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A SUPPLEMENTARY SIMULATION MODEL OF A NATIONAL ECONOMY FOR AGRICULTURAL SECTOR ANALYSIS

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The importance of agriculture in most developing economies and the special problems of agricultural development have led to a number of models specifically concerned with agricultural sector analysis (e.g., Singh, 1970 and Halter, Hayenga and Manetsch, 1969). However, any effort to model the agricultural sector as a separate entity requires that some parameters of the nonagricultural economy be treated exogenously. It is the purpose of this paper to discuss the importance of agricultural-nonagricultural interactions in agricultural sector planning and propose an elementary model of the total economy which can be used in conjunction with a detailed agricultural sector model for a more complete analysis of the agricultural sector.

There are several key interactions between the agricultural and nonagricultural economies which are relevant to agricultural sector analysis. In particular the flows of goods and services between agriculture and nonagriculture are important in developing economies for several reasons.

1) Food often constitutes over half the consumption expenditure of the nonagricultural population, providing the most important market for agricultural output.

2) Since over half the total population is usually in agriculture, the agricultural population is a vital market for expanding the domestic production of nonagricultural goods and services.

3) The initial stages of industrialization often consist of industries utilizing raw materials supplied by agriculture (e.g., the supply of cotton to textile manufacturing).

4) Agricultural modernization requires inputs of nonagricultural goods and services, again providing a domestic market for nonagricultural output.

In addition the agricultural and nonagricultural economies interact in the factor markets. Capital and foreign exchange are often scarce resources which must be allocated between agriculture and nonagriculture. Furthermore, the distribution of the labor supply between agriculture and nonagriculture depends on the rate of rural-urban migration, which in turn is affected by the rural-urban income differential.

Recognition of these interactions between the agricultural and nonagricultural economies is important to agricultural sector analysis for two reasons. Firstly, variables of the nonagricultural economy which are inputs into the agricultural economy become endogenous to the system. In a dynamic model this enables the full implications of agricultural policies for the agricultural economy to be considered after taking account of the various interactions and feedbacks from the nonagricultural economy. Secondly, the policy maker usually wishes to study the affect of agricultural policies on the national economy. This requires knowledge of the impact of agricultural policies on the nonagricultural economy.

An example of the effects of a policy of increasing agricultural export prices illustrates these points. Assuming that an increase in prices results in an increase in the production of export crops, both the demand for nonagricultural goods and services for production and consumption will be increased. Furthermore, the additional foreign exchange may be a stimulus for nonagricultural investment. The resulting increase in non-

agricultural income leads to an increased demand for food by the nonagricultural population. This in turn leads to repetition of these feedbacks and the generation of second and third round effects. By this interaction with the nonagricultural economy the original increase in agricultural income produces a multiplier effect in the agricultural economy. The full impact of the policy on the agricultural economy cannot be realized without making agriculture-nonagriculture interactions endogenous to the system. Furthermore, from a national viewpoint, increases in output and employment in the nonagricultural economy must be considered in evaluation of such agricultural policies. Again the need arises for a model of the national economy.

The present paper describes a simple simulation model of a total economy designed to interact with more detailed sector models. An overview of the model is given in Figure 1. It disaggregates the total economy (in this case the Nigerian economy) into a number of sectors of interest (e.g., manufacturing, agriculture, services, etc.) linked by means of an input-output table. At the beginning of each period, consumption and investment are generated endogenously in separate components of the model. In each case, only a few key variables are considered. For example, consumption is assumed to depend only on population and personal income. Exports are supplied exogenously to the model and aggregated with consumption and investment to give total final demands from each sector. Using conventional input-output techniques these final demands are translated in the production component into inter-industry flows, intermediate imports and value added for each sector. These results are then used in the construction of the

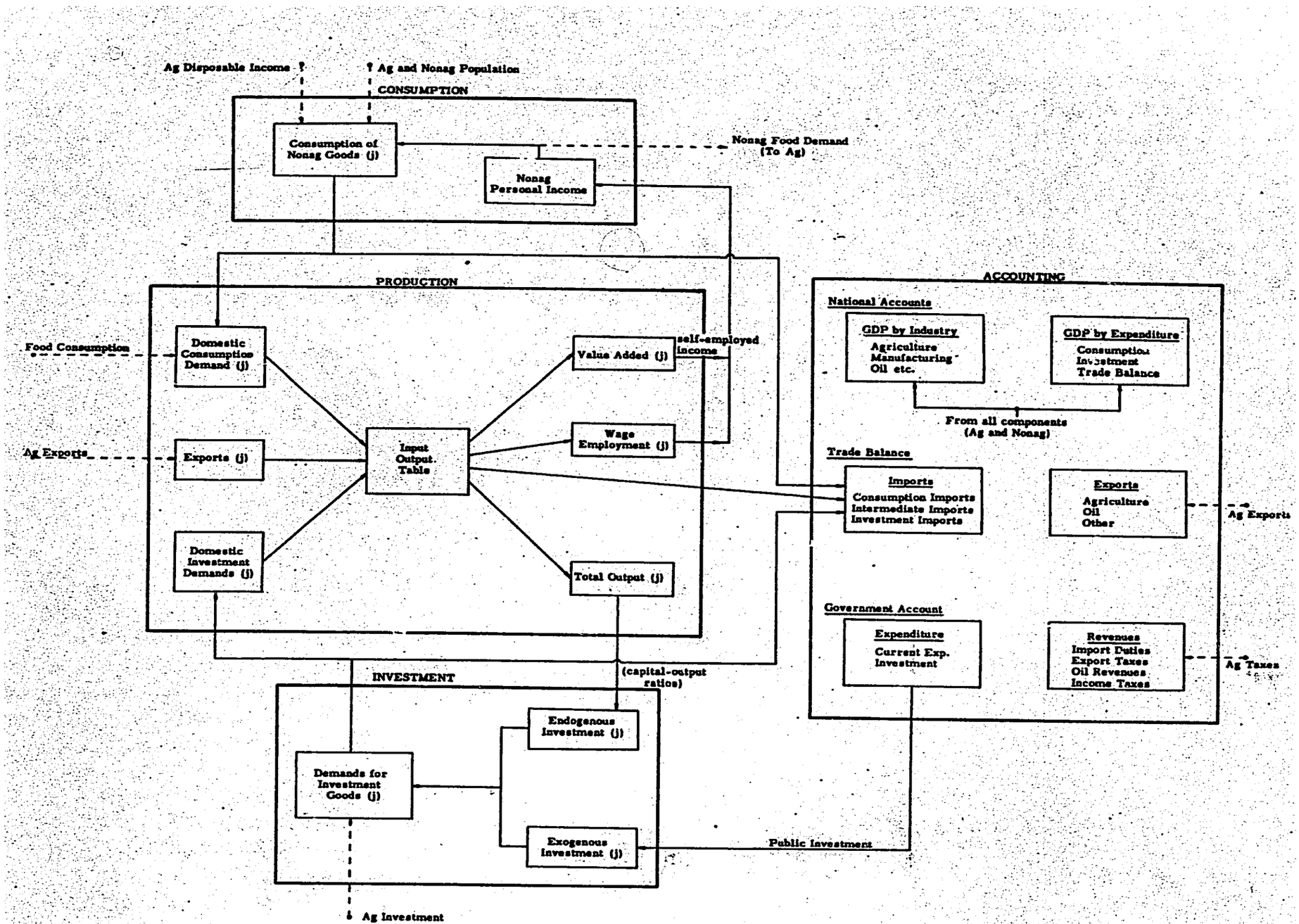

Figure 1 The National Model

national accounts and the computation of consumption and investment in succeeding periods. There are various lags and smoothing processes in the model which reflect the decision making behavior of producers and consumers and give stability to the system. For example, consumption is assumed to be a function of an exponentially lagged value of income rather than income in the current period.

The above model is an elementary means of describing the total economy. It is static in the sense that many parameters, particularly the input-output coefficients are exogenous to the system, although they may be varied exogenously over time to reflect structural changes in the economy. However, the model does go much further than static input-output analysis in making consumption, investment, imports and employment endogenous in the system.

Because of its simplicity the model has little value in detailed national policy formulation, although it may help in making aggregate economic projections and understanding the interactions between sectors. An example will be given later to show the different linkage effects of comparable increases in agricultural exports and oil exports. The essential point is that, although the model can show what the implications of a given increase in agricultural output is for the total economy (after the interactions discussed above are considered) it does not show how an increase in agricultural output may be achieved.

The present macro-model has been designed to interact with a detailed agriculture sector model. With only minor modifications it could also interact with any other sector model such as a model of small scale industry.

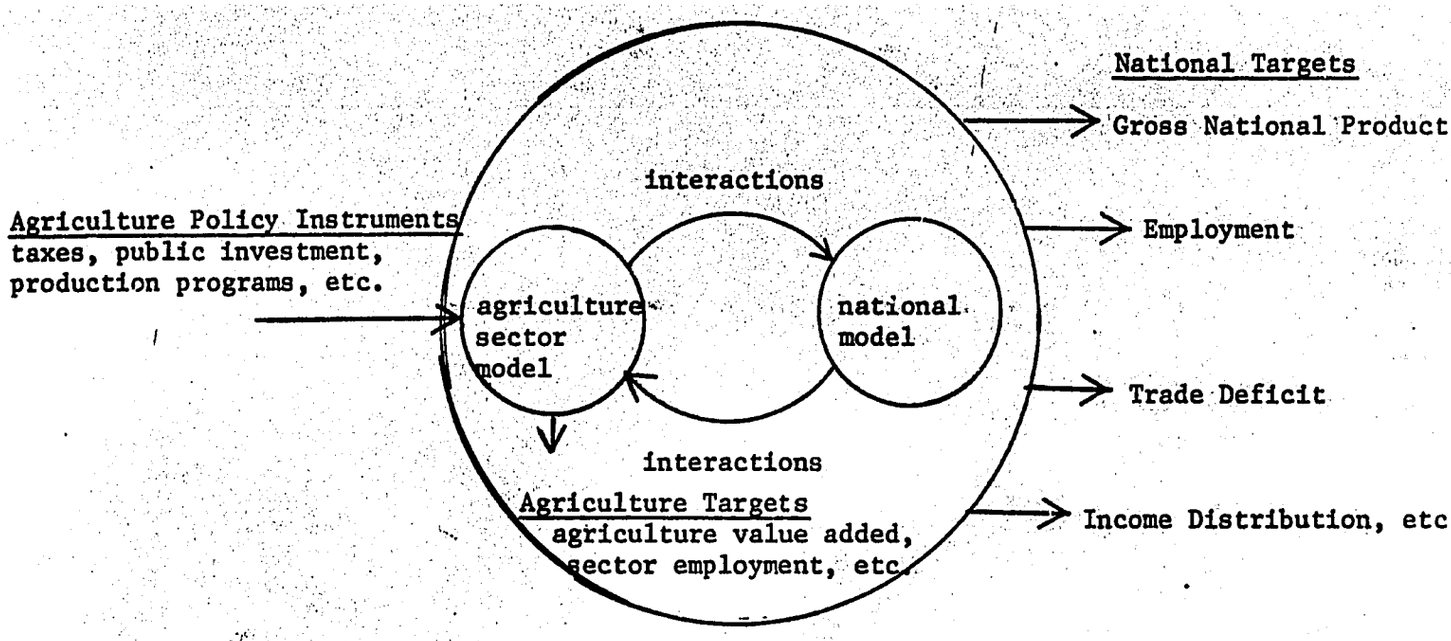

Figure 2 The National Model in a Policy Framework.

This type of interaction enables detailed policy evaluation within a sector as represented in Figure 2. In the total model, agriculture is represented by a single sector. However, merging it with the detailed agricultural models enables all the inputs and outputs of the sector to be computed endogenously taking account of the many ecological regions, commodities and other complex interactions of the sector. Thus, agricultural consumption, investment, exports, employment and the relevant input-output coefficients become functions of agricultural policy instruments. In turn, the non-agricultural sectors feed back to the agriculture sector models relevant variables (such as nonagricultural income which is an element of the demand for food), and these variables become endogenous to the agricultural system. This whole process allows policy experiments to be evaluated in the context of the total economy.

The various components of the macro-model are described below and a more detailed mathematical description of the model is given in the appendix. Some test runs and sensitivity analysis will be presented to illustrate the usefulness of the model.

Components of the Model

Exports

Exports are regarded as exogenous variables in the model. In the Nigerian case there are two main groups of exports: agricultural and petroleum. Agricultural exports are either assumed to grow at a rate reflecting recent historical trends or are computed endogenously in a

detailed agriculture sector model and fed to the macro-model. In the case of oil, future exports are a function of many uncertainties such as the success of exploration and international oil politics. Thus, optimistic and pessimistic time series projections were used to represent oil exports.

Consumption

The consumption component simulates the demands by various classes of consumers for domestically produced goods and services and for imports of goods and services. Presently only agricultural and nonagricultural classes of consumers are considered (approximating the rural and urban populations) although the model has the flexibility to account for different consumption behavior by regions and income levels when data are available.

The total consumption of goods and services of each sector[1/] is a function of the population and personal income of each class of consumers. (Equation (C4)) This function takes account of the different consumption levels and behavior of rural and urban populations. The relative prices of goods and services are assumed constant, except where the model interacts with a detailed agriculture sector model. Here the consumption of food by the agricultural and nonagricultural populations may be computed by the interaction of supply and demand, and fed to the aggregative model. The consumption of nonagricultural goods and services is then a function of personal income, population and the price of nonagricultural goods relative to food.

Finally, the demand for goods and services is totaled over all consumers and divided between domestic production and imports. The proportion imported is determined exogenously in the model although this proportion

1/ The term sector is used to refer to production sectors such as agriculture and manufacturing. A fuller discussion of the sectoral breakdown is given in the description of the production component.

is trended downward over time to reflect import substitution. The demand for domestically produced goods is then fed to the production component.

Investment

Investment in each sector is divided between public investment and private investment. Public investment is modeled as an exogenous variable in the system; this investment tends to be concentrated in the transportation, utilities and service sectors. With the exceptions of agriculture and oil, private investment is endogenously determined using incremental capital-output ratios for each sector. Inventories and replacement investment are assumed to be a fixed proportion of total gross investment.

Agricultural investment is either an exogenous variable of the system or is computed endogenously in an agricultural sector model. Some agricultural investment such as land clearing and cattle breeding are considered to require negligible intermediate inputs such as machinery or construction. Since this investment does not create any immediate demand for goods and services, it is not added to the investment demands for domestic production, but is included in the national accounts.

Investment in the oil industry consists of two types: exploration and production. Since exploration investment (the dominant form of current investment in Nigeria) is a long run process with highly uncertain outcome, it is impossible to relate investment to output by a capital-output ratio. Hence investment in the oil industry, though private, is assumed to be exogenously determined.

Finally, investment by households in residential construction generates a substantial source of domestic investment demand. This is computed as a function of personal income and population, with a relatively long delay attached to the effect of personal income changes.

These investments demands by each sector must be translated into demands for capital goods from each sector. For example, total investment in the manufacturing sector must be disaggregated into demands for construction, machinery, transport, etc., and imports. A matrix of exogenously specified coefficients, analogous to an input-output table is used to perform this disaggregation (Equation (I4)). The requirements for domestic production generated by investment are then fed to the production component.

Production

The basis of the production component is an input-output table of the economy. For the case of Nigeria, data collected by Carter for the year 1959, was used to construct an input-output table of the economy with 10 sectors divided into two groups, traditional and modern. Details of the composition of each of these sectors is given in Table 1. There are four small-scale sectors, agriculture, residual agriculture, small industry and small trade-services composed of firms employing less than ten persons. These firms generally use family labor and traditional methods of production. The remaining sectors all employ ten or more persons and use wage employment. Modern capital intensive methods of production are common in these sectors. This distinction on the basis of scale of industry is useful in simulating investment, employment and consumption since the small-scale sectors tend

to be more labor intensive and produce commodities with different consumer tastes.

The input-output table employed in the model is shown in Table 2. This table illustrates some typical aspects of a developing economy. The traditional small scale sectors are characterized by limited interaction with the rest of the economy relative to the large scale sectors. Likewise the large scale sectors have higher import requirements. However, in a rapidly growing economy such as Nigeria the structure of the economy as represented by an aggregated input-output table is likely to change over time. For example, the period 1960-1966 in Nigeria was characterized by the rapid growth of the oil industry. Whereas in 1959 the mining sector consisted mainly of coal and tin mining, by 1965 petroleum had become the dominant output of this sector resulting in possible changes in the input-output coefficients of this sector. Without further disaggregation it is not possible to reflect these changes endogenously. Another possible change in input-output coefficients can come about through substitution particularly import substitution where domestic sources of inputs are substituted for previously imported materials. Again making these changes endogenous in the system would require making imports competitive with domestic production (see for example Cheney 1963).

These processes of building new industries, changing techniques and import substitution are fundamental to the development process. Without making them endogenous in the system the model can have little value in national policy formulation. However, by reflecting these processes exogenously we are able to describe the growth of the economy and understand the implications of these changes for development.

Table 1 The Sector Breakdown in the National Model

Sector	Name	Composition of Sector
1	Agriculture	Main cash crops, food staples, and cattle
2	Residual Agriculture	Residual crops, residual livestock, fishery and forestry
3	Small Manufacturing	Carpentry, weaving, shoe making and other crafts
4	Small Scale Services	Petty trading and services
5	Mining	Metal and nonmetal mining and petroleum
6	Construction	Residential housing, private and public construction projects
7	Transport	Rail, boat, road, air
8	Utilities	Electricity and water
9	Large Manufacturing	Processed food, drink, tobacco, chemicals, metal manufacturing, etc.
10	Large Services	Large scale trading companies, banking, insurance, etc.

Given this input-output table the production component firstly aggregates the final demands of exports, investment and consumption and then by input-output techniques computes value added, imports and total output of each sector. Total output is fed to the investment component and value added and imports to the national accounts. Finally, personal income is computed. This consists of wage earnings for the modern sectors and income of the self-employed in the traditional sectors.

Wage employment in each sector is assumed to grow at the same rate as the output of the sector with an adjustment for productivity changes. (Equation (P7)). These productivity changes arise from many factors such as the under-utilization of the existing capital stock and increasingly

Table 2 Input-Output Coefficients of the Nigerian Economy for 1959

	Small Scale				Large Scale					
	1[a/]	2	3	4	5	6	7	8	9	10
1. Main Agriculture	.0	.0	.085	.0	.006	.0	.0	.0	.137	.0
2. Residual Agriculture	.0	.0	.068	.0	.0	.092	.0	.037	.025	.0
3. Small Manufacturing	.001	.001	.0	.008	.006	.021	.045	.068	.015	.010
4. Small Trade-Services	.001	.003	.040	.0	.012	.067	.016	.019	.007	.028
5. Mining-Oil	.0	.0	.001	.0	.0	.051	.008	.079	.007	.0
6. Construction	.0	.0	.0	.003	.007	.0	.0	.004	.002	.019
7. Transport	.003	.063	.037	.018	.018	.079	.0	.054	.027	.013
8. Utilities	.0	.005	.002	.0	.020	.001	.0	.0	.014	.007
9. Large Manufacturing	.0	.0	.021	.002	.007	.029	.023	.023	.0	.011
10. Large Services	.004	.003	.037	.023	.012	.010	.028	.018	.037	.0
Imports	.016	.014	.197	.009	.223	.228	.113	.135	.232	.031

a/ Each column shows the input requirements for production of one unit of output. For example, one unit of agricultural output (column 1) requires the input of .001 units of Small Manufacturers and .016 units of imports.

capital intensive techniques of modern production. The rate of change of productivity and wages are assumed to be exogenously determined in the model. Also included in wage employment is government employment which is related to government value added.

Earnings of the self-employed are assumed to be a proportion of value added with the remaining proportion being invested or remitted abroad. The proportion of value added accruing to the self-employed is very high for the traditional sectors and lowest for the mining and petroleum sectors.

Wage earnings and self-employed earnings are summed to give personal income which is fed to the consumption component. Clearly in these computations of personal income many factors such as taxes and wage rate determination have been ignored. Again the availability of a detailed sector model enables a much more sophisticated modeling of these variables for that sector.

National Accounts

At the end of each series of computations the model constructs a set of accounts. The national accounts include estimates of gross domestic product by branch of activity (e.g., agriculture, manufacturing, government, etc.) and by category of expenditure (consumption, investment and the trade deficit). This is a simple accounting procedure aggregating results from all components. Similarly the trade balance is computed as the total of all exports of goods and services less the total of all imports of goods and services, valued at F.O.B. prices. The computation of government revenues such as import duties requires exogenously specifying

such policy parameters as tax rates. These accounts form the basis of the output of the model used in evaluating agricultural policies at the macro-economic level.

Data Requirements of the Model

Corresponding to each component of the model is a key set of a parameters, the input-output coefficients of the production component, capital-output ratios of the investment component and income elasticities of demand of the consumption component. In each case the degree of disaggregation by sectors determines the amount of data required.

Increasingly input-output tables are becoming available in developing countries. In most cases these tables do not exceed twenty sectors but can be collapsed to ten sectors as we have done in the Nigerian case. Similarly, data for estimating consumption elasticities will not usually be a limiting factor in model building although disaggregation by rural and urban populations may not always be possible. Data on capital-output ratios and the determinants of investment probably involves the highest degree of uncertainty. This is so because often many factors affect the relationship between investment and output. In the case of Nigeria we found that there was a good deal of uncertainty as to the level of investment itself and this, of course, adds to the uncertainty in the capital-output ratios.

In particular, over the period 1959-1966 there are four independent and widely divergent estimates of investment for Nigeria (Langley (1963)). Part of the difference in these estimates arises in measurement of investment in agriculture. The official estimates include only investment in

plant and equipment while Helleiner, for example, includes the value of land development. In any event the total investment in agriculture is probably grossly underestimated and this limits the estimated contribution of agriculture to gross domestic product.

While aggregation of the economy into few sectors will reduce the data requirements[1/] it has disadvantages in the model's ability to describe the economy. A high degree of aggregation necessarily entails lumping together in one sector a number of diverse industries. In a dynamic economy each of these industries will be growing at different rates, changing the composition of the sector and hence the parameters associated with that sector. We have already discussed the case of the oil industry in Nigeria as an example of a rapidly growing industry which is likely to change the parameters of the minerals sector. In the short run such changes may be modeled exogenously, particularly if parameters such as input-output coefficients can be estimated at two or more points in time. Thus we used the work of Clark (1967) as a guide to the changes in the parameters of the model for Nigeria between the years 1959 and 1965. In the longer run such changes can only be modeled with a great deal of uncertainty.

Testing and Running of the Model

The model was tested and tuned on the basis of a comparison of output of the model and the official Nigerian national accounts. Since the initial conditions were estimated from the input-output study of Carter, the output

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1/ Since there are several matrixes of parameters, particularly the input-output table, disaggregation will tend to increase the data requirements exponentially rather than linearly.

of the model was not strictly comparable with the official accounts. Thus tuning of the model was based on causal comparison of growth rates and trends rather than formal statistical procedures. Because of the disruption of the economy after 1966 due to civil war, the period 1959-1966 was used as a basis for tuning.

As we noted above the greatest source of uncertainty was in the investment parameters and the change of all parameters over time. For example, large scale manufacturing has been growing at the rate of 10-15% per annum over the period. This growth rate can only be explained in terms of import substitution processes. Although we used the work of Clark (1969) as a guide to the changes in the import coefficients associated with this sector, considerable uncertainty still remained for further adjusting these parameters in the tuning-up process.

There are two serious shortcomings of the validation of the model. Firstly, the period of 7 years used for validation was not sufficiently long enough to enable confident use of the model in long term planning. Secondly, many of the variables such as investment used in comparing the simulated results with the real world are subject to a good deal of error in real world estimation. This can only be corrected by better collection of national statistics.

A series of runs is presented to illustrate the capability of the model. In table 2, Run 1 is a base run for the period 1959-1966 with exports held constant at a level approximating the actual export figures for those years. In Run 2, the level of agricultural exports has been

exogenously increased by £10 million for the period. The multiplier effects on the total economy of this increase is seen in Table 2, to be in the order of three. When the original increase in exports is allowed for, the multiplier effect is highest on the nonagricultural economy. Figure 3 traces these results over time for both the agricultural and nonagricultural economies. This shows that it takes from three to four years for the full multiplier effect to be achieved. The value of the model in evaluating the effect of agricultural policy on the total economy is obvious from these results. Run 3 of Table 2 shows similar results for the case of an exogenous increase in oil exports. As expected, because of profits remitted aboard and higher import requirements, the multiplier effects are considerably smaller.

Table 2 Illustrative Runs of the National Model

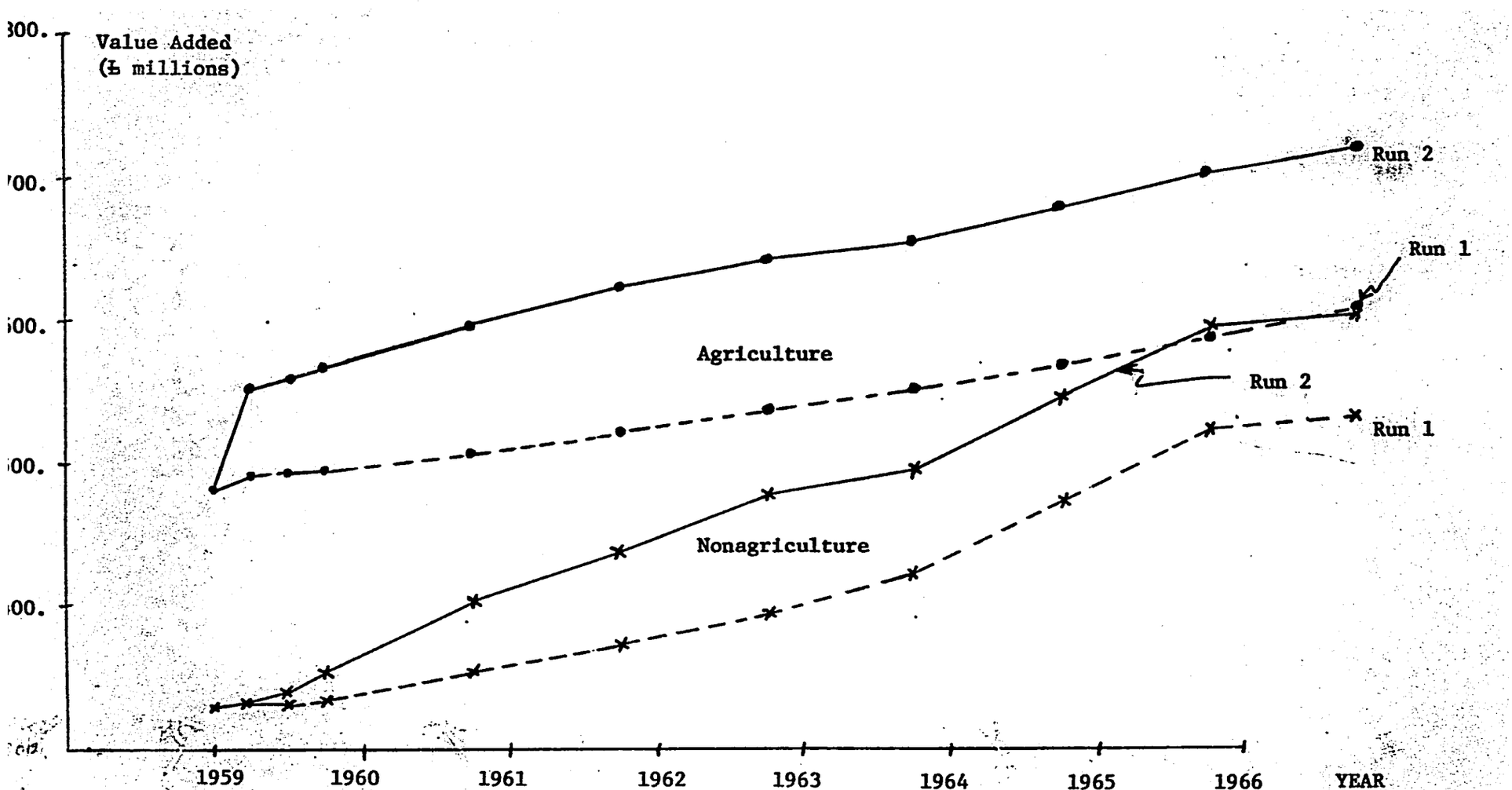
Run[a]	Agricultural Contribution to GDP	Nonagricultural Contribution to GDP	Total GDP[b] at Market Prices
	Year 1966/67--Millions Nigerian Pounds		
Run 1	707	630	1,461
Run 2	727	643	1,497
Δ[c]	20	13	36
Run 3	708	640	1,473
Δ	1	10	12

a/ Run 1--Base Run
Run 2--Exogenous increase of £10 million in agricultural exports, 1959-1966
Run 3--Exogenous increase of £10 million in oil exports, 1959-1966

b/ Includes government and indirect taxes

Figure 3 Time Path of Illustrative Runs of the Model

Run 1--Base Run
Run 2--£60 million increase in agricultural exports



Discussion and Conclusions

The model simulates behavior in the real world over the period 1959-66 with reasonable accuracy. Ideally, however, a longer period than 7 years would be required for confident validation. Because only key variables were used in each component of the model it is not generally able to simulate minor year to year fluctuations in the economy, although longer term trends will usually be reflected by the model.

The essential usefulness of the model lies in its ability to interact with detailed sectoral models to enable modeling of intersectoral multiplier effects and policy evaluation with respect to the total economy. The model also has value in making macro-economic projections taking into account interactions between sectors. This promises improvement over conventional economic projections for planning where such interactions are not formalized. Furthermore the model does enable a more complete understanding of the growth processes since it disaggregates the economy by production sectors (e.g., agriculture, manufacturing, oil, transport, etc.) and allocates the output of each sector by end use (i.e., consumption, investment, exports, and intermediate products). This matrix of interacting sectors and uses pinpoints the growing points of the economy.

There are many directions in which the model could be extended. Firstly, more variables could be introduced into the determinants of consumption and investment. For example, Holland (1963) in a simulation model of the Venezuelan economy incorporated the notion of expectations in investment behavior by including oil exports as an element of an aggregate investment equation. While a similar argument may hold for investment in Nigeria

we felt that for the present purposes this would detract from the generality of the model. However, in any application to planning a specific country such adjustments may be necessary to account for the uniqueness of that economy. What we have proposed in the present model is a skeletal framework of a few key variables upon which further refinements can be made in any specific application.

Secondly, the model needs to be further developed to include prices as endogenous variables of the system. In Holland's model of Venezuela prices are a function of capacity utilization where capacity is defined in terms of the capital stock. Again the generality of this approach is questionable since many factors additional to capital are likely to be important in determining the supply function of an industry. Indeed, in the case of Nigeria, Kilby (1969) has argued that entrepreneural ability is a critical determinant of supply response in Nigeria manufacturing. Furthermore, for Nigeria where price movements both absolute and relative were not substantial for the period of interest, the model's results are not greatly affected by the assumption of constant prices. However, a great deal of generality could be gained by including an additional component incorporating money supply, exchange rates and price determination. This is necessary for the model to be applied to countries with significant price instability.

Finally, further attention to the agricultural sector should enable the model to be directly used in agricultural planning, independently of a detailed agricultural sector model. For our purposes we have contracted the agricultural economy into one sector with a total output greater than

the remaining nine sectors. Within the existing framework the agricultural sector could be divided into a food sector and export crop sectors to evaluate the impact of various production campaigns. Alternatively where competition between crops for land and capital or prices determination are of interest, further model building would be required.

APPENDIX

This appendix gives a mathematical description of the model. The overall picture of the model has been given by Figure 1 in the body of the chapter. There is a switch in the program which is set to enable the model to run as a separate entity or in conjunction with a detailed agricultural sector model. In the following description it is assumed that a detailed agricultural sector model is available to provide estimates of agricultural investment and exports, food consumption and agricultural disposable income on a regional basis. The alternative method of computing these estimates for independent runs is shown in footnotes.

Exports

All exports are computed exogenously to the model. Exports of agricultural commodities are provided by the agricultural sector model and summed by equation (E1).[1/] Exports of residual crops, mainly timber, are assumed to grow at a fixed rate. Associated with agricultural exports are exports of transport and distribution services which are obtained in Equation (E2) by allocating a proportion of the marketing margins computed by the agricultural models to these sectors.

(E1) $EXTD_1(t) = \sum_i VALXPP_i(t)$

where:

$EXTD_1$ = total agricultural exports--thousand £/year

$VALXPP_i$ = value of agricultural exports at producer or processor prices in the ith region--thousand £/year (computed in the agricultural model).

1/ For independent runs, agricultural exports are assumed to grow at a rate reflecting past historical trends.

(E2) $EXTD_6(t) = 0.3*\sum_i TVAMEX_i(t)$

$EXTD_{10}(t) = 0.7*\sum_i TVAMEX_i(t)$

where:

$EXTD_6$ = transport exports--thousand Ł/year

$EXTD_{10}$ = service and trade exports--thousand Ł/year

$TVAMEX_i$ = marketing margin of export crops in the ith region--thousand Ł/year (computed in the agricultural model).

Oil exports are included simply as an exogenous time series, $EXTD_5(t)$. This time series may reflect pessimism or optimism concerning the outlook for oil exploration.

Consumption

The consumption component first computes the per capita disposable income of each class of consumers. The disposable income of the agricultural population is the sum of the disposable incomes provided by the agricultural model (Equation (C1)).

Profits retained, purchased inputs and cash food consumption have been subtracted from cash income to yield income available for nonagricultural consumption.1/

(C1) $PDSINC_1(t) = \left(\sum_i TAGDIP_i(t) + PINC_2(t)\right)/POP_1(t)$

1/ An alternative computation of agricultural disposable income is given by equation (C1.1)

(C1.1) $PDSINC_1(t) = \left(PINC_1(t) + PINC_2(t)\right)/POP_1(t)$

where $PINC_1$ = personal income generated by the main agricultural sector--thousand Ł/year (computed in the production component in Equation (P8))

where:

$PDSINC_1$ = total per capita disposable income in agriculture --Ł/year

$TAGDIP_i$ = total agricultural disposable income in the ith region--thousand Ł/year (computed in the agricultural model)

POP_1 = total agricultural population--thousands/year (computed in the population model)

$PINC_2$ = personal income generated by the residual agricultural sector--thousand Ł/year (computed in the production component in equation (P8))

The disposable income of the nonagricultural population is computed in Equation (C2) as the total of personal income from each nonagricultural sector less expenditure on food. Personal income is computed in the production component as wages and salaries for those employed in modern sectors and average earnings for those self-employed in traditional sectors.

$$\text{(C2)} \quad PDSINC_2(t) = \left(PINCNA - \sum_i TFCNAG_i(t)\right)/POP_2(t)$$

where:

$PDSINC_2$ = total per capita disposable income of the nonagricultural population--Ł/year

PINCNA = total personal income earned by the nonagricultural population--thousand Ł/year (computed in the production component by equation (P9))

$TFCNAG_i$ = total food consumed by the nonagricultural population in the ith region--thousand Ł/year (computed in the agricultural model)

POP_2 = total nonagricultural population--thousands.

Consumption demand for nonagricultural goods and services is determined by the elasticity of demand with respect to per capita income (Equation (C3)). That is the relative prices of nonagricultural goods are assumed constant.

(C3) $PCON_{i,j}(t) = ACON_{i,j} * PDSIND_i(t)^{ELAST_{i,j}}$, $j = 2,..10$

where:

$PCON_{i,j}$ = the per capita consumption of the jth commodity by the ith class of consumers--Ł/year

$ACON_{i,j}$ = an empirically determined constant

$PDSIND_i$ = the exponentially lagged value of per capita disposable income, $PDSINC_i$--thousand Ł/year

$ELAST_{i,j}$ = the income elasticity of demand of the ith class of consumers for the jth commodity.

Consumption of food staples is computed by Equation (C4), using estimates of food consumption computed in the marketing mechanism of the agricultural model.1/

(C4) $PCON_{1,1}(t) = \sum_i TFCAG_i(t)/POP_i(t)$

$PCON_{2,1}(t) = \sum_i TFCNAG_i(t)/POP_2(t)$

where:

$PCON_{i,1}$ = per capital consumption of food by the ith class of consumers valued at producer prices--Ł/year

$TFCAG_i$ = total food consumed by the agricultural population in the ith region--thousand Ł/year (computed in the agricultural model)

$TFCNAG_i$ = total food consumed by the nonagricultural population in the ith region--thousand Ł/year (computed in the agricultural model)

POP_i = population of the ith class of consumers--thousands.

1/ Alternatively food consumption is computed in Equation (C3.1) by extending Equation (C3) to cover the main agricultural sector.

(C3.1) $PCON_{i,j}(t) = ACON_{i,j} * PDSIND_i(t)^{ELAST_{i,j}}$, $j = 1,...10$

Total consumption of each commodity is then simply the sum of the consumption of each class of consumers (Equation (C5)).

(C5) $TCONS_j(t) = \sum_i POP_i(t)*PCON_{i,j}(t)$

where:

$TCONS_j(t)$ = total national consumption of the jth commodity--thousand Ł/year.

Equations (C6) and (C7) divide this consumption into domestically produced goods and imported goods. Imports are assumed to be a proportion of total consumption although it is possible for this proportion to vary exogenously to represent import substitution.

(C6) $CIMP_j(t) = CIMPP_j(t)*TCONS_j(t)$

where:

$CIMP_j$ = imports of the jth commodity--thousand Ł/year

$CIMPP_j$ = proportion of the total consumption of the jth commodity imported.

(C7) $DCD_j(t) = TCONS_j(t) - CIMP_j(t)$

where:

DCD_j = demand for domestically produced consumption goods--thousand Ł/year.

Domestic consumption demand, DCD_j, becomes part of final demand for domestic production while total consumption, $TCONS_j$, and imports, $CIMP_j$, are used in the construction of the national accounts.

Investment

Exogenous investment consists largely of public capital formation in the utilities, transportation and services sectors. In each time period, both the total amount of public investment and the allocation between sectors are exogenous variables. Investment in petroleum exploration and production is also included as an exogenous time series projection since investment in this sector is largely determined by factors outside of the economy. Although investment in the agricultural sector is exogenous to the model it is computed endogenously in the agricultural model and summed by Equation (I1) to give total investment.[1/]

(I1) $EXOG_1(t) = \sum_i CAPDP_i(t) + CAPDPP(t)$

where:

$EXOG_1$ = total investment in the agricultural sector (excluding land development)--thousand Ł/year

$CAPDP_i$ = investment in agricultural production in the ith region--thousand Ł/year (computed in the agricultural model)

CAPDPP = investment in agricultural processing--thousand Ł/year (computed in the agricultural model).

Endogenous investment is computed by Equation (I2). Because of the lack of data no effort was made to separately compute replacement investment and inventories. Rather the assumption was made that these investments form a fixed proportion of total investment and are included in the capital-output ratios.

1/ For independent runs of the model, agricultural investment, $EXOG_1(t)$, is assumed to grow at an exogenous rate reflecting recent historical trends.

(I2) $ENDOG_j(t) = PENDOG_j * CYMR_j * ROUTD_j(t)$

where:

$ENDOG_j$ = total endogenously derived investment in the jth sector--thousand £/year

$PENDOG_j$ = proportion of output privately produced in the jth sector

$CYMR_j$ = marginal capital-output ratio in the jth sector

$ROUTD_j$ = smoothed rate of change of output of jth sector--thousand £/year (from Equation (P1) of the production component).

Total demands for investment goods by all sectors excluding households is given in equation (I3) as the sum of exogenous and endogenous investment.

(I3) $RINV_j(t) = TEXOGI_j(t) + ENDOG_j(t)$

where:

$RINV_j$ = total demand for investment goods by the jth sector--thousand £/year

$TEXOGI_j$ = total exogenous investment in the jth sector (private and government)--thousand £/year.

These investment requirements of each sector for capital goods are translated into demands for capital goods from each sector by Equation (I4). A matrix, B, of endogenously specified coefficients measures the demand for investment goods from the jth sector generated by one unit of investment expenditure in the kth sector. An analagous set of coefficients determines the demands for imports of investment goods.

(I4) $DIND_j(t) = \sum_k B_{j,k} * RINV_k(t)$

$RIIMP_i(t) = BIMP_i * RINV_i(t)$

where:

$DIND_j$ = the demand for domestically produced investment goods from the jth sector--thousand Ł/year

$B_{j,k}$ = the demand for the jth good generated by one unit of investment in the kth sector

$RIIMP_j$ = the demand by the jth sector for imports of investment goods--thousand Ł/year

$BIMP_j$ = the demand for imports of investment goods generated by one unit of investment in the kth sector.

and:

$$\sum_j B_{j,k} + BIMP_k = 1.$$

Investment by households in residential construction is generated in Equation (I5). This investment is part of domestic investment demand for construction (sector 6) and is added in Equation (I6) to that generated by Equation (I4). Domestic investment demand then becomes an element of final demand.

(I5) $RESIN(t) = ARESIN*TPOP(t)*PCINCD(t)^{RESELY}$

where:

RESIN = investment in residential construction--thousand Ł/year

ARESIN = empirically determined constant

TPOP = total population--thousands

PCINCD = exponentially lagged value of average per capita income--thousand Ł/year

RESELY = demand elasticity for residential construction.

(I6) $DIND_6(t) = DIND_6(t) + RESIN(t)$

Finally, some investment such as investment in land clearing is considered non-intermediate investment in the sense that intermediate inputs are negligible. This investment does not enter final demand but for national accounting purposes is included in total investment by Equation (I7).

$$\text{(I7)} \quad TINV(t) = \sum_j RINV_j(t) + RESIN(t) + ONIINV(t)$$

where:

RINV(t) = total national gross investment--thousand Ł/year

$\sum_j RINV_j$ = investment of all production sectors--thousand Ł/year

RESIN = investment of households in construction--thousand Ł/year

ONIINV = other non-intermediate investment--thousand Ł/year

Production

Total final demand is the sum of the various demands for domestic production given by Equation (N17).

$$\text{(N17)} \quad FDY_j(t) = DCD_j(t) + DIND_j(t) + EXTD_j(t)$$

where:

$DCD_j(t)$ = domestic consumption demand for the jth commodity--thousand Ł/year (computed in the consumption component by equation (C7))

$DIND_j(t)$ = domestic investment demand for the jth commodity--thousand Ł/year (computed in the investment component by equation (J6))

$EXTD_j(t)$ = export demand for the jth commodity--thousand Ł/year (computed in the export component)

Given the vector of final demands, total output including intermediate demands is computed by means of the input-output table in Equation (P1).

(P1) $OUT(t) = [I - AIO]^{-1} * FDY(t)$

where:

OUT = row vector (OUT_j, j = 1, 10) of outputs of each sector--thousand Ł/year

I = the identity matrix

AIO = input-output matrix ($AIO_{j,k}$, j = 1, 10, k = 1, 10) where each element, $AIO_{j,k}$, represents the input of the jth sector required in the production of one unit of the kth good

FDY = column vector (FDY_k, k = 1, 10) of final demands from the kth sector--thousand Ł/year.

Given the total output of each sector, imports for intermediate use are computed by Equation (P2). It is assumed that these imports are not competitive with local production.

(P2) $RIMP_j(t) = RIMIO_j * OUT_j(t)$

where:

$RIMP_j$ = imports required for the production of the jth commodity--thousand Ł/year

$RIMIO_j$ = imports required for the production of one unit of the jth commodity.

The inputs of domestically produced intermediate goods are calculated in Equation (P3). Value added is then given in Equation (P4) as the difference between total output and total intermediate inputs and represents the returns to the factors of production; namely, land, labor and capital.

Value added also shows the contribution of each sector to gross national product in the national accounts.

(P3) $RINID_j(t) = \sum_k AIO_{j,k} * OUT_j(t)$

where:

$RINID_j$ = total of domestically produced inputs in the jth sector--thousand Ł/year.

(P4) $VALAD_j(t) = OUT_j(t) - (RINID_j(t) + RIMP_j(t))$

where:

$VALAD_j$ = value added in the jth sector--thousand Ł/year.

Finally, personal income of each sector is the total of wages of the wage earners and income of the self-employed. Earnings of the self-employed are given by Equation (P5) as a proportion of total value added. This proportion is very low for the modern sectors where wage earnings predominate and very high for the traditional sectors.

(P5) $SINC_j(t) = (1 - P_j) * VALAD_j(t)$

where:

$SINC_j$ = value of earnings of self-employed in the jth sector--thousand Ł/year

P_j = proportion of value added retained as returns to capital or remitted abroad in the jth sector

$VALAD_j$ = value added in the jth sector--thousand Ł/year.

Earnings from wage employment are given by Equation (P6). Changes in wage labor productivity are accounted for in Equation (P7).

(P6) $WINC_j(t) = RLAB_j(t)*OUT_j(t)*WAGE_j(t)$

where:

$WINC_j$ = value of earning from wage employment in the jth sector--thousand Ł/year

$RLAB_j$ = the number of labor units of wage employment required to produce one unit of the jth output (See Equation (P7))

OUT_j = total output of the jth sector--thousand Ł/year (from Equation (P1))

$WAGE_j$ = the average wage rate in the jth sector--thousand Ł/man-unit.

(P7) $RLAB_j(t) = (1 - RPROD_j)*RLAB_j(t-1)$

where:

$RLAB_j$ = as defined in Equation (P6) above

$RPROD_j$ = rate of increase in labor productivity in the jth sector.

Personal income is then the sum of wage earnings and earnings of the self-employed as in Equation (P8).

(P8) $PINC_j(t) = SINC_j(t) + WINC_j(t)$

where:

$PINC_j$ = personal income arising in the jth sector--thousand Ł/year

Personal income of the agricultural population may be computed by Equation (P9) or determined separately in an agricultural sector model. Equation (P10) sums personal income in the nonagricultural sectors including government. Government value added is exogenously determined.

(P9) $PINCAG(t) = PINC_1(t) + PINC_2(t)$

(P10) $PINCNA(t) = \sum_{i=3}^{10} PINC_i(t) + GOVALD(t)$

where:

PINCAG = personal income of the agricultural population--thousand Ł/year

PINCNA = personal income of the nonagricultural population--thousand Ł/year

GOVALD(t) = government payments of wages and salaries--thousand Ł/year.

The National Accounts

The national accounts component computes gross domestic product and the trade balance. Gross domestic product at factor cost is computed in Equation (N1). Both non-intermediate investment and government value added are exogenous in the model.

(N1) $GDPF(t) = \sum_j VALAD_j(t) + ONIINV(t) + GOVALD(t)$

where:

GDPF = gross domestic product at factor cost--thousand Ł/year

$VALAD_j$ = value added in the jth sector--thousand Ł/year (computed in the production component by Equation (P4))

ONIINV = other non-intermediate investment--thousand Ł/year

GOVALD = value added by all governments and marketing boards--thousand Ł/year.

In order to compute gross domestic product at market prices, total exports and imports must first be calculated at f.o.b. prices. Total imports are computed by Equation (N2).

(N2) $TIMP(t) = \left(\sum_j RIMP_j(t) + \sum_j RINIMP_j(t) + \sum_j CIMP_j(t)\right)/(1 - DUTIMR)$

where:

TIMP = total imports at f.o.b. prices--thousand Ł/year

$RIMP_j$ = imports for intermediate use in the jth sector at market prices--thousand Ł/year (computed in the production component by Equation (P2))

$RINIMP_j$ = imports for investment use in the jth sector at market prices--thousand Ł/year (computed in the investment component by Equation (I4))

$CIMP_j$ = imports of the jth commodity for consumption at market prices--thousand Ł/year (computed in the consumption component in Equation (C6))

DUTIMR = average rate of import duties.

Similarly total exports are computed by Equation (N3).

(N3) $TEXTD(t) = \sum_j EXTD_j(t) + VALDMB(t) + DUTEX(t)$

where:

TEXTD = total exports at f.o.b. prices--thousand Ł/year

$EXTD_j$ = value of exports of the jth commodity at producer prices--thousand Ł/year (computed in the export component)

VALDMB = value added by marketing boards--thousand Ł/year (computed in the agricultural model)

DUTEX = duties on exports--thousand Ł/year (computed in the agricultural model.

The trade deficit on current account is then the difference between exports and imports as in Equation (N4).

(N4) $DEFCT(t) = TEXTD(t) - TIMP(t)$

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