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AGGREGATE POLICY MODELS OF THE SIERRA LEONE ECONOMY WITH SPECIAL EMPHASIS ON THE SMALL SCALE ECONOMY**

Prepared by

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1. Introduction: Terms of Reference

The objective of this report was to support the initial stages of constructing a macro-economic model with emphasis on the rural sectors for Sierra Leone. The model should enable the analysis of various output, income and employment oriented policies within a comparative static general equilibrium framework. Particular emphasis should be given to the mechanism of linking the various linear programming components representing different small scale sectors of the rural economy within a broader context of a macro-economic model. In order to accomplish this, it was necessary to identify explicitly the structure of a national consistency model and to determine at least the basic structure of the various aggregated micro models of the rural economy. Moreover current priorities led to the request of a more detailed proposal for a model of the marketing, processing and transportation sectors.

The report contains a variety of detailed model designs and indicates areas where further data collection may be needed. However, it is evident that the model proposals, being made under a time constraint of three weeks, will need a continuous refinement based on the empirical findings and experiences accumulated during the survey year. Given the very broad range of data coming out of these surveys, it cannot be expected that all the information can finally be incorporated into the formal model. First of all, the handling of so many primary data will be time consuming in itself. Secondly, a variety of information concerning, e.g., seasonal fluctuations of consumption patterns, production data on crops or manufactured goods of minor importance, attitudes toward rural-urban migration or data on education can result in separate studies outside the aggregated model.

Any discussion of model types and model structure should also be concerned with problems of operationality and time constraints. At this stage this will exclude dynamic models simulating the development process. However, the basis should be laid on which the latter can be built later on.

This consultant's report is in many ways based on the results of intensive discussions within the Rural Employment Research Project, especially with Dr. Derek Byerlee and Dr. Dunstan Spencer. Thus, it is hopefully not just an outsider's proposal but reflects also the concepts and ideas pursued by the project team.

2. Macro-economic Aspects of Policy Evaluation to Promote Rural Incomes and Employment

This report is not the place to discuss the problems related to low incomes in rural areas, high rural-urban migration rates, a considerable urban unemployment and remarkable foreign exchange requirements for food imports that are currently being observed in Sierra Leone. These issues have been analysed in previous publications of the African Rural Employment Research Network. Instead, the following section contains just a brief list of policy issues that a model of the rural economy is supposed to answer. Clearly the purpose of the modeling exercise on the aggregate level of the rural economy as well as on the national level is an integration and aggregation of the industry-specific micro-level studies in order to:

1) check for consistency between the micro-level studies

2) evaluate national development strategies and specific policies as they affect:

   a) agricultural output
   b) rural income
   c) employment in rural and urban areas
   d) non-farm production
   e) foreign trade.

Particular emphasis will be given to the choice of appropriate technologies in agricultural and rural non-farm production since any decision in this area will have considerable employment effects.

The labor intensive small-scale sectors explicitly surveyed and analyzed in the project account for 90 percent of the employment in the country. Hence, any macro-economic policy evaluation on the national level has to be based on technology levels, income generation and migration decisions within these sectors. This micro-macro interaction must be the major guideline for the model building process. Yet the large scale sectors, although of relatively lower importance for employment, have to be included with respect

to their effect on income and demand, as well as on foreign exchange earnings and public financing.

A model based on these interactions should help to analyze the performance of the economy and explain the following variables: farm income (regional); total labor use (regional and by sectors); out-migration (between regions and sectors); degree of self-sufficiency in rice and fish; net foreign exchange earnings from rice, tree crops, rural manufactured goods and others; GNP from agricultural production, rural nonagricultural production and agricultural processing; and food consumption.

The model should be detailed enough to allow the evaluation of the following policy instruments:

1) policies affecting agricultural production: seed improvement, fertilizer supply, financing schemes, mechanisation and (ideally) extension;

2) policies affecting marketing and processing: importation of mills, location snd sizes of mills, road construction (affecting transportation costs), and technology of mills;

3) policies affecting nonagricultural small-scale production: import duties on cloth, die, ready-made shirts, etc., imports of these items;

4) policies affecting migration directly: government minimum wage rates and education expenditures; and

5) policies operating at the macro-level: rice imports, rice pricing, export pricing, and foreign capital aid or investment.

3. Aspects of Planning and Decision Making and Corresponding Model Types

The choice of the appropirate model type is closely related to the kinds of questions the model is supposed to answer. One may say that these are three basic model types that can be used for planning purposes on any level of aggregation:

Consistency Models: Examples are commodity balances, input-output models (intra-industry, inter-industry, inter-regional) and macro-econometric models (e.g., the type that was recently applied to employment problems by Thorbecke and Sengupta 1/).

Equilibrium Models: Examples are static and comparative static programming models (on the national level, the Israel model by Bruno 2/ is one example) or multiperiod models like the Mexico model by Goreux and Manne 3/).

Dynamic Simulation Models: Examples exist from Nigeria 4/ and Korea. One specific type includes dynamically linked micro-level programming models describing farmers' allocation decisions (applications exist from Germany 5/, India and Korea).

These model types are generally not initially exclusive, but each has its merits in some phase of the planning and decision making process. Those phases are related to:

1/ Thorbecke, E. and J. Sengupta, "A Consistency Framework for Employment, Output and Income Distribution Projections Applied to Colombia," Development Research Center, IBRD, Washington, 1972.

2/ Bruno, M., "A Programming Model for Israel," in The Theory and Design of Economic Development edited by I. Adelman and E. Thorbecke (Baltimore, 1966).

3/ Goreux, L. and A. S. Manne, Multi-Level Planning Case Studies in Mexico (Amsterdam, 1973).

4/ Manetsch, et. al., A Generalized Simulation Approach to Agricultural Sector Analysis with Special Reference to Nigeria (East Lansing, Michigan, 1971).

5/ de Haen, H. and T. Heidhues, "Recursive Programming Models to Simulate Agricultural Development: Applications in West Germany," Working Paper No. 18, Institute for Agricultural Economics, Goettingen, 1973.

a) Development of profound production data, input-output relationships, availability of resources and flow balances for goods, services or migrating people. Material balances and input-output tables will be needed to test this information for consistency.

b) Explaining of cause-and-effect relationships and conception of models to describe the behavior of the people within the respective system. The analysis may be applied to farmers' resource allocation, migration decision or to the allocation of resources on the macro-model. The analytic tools may be econometric models, as well as programming conceived as a descriptive rather than a prescriptive way.

c) Long range (comparative static) policy analysis, indicating which structure of the system (allocation of physical resources, of labor and population, distribution of income, etc.) will result as a response to alternative policies.

d) Dynamic evaluation of policy effects to predict the time path of future development and detect possible bottlenecks.

The amount of empirical information that is necessary to construct and to quantify the models is increasing in the order in which these questions are listed.

Currently the Rural Employment Project is mainly concerned with phase a, the development of an information system from primary data. This will be very time consuming and put a constraint on the time available for the analysis part. Therefore, it is envisaged that the current project does not go further than phase c, in which long range comparative static policy analyses will be performed. The exclusion of dynamic simulation is also necessary because the availability of time series data is rather limited. On the industry level there exist almost no data that extend over a period longer than

the survey year. Hence, the emphasis will be put on equilibrium models of the linear programming type. The advantage of this approach lies in the fact that the set of simultaneous inequalities on which the programming model will be based, can fairly easily be developed out of the consistency models (input-output type) that will have to be constructed in phase a to check the collected data. The following sections of this report will be concerned with the structure equilibrium models that can be used to go as far as phase c in the planning process.

As soon as time series data become available and if there is enough time within the project, these models should provide a basis to build dynamic models of the small-scale sectors (e.g., recursive programming on the micro-level).

4. Suggestions for a Macro Model: A Consistency Framework for Micro Models of the Small-Scale Sectors of Sierra Leone

4.1. Problem Definition and Model Identification

The final purpose of the research project is to evaluate policies to promote rural employment, increase rural incomes and provide incentives within the rural areas to reduce rural-urban migration. Many of these questions will require a detailed regionally disaggregated modeling approach on the micro level that allows the analysis of alternative technologies, credit and subsidy programs, extension and migration decisions. The various micro level studies will provide this framework.

In addition, a countrywide evaluation of employment and production programs requires a provision for consistency checks with the projected overall development of the economy. To list just a few, production and foreign trade of food and export crops must be consistent with rural and urban consumption. Rural-urban income differentials have to be consistent with assumptions determining the projected migration. Migration and regional population dynamics have to be consistent with sectoral employment projections. Rural-urban and urban-rural transfers of intermediate goods and services have to be consistent with production and input requirements. Finally prices have to be consistent with the costs of regional production, marketing, processing, transportation and government tax or subsidies.

Moreover, intersectoral linkages are not only relevant for consistency checks, but they do also have direct policy implications. A variety of

policies affecting employment and rural-urban income differentials are implemented on the macro level directly. Such policies include rice and rural input imports, rice and export crop pricing or foreign capital in flow.

Both, the consistency and the policy implications lead to the concept of a multisectoral macro model incorporated into the overall model. The macro model suggested here will have the following properties:

a) Unlike isolated macro-economic planning models it is not exclusively based on secondary data. As far as the labour intensive rural and small-scale sectors are concerned, the macro model uses the aggregated information provided by the micro level components. This information can be iteratively revised if necessary.

b) The model is designed to be flexible enough that it can be used for several purposes. One is the application for consistency checks by means of an intersectoral input-output table. This will include the projection of final demand components at the national level. Another area of application is the use for budgeting of various policy alternatives or development hypotheses within the constraints relevant at the macro level. A third is the use for planning purposes as constrained maximization of returns to some macro level policies according to alternative objective functions.

c) Being limited by time constraints and data shortages (the micro level survey will only provide cross-sectional and seasonal data, but no time series with yearly intervals) the model is designed for static and comparative static analyses. However, consideration will be given to render possible an extension for dynamic development planning at a later stage.

Following the aforementioned argumentation three major subaggregates will be distinguished within the overall model:

1) a multisectoral macro model,

2) a rural-urban migration model, and

3) an aggregate micro model of the labor intensive small-scale sectors.

The following diagram contains the main linkages between these submodels. As discussed before they will be subject to consistency checks but they may also be conceived of as the dynamic feedback linkages between the respective subsystems of the economy (Figure 4.1).

4.2 Definition of Macro Sectors

The delineation of sectors within the intersectoral macro model suggested below was designed such that:

a) it supports the analysis of policy issues related to employment,

b) it is consistent with the sectoral, demographic and geographical breakdown of the aggregate micro model, and

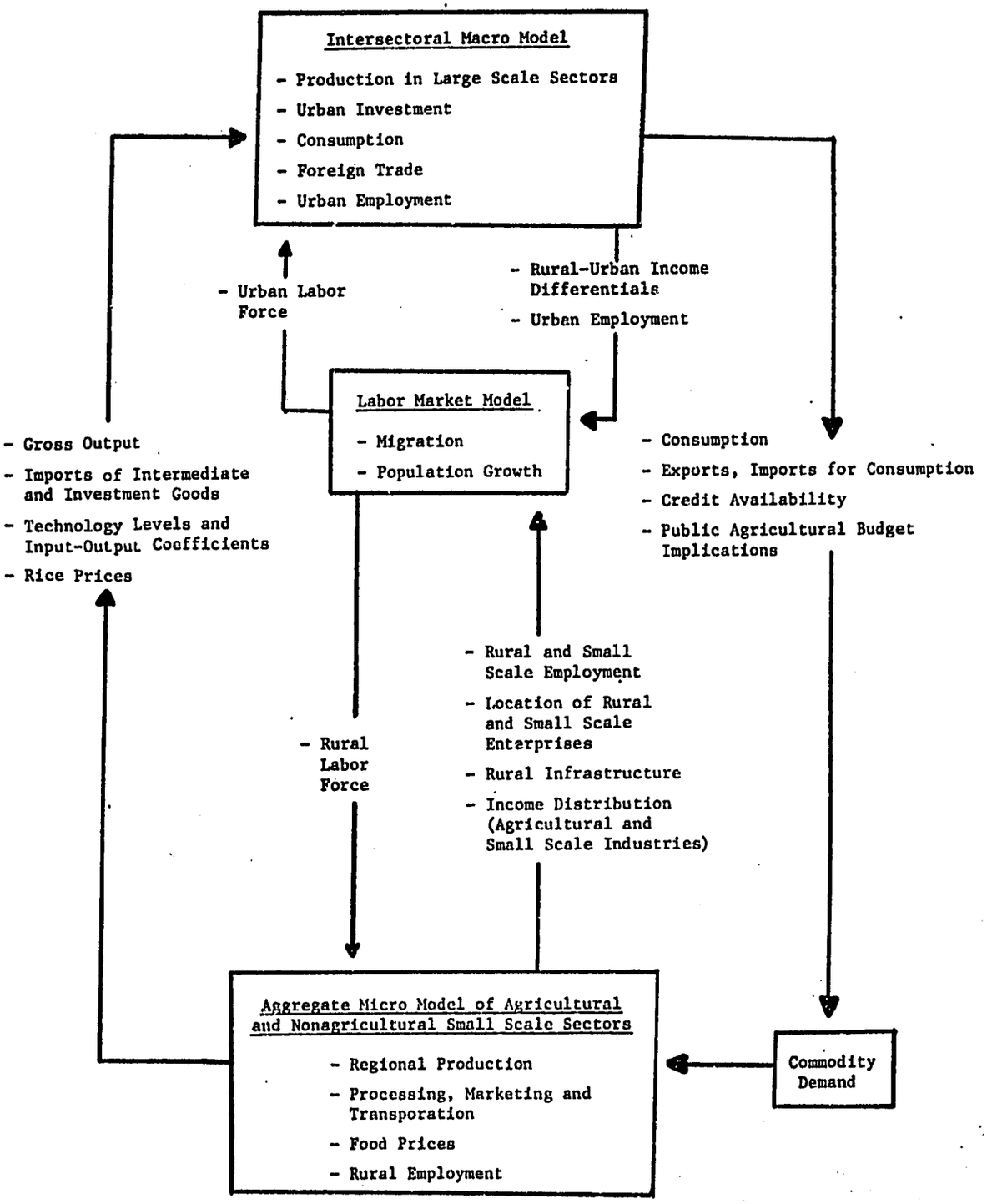
c) it is operational with respect to quantification and model solution.

I. Small Scale Sectors[1/] (Aggregate Micro Model)

Sector 1	Production of rice
2	Production of other food commodities
3	Production of export crops
4	Agricultural processing in rural areas (with locations of less than 2,000 inhabitants)
5	Agricultural Processing in small urban centers (between 2 and 2,000 inhabitants)

[1/] Adopting the definition of the National Accounts of Sierra Leone, large scale industries are those employing six or more persons excluding family members.

Figure 4.1. Schematic Representation of Linkages within an Integrated Rural Employment Model



Sector	6	Agricultural processing in large urban centers (2,000 or more inhabitants)
	7	Small scale manufacturing in rural areas
	8	Small scale manufacturing in small urban centers
	9	Small scale manufacturing in large urban centers
	10	Agricultural marketing and transportation
	11	Small scale nonagricultural trade

II. Large Scale Sectors[1/] (Macro Model)

Sector	12	Construction
	13	Mining
	14	Urban large scale manufacturing
	15	Large scale urban trade and services, including public utilities

The following diagram (Diagram 4.2) shows how these sectors can be related to the geographical breakdown of the population, which is important for employment and income computations. For the purpose of this model, the following definitions are suggested:

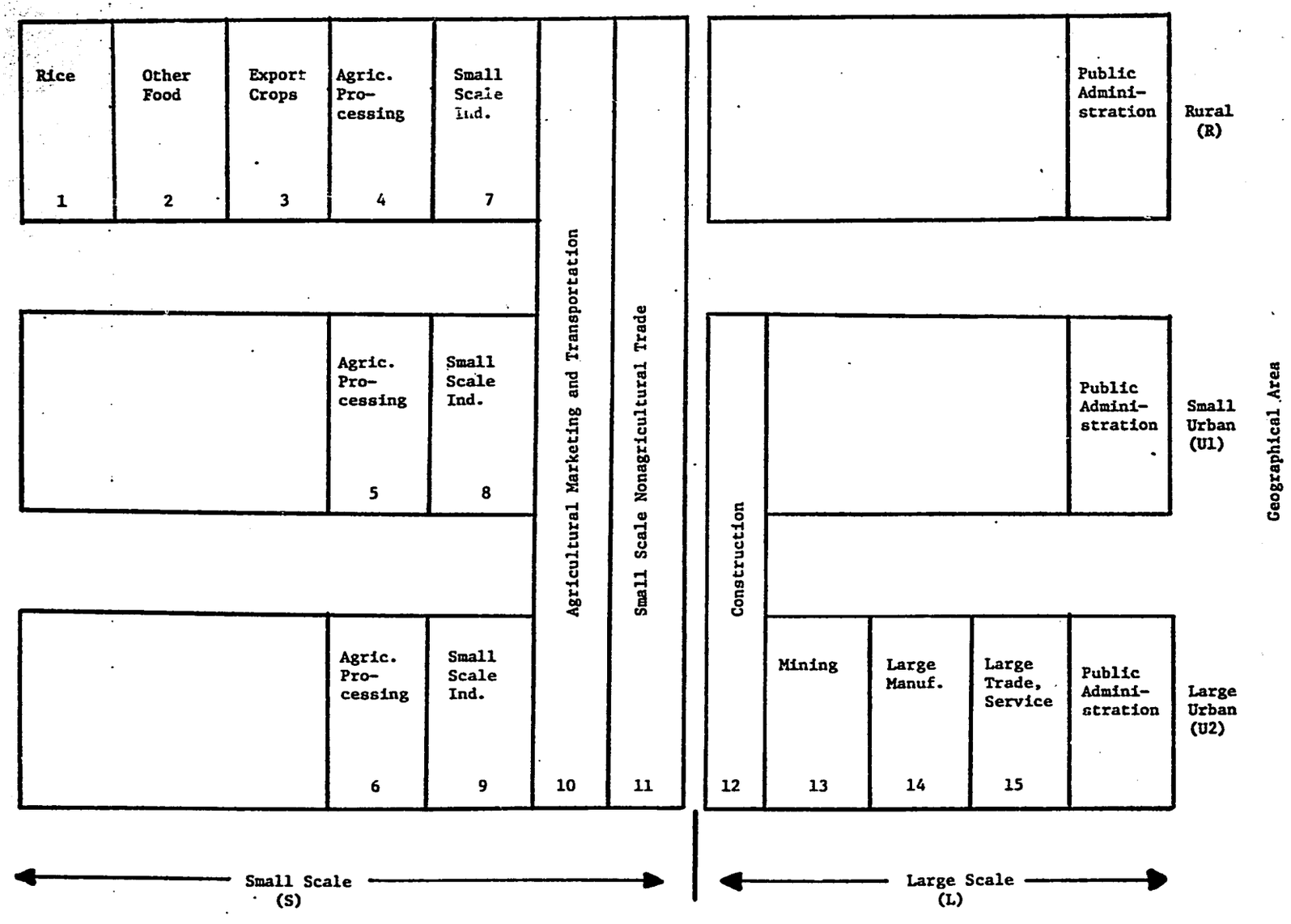
a) rural population - all people living in localities of less than 2,000 inhabitants

b) small urban population - all people living in localities of 2,000 but less than 20,000 inhabitants

c) large urban population - all people living in cities of 20,000 or more individuals.

[1/] Adopting the definition of the National Accounts of Sierra Leone, large scale industries are those employing six or more persons excluding family members.

Figure 4.2. Stratification of Sectors and Geographical Areas



4.3. Exogenous and Endogenous Variables of the Intersectoral Macro Model

4.3.1. Exogenous Variables

The following list of exogenous variables include:

a) uncontrolled exogenous variables,

b) policy instruments (designated by a P)

c) variables that are endogenous to either the aggregate micro model or the labor market model (designated by a *)

It should be mentioned that for some variables it will depend on the phase of model application whether they are exogenous or endogenous. Urban sectoral output, e.g., may be assumed to be exogenous in the consistency phase where only the resulting foreign trade might be computed for given final demand. On the other side, in the budgeting and comparative static optimization phase urban sectoral output and hence urban employment and investment will be endogenous as well. Following is a list of exogenous variables. The symbols refer to the algebraic presentation in the appendix.

$\bar{A}$	(p)	Total public expenditure on goods and services
G_i	(p)	Public consumption of domestically produced[1/] goods or services from sector i (i-1,...,15)
$\bar{X}_i$	(*)	Gross output from rural or small scale sector i (i=1,...,10)
$\bar{B}_i^S$	(*)	Investment goods from urban sector "i" required by the small scale sectors (i=11,...,15); examples, construction work

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[1/] Imports for public current accounts are neglected at this time.

N^R	(*)	Rural population. It is assumed that this population provides the labor force for sectors 1, 2, 3, 4, 7 and a certain proportion of sectors 10 and 11.
N^{U1}	(*)	Population living in small urban areas. It is assumed that this population provides the labor force for sectors 5, 8 and a certain proportion of sectors 10, 11 and 12.
N^{U2}	(*)	Large urban population. This population provides the labor force for sectors 6, 9 and a certain proportion of sectors 10, 11 and 12.
L^{U1}	(*)	Labor force in small urban centers.
L^{U2}	(*)	Labor force in large urban centers.
$\overline{M}_v^R$, $\overline{M}_v^{U1}$	(*)	Imports of investment goods for small scale sectors in geographical areas R and U1 respectively; examples: machettes, tractors.
$\overline{M}_x^R$, $\overline{M}_x^{U1}$	(*)	Imports of intermediate goods for small scale sectors in geographical areas R and U1 respectively; examples: fertilizer, cloth to dye.
$\overline{I}_i$	(*)	Gross investment in small scale sector "i".
F	(P)	Foreign exchange available from sources other than imports.
X_i^F		Upper or lower flexibility bounds on the level of output of urban sector (i) (i=11,...,15).
P_1	(*)	Consumer price of rice.

4.3.2. Endogenous Variables

X_i	Gross output of large scale and nonagricultural urban sector "i" (i=11,...,15).
I_i	Gross investment of large scale and nonagricultural urban sector "i" (i=11,...,15).
B_i	Investment goods produced by sector "i" (i=11,...,15).

C_i^R, C_i^{U1}, C_i^{U2}	Final goods from sector (i), produced domestically and consumed by population group R, U1 or U2 respectively (for rice: total consumption [C_1]).
M_x^{U2}	Imports of intermediate goods used in the large scale sectors (noncompetitive).
M_r^{U2}	Imports of investment goods used for investment in large scale sectors (noncompetitive)
M_c^R, M_c^{U1}, M_c^{U2}	Noncompetitive imports of goods from sector i, consumed by population group R, U1 or U2 respectively.
M_1^R, M_1^{U1}, M_1^{U2}	Competitive imports of rice, consumed by population group R, U1 or U2.

4.4. Structure of the Intersectoral Macro Model

Basically the macro model consists of a simultaneous set of linear equations, some of which have the form of inequalities depending on the actual purpose of model application (consistency, budgeting, optimisation). The major components of this model are:

a) an input-output table (commodity balances)

b) a set of savings and consumption functions for three population groups

c) a set of capital goods constraints

d) import and export balances

e) foreign exchange constraints

f) urban labor constraints

g) a set of constraints to specify the predetermined levels of rural and small scale industry sector variables

h) national and sectoral accounting equations.

By introducing three population groups with specific savings behavior and consumption patterns the model will help to evaluate the income and consumption effects and thus the level of food self sufficiency resulting from population growth and migration. Moreover, the model will provide a means to explain urban unemployment rates as a function of urban labor force projections resulting from the computed large scale and nonagricultural urban production. Exogenous variations of factor intensities (i.e., capital-labor ratios) within the urban sectors will also be analyzed with respect to their effect on urban unemployment. Finally, a public employment will be considered to be exogenously determined by the size of the public budget and minimum wage policies.

The following page contains a schematic representation of the activity matrix. An algebraic specification is given in the appendix (Figure 4.3.).

4.5. Model Applications: Macro Economic Implications of Micro Level Rural Employment Policies

Following is a brief summary of the potential scope of model applications at the macro level.

As discussed earlier, the model is designed to evaluate the macro level implications of micro level employment and income policies. Given the production in the agricultural and small scale industry sectors, given the resulting input-output coefficients and given population growth and migration decisions, the model will show the impact on urban production, foreign trade and urban income and employment. This however will require a series of consistency checks.

Figure 4.3. Schematic Matrix Representation of the Macro Model

Activities (Endogenous) / Constraints	Production			Consumption of Domestic Products			Investment		Exports	Imports	Urban Unemployment	Savings	Accounting
	Rural Small Scale	Urban Small Scale	Large Scale Nonagr. Urban	Rural	Medium	Urban	Rural and Small Scale	Large Scale Nonagr. Urban					
Commodity Balances	X	X	X	X	X	X	X	X	X				X
Consumption Functions				X	X	X				X		X	X
Capital Goods Constraints			X				X	X		X			
Imports Intermediate Investment Consumption	X	X	X				X	X		X X X			X
Exports									X				X
Foreign Exchange									X	X			
Urban and Public Employment		X	X								X		X
Predetermined Levels of Rural Sectors	X	X					X						
Savings												X	X
National Accounting													X

Clearly, the structure of the macro model itself will always provide internal consistency within the macro model. However, the building block approach, i.e., the nonsimultaneous computation of the three subaggregates, may lead to intercomponent inconsistencies. The latter refer to:

Macro Model	Aggregate Micro Model
Rural and Urban consumption	Production and foreign trade of food and export crops
Aggregate input-output coefficients	Technologies and input requirements by production, trade, processing and local manufacturing activities
Rice consumption	Rice prices
Public budget implications	Revenues from and public investment in agriculture

Macro Model	Labor Market Model
Rural-urban income differentials, urban employment	Intersectoral and interregional migration
Current government accounts, public wage rates	Public employment

The purpose of the intercomponent consistency checks at the macro level will be to conduct repeated model calculations until the inconsistencies lie within a certain range. At this time it seems not advisable to develop a formal iteration algorithm that would lead to convergence automatically. A non-formal adjustment of model parameters "by hand" may be more appropriate and sufficient.

Once the macro model is reasonably consistent with the other subaggregates, it may also be used for independent comparative static computations. These may include:

a) input-output projections,

b) constrained optimization (e.g., find the maximum value of total final consumption, as proposed in the appendix),

c) parametric variation of some policy variables (e.g., foreign exchange, public consumption) or other exogenous variables (e.g., urban labor force).

Used in an optimization model the model solution will contain a primal and a dual, i.e., both an allocation and a pricing problem will be solved. The latter may probably help to identify bottlenecks for further development and show how they are affected by the policies under consideration.

4.6. Model Parameters and Need for Further Data Collection

Data collection and quantitative information is necessary for the exogenous variables and for the model parameters that are not predetermined in other components. The model parameters are defined as follows:

a_{ij}	interindustry input-output coefficients for goods and services transferred from "i" to "j"
b_{ij}	capital required from sector "i" per unit of gross investment in sector "j"
k_i	incremental capital-output ration in sector "i"
λ_i	replacement rate in sector "i"
s	average propensity to save, specific for population groups R, U1 and U2
d_i	constant in consumption function "i"
ε_i	elasticity of demand for commodity group "i", produced domestically, with respect to expenditure; specific for population group R, U1 and U2
n_i	own price elasticity for commodity group "i"; specific for population group R, U1 and U2
m_j^x	import requirements of intermediate goods per unit of output of sector j

m_j^v	import requirements of investment goods per unit of investment in sector "j"
u_i	elasticity of import of consumer goods from sector "i" with respect to expenditure; specific for population group R, U1 and U2
w_1, w_2	parameters of regression function relating public administration employment to
g	regional breakdown of public administration, defense and services (R, U1 and U2)
r	regional breakdown of overlapping sectors 10, 11 and 12 into areas R, U1 and U2
l_j	labor input per unit of output in sector "j".

The following figure (Figure 4.4.) indicates the data sources available or necessary to quantify parameters and variables not predetermined in the other components.

Figure 4.4. Sources for Data of the Macro Model

Source / Parameter Variable	Levels of Aggregation	
	Small Scale Sectors	Large Scale Sectors
a, b, k, λ, m^x, m^v, l	Predetermined in aggregate micro model - original data from primary survey (F, MP, SSI)	Secondary sources. In some cases complemented by on contact questionnaires
	Rural Localities	Urban Localities
s, d, ε, n, u, r	Estimates from primary data (household survey C)	Estimates from secondary sources, central office of statistics: household expenditure survey
g, r	Both primary and secondary	
	National Level	
w_1, w_2,	Regression model to explain public employment	
A, PWS	Policy variables, based on National Accounts	
$\overline{W}$	Policy variable	

5. The Aggregate Micro Component

Using the definitions suggested in the description of the intersectoral macro component, the aggregate micro component will contain the following subcomponents:

a) the farm level subcomponent (F),

b) the marketing, processing and transportation subcomponent (MPT),

c) the small scale manufacturing subcomponent (SSI).

The following section contains some thoughts about:

a) the regional and demographic aggregation of the three subcomponents,

b) the linkages between the subcomponents,

c) the internal structure of each subcomponent, the related questionnaires and additional data needs,

d) the sectoral aggregation and designation of information necessary for the intercomponent linkages to the macro and the migration component.

5.1. The Regional and Demographical Aggregation of the Three Subcomponents

All three studies are in one way or another disaggregated into regions or localities of different size to account for interregional differences in production techniques, geographical concentration and specific characteristics of urban demand, transportation costs and migration. Separate analyses and evaluations of individual firm decision problems within any of the subcomponents may be performed using various regional breakdowns on a representative firm basis as well as on aggregate levels. Representative farm or firm models may help to understand problems of individual firm growth or decay, firm size, investment in integer equipment units or questions of entrepreneural efficiency.

For the purpose of consistent countrywide analyses of production, rural employment and incomes under given national demand constraints and competition among firms and industries for rural labor and for capital it will be necessary to aggregate the samples up to the relevant regional and national levels. In order to be able to merge the three sub-components eventually into one aggregate micro model, it will be necessary that a consistent delineation of regional and demographical subaggregates is done. The following figure (Figure 5.1.) contains a disaggregation scheme for each subcomponent that should be maintained within the aggregate micro model. Moreover a regional breakdown of demand is proposed.

Figure 5.1. Aggregation Levels of Subcomponents to be Maintained in the Aggregate Micro Model

Regions / Sub-Components	Resource Region					Urban Demand Centers
	1 Size of Locality		• • •	8 Size of Locality		
	R	U1+U2	• • •	R	U1+U2	
F		—	• • •		—	—
MP			• • •			
SSI			• • •			
Food-Demand			• • •			
SSI-Demand	No Regional Disaggregation					

F = Farm level;
MP = Marketing and Processing
SSI = Small Scale Industries

For the purpose of modeling transportation of domestically produced commodities to the centers of consumption (for processing) as well as of imported goods into the country, it seems necessary to define two urban demand centers (Western Area and Kone Area) in addition to the eight resource regions. Moreover, regional centers have to be defined to compute transportation costs. Following is a list of suggested centers:

Figure 5.2. Regions and Regional Centers

Region		Center	Region		Center
B	No. 1	Rokupr	G	No. 6	Kenema
C	2	Bomthe	H	7	Kabala
D	3	Port Loko	I	8	Bo
E	4	Tormabur	West. Area	9	Freetown
F	5	Makeni	Kone Area	10	Sefadu

5.2. Linkages Between Farms, Processing and Small Scale Industries

Since it is envisaged that all three studies related to the subcomponents will use linear programming for the analysis, it is suggested to construct an interregional linear programming model for the aggregate micro model also. This would enable the analysis of interdependencies of the rural and urban small scale sectors with respect to their employment effects and it would solve the intracomponent consistency problem automatically. It is beyond the terms of reference of this report to develop the details of the mathematical model structure. Instead, a schematic matrix representation

of the linkages within the aggregate micro model is shown in Figure 5.3. The model accounts for the following major interactions between small scale sectors and between regions:

a) within the sectors: interregional competition to satisfy the consumer demand, given foreign trade policies; interregional competition for sector specific resource constraints (e.g., fertilizer, agricultural budget, etc.)

b) between sectors: intraregional competition for employment of the rural and urban labor force respectively; interregional competition for nationally fixed resources (e.g., government loans or subsidies for the rural sectors, foreign exchange for equipment, imports, etc.).

The activity groups of the aggregate micro model are related to:

a) sectoral and regional production,

b) inter- and intra-regional transportation,

c) imports of food and small scale sector inputs,

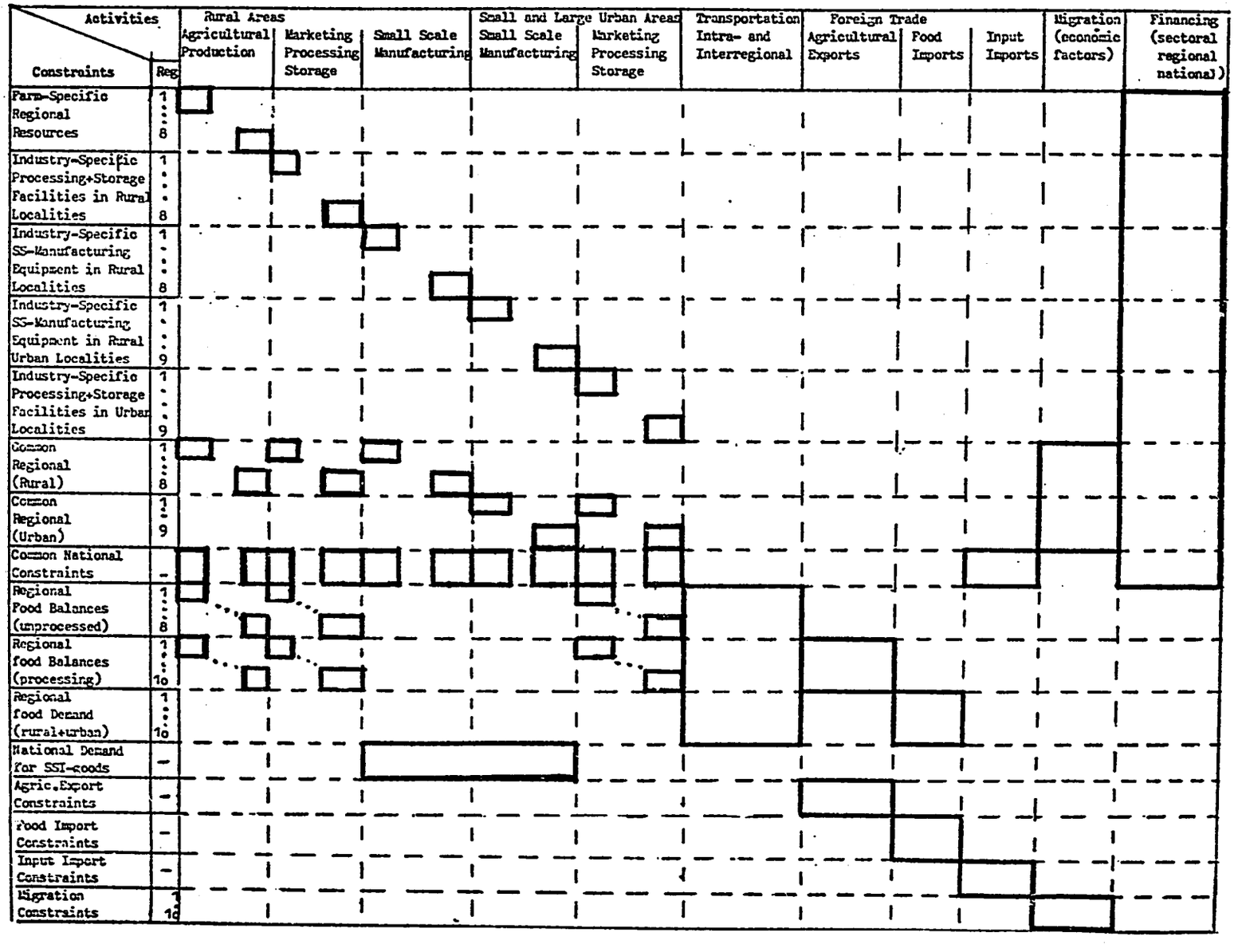
d) exports,

e) migration and rural unemployment, and

f) financing.

The sets of sectoral production activities, disaggregated by regions--partly by sizes of locality--includes financing, investment, purchasing of inputs, hiring of labor, choice of technology, etc. The provision of alternative technologies is particularly important for the purpose of this study, i.e., the analysis of rural employment and cost effects of investment strategies with alternative technology levels. Using this approach, the costs of labor employment and capital investment are determined endogenously depending on the alternative employment or investment opportunities within the

Figure 5.3. Linkages between Subcomponents within the Aggregate Micro Model



small scale sectors or--via migration or national credit markets respectively--even in the large scale sectors. Transportation includes the intraregional transfer at zero (or low) cost from the farm to the consumers, i.e., it also includes transfers for subsistence consumption.

The model contains the following groups of constraints:

a) Farm or industry-specific constraints (farm land, processing mills, sewing machines, blacksmith equipment, etc.);

b) Regional resources that are commonly used by farms, mills, small scale manufacturers, etc., disaggregated by size of localities. This refers mainly to the labor force (by seasons);

c) Nationally fixed resources or policy constraints;

d) Regional food balances for unprocessed and processed products including export crops. These help to determine the amount of output to be processed as well as the transportation of husk rice, palm dates and cassava to be processed outside the region of production;

e) Regional food demand constraints assuring that the net domestic supply plus imports in any region satisfies the demand (both self consumed and marketed) determined in an exogenous demand projection. Stepwise linear price demand function can be introduced here if desired, e.g., for rice. The constraints are connected to the supply by transportation activities;

f) National demand for products of the small scale manufacturing industries. Here a regional breakdown of demand is not planned at this moment. However, if empirical evidence indicates regional preferences for specific items this can be accounted for in the common regional resource constraints;

g) Foreign trade constraints. They include both balances and limits to foreign exchange as well as policy determined trade limits to specific products. The latter refers particularly to the import and import price policies for rice under the control of the Rice Corporation;

h) Migration constraints. Although migration will be analyzed within a separate model component, it may be useful to include a limited migration subcomponent in the aggregate micro model. It may help to determine levels and directions of migration flows as affected by economic factors and thus provide additional information for the migration component. The objective function coefficients of the migration activities could be the unskilled labor income in large scale sectors, the government ninimum wage or it could be endogenously determined if migration between the rural and small scale sectors is considered. If the labor force of different categories is exclusively determined within the separate migration component, this can be expressed by zero-migration constraints and the dual solution (shadow prices) will indicate the economic implications of that assumption.

5.3. Internal Structure of Subcomponents and Additional Data Needs

Following are some brief comments on the structure of the subcomponents and related data needs. Since the marketing, processing and transportation component seems to have a high priority at the moment and since a modeling concept does not yet exist, it is discussed in more detail than other subcomponents.

5.3.1. Agricultural Production Subcomponent

The structure of this component will be based on the model developed by the Spencer[1/] so far as rice is concerned. Another farm-level planning model is contained in a feasibility study by H. Brandt, et. al.[2/]

The information coming out of the farm level questionnaires seem to cover the data needs of a static linear programming model of the farm operation. Some additional information may be needed if the model is required to explain the farmers; risk aversion behavior, probably one of the major reasons for the traditional product mix.

Certainly there are a variety of ways to include risk aversion in the model. One implicit way would be to include upper and lower flexibility bounds on the production of individual crops. Then the problem would be how to quantify those bounds.

Another way that is using linear programming and is explicitly based on farm level interview (and hence probably feasibile in this project) is the concept of security constraints proposed by Boussard and Petit.[3/] It is described in detail in the reference given below, and has been successfully applied in several countries. The concept is based on the assumption that farmers will not select a production plan $(x_1,\ldots,x_n)$ in which they risk reduc-

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[1/] D. S. C. Spencer, "The Efficient Use of Resources in the Production of Rice in Sierra Leone: A Linear Programming Study," Ph.D. Dissertation, University of Illinois, Urbana, 1973.

[2/] H. Brandt, et. al., Feasibility Study of an Inland Valley Swamp Development Programme Unit in the Northern Province of Sierra Leone, German Development Institute, Berlin, 1973.

[3/] Boussard, J. M. and M. Petit, "Representation of Farmers' Behavior Under Uncertainty with a Focus-Loss Constraint," Journal of Farm Economics, Vol. 49 (1967), pp. 869-880.

ing their income below a minimum (MINI) sufficient to cover unavoidable expenses including consumption and fixed charges. The authors define a focus loss P_i for every crop, which they determine from farm interviews, and which is the deviation from the average yield that the farmer would be "very surprised" to exceed in any year. The behavioral assumption is then made that farmers try to maximize the average value of their income $\Sigma_i c_i x_i$ under the constraint that the focus loss is not bigger than the permissable loss (LOSS), i.e., to the difference between mean income and minimum income (minus shorter borrowing [STBO]):

$$\Sigma_i c_i x_i - \text{LOSS} - \text{STBO} = \text{MINI}$$

A series of additional security constraints makes sure that the focus loss on one crop cannot exceed the fraction 1/k of the total loss:

$$P_i x_i - 1/k \text{ LOSS} \leq 0 \qquad i = 1,\ldots,m$$

A matrix representation of the approach is given in the reference on page 875. Data needs for such an approach would be:

a) Minimum income per farm household;

b) Focus loss per crop; and

c) Fraction 1/k of total permissible loss, which will most likely be the same for all crops. While the value of k has been of relatively little influence on the results in previous model applications (1/k = 1/3 was used in the cited study, the quantification of the crop-specific focus losses will have to be done carefully). The farm level survey might provide information by adding some additional questions.

5.3.2. Marketing, Processing and Transportation Subcomponents

The purpose of including this component is the analysis of alternative processing technologies and locations of processing firms, of appropriate storage facilities and the computation of an efficient transportation network. Specific problems to be considered are the investment in new processing equipment on alternative technology levels with the possibility of returns to scale, inter-regional differences in efficiency of currently available technologies and different storage losses connected with different kinds of stores. Processing will be included for rice and palm oil. The technologies of rice processing will be:

a) hand processing (parboiling and milling),

b) small hullers, and

c) large mills.

Similarly, there are three palm processing technologies:

a) hand pounding,

b) small hand-operated mechanical oil mills, and

c) large pioneer oil mills.

Transportation will have to be considered in the model for unprocessed as well as processed rice and palm oil, for other food ready to be consumed, and for export crops. To include all possible region-to-region combinations for transportation of every commodity would clearly enlarge the matrix too much. For the eight resource regions plus two urban demand centers, one would get 8 x 10 = 80 transportation activities for every commodity. Since the road and river system of Sierra Leone does often times not allow to take the shortest geographical connection between two regional centers anyway. the following simplification of the transportation matrix is suggested. It

is based on the observation[1/] that the unit transportation costs do not vary with the distance. The simplification means that one includes transportation only between adjacent regions so that transportation between two nonadjacent regions will need more than one transportation activity. Using the region numbers and centers shown in Figure 5.2., we arrive at thirty-nine possible transportation activities, including transports within the region. They are listed in Figure 5.4.

Figure 5.4. Possible Transportation Directions in the Transportation Model

From	To	From	To
1	1, 9, 3	6	6, 10, 4, 8
2	2, 9, 4, 8	7	7, 5
3	3, 9, 1, 5, 8	8	8, 2, 3, 4, 5, 6, 9, 10
4	4, 2, 8, 6	9	9, 1, 2, 3
5	5, 3, 8, 7, 10	10	10

Looking at the individual goods to be transported it is possible to exclude some more transportation activities if a particular resource region is not suitable to produce this good and is not passed through by any other transportation of that good. Following is a list of commodities to be transported:

[1/] See also, Government of Sierra Leone (Ministry of Agriculture and Natural Resources), "Rice Milling and Marketing Study," prepared by Agrar- und Hydrotechnik, Essen, Germany, 1973.

Rice, husk
Rice, milled (not from 9)
Palm dates (only intra-regional)
Palm oil (not from 9)
Palm kernel
Cassava, unprocessed
Cassava, gari and foofoo
Groundnuts
Fish
Ginger (only from 8 to 9)
Pepper
Other vegetables
Other fruits
Beef (from 5 and 7 to all others)
Piassava (4-8, 2-9, 8-9)
Coffee (6-8, 4-8, 8-9, 2-9, 3-9, 1-9)
Cocoa (only from 6 and 4 to 9)

The following matrix (Figure 5.5) contains a proposal on how to model the processing, storage and transportation of rice. The economies of scale will require mixed integer programming.[1/] The other commodities will require much less matrix space.

Parameters of the MPT model for rice are:

h, s, p	recovery rates from rice milling using hand pounding, small and large mills respectively
f_i, c_i	regional proportion of storage loss rate using farm level or commercial stores respectively; computed from a national average loss rate of "f" times the regional demand proportion: $(d_i/\Sigma_i\ d_i) \cdot f = f_i$
b_i, g_i	unit milling capacity (measured in tons husk rice) per small or large mill respectively
k	acquisition costs per milling machine x
l	labor requirements.

Moreover the objective function and possibly additional cost and income equations will require operating costs for processing and storage, transportation costs and world market prices. Solving the model (e.g., cost minimization) will yield processing levels, transport flows and as the dual solution-regional rice prices. The latter can be fed into the rice demand function of the macro model.

[1/] Simplifications will have to be investigated by looking through the literature.

Figure 5.5. Modeling for Marketing, Processing, Storage and Transportation of Rice[1]

Activities / Constraints	Reg.	Production 1 ... 8	Transfer for Processing 1 ... 8	Processing: Hand 1...10	Processing: Small Milles 1...10	Processing: Large Milles 1...10	Storage: Farm –	Storage: Commercial –	Transportation[3] rough rice: from Region 1	...	from Region 8	Transportation[3] milled rice: from region 1	...	from Region 10	Foreign Trade: Im	Foreign Trade: Ex	Investment[2] small Region 1...10	Investment[2] large Region 1...10	New Storage –	Financing –	
Regional Product Balances	1 ⋮ 8	$-a_1 \ldots -a_8$							1...1	⋱	1...1										≤ C
Regional Supply Balances (Husk Rice)	1 ⋮ 10		1 ⋱ 1						-1 ⋱ -1	...	-1 ⋱ -1										≤ C
Balances for Processing Technology	1 ⋮ 10		-1 ⋱ -1	1 ⋱ 1	1 ⋱ 1	1 ⋱ 1															≤ C
Regional Supply Balances (Milled + Imports)	1 ⋮ 10			$-h_1 \ldots -h_{10}$	$-s_1 \ldots -s_{10}$	$-p_1 \ldots -p_{10}$						1...1	⋱	1...1	-1	1					≤ O
Regional Demand Constraint	1 ⋮ 10						$f_1 \ldots f_{10}$	$c_1 \ldots c_{10}$				-1 ⋱ -1	-1 ⋱ -1	-1 ⋱ -1							≥ $d_1 \ldots d_{10}$
Milling Capacity Small Mills	1 ⋮ 10				1 ⋱ 1												$-b_1 \ldots -b_{10}$				≤ $k_1 \ldots k_{10}$
Milling Capacity Large Mills	1 ⋮ 10					1 ⋱ 1												$-g_1 \ldots -g_{10}$			≤ $k_1 \ldots k_{10}$
Storage Capacity: Balance	–			1...1	1...1	1...1	-1	-1													≤ O
Storage Capacity: Farm	–						1														≤ C
Storage Capacity: Commercial	–							1											-1		≤ C
Finance Supply	–																$k_s \ldots$	$k_l \ldots$	k	-1	≤ S
Creditlimit	–																				≤ M
Regional Labor Constraints (seasonal)	1 ⋮ 10	$l_1 \ldots l_8$ 0		$l_1 \ldots l_8$ 0	$l_1 \ldots l_{10}$	$l_1 \ldots l_{10}$															≤ $L_1 \ldots L_{10}$

1) Symbols are different from those used for the other models. 2) Investment activities for large mills are integer. 3) Exclude non relevant transportation activities (see text).

5.4. Sectoral Aggregation and Feedback to the Macro and to the Labor Market Model

The major linkages between the aggregate micro model, the macro model, the labor market model and the commodity demand model have been discussed in section 4. Moreover, the proposed structure of the micro model of small scale sectors indicates which activities should be aggregated to get the eleven small scale sectors for the macro model. The level of these sectors' output as well as the aggregated input-output coefficients will be taken from the optimal solution obtained for the micro model. Thus, the technology represented by the Leontieff production functions of the macro model is not fixed but depends on substitution processes taking place within the small scale sectors.

APPENDIX

Intersectoral Macro Model - Algebraic Representation

1. Commodity Balances[1/]

$$X_i + \sum_{j=1}^{15} a_{ij} X_j + C_i^R + C_i^{U1} + C_i^{U2} + \sum_{j=1}^{15} b_{ij} I_j + E_i + G_i + M_1 \leq o$$

$i = 1, \ldots\ldots, 15$ Eq 1,..., 15

$(M_1 = 0 \text{ if } i \neq 1)$

2. Investment Constraints

2.1 Large Scale Sectors

Assuming (for simplification) a linear capacity increase $(X_i - X_i^o)/T$ between the base year O and the projection year T and a marginal capital-output ratio k_i, we get the average necessary net investment I_i^N:

$$I_i^N = (X_i - X_i^o) . k_i/T$$

Assuming further that replacement R_i is related to gross output (due to constant capacity utilization)

$$R_i = \lambda_i X_i$$

we get gross investment I_i

$$I_i = R_i + I_i^N$$

yielding the set of equations for large scale sectors

$$X_i(k_i + \lambda_i) - T.I_i = k_i X_i^o; \quad i = 12,\ldots,15; \quad \text{Eq. } 16\ldots,19$$

1/ $M_1 = M_1^R + M_1^{U1} + M_1^{U2}$ appears only in equation 1 for rice and designates competitive imports of rice.

2.2 Small Scale Sectors (predetermined)

$I_i = \bar{I}_i \quad i = 1, \ldots, 11 \qquad$ Eq.2o,....., 3o

3. Small Scale Sector Production Constraints (predetermined)

$X_i = \bar{X}_i \quad i = 1, \ldots, 11 \qquad$ Eq.31,....., 41

4. Flexibility Bounds for Selected Large Scale Sectors (possibly necessary to reflect constraints on skills, management, speed of expansion etc. that are not explicitely included in the model)

$X_i \leq X_i^F \quad i = 12, \ldots, 15 \qquad$ Eq.42,....., 45

5. Savings (public plus private)

$C^R = (1 - s^R)\ GDP^R \qquad$ Eq.46

$C^{U1} = (1 - s^{U1}) GDP^{U1} \qquad$ Eq.47

$C^{U2} = (1 - s^{U2}) GDP^{U2} \qquad$ Eq.48

6. Sectoral Consumtion Functions

Let us assume a set of consumption functions with constant expenditure elastities ε_i and price elasticities η_i

$$C_i = d_i \left[(1-s)\ GDP\right]^{\varepsilon_i} \cdot P_i^{\eta_i} = d_i\ C^{\varepsilon_i}\ P_i^{\eta_i}$$

Except for rice (i=1) we neglect price effects, since we have to do with larger commodity aggregates and since prices for the large scale sector output are not available prior to the computation. The rice price will be predetermined in the aggregate micro model.

Let us further assume a piecewise linear approximation of the consumption function in the neighborhood of the initial expenditure shares (C_i^o/C^o)

$$C_i - C_i^o = \frac{dC_i^o}{dC^o}(C - C^o) + \frac{dC_i^o}{dP_i^o}(P_i - P_i^o)$$

with

$$\frac{dC_i^o}{dC^o} = \varepsilon_i \frac{C_i^o}{C^o} \text{ and } \frac{dC_i^o}{dP_i^o} = \eta_i \frac{C_i^o}{P_i^o}$$

Neglecting the price term we get

$$- C_i + \varepsilon_i \frac{C_i^o}{C^o} C = C_i^o (\varepsilon_i - 1)$$

and introducing population N, we get per capita consumption functions

$$- \frac{C_i}{N} + \varepsilon_i \frac{C_i^o}{C^o} \cdot \frac{C}{N} = \frac{C_i^o}{N^o} (\varepsilon_i - 1)$$

Definig the initial expenditure shares by γ_i

$$\gamma_1 = \frac{C_i^o}{C^o}$$

and the initial per capita consumption by δ_i

$$\delta_i = \frac{C_i^o}{N^o}$$

and using the supercripts R, U1 and U2 for the three population groups, we get the following equations: 1/

$$\varepsilon_1^R \gamma_1^R C^R - C_1^R = N^R \delta_1^R (\varepsilon_1^R - 1 + \eta_1^R - \eta_1^R P_1/P_1^o); \text{ Eq. 49}$$

1/ For rice we take total consumption (including competitive imports) and hence the corresponding elasticities.

$$\varepsilon_i^R \ \gamma_i^R \ C^R - C_i^R = N^R \ \delta_i^R \ (\varepsilon_i^R - 1)$$

$i = 2, \ldots\ldots, 15$ Eq.5o, ..., 63

For small urban (U1) and urban (U2) population groups we get the respective equations in the same way (Eq.65,..., 93).

7. Import Constraints

7.1 Imports of intermediate goods, large scale sectors.

$$\sum_{j=2}^{15} m_j^x \ X_j = M_x^{U2} \qquad \text{Eq. 94}$$

7.2 Imports of investment goods, large scale sectors

$$\sum_{j=12}^{15} m_j^v \ I_j = M_v^{U2} \qquad \text{Eq. 95}$$

7.3 Imports of non competitive consumer goods

Assuming linearized import demand functions as for domestically produced goods:

$$M_i - M_i^o = \frac{dM_i^o}{dC^o} \ (C-C^o)$$

and defining μ_i as the elasticity of imports of commodity 'i' with respect to expenditure changes, we get total imports of non competitive consumer goo for each population group in the same way as consumption of domestic products. Let $\bar{\gamma}_i$ be expenditure share of imports and $\underline{\delta}_i$ be per capita imports:

$$- M_c^R + C^R \sum_{i=1}^{15} \mu_i^R \ \bar{\gamma}_i^R = N^R \sum_{i=1}^{15} \underline{\delta}_i^R \ (\mu_i^R - 1) \qquad \text{Eq. 96}$$

For small urban (U1) and urban (U2) population groups we get the equations in the same way. Eq. 97,98

Overall Consumption Good Balances

$$M_c^R - C^R + \sum_{j=1}^{15} C_j^R = o \qquad \text{Eq. 99}$$

$$M^{U1} - C^{U1} + \sum_{j=1}^{15} C_j^{U1} = o \qquad \text{Eq. 1oo}$$

$$M_c^{U2} - C_j^{U2} + \sum_{j=1}^{15} C_j^{U2} = o \qquad \text{Eq. 1o1}$$

8. Foreign Exchange Requirements

$$M^R + M^{U1} + M^{U2} - E^R - E^{U1} - E^{U2} \leq F \qquad \text{Eq. 1o2}$$

9. Urban Employment

9.1 Employment in Public Administration.

Assuming that national employment in public administration L_G is a function of Public Wages and Salaries Account PWS and the governmental minimum wage rate W, we get

$$L_G = w_1 \text{ PWS} + w_2 W \qquad \text{Eq. 1o3}$$

From this we take certain (policy determined) proportions (g) to indicate the geographical distribution of public administration employment by the three geographical areas

$$L_G^R = g^R L_G \qquad \text{Eq. 1o4}$$

$$L_G^{U1} = g^U L_G \qquad \text{Eq. 1o5}$$

$$L_G^{U2} = L_G - L_G^R - L_G^{U1} \qquad \text{Eq. 1o6}$$

9.2 Urban Total Employment

Small Urban

$$l_5X_5 + l_8X_8 + \sum_{i=10}^{12} r_i^{U1}\, l_iX_i + L_G^{U1} + U^{U1} = L^{U1} \qquad \text{Eq. 107}$$

Urban

$$l_6X_6 + l_9X_9 + \sum_{i=10}^{12} r_i^{U2}\, l_iX_i + L_G^{U2} + U^{U2} = L^{U2} \qquad \text{Eq. 108}$$

r_i is the breakdown of overlapping sectors among geographical areas. U is unemployment.

10. National and Sectoral Accounting

10.1 Current Public Expenditure on Goods and Services and it's Composition.

$$A = \bar{A} \qquad \text{Eq. 109}$$

Total public administration, defence and services (education, health)

$$PWS = A - \sum_{i=1}^{15} G_i \qquad \text{Eq. 110}$$

government minimum wage rate

$$W = \bar{W} \qquad \text{Eq. 111}$$

10.2 Investment

Rural

$$I^R = \sum_{j=1}^{7} I_j + r_{10}^R\, I_{10} + r_{11}^R\, I_{11} \qquad \text{Eq. 112}$$

Small Urban

$$I^{U1} = I_5 + I_8 + \sum_{j=10}^{12} r_j^{U1} \; I_j \qquad \text{Eq. 113}$$

Urban

$$I^{U2} = L_6 + I_9 + \sum_{j=10}^{12} r_j^{U2} \; I_j + \sum_{j=13}^{15} I_j \qquad \text{Eq. 114}$$

10.3 <u>Exports</u>

Rural

$$E^R = \sum_{j=1}^{7} E_j + r_{10}^R \; E_{10} + r_{11}^R \; E_{11} \qquad \text{Eq. 115}$$

Small Urban

$$E^{U1} = E_5 + E_8 + \sum_{j=10}^{12} r_j^{U1} \; E_j \qquad \text{Eq. 116}$$

Urban

$$E^{U2} = E_6 + Eq + \sum_{j=10}^{12} r_j^{U2} \; E_j + \sum_{j=13}^{15} E_j \qquad \text{Eq. 117}$$

10.4 <u>Imports</u>

Rural

$$M^R = \bar{M}_x^R + \bar{M}_v^R + M_c^R + M_1^R \qquad \text{Eq. 118}$$

Small Urban

$$M^{U1} = \bar{M}_x^{U1} + \bar{M}_v^{U1} + M_c^{U1} + M_1^{U1} \qquad \text{Eq. 119}$$

Urban

$$M^{U2} = M_x^{U2} + M_v^{U2} + M_c^{U2} + M_1^{U2} \qquad \text{Eq. 12o}$$

1o.5 GDP

Rural

$$GDP^R = \sum_{j \varepsilon R} X_j = \sum_{i \varepsilon R} \sum_{j=1}^{15} a_{ij} X_j + g^R PWS \qquad \text{Eq. 121}$$

$$R = (1, \ldots\ldots, 7, 1o, 11)$$

Small Urban

$$GDP^{U1} = \sum_{j \varepsilon U1} X_j - \sum_{i \varepsilon U1} \sum_{j=1}^{15} a_{ij} X_j + g^{U1} PWS \qquad \text{Eq.122}$$

$$U1 = (5, 8, 1o, 11, 12)$$

Urban

$$GDP^{U2} = \sum_{j \varepsilon U2} X_j - \sum_{i \varepsilon U2} \sum_{j=1}^{15} a_{ij} X_j + g^{U2} PWS \qquad \text{Eq. 123}$$

$$U2 = (6, 9, 1o, \ldots\ldots, 15)$$

11. Objective Function (Example)

Maximize $C^R + C^{U1} + C^{U2} + M_c^R + M_c^{U1} + M_c^{U2} + M_1^R + M_1^{U1} + M_1^{U2}$