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Short-run Energy–Economy Interactions in Egypt

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Summary. – This paper discusses the short-run adjustment mechanism of the Egyptian economy to changes in the domestic price of oil. The effects of oil price increases have been analysed in the framework of a short-run macroeconomic model with an explicit treatment of energy. The results suggest that a reduction in petroleum use induced by a rise in the price of oil will impose difficult adjustment problems for the economy in the short run in terms of increase in inflation, fall in the share of wage income and sharp output losses. The analysis also indicates that energy demand management through appropriate petroleum pricing strategy cannot bring about desirable impacts on the economy unless efforts are made to reduce cost pressures originating from other energy sectors.

1. INTRODUCTION

The decade of the 1970s produced important political and economic changes in Egypt, many of which have their origins in the economic liberalization policy and the 'open door' posture. In particular, five principal factors are responsible for increasing both the level of economic activity and foreign exchange earnings of the country. The factors may be enumerated as follows: (i) the expansion of oil production and natural gas resources, in conjunction with the rapid increases in the world price of oil throughout the 1970s; (ii) the large inflow of worker remittances due to increasing labour out-migration and apparent growth of confidence in the Egyptian economy; (iii) the liberalization policies designed to encourage inflows of foreign capital; (iv) the reopening of the Suez canal; and (v) the increase in tourism. Together, these five factors evolved throughout the 1970s, shaping the country's economy and attendant social and political adjustments. By the end of the decade these factors had set in motion a set of economic interactions that will substantially transform the country's economy throughout the 1980s. They are leading to important structural changes in the economy in terms of changes in the structure of demand, role of foreign trade and allocation of resources. However, these five sources of foreign earnings – the favourable factors for the economy – cannot continue indefinitely into the future.

Recent developments suggest that the Egyptian economy has entered a transitional phase in its growth process undergoing a period of transformation towards a new equilibrium. Processes of adjustment and adaptation are inevitable in being characteristic transitional phases as distinct from the steady state phenomenon which is consistent with and observed in long-run equilibrium. Therefore, it is important to understand the short-run adjustment mechanism of the interdependent economic system which would provide reasonable guidelines for appropriate policy measures. There are many countervailing forces in the Egyptian economy, and these five factors differ in their impacts and their overall contribution to growth.

Clearly, the most significant contribution to the recent economic upsurge has been provided by the petroleum sector, which is strong, well managed and provides a steady

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stream of revenue for the government. The petroleum sector does not exist in isolation from the rest of the economy and analysis of its effects must take into account the strong two-way linkage with the economy. The contribution of the petroleum sector to GDP at factor cost increased from 3% in 1975 to 16% in 1979 and export earnings jumped almost six times during this period. By 1982 oil exports provided $2.76 billion to the economy.

A major problem arises from the question of whether the increased earnings from the petroleum sector can be maintained in the face of two obstacles: a highly subsidized domestic price of oil which is encouraging domestic consumption and a large degree of uncertainty that prevails in reserve generation and the future production possibilities of oil.

The domestic price of petroleum in Egypt is about one-fifth of the international market price equivalent. Low petroleum prices have led to rapid increases in domestic utilization. Government officials have recently stated that by 1984 both consumption of petroleum products and output will rise by 11–12% and the exportable surplus of domestic petroleum production over consumption may be eliminated completely.[1]

This two-fold dilemma has heightened awareness for energy conservation, domestic pricing policy and better management of energy demand at the national level such that petroleum reserves are not entirely diverted from exports to the domestic market. The crucial policy issue in this context is to change the administered price system of petroleum products toward a more viable domestic price structure which would be more closely in line with international markets. The problem is whether price-induced conservation is likely to occur and to determine the macroeconomic consequences of an overall reduction in petroleum use.

Among the critical questions to be resolved are the following: what will be the effects of rising energy costs on the other sectors of the economy? Will the economy be able to adapt to this change? To a large extent the adjustments will depend on the flexibility of energy use in the consumption pattern of households and in the production functions underlying industrial sectors. In other words, the structure of energy–economy interactions depends to a large extent on the critical role that petroleum plays both in the consumption basket and as a factor of production (that is, on the values of the relevant elasticities).

Egypt's energy profile can be characterized as follows: almost 70% of energy use is petroleum-based, the remainder is mainly hydroelectric power, with small, but potentially important prospects for natural gas. In a macroeconomic context, therefore, if substitution possibilities exist in production processes (e.g. between petroleum and natural gas), it is important to determine whether the negative macroeconomic impact of rising energy prices can be mitigated through appropriate price policies or if other constraints in the economy will need to be recognized as well. In this context, for Egypt's energy predicament, it is useful to investigate whether the production possibilities in the natural gas sector impose significant constraints on the economy's adjustment process. The effects of the above kinds of restrictions can be examined under alternative assumptions regarding how the different sectors of the economy adjust to reach market equilibrium (i.e. alternative rules for model closures). For example, price determination differs substantially across sectors and these differences are critical to the overall economic adjustments and to the policy options available for changing domestic price structures. Among issues of concern are the following: if the short-run adjustment to an oil price increase drives down output and puts upward pressure on prices, can the short-run underutilization of production capacity be mitigated through appropriate macroeconomic policies? With these questions in mind we have formulated a macroeconomic model of the Egyptian economy to trace the short-run energy–economy interactions and address issues of the above nature.

The paper is organized in the following way: Section 2 gives a brief overview of the model. Section 3 presents the results of alternative simulation runs. Section 4 summarizes the results of the analysis. The database and the structure of the model equations along with a brief discussion of the values of the parameters derived are presented in an appendix.

2. OVERVIEW OF THE MODEL

Despite rapid changes in the Egyptian economy, several features continue to stand out. These include a dominant agricultural sector, a growing construction sector, an expanding industrial base and a dramatic growth in the petroleum sector. Domestic economic policies – inherited from the revolution of 1952 – include extensive subsidies for industrial inputs, energy products and foodstuffs. In agriculture, imports serve to clear the market. Only in construction are prices allowed to adjust to market forces. In all other sectors quantities adjust to demand. The traditional dualism in the economy – agriculture vs the rest of the economy – may well be supplanted by a trilateral structure; agriculture, rest of the economy and a strong energy sector. With these distinctive features in mind, we have a short-run, 10-sector, macroeconomic model of the Egyptian economy to examine its critical adjustment problems.

(a) *Theoretical structure*

The theoretical structure of this model is specified in accordance with the computable general equilibrium models formulated by Taylor (1983) and Taylor *et al.* (1980) emphasizing the particular structural characteristics of developing countries. Such models are based around the identities of a social accounting matrix (SAM) and incorporate additional technical and behavioural relationships to make the model determinate and represent the distinctive aspects of the specific economy being analysed. The closure rules behind these models are based on a combination of different schools of thought inspired by Keynes, Kalecki and the different adherents of the Cambridge school. The model focuses attention on the particular variables that need to adjust to bring about the overall macrobalance, i.e. saving equal to investment. Different models can be constructed around the different accommodating variables that would adjust to satisfy the basic macroidentity in the economy. Aggregate demand determined markets of the Keynesian type are included where chronic excess capacities are the essential features of the sectors and price clearing markets are assumed where bottlenecks and shortages are present. Generalized models of development are not useful for analysing particular cases. Different structural characteristics are important in case of different countries and the appropriate adjusting variables need to be emphasized accordingly.

The Egyptian macroeconomic model is built around a social accounting matrix (SAM) for the Egyptian economy in the national accounts year of 1977.[2] The model incorporates a complex set of general equilibrium interactions in the price and quantity clearing sectors in the commodity market.[3] The model, however, is of a short-run nature and does not incorporate the dynamics of the system. It is designed specifically around a base year to assist in understanding immediate responses to policy changes. Investment has been modelled merely as a component of aggregate demand and the capital accumulation process of investment has not been considered. It has been specifically designed to explore the short-run adjustment mechanism of the system.

The 10 sectors along which the model is built are the following: (1) agriculture; (2) construction and housing; (3) heavy industry; (4) light industry; (5) transportation; (6) sectors in the rest of the economy; (7) Suez; (8) oil extraction; (9) oil refining; and (10) other energy, namely electricity and a nascent natural gas component.

The overall macrobalance in this structural model is decomposed sectorally. The mechanisms through which excess demand in each sector adjust to zero are the following:

(i) The agricultural sector is assumed to have an adjusting 'competitive import' level.[4] Both prices and supply are assumed to be fixed in the short run.
(ii) The construction sector's stability mechanism is built around an adjusting price. Prices are assumed to vary freely to bring about equilibrium because capacity in the construction sector is fully utilized in the short run.
(iii) For all the other sectors in the economy adjusting outputs occur due to the prevalance of chronic excess capacities.[5]

Prices in all the quantity clearing sectors are determined by fixed producers' mark-up over variable costs as opposed to the neo-classical cost function. The wage rates are assumed to have been determined institutionally (which correspond to the Keynesian assumption of short-run predetermined nominal wages) and the coefficients of production are fixed in the initial version of the model. For purposes of analysis, some of the technological coefficients have been taken as flexible, as reported below, in an alternative version of the model. The model draws upon the well-known linear expenditure system of demand equations to arrive at the sectoral consumption level. Given the different behavioural assumptions and the different identities built around the social accounting matrix, the solution is determined through several adjustment mechanisms, namely Keynesian output response in the quantity-clearing sectors, a 'forced saving' mechanism via the rise in the prices of output relative to wage, adjustments in the trade deficit and the surplus available in the government current account.

As noted earlier, the formulation of the structural equations for this model are closely related to the model formulation made by Taylor (1983) for India. However, two important extensions to represent the Egyptian case are made, and these extensions may be relevant for other classes of countries with similar macroeconomic features and a strong petroleum sector. These extensions are necessitated by the realities of the Egyptian case:

- The energy sector is disaggregated in terms of oil extraction, oil refining and other energy (i.e. predominantly natural gas and electricity). Egypt has a 'mixed' energy portfolio which must be clearly represented.
- The pricing equations are reformulated to incorporate the assumption of price responsive technological coefficients in the petroleum intensive sectors. This extension is essential to capture the flexibility of energy use in production processes.

(b) *Relevance for the Egyptian case*

Models of the above general equilibrium nature in a multisectoral framework may provide highly useful insights and guidelines for investigating macropolicy issues. They are especially relevant in the Egyptian case, where the government is actively engaged in bringing about economic changes through direct policy measures. Such models are different from the earlier computable general equilibrium models, popularly known as GEM models, which were applied in the case of Pakistan by McCarthy and Taylor (1980) and in the case of Egypt by Eckaus, McCarthy and Mohie-Eldin (1979).

Earlier views of the Egyptian economy specified in the GEM models incorporated the general equilibrium links between production structure, income of different groups and patterns of demand through flexible prices. Thus, a market clearing mechanism provided the interaction between demand, production and factor use. These models are essentially neo-classical in spirit and follow the general equilibrium notion that goes back to Walras. The GEM models assume Cobb-Douglas production functions which allow for smooth substitution, constant return to scale and constant factor shares. Moreover, perfect competition is usually assumed in the factor markets for arriving at the dual cost function. Thus the obvious disadvantage of the GEM models are the highly neo-classical nature of the models which are clearly suspect in the framework of developing countries like Egypt.

Clearly, the important assumption of price responsiveness, smooth substitutability between the different primary inputs, perfectly competitive nature of factor markets do not hold in developing economies where institutional features and structural rigidities result in behaviour far removed from the neo-classical assumptions. This is especially the case in Egypt where institutional factors established since the 1952 Revolution have introduced large-scale rigidities which blantantly violate neo-classical assumptions. Such notions impose serious distortions in analysis and for identifying policy adjustments. In short, neo-classical, general equilibrium analytical structures are singularly inappropriate in the Egyptian case, where public policy – social and economic programmes – is clearly in violation of the critical neo-classical assumptions.

(c) *Macroresponses in the Egyptian economy*

The major macroeconomic consequences that may be evaluated through the model may be classified in the following categories:

(i) *effects on sectoral output* – since the industrial sectors are characterized by excess capacities, the short-run macro-adjustment takes place in terms of changes in output (i.e. capacity utilization);

(ii) *effects on sectoral prices* – the changes in relative prices play a key role in the short-run adjustment process and help us to evaluate the inflationary impacts of policy changes;

(iii) *impacts on income shares in terms of wages, profits and government income* – value-added is disaggregated into four categories, namely agricultural income, wages, government profits and private sector profits. The assumption of fixed wages and mark-up pricing enables us to arrive at different functional distributions of income (i.e. through the 'forced savings mechanism');

(iv) *impacts on balance of payments* – the effects on balance of payments are evaluated in terms of changes in the level of competitive and non-competitive imports.

3. EMPIRICAL RESULTS

An initial set of simulation analyses was undertaken to examine the major macroeconomic adjustments. This section reports the results of the following simulation runs:

(a) an increase in the level of aggregate investment demand;
(b) an increase in the domestic price of petroleum via changes in the mark-up rate;
(c) introduction of a fiscally neutralizing policy measure to offset the impact of petroleum-price induced contraction;
(d) an increase in the domestic price of oil with flexible technological coefficients in the petroleum intensive sectors under alternative closure rules for the natural gas sector.

(a) *Effects of increased investment demand*

In the initial experiment the total aggregate level of investment demand (in nominal terms) is increased by 10% (i.e. L.E. 221.69 million). Our main interest is to examine the responses of the accommodating variables which would give us an improved understanding of the structure of the model.

It is evident from Table A-1 (in the appendix) that the largest component of investment demand is met by goods from the construction sector. As a result the variation in the demand for investment goods is mainly reflected in terms of a rise in the aggregate demand for construction sector products. Since the construction sector has fixed capacity in the short run the increase in aggregate demand will lead to an increase in prices by 15%. This, however, will not lead to much of a cost-push inflation in the other sectors of the economy owing to limited sales of intermediate inputs by the construction sector to the other sectors of the economy.

The aggregate level of prices in the economy will increase by 5%. The price index of investment goods will increase by a much larger extent (by 9%). This increase will result in a net increase of demand for investment goods in real terms by L.E. 53.135 million (as against a nominal increase of L.E. 221.69 million). An increase in prices in the construction sector will lead to a proportionate increase in income generated by the construction sector which will put upward pressure on demand for all commodities.

An increase in aggregate demand for investment goods (in real terms) will also result in an expansion of output and income in the other sectors of the economy. All this will lead to an increase in real value added by L.E. 149.504 million. The results of this experiment are summarized in column B of Table 1.

The familiar multiplier and centred arc elasticity measures[6] with respect to shifts in real investment demand are shown in Table 2. The values of the elasticities show that all of the accommodating variables will respond positively to a change in the real aggregate demand for investment goods in the economy. The high elasticity measure of the construction sector prices (6.24) reveals the sensitive nature of this sector to a change in the economy's level of real investment demand. The sensitivity measure of the competitive level of imports in the agricultural sector is also high (2.59) because of the high demand pressures that are generated for the goods in this sector. It also acts as a vehicle to increase foreign savings to meet the rise in investment demand. The elasticity measure of the real value added of 0.82 reveals the limited expansionary impact in real terms of an increase in aggregate investment demand.

We observe a fall in the share of wage income and a rise in the share of profit income resulting from a change in prices brought about by the construction sector. The saving shares also adjust to bring about the new investment-saving equality. The government's share in savings falls from 0.6327 to 0.6102 and that of the households from 0.5904 to 0.5595.

The main burden of adjustment falls in the trade sector (from −0.2231 to −0.1696) because of the rise in the level of competitive imports in the agricultural sector and non-competitive imports in the other sectors resulting from an expansion in output.

(b) *Effects of a rise in the domestic price of petroleum*

As Egyptian energy prices have been extremely low, on the average about one-fifth of their international market price equivalent, they obviously have not provided the appropriate price signals to the economy.[7] Our objective in this policy run is to evaluate the short-run macroeconomic impacts and adjustments in the economy that would result from a rise in the price of oil. For purposes of analysis, the domestic price of petroleum has

Table 1. *Empirical results of different simulation runs*

Sectors	Prices	A	B	C	D
Construction and housing	P2	1.0	1.153	0.983	0.996
Heavy industry	P3	1.0	1.002	1.067	1.068
Light industry	P4	1.0	1.000	1.01	1.01
Transportation	P5	1.0	1.006	1.047	1.048
Rest of the economy	P6	1.0	1.002	1.023	1.023
Suez	P7	1.0	1.000	1.04	1.041
Oil extraction	P8	1.0	1.003	1.076	1.077
Oil refining	P9	1.0	1.003	1.535	1.536
Other energy	P10	1.0	1.002	1.11	1.11
	Gross output (in million LE)				
Heavy industry	X3	785.619	794.737	774.598	785.915
Light industry	X4	3655.81	3722.97	3609.49	3664.79
Transportation	X5	494.243	505.975	478.732	492.358
Rest of the economy	X6	3958.58	4007.50	3914.80	4042.32
Suez	X7	185.40	185.492	185.316	185.558
Oil extraction	X8	266.333	267.936	262.311	265.006
Oil refining	X9	287.856	291.522	277.368	284.039
Other energy	X10	116.538	118.665	112.893	115.689
	Competitive imports (in million LE)				
Agriculture	M1	568.198	604.188	545.68	578.022
	Consumption (in million LE)				
Agriculture	C1	933.667	949.244	925.598	934.449
Construction and housing	C2	156.763	150.514	155.752	157.29
Heavy industry	C3	128.834	132.871	122.267	124.467
Light industry	C4	1873.40	1924.72	1837.63	1866.74
Transportation	C5	186.453	195.502	173.377	178.82
Rest of the economy	C6	1132.80	1171.92	1094.96	1117.67
Oil refining	C9	53.4077	54.4938	46.0192	46.44
Other energy	C10	39.4407	40.6239	36.7453	37.373
	Sources of saving (in million LE)				
Government savings	GSAV	1574.54	1653.44	1603.01	1524.64
Household savings	HHSAV	1469.07	1515.85	1461.07	1485.46
Trade deficit	DEF	–555.144	–459.769	–568.972	–514.969
Agricultural income of households	HYA	1581.48	1581.48	1575.09	1575.07
Profit income of household	YHP	1469.05	1649.45	1472.11	1518.86
Wage income of household	YW	2979.43	3012.2	2949.91	3009.37
Government profit income		1575.3	1640.64	1699.47	1729.4
	Aggregate Price Index	1.00	1.05	1.028	1.030
	Real value-added (in million LE)	7605.22	7754.724	7485.17	7607.3
	Nominal value-added (in million LE)	7605.22	7883.575	7696.56	7832.7

A = Base case.
B = Increased investment demand (10%).
C = Increased petroleum mark-up (200%). The mark-up rate in the petroleum sector has been increased three times to simulate the oil price rise scenario. A three-fold increase in the mark-up of the petroleum sector leads to an increase of approx. 54% in the price of petroleum (P9 = 1.535).
D = Increased fiscal expenditure policy (8%).

Table 2. *Multiplier and elasticity measures of accommodating variables with respect to changes in real investment*

Sectors		Multiplier	Elasticity
	Gross output		
Heavy industry	X3	0.17	0.48
Light industry	X4	1.26	0.77
Transportation	X5	0.22	0.98
Rest of the economy	X6	0.92	0.52
Suez	X7	0.0017	0.02
Oil extraction	X8	0.03	0.25
Oil refining	X9	0.07	0.54
Other energy	X10	0.04	0.76
	Competitive imports		
Agriculture	M1	0.68	2.59
	Prices		
Construction and housing	P2	0.003	6.24
	Real value-added	2.81	0.82
	Total value-added	5.24	1.51

been taken as 20% of the international price in the base run of the model.

The rise in the price of petroleum has been simulated by increasing the prespecified mark-up rate in the petroleum sector by 200%. This mark-up rise increases the price in the petroleum sector by approx. 54%, which brings the petroleum prices closer to the international market-price equivalent by 10%. Although this is a modest increase in the direction of the international market-price equivalent, it departs substantially from the current price structure.

The immediate consequence of this price increase is a rise in the variable costs of production in the other sectors of the economy reflected directly in terms of higher prices for their products. The results of changes in the relative prices of the different outputs are depicted in column C of Table 1. A major effect is a cost-push inflation which occurs in the other sectors of the economy. This is due to the significant role of petroleum as an intermediate input.

The responses of the increases in the sectoral price levels will vary over the different sectors. The price level in the heavy industries, transportation, crude oil and 'other energy' sectors will increase by 7%, 5%, 8% and 11%, respectively. The aggregate level of prices in the economy will increase by almost 3%.

The changes in relative prices will lead to a rise in the level of mark-up income from the petroleum sector. A large proportion of the higher mark-up income will be going into the hands of the Egyptian government owing to the large share of the government in the petroleum sector and the other sectors of the economy. This will result in higher government savings, leading to leakages in purchasing power. Real wages will fall owing to the assumption of short-run predetermined nominal wages. Thus income will be redistributed from wage to profit recipients. The share of the increased profit-income for the government sector will rise from 0.2071 to 0.22, whereas the wage share of the wage earners will fall from 0.3918 to 0.3818.

The level of consumption will decline as a result of the higher relative prices. All this would generate a downward pressure on the level of aggregate demand. This depression of demand will result in lower prices in the construction sector, lower level of competitive imports in the agricultural sector and a decline in output in all of the quantity clearing sectors. Thus an increase in the domestic price of oil will lead to a reduction in economic activity of the different sectors of the economy. By far the largest drop in output will occur in the transportation sector. The reasons are the strong input–output linkage between the petroleum sector and the transportation sector and the high value of elasticities in this sector which are evident from Table A–4 (in the appendix). Real value-added will fall by approximately L.E. 120 million (2%) and household consumption of petroleum products will decline merely by L.E. 7 million (13%).

Overall, the rise in domestic petroleum

prices will create difficult macroeconomic adjustments for the economy in the short-run involving increased inflation (due to cost-push inflationary pressures originating from the petroleum sector) and contraction of output (brought about by a fall in aggregate demand) leading to underutilization of capacity.

This contraction may be offset through fiscally neutralizing measures, namely an expansion in the government expenditure policy. We find that if government expenditure is increased by 8% this policy might offset the negative impact on real value-added and add negligibly to inflation.

The results corresponding to this policy run are presented in column D of Table 1. This experiment also helps us to separate income effect from the substitution effect by keeping the real value-added at its original level. The new consumption basket represented by column D now gives us the demand responses generated by the substitution effect alone. We may also note that the conservation in the uses of petroleum by consumers arises mainly due to the operation of the substitution effect (of a change in price) due perhaps to the small share of petroleum in the consumers budget. In terms of the sectoral responses of output, we find that there is clearly a shift in output patterns in favour of sectors 4 and 6. This is mainly due to the fact that a large part of the demand for sectors 4 and 6 comes from the government sector, hence they gain more than the others from the policy change.

(c) *Effects of a rise in the price of petroleum with some price responsive technological coefficients and alternative rules for closures for the natural gas sector*

Much of the demand for petroleum products comes from the industries in the form of intermediate inputs. So far, we have assumed that technological coefficients are fixed: that they are used in fixed proportion and no substitution is possible. In fact, we know that possibilities exist for substitution away from petroleum input, especially by replacing fuel oil by natural gas. Considerable scope for conversion exists in a number of industries in the Egyptian economy namely iron and steel, cement, fertilizers, cotton textiles, etc. Since most of these industries are aggregated in sectors 3 and 4 we have replaced the constant technological coefficients using petroleum and natural gas in these sectors by making them price responsive. For this analysis we now recognize that substitution possibilitie: between petroleum and natural gas in se and 4.

We assume that petroleum and natu enter separably into the unit cost fu This enables us to obtain a Constant Ela of Substitution (CES)[8] unit cost fu corresponding to the use of 'aggregate' (in terms of petroleum and natural gas) d from factor demand equations and r gas in sectors 3 and 4.

The unit cost of 'aggregate energy' in s 3 and 4 may be represented as follows:

$$EP_i = [(\alpha_9^i)^{\sigma_i}(P_9)^{1-\sigma_i} + (\alpha_{10}^i)^{\sigma_i}(P_{10})^{1-\sigma_i}]^{1/(1-\sigma_i)}$$

where $i = 3, 4$

EP_i = price of 'aggregate energy' in sectoı

α_9^i = distribution parameter of petrc used in the CES aggregate energy tion in sector i

α_{10}^i = distribution parameter of 'other en used in the CES aggregate energy tion in sector i

P_9 and P_{10} = price level in sector 9 an respectively

σ_i = elasticity of substitution between p leum and 'other energy' in sector i

The 'fuel shares' or energy coefficient obtained by using Sheppard's Lemma, i.e. first derivative of the respective cost functi The relevant price responsive input–ou coefficients will take the following form:

$$A9E_i = (\alpha_9^i \frac{EP_i}{P_9})^{\sigma_i} \qquad \text{where } i = 3, 4$$

$$A10E_i = (\alpha_{10}^i \frac{EP_i}{P_{10}})^{\sigma_i} \qquad \text{where } i = 3, 4$$

$A9E_i$ = ratio of petroleum use to 'aggre energy' in sector i

$A10E_i$ = ratio of 'other energy' use to 'ag gate energy' in sector i.

The material balance equations for sect 9 and 10, the pricing and variable cost equati for sectors 3 and 4 will have to be reformula to incorporate the flexible technolog coefficients and the 'aggregate prices of ener in the respective sectors.

Given data constraints at present, no forı econometric estimation of the elasticity substitution between oil and natural gas been attempted. There are very few estima available for the elasticity of substitution e for other developing countries. A recent study made by Wood (1983)[9] shows that the elasticities of substitution between petroleum oil and natural gas are higher than unity. We have assumed an elasticity of substitution of 1.5 for both the light industry and the heavy industry sectors.

In order to capture the particular characteristics of the Egyptian economy and its unique 'distortions', we have made three alternative assumptions (on closures) regarding the natural gas sector:

- the natural gas sector is assumed to be quantity clearing (which has been the assumption throughout our analysis);
- the supply of the natural gas sector is taken to be fixed in the short run and the adjustment mechanism is built around flexible prices;
- the short-run supply response function in the natural gas sector responds positively to changes in its own price and takes the following form:

$$X_{10} = \bar{X}_{10}\left(\frac{P_{10}}{\bar{P}_{10}}\right)^{\gamma}$$

where γ is the parameter of the supply response function.[10] P_{10} = initial price of natural gas; $\bar{X}_{10}$ = predetermined level of natural gas output; X^{10} = level of gross output in the natural gas sector.

The results of our analysis are summarized in Table 3. We observe that the technological coefficients are sensitive to changes in petroleum prices in all three cases. However, the price responsiveness (i.e. the resulting induced conservation of petroleum products), varies with the particular assumptions on closures that have been made for the natural gas sector. Given the assumption of excess capacity in the natural gas sector, the substitution away from petroleum to natural gas does not cause any additional increases in the price of the natural gas sector. The flexibility of petroleum use can help to ameliorate some of the contractionary impact on the real value-added to the economy.

However, if the supply in the natural gas sector remains fixed, this leads to a substantial rise in the price of natural gas by almost 30%. This results in a high rate of inflation in the economy and the contractionary effect becomes more severe. The results are summarized in column D of Table 3. This shows that a high elasticity of substitution coupled with fixed supply in the short run may not lead the Egyptian economy to desired long-run results. Hence it is important to capture and analyse the macroimpact of the other restrictions in the economy.

If the short-run supply of natural gas responds to changes in prices then the upward pressures on the price of natural gas may be offset to a large extent. The price of natural gas increases by only 5 percentage points. The results of this experiment are shown in column E. The solution indicates that if the substitution possibilities between oil and natural gas are high in certain sectors and the supply of the natural gas sector responds accordingly, the negative macroeconomic impact of rising energy prices may be mitigated to a certain extent.

This adjustment illustrates the importance of the implications of the alternative closure rules for determining an appropriate petroleum price strategy. In other words, energy demand management alone cannot bring about the desirable impacts on the economy unless efforts are made to remove cost pressures originating from other structural constraints.

(d) *Petroleum pricing and energy conservation*

The elasticity measures summarized in Table 4 help us evaluate the effectiveness of petroleum pricing policy for the curtailment of energy demand in the short run. We find that the values of the elasticity measures are fairly sensitive to assumptions of flexibility of energy use in the production processes and to the market clearing assumptions in the natural gas sector.

The elasticity measure under scenario A (−0.0879) and scenario A′ (−0.0316) reveal the fact that with rigid technological coefficients, the fall in energy demand mainly takes place through the operation of the contractionary income effect. As expected, the elasticity measures with flexible technological coefficients are relatively larger (−0.1744) and the price effect also seems to be much stronger (as revealed by the elasticity measure of −0.121 under scenario β'). The shift of energy demand to sector 10 is also apparent from the positive elasticity measures in the natural gas sector. The elasticity measure of −0.0676 under the assumption of the price clearing natural gas sector reveals the ineffectiveness of petroleum pricing as a policy measure for inducing energy conservation under the presence of structural constraints in the natural gas sector. On the whole the short-run elasticity measures seem

Table 3. *Results of simulation runs with an increase in mark-up in the petroleum sector by 200%* and flexible technological coefficients under alternative closure rules for the natural gas sector*

				Flexible technological coefficient		
					Price clearing natural gas sector	
Sectors		A	B	C	D	E
Heavy industry	Ratio of petroleum use to 'aggregate energy'	0.655	0.655	0.532	0.595	0.549
Heavy industry	Ratio of natural gas use to 'agreggate energy'	0.344	0.344	0.492	0.409	0.468
Light industry	Ratio of petroleum use to 'aggregate energy'	0.561	0.561	0.432	0.497	0.449
Light industry	Ratio of natural gas use to 'aggregate energy'	0.439	0.439	0.595	0.509	0.571
	Prices					
Construction and housing	P2	1.00	0.983	0.984	0.981	0.985
Heavy industry	P3	1.00	1.067	1.063	1.077	1.058
Light industry	P4	1.00	1.01	1.01	1.012	1.009
Transportation	P5	1.00	1.047	1.047	1.052	1.046
Rest of the economy	P6	1.00	1.023	1.023	1.026	1.022
Suez	P7	1.00	1.04	1.040	1.044	1.039
Oil extraction	P8	1.00	1.076	1.076	1.08	1.074
Oil refining	P9	1.00	1.535	1.535	1.542	1.532
Other energy	P10	1.00	1.11	1.11	1.288	1.051
	Gross output					
Heavy industry	X3	785.619	774.598	774.96	773.115	775.65
Light industry	X4	3655.61	3609.49	3611.65	3603.18	3614.77
Transportation	X5	494.243	478.732	479.266	477.152	480.032
Rest of the economy	X6	3958.58	3914.80	3915.63	3909.33	3917.93
Suez	X7	185.40	185.316	185.318	185.306	185.334
Oil extraction	X8	266.333	262.311	258.761	259.988	258.334
Oil refining	X9	287.856	277.368	267.417	270.976	266.175
Other energy	X10	116.538	112.893	125.121	116.538	128.561
	Competitive imports					
Agriculture	M1	568.198	545.68	546.717	542.696	548.206
	Aggregate Price Index	1.00	1.028	1.0264	1.032	1.0278
	Real value-added	7605.22	7485.17	7496.89	7472.93	7489.68
	Total value-added	7605.22	7695.56	7694.78	7710.21	7697.61

A = Base case.
B = Rigid technological coefficient.
C = Quantity clearing natural gas sector.
D = Fixed supply of natural gas.
E = Incorporation of short-run supply response function in the natural gas sector.

*The mark-up rate in the petroleum sector has been increased three times to simulate the oil price rise scenario. A three-fold increase in the mark-up of the petroleum sector leads to an increase of approx. 54% in the price of petroleum (P9 = 1.535).

to indicate the limited effectiveness of the petroleum pricing policy in curtailing energy demand in the short run.

4. CONCLUSION

The above analysis suggests the following points.

First, an increase in the domestic price of oil will encourage the curtailment of petroleum use and induce some amount of conservation of oil resources. This may be redirected to exports or conserved for future use.

Second, the reduction in petroleum use, however, will impose short-run adjustment problems for the economy in terms of an increase in inflation, fall in the share of wage income and sharp output losses. A concomitant increase in aggregate demand through expansionary government expenditure policies may help to restore some of the lost income and stimulate the economy.

Third, the popular emphasis in macroeconomic policy for counteracting the negative economic effects to date has been effective energy-demand management policies. Since household consumption forms a very small portion of total petroleum demand in Egypt, the demand effects will have to operate through interfuel substitution in the industrial sector. Our analysis suggests that a high elasticity of substitution in the production processes between petroleum and natural gas will not bring about the desirable changes in the short run in terms of conservation of petroleum use and amelioration of the negative macroeconomic impacts unless efforts are made to increase the short-run supply of natural gas as well. In other words, for the price of oil to provide the right signal for resource allocation in the economy the other institutional and structural constraints need to be recognized and analysed as well.

Fourth, the results presented in this report stress that the macroeconomic implications of domestic petroleum pricing strategies in Egypt are extremely important and should be considered carefully. Simply suggesting lifting of domestic subsidies, or increasing domestic energy prices to world prices, will not have the intended effects unless other measures are adopted as well. Treating the energy sector in isolation from the rest of the economy could be counterproductive and lead to adoption of measures that may even have detrimental effects in the short run. An overall energy/economy strategy is required in which adjusting domestic prices toward international prices is only one element.

However, it should be borne in mind that although oil price increases slow down economic activity, these effects may be small and temporary when seen from a long-run perspective as the dynamics of the system are taken into account. For instance, the expansion of government revenue resulting from oil price increases and increase in exports from curtailment of energy consumption can be highly beneficial from a long-run perspective if they are directed towards productive investments. However, in this paper we do not consider the longer run adjustments to short-run interventions.

Table 4. *Elasticity measures of gross output with respect to changes in oil prices*

Sector	A	A'	B	B'	C	C'	D	D'
Oil refining	−0.0879	−0.0316	−0.1744	−0.121	−0.1417	−0.0676	−0.1862	−0.1341
Other energy	−0.07527	−0.0173	0.1683	0.2205	*	*	0.2335	0.2723

A = Rigid technological coefficients.
A' = Case A with neutralizing fiscal expenditure policy (8%).
B = Quantity clearing natural gas sector.
B' = Case B with neutralizing fiscal expenditure policy (7.5%).
C = Fixed supply of natural gas sector.
C' = Case C with neutralizing fiscal expenditure policy (9%).
D = Incorporation of short-run supply response function in the natural gas sector.
D' = Case D with neutralizing fiscal expenditure policy (7%).
*Undefined.

NOTES

1. See *Middle East Economic Survey* (28 March 1983).

2. At the time the analysis was undertaken no social accounting matrix or comprehensive data to formulate one for a later date was available. The then existing 1976 matrix did not serve our purpose as it did not incorporate sufficient sectoral detail for energy.

3. The model has been closed in the commodity market in terms of investment-saving equality. Given the paucity of data an extension of the model to the financial market was not feasible. Hence, an implicit assumption of neutrality of money in the short run has been made in our analysis. We are currently considering incorporating a financial market in the model.

4. Imports into the economy which are also produced within the country are labelled as 'competitive imports', e.g. cotton imports into Egypt.

5. Underutilized capacity has been defined in the sense of firms having excess capacity owing to insufficient demand in an oligopolistic structure.

6. Centred arc elasticity approximations are calculated in the following way:

$$\text{Elast } X_i = \frac{\hat{X}_i - X_i}{\hat{I}_i - I_i} \cdot \frac{\hat{I}_i + I_i}{\hat{X}_i + X_i}$$

$\hat{I}_i$ is the perturbed value for I_i

I_i is the unperturbed value for I_i

$\hat{X}_i$ is the value calculated for X_i in the perturbed simulation.

7. See J. R. La Pittus, 'CDSS Policy Issues Facing Egypt' (USAID/Cairo, 11 February 1982) for a useful discussion of energy price distortions in Egypt.

8. For a description of the CES function, see K. J. Arrow, H. B. Chenery, B. S. Minhas and R. M. Solow, 'Capital and labor substitution and economic efficiency', *Review of Economics and Statistics* (1961).

9. These results have been obtained by an ongoing study conducted by David O. Wood at the Energy Laboratory of MIT. See M. Sehary, R. Villarreal and D. O. Wood, 'Industrial Fuel and Electricity Demand in Mexico', Final Report to the Instituto Tecnologico Autonomo de Mexico (1983).

10. The value for γ has been taken as 2.

REFERENCES

Arrow, K. J., H. B. Chenery, B. S. Minhas and R. M. Solow, 'Capital and labor substitution and economic efficiency', *Review of Economics and Statistics*, Vol. 43 (1961), pp. 225-250.

Berndt, Ernst R. and David O. Wood, 'Technology, prices, and the derived demand for energy', *Review of Economics and Statistics*, Vol. 57 (1975), pp. 259-268.

Chenery, H. B., *Structural Change and Development Policy* (London: Oxford University Press, 1979).

Choucri, Nazli and M. Zaki Shafei, *Energy Policy Project: Petroleum and Natural Gas in Egypt – Final Report* (MIT Technology Adaptation Program, Report 83-11, June 1983).

Dervis, Kemal, Jaime de Melo and Sherman Robinson, *General Equilibrium Models for Development Policy* (New York: Cambridge University Press, 1979).

Diewert, W. E., 'An application of the Shepard duality theorem: A generalized Leontief production function', *Journal of Political Economy*, Vol. 79 (1971), pp. 481-507.

Eckaus, Richard S., F. Desmond McCarthy and Amr Mohie-Eldin, 'Multi-Sector General Equilibrium Models for Egypt', Monograph No. 233. Cairo University/Massachusetts Institute of Technology Technological Planning Program (1979).

Eckaus, Richard S., F. Desmond McCarthy and Amr Mohie-Eldin, 'A Social Accounting Matrix for Egypt, 1976', *Journal of Development Economics* (1981).

Ikram, Khalid, *Egypt: Economic Management in a Period of Transition* (Baltimore, Maryland: Johns Hopkins University Press, 1980).

Johansen, L., *A Multi-Sectoral Study of Economic Growth* (Amsterdam: North Holland Press, 1960).

Kaldor, Nicholas, 'Alternative theories of distribution', *Review of Economic Studies*, Vol. 23 (1955), pp. 83-100.

Kalecki, Michal, 'Costs and prices and distribution of national income', in *Selected Essays on the Dynamics of the Capitalist Economy* (New York: Cambridge University Press, 1971a).

Kalecki, Michal, 'Political aspects of full employment', in *Selected Essays on the Dynamics of the Capitalist Economy* (New York: Cambridge University Press, 1971b).

McCarthy, Desmond F. and Lance Taylor, 'Macro food policy planning: A general equilibrium model for Pakistan', *Review of Economics and Statistics*, Vol. 62 (1980), pp. 107-121.

Senhary M., R. Villareal and D. O. Wood, 'Industrial Fuel and Electricity-Demand in Mexico', Final Report to the Instituto Technologico Autonomo de Mexico (1983).

Sen, Amartya K. (ed.), *Growth Economics* (New York: Penguin Books, 1971).

Taylor, Lance, *Macro Models for Developing Countries* (New York: McGill, 1979).

Taylor, Lance, *Structuralist Macroeconomics: Applicable Models for the Third World* (New York: Basic Books, 1983).

Taylor, Lance, 'Theoretical foundations and technical implications', in C. R. Blitzer, P. B. Clark and L. Taylor (eds.), *Economy-Wide Models and Development Planning* (New York: Oxford University Press, 1975).

Taylor, Lance, Edmar Bacha, Eliana A. Cardoso and L. Frank Lysy, *Models of Growth and Distribution for Brazil* (New York: Oxford University Press, 1980).

Woodruff, David, *Linear Programming Analysis of the Use of Natural Gas in Egypt* (MIT Technology Adaptation Program, Report 83-5, November 1982).

APPENDIX

1. *Social Accounting Matrix*

The macrodata framework is based upon a simple social accounting matrix (SAM) for Egypt for 1977, a year chosen specifically for its use as a 'base' for analysis. The main sources of data for the 1977 SAM are the following:

- a 1977 10-sector input–output table prepared at MIT which was aggregated from a 32-sector input–output table;[1]
- the 1976 11-sector social accounting matrix prepared through collaborative efforts between MIT and Cairo University;
- the Egyptian National Accounts (UN Yearbook of 1979).

The purpose of the 1977 matrix is to produce a clear view of the economy without too much detail so that it could be easily read and understood by analysts for policy purposes.

The 22 × 20 Social Accounting Matrix for Egypt for the national year of 1977 is presented in Table A-1. This is a snapshot matrix representation of the national income accounts which states that receipts must equal expenditure for all sectors of the economy. All matrix identities are represented in value terms (i.e. money flows) in 1977 domestic prices in Egypt (in units of million L.E.).

The inter-industry quadrant of Table A-1 is composed of 10 sectors, as specified above for the macromodel. Given the input–output coefficients from the 1977 input–output table, the 1977 SAM is an expanded version of the final demand figures that were obtained from the UN National Income Accounts. In other words, given the final demand figures and the input–output coefficients from the 1977 input–output matrix, gross output was obtained by the standard formula,

$$X = (I-A)^{-1}F$$

where X is a 10-sector column vector of gross output levels (which are the first 10 elements of column 20 and row 22 respectively) and A is a 10 × 10 matrix of input–output coefficients and F is a column vector of final demands. Thus, given the Leontief inverse matrix, the sectoral gross output totals are obtained to support the intermediate and final demand components of each sector.

The input–output flow table is represented by the northwest quandrant (i.e. rows 1-10) and columns 1-10) of Table A-1, which depicts the structural interdependence of production in the different sectors of the economy. It shows the flows of goods and services which are both produced and consumed in the process of production referred to as inter-industry flows or intermediate demand. The elements in this quadrant are payments between production processes and do not enter national income. The second (north-east) quadrant (i.e. rows 12-16) shows various elements of final demand for the output of each sector.

The different elements of final demand in the Egyptian SAM consist of (i) private consumption; (ii) government consumption; (iii) total demand for investment goods, which consists of gross capital formation and stock changes; and (iv) total exports. Competitive imports, presented in column 17, enter the final demand quadrant with a negative sign because they are treated essentially as nationally produced output and thus increase the value of total supply. Thus the first 10 rows represent the demand supply balances of the output in the 10 sectors.

The aggregate values of all the final demand figures were obtained from the national income accounts. However, the sectoral breakdown of the demand figures were made according to the 1977 input–output table. The sectoral classifications adopted in the national accounts are slightly different from the sectoral breakdowns used in the 1977 SAM designed for this analysis.[2]

It is evident from Table A-1 that the quadrant immediately below the input–output flow table contains detailed information on payments to the factors of production (i.e. value-added by productive activities) in the different sectors in terms of household wage income, household profit income, agricultural income and government income. Information on competitive imports, indirect taxes and production subsidies are also summarized in rows 18-20.

Data on total imports have been obtained from the UN National Accounts (i.e. L.E. 2260.0) and allocated between three major uses, namely competitive imports, non-competitive imports (which are used in production) and capital formation. Data on this input breakdown were obtained from the 1980 UNCTAD Handbook of Trade Statistics and the 1980 United Nations International Trade Statistics. Disaggregation of the non-competitive imports across the different sectors was made according to the 1977 input–output table. National account figures record the total amount of indirect taxes as (L.E. 857.6) which were split among the different sectors in the SAM in proportion to the value-added generated in the relevant sectors.

For the Egyptian case data on subsidies are confusing, given the government accounting conventions and difficulties of obtaining a set of consistent figures.

Table A-1. *Social accounting matrix of Egypt, 1977 (in million LE)*

	1 Agriculture	2 Construction	3 Heavy industry	4 Light industry
1. Agriculture	474.22	0.0	3.39	1039.70
2. Construction	0.60	13.21	1.63	4.36
3. Heavy industry	14.34	96.20	157.83	91.59
4. Light industry	7.31	134.21	19.74	592.39
5. Transportation	2.51	5.00	6.11	23.16
6. Rest of economy	24.66	215.39	36.86	152.50
7. Suez	0.0	0.0	0.0	0.0
8. Oil extraction	0.17	18.11	11.26	8.28
9. Oil refining	9.72	9.66	39.32	20.95
10. Other energy	0.16	2.07	20.65	16.39
11. Σ(1-10)	533.69	493.85	296.79	1949.32
12. H.H. wage income		405.74	124.87	581.53
13. H.H. profit income		295.89	32.76	259.03
14. Agricultural income	1581.48			
15. Total private income Σ(12-14)	1581.48	701.63	157.63	840.56
16. Government income	142.20	78.65	139.67	481.09
17. Gross savings				
18. Imports	83.25	91.66	114.42	427.69
19. Producer/consumer subsidy	−46.03			−299.24
20. Indirect taxes			77.18	257.28
21. Direct taxes				
22. Total gross output	2294.59	1365.79	785.69	3656.70

	5 Transportation	6 Rest of economy	7 Suez	8 Oil extraction
1. Agriculture	8.71	86.72	0.0	0.0
2. Construction	10.39	13.32	0.0	0.54
3. Heavy industry	1.61	86.38	0.64	5.27
4. Light industry	20.26	214.35	4.06	6.36
5. Transportation	5.34	163.04	0.39	0.71
6. Rest of economy	43.87	216.04	2.44	4.63
7. Suez	0.0	7.53	0.0	0.0
8. Oil extraction	0.0	0.67	0.0	0.23
9. Oil refining	22.0	69.48	1.68	4.55
10. Other energy	5.67	20.27	0.36	0.68
11. Σ(1-10)	117.85	877.80	9.57	22.97
12. H.H. wage income	123.24	1384.25	17.59	10.09
13. H.H. profit income	13.14	812.09	0.0	34.53
14. Agricultural income				
15. Total private income Σ(12-14)	136.38	2196.34	17.59	44.62
16. Government income	205.94	110.74	158.24	157.26
17. Gross savings				
18. Imports	49.51	327.04	0.0	7.24
19. Producer/consumer subsidy	−15.35	−15.35		
20. Indirect taxes		463.11		34.30
21. Direct taxes				
22. Total gross output	494.33	3959.68	185.40	266.39

	9 Oil refining	10 Other energy	11 Σ(1-10)	12 Private consumption
1. Agriculture	0.0	0.0	1612.74	933.89
2. Construction	2.06	0.35	46.46	156.77
3. Heavy industry	2.86	0.14	456.86	128.84
4. Light industry	2.22	0.73	1001.63	1874.08
5. Transportation	0.21	~~21.11~~ 2.11	208.58	186.51
6. Rest of economy	23.32	3.10	722.81	1133.01
7. Suez	0.0	0.0	7.53	0.0
8. Oil extraction	102.94	0.0	141.66	0.0
9. Oil refining	12.94	8.97	199.27	53.61
10. Other energy	1.09	0.0	67.34	38.29
11. Σ(1-10)	147.64	15.40	4464.88	4505.00
12. H.H. wage income	10.88	21.59	2679.78	
13. H.H. profit income	11.10	11.65	1470.19	
14. Agricultural income			1581.48	
15. Total private income Σ(12-14)	21.98	33.24	5731.45	
16. Government income	50.53	49.77	1574.09	
17. Gross savings				1469.41
18. Imports	58.38	8.41	1167.60	
19. Producer/consumer subsidy	−7.67		−383.64	−188.96
20. Indirect taxes	17.15	8.58	857.60	
21. Direct taxes				246.00
22. Total gross output	288.01	115.40	13411.98	6031.45

	13 Government expenditures	14 Gross fixed investment	15 Stock changes	16 Total exports
1. Agriculture	58.63	0.18	18.97	238.88
2. Construction	75.80	1086.76	0.0	0.0
3. Heavy industry	38.61	74.49	39.12	47.77
4. Light industry	144.83	288.77	172.23	217.56
5. Transportation	28.53	0.0	0.0	70.71
6. Rest of economy	1195.40	319.20	43.6	545.66
7. Suez	0.0	0.0	0.0	177.87
8. Oil extraction	0.0	0.0	5.22	119.51
9. Oil refining	24.43	0.0	1.46	52.04
10. Other energy	9.77	0.0	0.0	0.0
11. Σ(1-10)	1576.00	1769.40	280.60	1470.00
12. H.H. wage income				300.00
13. H.H. profit income				
14. Agricultural income				
15. Total private income Σ(12-14)				
16. Government income				
17. Gross savings	529.09			490.00
18. Imports		438.50		
19. Producer/consumer subsidy	572.60			
20. Indirect taxes				
21. Direct taxes				
22. Total gross output	2677.69	2207.90	280.60	2260.00
		2488.50		

(cont.)

Table A-1 (*cont.*)

	17 Competitive imports	18 Indirect taxes	19 Direct taxes	20 Total gross output
1. Agriculture	−568.70			2294.59
2. Construction	0.0			1365.79
3. Heavy industry	0.0			785.69
4. Light industry	−42.4			3656.70
5. Transportation	0.0			494.33
6. Rest of economy	0.0			3959.68
7. Suez	0.0			185.40
8. Oil extraction	0.0			266.39
9. Oil refining	−42.8			288.01
10. Other energy				115.40
11. Σ(1-10)	−653.90			13411.98
12. H.H. wage income				2979.78
13. H.H. profit income				1470.19
14. Agricultural income				1581.48
15. Total private income Σ(12-14)				6031.45
16. Government income		857.60	246.00	2677.69
17. Gross savings				2488.50
18. Imports	653.90			2260.00
19. Producer/comsumer subsidy				0.0
20. Indirect taxes				857.60
21. Direct taxes				246.00
22. Total gross output	0.0	857.60	246.00	27973.22

As a rough approximation the total amount of subsidies has been taken as 7.8% of the GDP at market prices.[3] The total subsidies were taken as L.E. 572.60. This figure was broken down in terms of consumption and production subsidies. Consumption subsidies were credited to the household sector and production subsidies were distributed among the different sectors in line with the 1976 SAM. Now the total gross value-added becomes residuals to make total sector costs (i.e. columns 1-10) equal to receipts (i.e. rows 1-10) – which constitutes the basic SAM accounting identity. Rows 12-16 show how this gross value-added is paid out in terms of factor payments to households, private and government enterprises in terms of wage income, profit income, agricultural income and government income.

The decomposition of value-added in terms of wage income and capital income was based on the UN national income accounts data. However, the further breakdown of profit income into its public (i.e. government) and private components was based on the basis of ratios of capital stock in the private and public sector.[4]

The first 10 columns give the breakdown of the cost-structures of the different producing sectors in terms of intermediate inputs, payments to government and households, imports used as inputs to production and indirect taxes less subsidies. These column sums of total cost of production are equal to the row sums of sales which is the basic accounting principle underlying the SAM (see Table A-1).

The total private income which includes different sources of household income plus remittances from abroad (L.E. 300 million) is presented in row 15. Workers' remittances from abroad were approximately 10% of total wage income in 1977 and this proportion has increased very rapidly in the later years. Household uses of total private income are in column 12. This entry consists of consumption of nationally produced goods (i.e. L.E. 4505 million), payment of direct taxes to the government and the rest is savings. Consumer subsidies enter the expenditure column with a negative sign. They are treated essentially as income for the household sector. Total private household income is represented at the end of row 15 (i.e. L.E. 6031.45) which equals household uses of income at the bottom of column 12. Government expenditures are summarized in row 13, including government purchases of goods and services from the different sectors (L.E. 1576 million), payment of production and consumption subsidies (L.E. 572.60). The rest is credited to government savings (L.E. 529.09). The composition of government income in terms of profit income accruing to public sector enterprises, direct taxes, and indirect taxes is represented in row 16.

By definition of SAM accounting the row and column sums specifying government income and expenditure are equal (L.E. 2677.69 million). Competitive and non-competitive imports are in row 18 and information on value of exports and remittances (in domestic prices) is in column 16. The balancing item which makes the respective row and column equal is net foreign savings (L.E. 490.00 million) generated in this sector.

Finally, we find that the savings–investment equality is satisfied, which is evident from the total amount of savings generated by the different sources (i.e. row 17) described above and the total expenditure on capital formation and stock changes summarized in columns 14 and 15.

Thus Table A-1 (SAM-77) provides us with the basic macro-data framework around which the computable general equilibrium model will be built.

2. *Model equations*

Detailed symbolic representations of the equations of the model along with the definitions of endogenous and exogenous variables and parameters are presented in Tables A-2 and A-3. The model presented in Table A-2 is the basic model with fixed technological coefficients which has been used for analysing the main base case results. For purposes of analysis the model has subsequently been modified in terms of flexible technological coefficients for petroleum in certain sectors.

Table A-2. *Equations for the structural macroeconomic model of Egypt*

I. *Demand-supply balance by sector*

$$X_1 = \sum_{\substack{j=1 \\ j\neq 2}}^{6} a_{1j}X_j + C_1 + G_1 + I_1 + S_1 + E_1 - M_1 \qquad (1)$$

$$X_2 = \sum_{\substack{j=1 \\ j\neq 7}}^{10} a_{2j}X_j + C_2 + G_2 + I_2 \qquad (2)$$

$$X_3 = \sum_{j=1}^{10} a_{3j}X_j + C_3 + G_3 + I_3 + S_3 + E_3 \qquad (3)$$

$$X_4 = \sum_{j=1}^{10} a_{4j}X_j + C_4 + G_4 + I_4 + S_4 + E_4 - M_4 \qquad (4)$$

$$X_5 = \sum_{j=1}^{10} a_{5j}X_j + C_5 + G_5 + E_5 \qquad (5)$$

$$X_6 = \sum_{j=1}^{10} a_{6j}X_j + C_6 + G_6 + I_6 + S_6 + E_6 \qquad (6)$$

$$X_7 = a_{76} + E_7 \qquad (7)$$

$$X_8 = \sum_{\substack{j=1 \\ j\neq 5,7}}^{9} a_{8j}X_j + S_8 + E_8 \qquad (8)$$

$$X_9 = \sum_{j=1}^{10} a_{9j}X_j + C_9 + G_9 + S_9 + E_9 - M_9 \qquad (9)$$

$$X_{10} = \sum_{j=1}^{9} a_{10j}X_j + C_{10} + G_{10} \qquad (10)$$

(*cont.*)

Table A-2 (*cont.*)

II. *Investment demand*

$$I_i = IN_i/PI \qquad i = 1\text{-}4, 6 \qquad (11\text{-}15)$$

$$PI = \sum_{i=1}^{6} ww_i P_i \qquad (16)$$

III. *Generation of income in the agricultural sector*

$$Y_1 = P_1 X_1 - \left(\sum_{\substack{i=1 \\ i \neq 7}}^{10} a_{i1} P_i + a_{01} P_{01} \right) X_1 + SUB1\ P_1\ X_1 \qquad (17)$$

$$GA_1 = \rho_1 Y_1 \qquad (18)$$

$$HYA = Y_1 - \rho_1 Y_1 \qquad (19)$$

IV. *Generation of income in the construction sector*

$$Y_2 = P_2 X_2 - \left(\sum_{\substack{i=2 \\ i \neq 7}}^{10} a_{i2} P_i + a_{02} P_{02} \right) X_2 - w_2 X_2 \qquad (20)$$

$$GC_2 = \rho_2 Y_2 \qquad (21)$$

$$HPC = Y_2 - \rho_2 Y_2 \qquad (22)$$

V. *Price equations for quantity clearing sectors*

$$tt_i = KS_i (X_i / k_i)^{\eta_i} \qquad \text{for } i = 3\text{-}6,\ 8\text{-}10 \qquad (23\text{-}29)$$

$$P_i = \frac{(1 + t_i)(1 + tt_i)}{1 - (1 + t_i)(1 + tt_i) a_{ii} (1 - SUB_i)} \left[\sum_{\substack{i=1 \\ i \neq j}}^{10} a_{ji} P_i + w_i + a_{oi} P_{oi} \right] \qquad \text{for } i = 3, \ldots, 10 \qquad (30\text{-}37)$$

VI. *Variable cost equations*

$$VC_i = \sum_{j=1}^{10} a_{ji} P_i + w_i b_i + a_{oi} P_{oi} - SUB_i P_i a_{ii} \qquad \text{for } i = 3, \ldots, 10 \qquad (38\text{-}45)$$

VII. *Government share of profits*

$$GR_i = \rho_i tt_i VC_i X_i \qquad \text{for } i = 3, \ldots, 10 \qquad (46\text{-}53)$$

VIII. *Wage income*

$$Y_w = \sum_{1=2}^{10} w_i X_i + R \qquad (54)$$

(*cont.*)

Table A-2 (*cont.*)

IX. *Household profit income*

$$YHP = \sum_{i=3}^{10} tt_i VC_i X_i - \sum_{i=3}^{10} GR_i + HPC \tag{55}$$

$$Y = YHP + Y_w + HYA \tag{56}$$

$$D_h = (1 - S_h)\left[(1 - dt)Y_w + (1 - t_z)YHP + HYA + CSUB\right] \tag{57}$$

$$\hat{D}_h = \sum_{\substack{i=1 \\ i \neq 7,8}}^{10} \theta_i P_i \tag{58}$$

X. *Sectoral consumption functions*

$$C_i = \theta_i + \frac{MP_i}{P_i}(D_h - \hat{D}_h) \qquad i = 1\text{–}6 \text{ and } 9\text{–}10 \tag{59-66}$$

XI. *Closure rules*

$$X_i - \bar{X}_i = 0 \qquad i = 1 \text{ and } 2 \tag{67-68}$$

XII. *Government revenue and expenditures*

$$T^{ind} = \sum_{\substack{i=3 \\ i \neq 5,7}}^{10} t_i(1 + tt_i)VC_i X_i \tag{69}$$

$$T^d = dt \cdot Y_w \tag{70}$$

$$GREV = tzYHP + T^{ind} + T^d + GA_1 + GC_2 + \sum_{i=2}^{10} GR_i + \sum_{\substack{i=1 \\ i \neq 2}}^{9} (PE_i - P_i)E_i \tag{71}$$

$$GEXP = \sum_{\substack{i=1 \\ i \neq 7,8}}^{10} P_i G_i + \sum_{\substack{i=1 \\ i \neq 2,3 \\ 7,8}}^{9} P_i SUB_i X_i + CSUB \tag{72}$$

XIII. *Trade deficit*

$$DEF = P_1 M_1 + P_4 M_4 + P_9 M_9 + P_{oi} IN_m + \sum_{\substack{i=1 \\ i \neq 7}}^{10} a_{oi} Poi X_i - \sum_{\substack{i=1 \\ i \neq 2}}^{9} PE_i E_i \tag{73}$$

XIV. *Saving-investment balance*

$$DEF + (GREV - GEXP) + S_h((1 - dt)Y_w + (1 - t_z)\, YHP + HYA + CSUB) =$$

$$\sum_{i=1}^{6} P_i I_i + P_{oi} IN_m + \sum_{\substack{i=1 \\ i \neq 2,5,7}}^{9} P_i S_i \tag{74}$$

Table A-3. *Symbol declarations in the structural macroeconomic model of Egypt*

Symbol	Definition	Symbol	Definition
Endogenous		*Exogenous (cont.)*	
C_i	Consumption level in sector i, i = 1–6, 9 and 10	G_i	Government demand for commodities in sector i, i = 1–6, 9, 10
DEF	Trade deficit	IN_m	Investment demand for imports
D_h	Consumption spending from household income	IN_i	Investment demand in nominal terms in sector i, i = 1–4, 6
$\hat{D}_h$	Subsistence level of consumption	K_i	Capital stock in sector i, i = 3–6, 8–10
GA_1	Government income from the agricultural sector (sector 1)	M_i	Level of competitive imports in sector i, i = 4, 9
GC_2	Government profit income from the construction sector (sector 2)	PE_i	World price of exports in sector i, i = 1, 3-9
$GEXP$	Government expenditure	P_{oi}	World price of IN_m
$GREV$	Government revenue	Poi	World price of imports
GR_i	Government share of profits in sector i, i = 3–10	R	Remittances
HPC	Households profit income from the construction sector (sector 2)	SUB_i	Rate of production subsidies in sector i, i = 1, 4, 5, 6, 9
HYA	Households income from the agricultural sector (sector 1)	S_i	Changes in stocks in sector i, i = 1, 3, 4, 5, 6, 8, 9
I_i	Investment demand in real terms for sector i, i = 1–4, 6	tt_7	Mark-up rate in sector 7
M_1	Competitive level of imports in sector 1	t_z	Rate of taxes on profit income
PI	Aggregate level of prices for investment goods	w_i	Wage/output ratio in sector i, i = 2-10
P_i	Price level in sector i, i = 2–10	t_i	Rate of indirect taxes, i = 3, 4, 6-10
SAV	Total savings in the economy	P_1	Price level in sector 1
T^d	Direct taxes paid from wage income		
T^{ind}	Total indirect taxes	*Parameters*	
tt_i	Mark-up rate in sector i, i = 3–10	a_{ij}	Sectoral input–output coefficient, i, j = 1-10
VC_i	Variable cost per unit of output in sector i, i = 3–10	a_{oi}	Import coefficient in sector i, i = 1–6, 8–10
X_i	Gross output level in sector i, i = 1–10	kS_i	Constant used in supply response function, i = 3–6 and 8–10
Y	Total income of households		
Y_w	Total wage income	MP_i	Marginal propensity to consume in sector i, i = 1–6, 8–10
Y_1	Total income generated in the agricultural sector (sector 1)	ρ_1	Share of government in public sector enterprises in sector i, i = 1-10
Y_2	Total income generated in the construction sector (sector 2)	S_h	Savings ratio
YHP	Household profit income	η_i	Elasticity in the supply response function in sector i, i = 3–6, 8–10
Exogenous		θ_i	Subsistence level of consumption in sector i, i = 1–6, 8–10
$\bar{X}_i$	Fixed output level in sector i, i = 1, 2		
$CSUB$	Total consumer subsidies	ww_i	Weights in the investment price index in sector i, i = 1–4, 6
dr	Rate of taxes on wages		
E_i	Level of exports in sector i, i = 1, 3–9		

In this section, we shall describe the model equations contained in Table A-2, adopting a convention of sequential description. Equations 1-10 are the material balance equations which represent the basic demand-supply balance in the social accounting framework. The model is based on the notion that the agricultural sector is import clearing, i.e. the levels of competitive imports will adjust to bring about the demand-supply balances. This sector has an administered system of prices and output is fixed in the short run. The construction sector is price-clearing because of the fixed capacity assumption in the short run. All of the other sectors in the economy are quantity clearing because of the presence of unutilized capacities.

Equation 1 represents the supply of gross output in sector 1 ($X1$). The available supply equals the amount of intermediate sales between sectors (for instance $a_{1j}X_1$ represents intermediate sales of agricultural products to the other sectors), the demand for consumption goods (C_1), demand for investment goods (I_1) and changes in stock (S_1), government expenditure on goods and services (G_1), level of exports (E_1) minus the level of competitive imports (M_1). All of the other material balance equations can be interpreted in a similar fashion.

Equations 11–15 represent demand for investment goods in real terms. Demand for investment goods has been converted into real terms by deflating the quantity of nominal investment (IN_i) by an appropriate weighted price index PI. The investment price index is represented by PI in equation 16. Thus real investment falls if prices go up and helps to bring about equilibrium by reducing excess demand.

Equation 17 represents agricultural income Y_1 which consists of value-added in that sector plus a production subsidy on the amount of output produced in that sector. Profit income in the construction sector is denoted by Y_2 in equation 20 which consists of sectoral value-added minus wage income accruing in that sector. GA_1 and GC_2, represented by equations 18 and 21, give the shares of government in the agricultural and construction sectors respectively.

The mark-up rate (which is the amount added to the 'cost price' to determine the 'selling price') is taken as a function of the output–capital ratio in some of the quantity clearing sectors. The functions relating the mark-up rate to the output–capital ratios are represented in equations 23–29. Alternative values of the elasticity of the mark-up with respect to the degree of capacity utilization determine the precise nature of the relationship between the level of output and the price level. For convenience the assumption of zero elasticity has been used in the base runs implying fixed mark-up rates in the different sectors.

Equations 30–37 give the price equations for all the quantity clearing sectors with prices being determined on the basis of mark-up and indirect taxes over variable costs per unit of output. Variable costs per unit of output are represented in terms of equations 38–45. They include costs of intermediate inputs, wage costs and import costs less production subsidies.

Government share of profits is represented in equations 46–53. The fraction (P_i) gives the proportion of the government's share in public sector enterprises. Total wage income is defined by equation 54.

Equation 55 (YHP) gives the aggregate level of private profit income which is the sum of mark-up over variable costs less the share of government profit income obtained from public sector enterprises. Y defined in equation 56 gives the total aggregate level of private income, wage income, plus income generated in the agricultural sector.

Consumer behaviour in the model has been formulated on the basis of the linear expenditure system of equations (LES) contained in equations 57–66 for determining the levels of sectoral consumption. D_h in 5 gives the total private consumption spending which is obtained by deducting savings, profit taxes, and wage taxes, and adding consumption subsidies (which effectively increase consumer income). The two important sets of parameters in the LES are the subsistence level of consumption (θ) and the marginal propensity to consume (MP_i). The Engel elasticities were estimated from the family budget data of Egypt (1973–74) and utilized to obtain the above two sets of parameters. The procedures for estimation of these parameters are illustrated in Taylor (1979).[5] The price and income responsiveness of the sectoral levels of consumption are determined by the MP_i parameters across the different sectors.

Equations 67 and 68 set the levels of output in the import and price clearing agricultural and construction sectors at predetermined levels (X_1 and X_2) which are needed to make the system determinate.

T^{ind} in equation 69 represents the total indirect taxes obtained by the government. $GREV$ in equation 71 depicts the government revenue which consists of profit taxes, indirect taxes, direct taxes (i.e. T^d computed in equation 70) and the share of government profits from the public sector enterprises plus the revenues generated from the differential between domestic and foreign prices of exports.[6] The level of government expenditure is given by equation 72 which is determined by the predetermined levels of government demand for commodities G (across sectors) and the level of expenditure incurred on the production and consumption subsidies.

Equation 73 (DEF) represents trade deficit which consists of payments for competitive and non-competitive imports less earnings from exports (valued at world prices) and remittances.

Finally the savings and investment equations are introduced. Total savings in the model are generated from three sources, namely the trade deficit, surplus in the government account and savings generated in the household sector. Total investment in the system is determined by the level of capital formation and stock changes. Since the savings–investment equality is a derived relationship in the model, it provides a good check for the numerical solution.

3. *Parameterization*

The input–output coefficients are obtained directly from the 1977 SAM by taking the ratio of intermediate purchases from different sectors to the level of gross output in the purchasing sector.

The parameters of the LES have been estimated by using the family budget survey data of Egypt for 1974–75. The values of the parameters are depicted in Table A–4. The wage–output ratios (b_i) have been obtained by dividing the total wage income by the level of gross output. The mark-up rates, the unit variable costs, the indirect tax rate, the production subsidies have been calculated directly from the SAM. All sectoral levels of prices have been scaled to unity for the base solution. The savings ratio for the household and the initial values of all of the relevant variables are directly read from the SAM.

4. *Solution*

The models in Table A-2 are of a highly non-linear nature and are currently being solved on the TROLL system (operating on the IBM VM/370) by making use of a Newton–Raphson non-linear equation algorithm. In general terms the solution algorithm follows the following procedure.

The entire system of equations can be substituted and rearranged to a set of sectoral excess demand

Table A–4. *Parameters of the linear expenditure system of demand equations*

Sector	Income elasticity	Own price elasticity	Marginal propensity to consume (ratio)	Subsistence level of consumption (in million LE)
Agriculture	0.58	–0.38	0.12023	663.136
Construction and housing	0.97	–0.50	0.03363	81.09
Heavy industry	1.12	–0.57	0.03203	56.763
Light industry	0.96	–0.69	0.40012	973.08
Transportation	1.9	–0.95	0.07866	9.4605
Rest of the economy	1.26	–0.75	0.31689	418.965
Oil refining	0.75	–0.38	0.00892	33.337
Other energy	1.12	–0.56	0.00952	18.02

equations. Then a set of initial values are specified for the adjusting variables, namely competitive imports for sector 1, a price level for sector 2, and an initial set of quantities for all other sectors, and the excess demands are calculated; then the initial set of values is revised for the adjusting variables till equilibrium is reached, i.e. excess demands in all sectors are approximately close to zero. Different algorithms use different methods for revising the values of the adjusting variables between iterations.

Given the values of the different parameters and exogenous variables, a convergent solution of the model in the base run would generate the 1977 SAM for Egypt represented in Table A–1.

APPENDIX NOTES

1. See Table A–1 for the composition of the 10 sectors from the 32-sector classification in Nazli Choucri and M. Zaki Shafei, ***Resource Development and Policy in Egypt: Petroleum and Natural Gas – Summary and Conclusion*** (MIT Technology Adaptation Program, Report No. 83-3, January 1983).

2. The sectoral breakdown in the national income accounts is as follows: (i) agriculture, (ii) mining and quarrying, (iii) manufacturing, (iv) electricity, gas and water, (v) construction, (vi) wholesale and retail trade, (vii) transport and communication, (viii) finance, insurance and business services, (ix) community, social and personal services.

3. Data on subsidies have been obtained from technical reports prepared by the World Bank.

4. See Table 6 in Youssef Boutros-Ghali and Lance Taylor, 'Labor Force Macroeconomics in Egypt: Structure of a General Equilibrium Model', MIT Working Paper No. 265 (October 1980).

5. See Appendix B in Lance Taylor, *Macro Models for Developing Countries* (New York: McGraw-Hill, 1979).

6. The world prices of agricultural goods, crude oil and petroleum products have been taken to be three, four, and five times as much as the domestic prices of the respective products.