficiently to generate the same trade deficit as with tariff protection, but in a less distortionary fashion.

For the third scenario, with more rapid growth in export demand, the repercussions are quite strong. By 2020, the economy has reached "full" employment —an unemployment rate of 5%[14]— as opposed to 19% for the basic Tiger, an achievement that marginally boosts aggregate growth. To validate the initial trade deficit (fixed in foreign currency), the exchange rate appreciates strongly compared to the other Tiger scenarios; this has a strong positive impact on real household consumption. Thus, this scenario demonstrates that strong export performance can have a decisive impact on real household welfare and on the economy's ability to absorb marginal labor .

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[13]For example, in 2020 for the Tiger scenario, household and enterprise direct tax rates are, respectively, 1.8% and 15.5%. For the scenario with an economy-wide tariff cut, the corresponding rates are 3.1% and 26.7%.

[14]However, the improvement in the average real wage is quite small, indicating that the labor-market bottleneck constrains aggregate growth only to a minor extent.

Table 6. Results for alternative foreign trade scenarios

	Value: 1990	2020 value or 1990-2020 growth rate: Tiger	Agricultural tariffs removed	All tariffs removed	Rapid export demand growth
GDP per capita at market prices (% growth/year)	—	3.10	3.11	3.13	3.46
Household per capita consumption (index 1990=100)	100.0	194.0	194.4	194.6	288.8
Unemployment (%)	20.0	18.5	17.7	15.5	5.0
Imports (% of Nominal GDP)	34.7	55.0	56.2	59.3	36.9
Exports (% of Nominal GDP)	18.5	49.0	50.1	53.0	34.1
Trade deficit (% of Nominal GDP)					
Total	16.3	6.0	6.1	6.4	2.8
Food & agriculture	10.2	11.8	12.2	12.7	10.3
Other	6.1	-5.7	-6.1	-6.3	-7.6
Exchange rate (£E/$; index 1990=100)	100.0	127.9	131.0	135.3	83.0
Wheat self-sufficiency rate (%)	44.6	40.8	38.5	39.7	10.8
Food self-sufficiency rate (%)	79.3	76.0	75.8	76.5	78.3
GDP at factor cost (% growth/year)					
Total	—	5.09	5.11	5.13	5.35
Agriculture	—	3.33	3.32	3.32	3.74
Non-Agriculture	—	5.61	5.62	5.66	5.82
Share of agriculture in real GDP at factor cost (%)	29.1	17.4	17.3	17.1	18.3

Note: See Table 5 for explanations.

Valuing Water

In the Egyptian environment, water is not priced and the right to use water is associated with land ownership. In our model, the simulated value of the land/water aggregate arises from its marginal productivity in production and incorporates both the value of the raw land and the water right associated with land ownership. It is assumed that both land and water are allocated efficiently across the different crops. The model simulations can be use to allocate the total value of the land/water aggregate between raw land and water, a value which is unobservable in Egypt since there are not separate and liberalized markets for raw land and water.

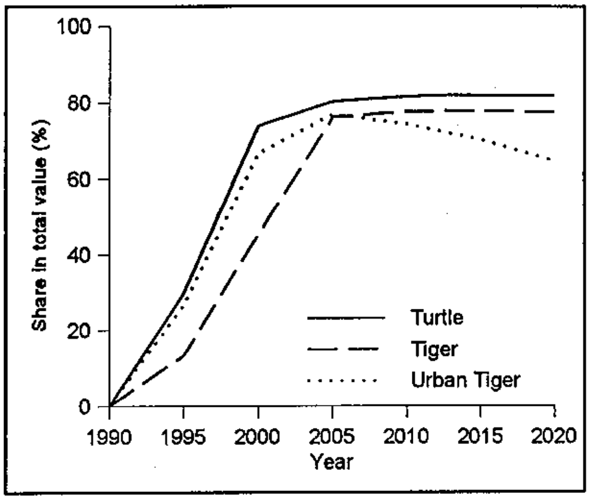

Figure 2: Share of Total Value of Land/Water Aggregate Allocable to Water

Figure 2 shows the water share of the total value of the land/water aggregate for three of the above scenarios: Turtle, Tiger, and Urban Tiger. The results indicate that over time, as water becomes relatively scarce, its value to farmers will exceed that of raw land. The differences in the water shares across the scenarios and over time reflects the extent to which agricultural commodity demands are directed toward water-intensive crops, in its turn a reflection of economic interactions, both domestically and with the outside world. The fact that, water-intensive crops (for example rice) tend to have relatively low income-elasticities of demand lowers the value share for water, other things being equal.

Sensitivity Analysis: Water Supply and Productivity Growth

In the long run, there is considerable uncertainty about Egypt's future agricultural water supplies. In the basic Tiger scenario, the assumption of a simultaneous 2.5% productivity growth in output per unit of both land and water may be excessively optimistic. While the Green Revolution has led to increases in land yields of this magnitude, they have often been associated with an *increase* in water use per land unit.

To explore the sensitivity of the results to different assumptions about water use, we ran a series of variations on the Tiger scenario. We reduced agricultural water supplies in steps of 10%, with declines ranging from 0 to 60 percent and taking place gradually between 1990 and 2020. (The basic Tiger scenario specified a 20% decline.) These experiments can be seen as simulating the impact of smaller water supplies or, alternatively, they can be interpreted as exploring the impact of lower productivity growth for water relative to other factors, including land. For example, a 50% decrease in the water supply (or in water productivity) in 30 years corresponds to an annual productivity decline of 2.28%. The same outcome could be achieved by reducing water productivity growth from 2.5% to 0.22% per year; *i.e.* to a growth rate below the Turtle level.[15]

The results of these sensitivity simulations are summarized in Table 7 and Figures 3 and 4. Cuts up to 20% do not impose severe constraints on the economy. It is apparently not too difficult to marginally change the crop mix to make better use of water, especially given that the water constraint was not binding in the base year. For larger cuts, the effects are more severe. Nevertheless, the changes in most economywide indicators —GDP growth, household consumption, and trade— are manageable even for a 60% cut in water availability (or, from a different perspective, an annual decline in water supplies by 0.5% with no change in water productivity). The major exception is unemployment: in 2020, it encompasses 34% of the labor force (as opposed to 19% for the basic Tiger), illustrating the high sensitivity of labor absorption to marginal changes in growth.

Within the agricultural sector, the changes are more drastic. Compared to the basic Tiger, agricultural growth shrinks considerably, reaching merely 2% per year, when a 60% water cut is imposed. In response to water cuts, agricultural capital and labor intensities increase along with increased relative agricultural prices.[16] In 1990, the real share in agricultural value-added of the land/water aggregate was 38%. By 2020, this share ranges from 26% for no water cut to 21% for a 60% cut. As shown in Figure 3, a growing share of summer land is left uncultivated and, starting between 40% and 50% cuts, winter land also is taken out of production. Accordingly, as shown in Figure 4, the water share in aggregate water and land incomes climbs from zero to 100%. As land returns decline, it would become easier to convert agricultural land to non-agricultural uses. Reduced water supplies bring about significant changes in the cropping pattern; in this environment, cotton, fruit and vegetables are relatively competitive whereas other crops, including rice, virtually disappear. Given their lower water requirements, winter crops, including wheat, are favored since they make more productive use of the remaining scarce water. (See Table A2.4 for details.)

[15]The corresponding annual rates of decline are 0.35% for a 10% cut, 0.74% for a 20% cut, 1.18% for a 30% cut, 1.69% for a 40% cut, and 3.01% for a 60% cut.

[16]The ease with which this takes place is determined by the elasticity of substitution between factors in the agricultural value-added functions—here a value of 0.4 is used. The fact that substitutability between water and land is zero may lead to a negative bias for these scenarios.

Table 7. Results for tiger scenarios with different cuts in water supply

	Value: 1990	2020 value or 1990-2020 growth rate: Tiger-0	Tiger-20	Tiger-40	Tiger- 60
Water supply cut (%)	—	0.0	20.0	40.0	60.0
GDP per capita at market prices (% growth/year)	—	3.19	3.10	2.93	2.61
Household per capita consumption (index 1990=100)	100.0	199.6	194.0	182.5	164.3
Unemployment (%)	20.0	15.0	18.5	24.0	34.4
Imports (% of Nominal GDP)	34.7	54.5	55.0	59.8	63.5
Exports (% of Nominal GDP)	18.5	48.5	49.0	53.4	56.4
Trade deficit (% of Nominal GDP)					
Total	16.3	6.0	6.0	6.5	7.1
Food & agriculture	10.2	10.4	11.8	15.8	19.5
Other	6.1	-4.4	-5.7	-9.4	-12.4
Exchange rate (£E/$; index 1990=100)	100.0	132.3	127.9	128.2	124.3
Wheat self-sufficiency rate (%)	44.6	32.7	40.8	47.8	32.6
Food self-sufficiency rate (%)	79.3	77.0	76.0	69.6	65.8
GDP at factor cost (% growth/year)					
Total	—	5.16	5.09	4.99	4.75
Agriculture	—	3.52	3.33	2.91	2.01
Non-Agriculture	—	5.65	5.61	5.56	5.43
Share of agriculture in real GDP at factor cost (%)	29.1	18.0	17.4	15.8	13.0

Note: See Table 5 for explanations.

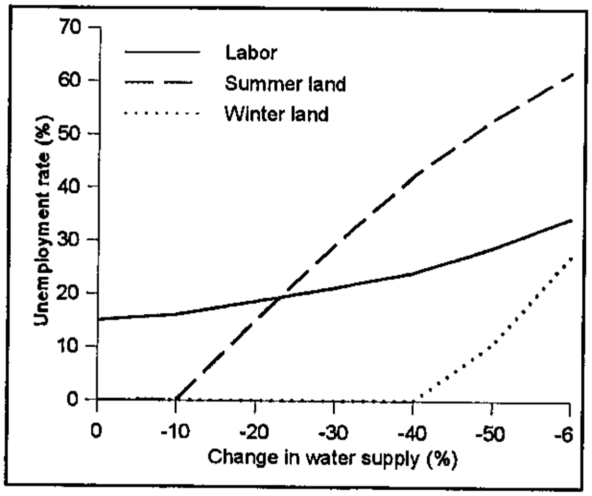

Figure 3: Factor Unemployment Rates with Reduced Water Supplies, Tiger Scenarios

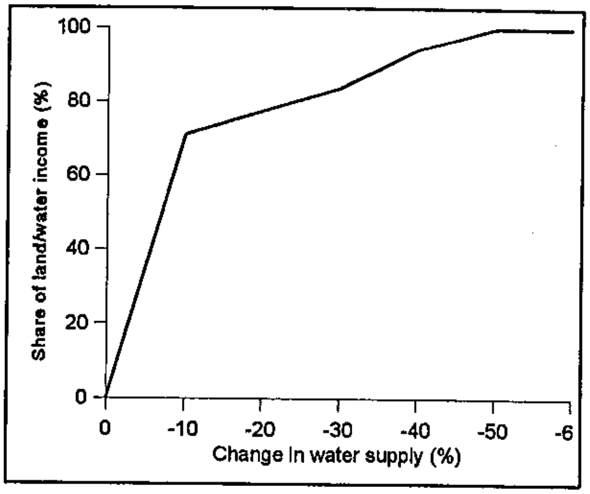

Figure 4: Water Share in Total Land/Water Income, Tiger Scenarios, 2020

4. Conclusion

In 1960, Egypt's per capita income was 60% above South Korea's. Thirty years later, it reached merely 11% of the South Korean level (Mason 1984, p. 8; World Bank 1992, p. 219). The exceptional South Korean performance and the relatively lackluster Egyptian growth reflect differences over the long run in investment levels, choice of development strategy, policy management, and other considerations. This paper considers alternative future scenarios for Egypt from 1990 to 2020, also a period of 30 years, using a dynamic CGE model with a detailed treatment of the agricultural sector. In terms of method, the model, expressed as a mixed-complementarity problem, formulates agricultural resource constraints in a fashion that is innovative in the context of CGE models, permitting not only full utilization with flexible prices but also excess supplies with a zero price. In all scenarios, we assume that Egypt's economy will be market-oriented and competitive; that there will be mechanisms in place for achieving an efficient allocation of water in agriculture; and that growth will occur in an environment of general macroeconomic balance. As indicated by its title, this paper should be seen as exploratory: the model needs to be more closely adapted to Egypt's economic structure; better data is needed; and the empirical foundations for the alternative scenarios may be strengthened.[17]

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[17]In terms of the model structure, it may be desirable to strengthen the hydrological aspects, and explore means of making the mix between water and land price-responsive (while still permitting a dual market regime for both water and land). It would be of interest to incorporate stylized facts reflecting the impact of economic openness on productivity growth along the lines in Lewis *et al.* (1995).

We consider two broad scenarios: the "Turtle," which extrapolates on the basis of the productivity growth and investment levels characteristic of Egypt's recent past; and the "Tiger," which combines key aspects of successful East Asian economic performance (using Korean data as a proxy) with Egyptian resource constraints and production structure. The results for the Turtle scenario are grim. Per-capita income remains roughly the same in 2020 as 30 years earlier. As the country's labor force grows dramatically, the labor market moves toward a crisis, with some unsustainable combination of increasing unemployment and falling real wages. On the other hand, the "Tiger" scenarios, which assume that Egypt achieves rates of investment and productivity growth typical of South Korea and other high-performance East Asian economies, are more encouraging. When combined with rapid growth in export demand, per-capita household income almost triples, while full employment is also achieved.

Sensitivity analysis of the results for the Tiger scenario suggests that export-demand growth and balanced rapid productivity growth (not excluding agriculture) are of crucial importance. While having a positive effect, the removal of distorting import tariffs is alone of minor importance. Increasing water scarcity (due to water cuts or lower water productivity growth) have a strong negative impact on agricultural performance and labor absorption without, however, significantly reducing growth in aggregate output and income. The unemployment rate is the aggregate indicator that is most sensitive to changes in economic performance, assuming downward rigidity of real wages.

The broader policy implications from this analysis are clear: Egypt should attach top priority to measures that promise to raise balanced long-run productivity growth (covering both agriculture and other sectors); encourage high investment rates; and seek foreign trade agreements that give access to export markets while lowering import tariffs in return. The gains from increased exports far outweigh the costs of structural adjustments required from opening domestic markets. In searching for a successful Egyptian development strategy, it is potentially fruitful to learn from South Korea and other successful East Asian economies.[18]

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[18]For recent research assessing the relevance of East Asian industrial policy to Egypt, see Said *et al.* (1995).

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Appendix 1: The Egyptian AGRO-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. The AGRO-CGE model combines an activity-analysis representation of agricultural resource (land and water) technology with a neoclassical representation elsewhere. Inequality constraints impose upper limits on the use of agricultural resources. While the activity-analysis specification of agricultural technology in this version is simple, the model is capable of replicating or being linked to more elaborate agricultural sector models.

Table A1.1 provides a listing of the equations of a simplified version of the AGRO-CGE model. The simplified model in Table A.1 focuses on 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 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 and are hence not independent equations. The simple 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.

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). The full model has two land types, corresponding to summer and winter cropping. Given that there are multiple 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; the land constraint equation would 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 display the same kind of complementary slackness as the shadow price system in an agricultural sector mathematical 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, there are two approaches that can be used to solve the model. First, the model can be seen as a nonlinear mixed complementarity problem (MCP) in which the land and water prices, W^{FED} and W^{H2O}, are "complementary" to the land and water supply-demand inequalities. Complementarity simply means that the product of the non-negative price times the corresponding excess-supply inequality must equal zero, as noted earlier. Imposing the two complementary slackness conditions explicitly guarantees that the model operates on the production possibility frontier while also satisfying the market equilibrium pricing equations. Recently developed MCP solvers work well on this particular model.[19] This is the approach we have used in this paper.

The second approach to solving the AGRO-CGE model is to introduce an explicit maximand and treat the model as a nonlinear programming problem. 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, a condition which characterizes a profit-maximizing market equilibrium.

Given that the AGRO-CGE model has a single consumer, the obvious choice of maximand is consumer welfare. In a competitive economy with no distortions, maximizing consumer welfare will generate a profit-maximizing and utility-maximizing market equilibrium, and is equivalent to maximizing the sum of consumers' and producers' surplus in the economy. 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 model will generate a market solution and any differences between the simulated market prices and the shadow prices, given the maximand, measure the welfare costs associated with the distortions.

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[19]See Rutherford (1995) for a description of MCP algorithms, their application to CGE models, and their implementation in the GAMS language.

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. 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.[20]

While the AGRO-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. However, we do assume that, at the next level, the 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, what would be the market-clearing price?

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[20]For other choices of numeraire, relative solution prices will equal relative shadow prices.

Table A1.1: Equations of a Simplified AGRO-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	$W_i^{LND} = \frac{\partial V_i}{\partial LND_i} P_i^V$	Demand for land/water.
11	$W^K = \frac{\partial V_i}{\partial K_i} P_i^V$	Demand for capital.
12	$W^L = \frac{\partial V_i}{\partial L_i} P_i^V$	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	$\bar{FED} \geq \sum_i FED_i$	Land supply-demand.
18	$\bar{H2O} \geq \sum_i H2O_i$	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

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

Appendix 2: Supplementary Tables

Table A2.1. Elasticity values used in model.

Sector	LES	Armington	CET	CES	Export demand
Berseem	—	—	—	0.80	—
Cotton	0.58	0.60	—	0.40	—
Fruit	1.26	0.30	0.80	0.40	-7.5
Maize	0.29	8.00	0.50	0.40	-7.5
Other summer crops	0.29	0.30	1.50	0.40	-7.5
Other winter crops	0.29	0.30	1.50	0.40	-7.5
Rice	0.29	6.00	0.50	0.40	-7.5
Sugar Cane	—	2.00	—	0.40	—
Summer vegetables	1.26	0.30	0.80	0.40	-7.5
Winter vegetables	1.26	0.30	0.80	0.40	-7.5
Wheat	0.29	8.00	—	0.40	—
Livestock	1.26	0.30	1.50	0.40	-7.5
Oil	1.26	2.00	2.00	—	$-\infty$
Food Processing	0.87	0.33	2.00	0.60	-7.5
Cotton Ginning	0.29	0.33	2.00	0.60	-7.5
Textiles	1.07	0.33	2.00	0.60	-7.5
Other Industry	1.07	0.33	2.00	0.60	-7.5
Electricity	1.26	0.33	1,50	0.40	-2.5
Construction	0.29	0.33	2.00	0.60	-2.5
Services	1.26	0.33	2.00	0.60	-2.5

Note: For a brief survey of elasticities of CGE models, Löfgren (1994a).
Abbreviations:
LES = Household income elasticity of demand in LES demand functions;
Armington = Elasticity of substitution between imports and domestic goods in CES aggregation function;
CET = Elasticity of transformation between exports and domestic sales in CET function;
CES = Elasticity of factor substitution in CES value-added functions.

Table A2.2. Cropping patterns and resource prices for alternative productivity and investment scenarios

	Value 1990	Value for the year 2020: Turtle	Tiger	Urban Tiger
Summer Land		----- Percent composition -----		
Cotton	16.5	22.7	27.8	26.2
Fruit	12.6	16.0	13.5	18.0
Maize	39.3	16.0	23.2	13.5
Other Crops	2.7	3.9	2.8	4.6
Rice	17.2	10.2	7.6	7.9
Sugar Cane	4.4	3.3	3.0	3.4
Vegetables	7.3	7.4	7.1	10.7
Excess Supply	0.0	20.5	15.1	15.7
Total Supply	100.0	100.0	100.0	100.0
Winter Land				
Long Berseem	25.0	26.8	24.2	29.6
Short Berseem	16.5	22.7	27.8	26.2
Fruit	12.6	16.0	13.5	18.0
Other Crops	7.6	9.4	6.3	10.3
Sugar Cane	4.4	3.3	3.0	3.4
Vegetables	3.1	3.0	2.8	3.9
Wheat	30.8	18.9	22.4	8.6
Excess Supply	0.0	0.0	0.0	0.0
Total Supply	100.0	100.0	100.0	100.0
Resource rents/prices		----- 1989/90 £E -----		
Summer land (£E/feddan)	701	0	0	0
Winter land (£E/feddan)	628	343	1624	1671
Water (£E/'000 m^3)	0	359	1287	712

Table A2.3. Cropping patterns and resource prices for Tiger scenarios with alternative foreign trade assumptions

	Value 1990	Value for the year 2020: Tiger	Agricultural tariffs removed	All tariffs removed	Rapid Export Growth
Summer Land		----- Percent composition -----			
Cotton	16.5	27.8	27.9	27.9	25.7
Fruit	12.6	13.5	13.5	13.3	19.6
Maize	39.3	23.2	22.8	23.0	14.4
Other Crops	2.7	2.8	2.8	2.7	3.6
Rice	17.2	7.6	7.6	7.7	7.0
Sugar Cane	4.4	3.0	3.0	2.9	3.3
Vegetables	7.3	7.1	7.3	7.3	12.3
Excess Supply	0.0	15.1	15.2	15.2	14.1
Total Supply	100.0	100.0	100.0	100.0	100.0
Winter Land					
Long Berseem	25.0	24.2	25.3	24.7	34.2
Short Berseem	16.5	27.8	27.9	27.9	25.7
Fruit	12.6	13.5	13.5	13.3	19.6
Other Crops	7.6	6.3	6.2	6.2	7.2
Sugar Cane	4.4	3.0	3.0	2.9	3.3
Vegetables	3.1	2.8	3.0	2.9	3.3
Wheat	30.8	22.4	21.2	22.0	6.0
Excess Supply	0.0	0.0	0.0	0.0	0.0
Total Supply	100.0	100.0	100.0	100.0	100.0
Resource rents/prices		----- 1989/90 £E -----			
Summer land (£E/feddan)	701	0	0	0	0
Winter land (£E/feddan)	628	1624	1588	1563	3354
Water (£E/'000 m^3)	0	1287	1206	1242	882

Table A2.4. Cropping patterns and resource prices for Tiger scenarios with alternative water cuts

	Value 1990	Value for the year 2020: Tiger-0	Tiger-20	Tiger-40	Tiger- 60
Summer Land		----- Percent composition -----			
Cotton	16.5	27.1	27.8	28.1	18.5
Fruit	12.6	13.9	13.5	13.2	10.9
Maize	39.3	29.3	23.2	3.7	0.3
Other Crops	2.7	2.3	2.8	2.3	1.9
Rice	17.2	14.1	7.6	2.2	0.3
Sugar Cane	4.4	4.9	3.0	2.4	1.6
Vegetables	7.3	8.4	7.1	5.7	4.4
Excess Supply	0.0	0.0	15.1	42.4	61.9
Total Supply	100.0	100.0	100.0	100.0	100.0
Winter Land					
Long Berseem	25.0	25.4	24.2	21.3	18.8
Short Berseem	16.5	27.1	27.8	28.1	18.5
Fruit	12.6	13.9	13.5	13.2	10.9
Other Crops	7.6	6.3	6.3	6.2	5.6
Sugar Cane	4.4	4.9	3.0	2.4	1.6
Vegetables	3.1	3.5	2.8	2.4	1.9
Wheat	30.8	18.9	22.4	26.3	15.3
Excess Supply	0.0	0.0	0.0	0.0	27.4
Total Supply	100.0	100.0	100.0	100.0	100.0
Resource rents/prices	----- 1989/90 £E -----				
Summer land (£E/feddan)	701	4056	0	0	0
Winter land (£E/feddan)	628	3602	1624	418	0
Water (£E/'000 m^3)	0	0	1287	2071	3090

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