

EXERCISES IN GENERAL EQUILIBRIUM MODELING USING GAMS

HANS LÖFGREN

**(KEYS TO THESE EXERCISES
ARE PUBLISHED SEPARATELY.)**

[\[appended\]](#)

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Löfgren, Hans

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PREFACE

Over the past decade, the increasing power and reliability of microcomputers and the development of sophisticated software designed specifically for use with them has led to significant changes in the way quantitative food policy analysis is conducted. These changes cover most aspects of the analysis, ranging from the collection and analysis of socioeconomic data to the conduct of model-based policy simulations. The venue of the computations has shifted from off-site mainframes dependent on highly trained operators and significant capital investment in supporting equipment, to desktop and laptop computers, dependent only on the occasional availability of electricity. This means that it is now feasible to quickly transfer new techniques between IFPRI and IFPRI's collaborators in developing countries, that the costs of policy analysis have been substantially reduced, and that a new level of complexity and accuracy in policy analysis is now possible.

As with any new technology, however, there are substantial costs in time and money involved in learning the most efficient ways of using this new technology and then transmitting these lessons to others. This series, *Microcomputers in Policy Research*, represents IFPRI's collective ongoing experience in adapting microcomputer technology for use in food policy analysis in developing countries. The papers in the series are primarily for the purpose of sharing these lessons with potential users in developing countries, although persons and institutions in developed countries may also find them useful. The series is designed to provide hands-on methods for quantitative food policy analysis. In our opinion, examples provide the best and clearest form of instruction; therefore, examples—including actual software codes wherever relevant—are used extensively throughout this series.

This fourth book in the series, *Exercises in General Equilibrium Modeling Using GAMS* by Hans Löfgren of IFPRI, presents a set of exercises relating to computable general equilibrium (CGE) models. CGE models represent one type of economywide model used in policy analysis. This type of model explicitly recognizes that changes that affect one part of the economy can have repercussions throughout the economy. The model is particularly useful in capturing the indirect effects of a policy change. The exercises in this book were developed for use in a master's level course in CGE modeling taught by the author while at the American University of Cairo, and they have been further refined through the recent work of IFPRI's Trade and Macroeconomics Division. The purpose of the book is to develop the ability of the reader to construct, modify, and conduct food policy simulations with CGE models using the GAMS language. The book comes with a CD-ROM with a limited-capacity version of GAMS.

Howarth Bouis and Lawrence Haddad, Series Editors

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EXERCISE 1

This exercise involves implementing a simple CGE model in GAMS. The model is presented below, in both verbal terms and in the form of a mathematical statement. The model presentation is followed by a SAM that includes the data needed to solve the model using “calibration.” That is, on the basis of a data set for a base period, the parameters of the model are estimated in a manner that enables the model (general equilibrium) solution to precisely replicate the base-year data set. Behavioral parameters are calibrated as if the base-year economy was indeed in equilibrium. The functional forms for the various relationships embodied in this exercise have been selected so as to assure that all parameters can be derived from the accompanying SAM. (With a few exceptions, this is also true for the rest of the exercises in this manual.)

VERBAL MODEL PRESENTATION

The model assumes that producers maximize profits subject to production functions, with primary factors as arguments, while households maximize utility subject to budget constraints. Cobb-Douglas functions are used both for producer technology and the utility functions from which household consumption demands are derived. Factors are mobile across activities, available in fixed supplies, and demanded by producers at market-clearing prices (rents). On the basis of fixed shares (derived from base-year data), factor incomes are passed on in their entirety to the households, providing them with their only income. The outputs are demanded by the households at market-clearing prices.

The model satisfies Walras’ law in that the set of commodity market equilibrium conditions is functionally dependent. Any one of these conditions can be dropped. The proposed model drops the equilibrium condition for the nonagricultural commodity. The model is homogeneous of degree zero in prices. To assure that only one solution exists, a price normalization equation, in this case fixing the consumer price index (CPI), has been added. After these adjustments, the model has an equal number of endogenous variables and independent equations. Given this definition of the price normalization equation, all simulated price changes can be directly interpreted as changes vis-à-vis the CPI. The model is disaggregated into two households (urban and rural), two factors (labor and capital), and two activities and associated commodities (agriculture and nonagriculture). The explicit distinction between activities and commodities facilitates model calibration, but it is not necessary for the CGE models in this manual. The distinction, however, is needed for models that deviate from a one-to-one mapping between activities and commodities, that is, for models where at least one activity produces more than one commodity and/or at least one commodity is produced by more than one activity. The label “simple” is well deserved

because the model does not include a government, intermediate demands, savings, investment, or an outside world.

MATHEMATICAL MODEL STATEMENT

The mathematical statements and the GAMS input files that accompany this volume follow the current standard notation used in CGE models developed in IFPRI's Trade and Macroeconomic Division. All endogenous variables are written in uppercase Latin letters, whereas parameters (including variables with fixed or exogenous values) have lower-case Latin or Greek letters. Subscripts refer to set indexes, with one letter per index. Superscripts are part of the parameter name (that is, not an index). In terms of letter choices, variables and parameters for commodity and factor *quantities* start with the letter *q*; for commodity and factor *prices*, the first letters are *p* and *w*, respectively.⁴

Notation

$a \in A$	activities {AGR-A agricultural activity NAGR-A nonagricultural activity}
$c \in C$	commodities {AGR-C agricultural commodity NAGR-C nonagricultural commodity}
$f \in F$	factors {LAB labor CAP capital}
$h \in H$	households {U-HHD urban household R-HHD rural household}

Sets

Parameters

ad_a	efficiency parameter in the production function for activity <i>a</i>
cpi	consumer price index (CPI)
$cwts_c$	weight of commodity <i>c</i> in the CPI
$shry_{hf}$	share for household <i>h</i> in the income of factor <i>f</i>
qfs_f	supply of factor <i>f</i>
α_{fa}	share of value-added for factor <i>f</i> in activity <i>a</i>
β_{ch}	share in household <i>h</i> consumption spending of commodity <i>c</i>
θ_{ac}	yield of output <i>c</i> per unit of activity <i>a</i>

Variables

P_c	market price of commodity <i>c</i>
PA_a	price of activity <i>a</i>
Q_c	output level in commodity <i>c</i>
QA_a	level of activity <i>a</i>
QF_{fa}	demand for factor <i>f</i> from activity <i>a</i>
QH_{ch}	consumption of commodity <i>c</i> by household <i>h</i>
YF_{hf}	income of household <i>h</i> from factor <i>f</i>
WF_f	price of factor <i>f</i>
YH_h	income of household <i>h</i>

⁴For a discussion of style in economic modeling, see Kendrick (1984).

Equations *Activity Production Function*

**Production and
Commodity Block**

$$QA_a = ad_a \cdot \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \quad a \in A \quad (1)$$

Factor Demand

$$WF_f = \frac{a_{fa} \cdot PA_a \cdot QA_a}{QF_{fa}} \quad f \in F, a \in A \quad (2)$$

Activity Price

$$PA_a = \sum_{c \in C} \theta_{ac} \cdot P_c \quad a \in A \quad (3)$$

Commodity Output

$$Q_c = \sum_{a \in A} \theta_{ac} \cdot QA_a \quad c \in C \quad (4)$$

Institution Block *Factor Income*

$$YF_{hf} = shry_{hf} \cdot WF_f \cdot \sum_{a \in A} QF_{fa} \quad h \in H, f \in F \quad (5)$$

Household Income

$$YH_h = \sum_{f \in F} YF_{hf} \quad h \in H \quad (6)$$

Household Demand

$$QH_{ch} = \frac{\beta_{ch} \cdot YH_h}{P_c} \quad c \in C, h \in H \quad (7)$$

**System Constraint
Block** *Factor Market Equilibrium*

$$\sum_{a \in A} QF_{fa} = qfs_f \quad f \in F \quad (8)$$

Output Market Equilibrium

$$Q_c = \sum_{h \in H} QF_{ch} \quad c \in C \quad (9)$$

Price Normalization Equation

$$\sum_{c \in C} cwt_s_c \cdot P_c = cpi \quad (10)$$

DATA BASE The data base of the model is presented in Table 2.

Table 2—Social accounting matrix for Exercise 1

	AGR-A	NAGR-A	AGR-C	NAGR-C	LAB	CAP	U-HHD	R-HHD	TOTAL
AGR-A			125						125
NAGR-A				150					150
AGR-C							50	75	125
NAGR-C							100	50	150
LAB	62	55							117
CAP	63	95							158
U-HHD					60	90			150
R-HHD					57	68			125
TOTAL	125	150	125	150	117	158	150	125	

TASK With the help of an ASCII editor, input the above model using GAMS syntax. Solve the model in GAMS and verify that the solution can replicate the above SAM (Table 2).

HINTS AND SUGGESTIONS

1. Before attempting to do this exercise, the reader should be familiar with GAMS, at least at the level of the tutorial Chapter 2 in the user's guide (Brooke, Kendrick, Meeraus, and Raman 1998, 5–28). The rest of the guide is also an indispensable reference.
2. You may run the input file in GAMS at any point in the process of constructing the model. If the model is incomplete and hence not solved, GAMS will nevertheless check that the input conforms with its syntax, report any errors, and, in the absence of errors, carry out other instructions, including displays. To catch errors at an early stage, it is often helpful to inspect the results of displays of elements (sets, variables, and parameters), that have been defined via operations.
3. A timesaving device when developing the model is to use mechanical searches for text segments, including “****,” which is used to indicate errors in the output file of GAMS. (By default the output file is called myfile.lst if the input file is called myfile or myfile.gms.)
4. The above mathematical statement is provided in a format that can be easily implemented in GAMS. It is advisable to use the same notation (subject to various minor transformations) since this will save effort (no additional notation is needed) and make it easier to move between the mathematics and GAMS.⁵

⁵Note that GAMS is case-insensitive. Nevertheless, it is easier to read a GAMS statement where the distinction between variables and parameters is evident, for example with parameters in lower case and variables in upper case (the convention followed in this manual).

For example, the first equation, with PRODFN as its declared name, may be input as follows:

```
PRODFN(A)..
      QA(A) =E= ad(A)*PROD(F, QF(F,A)**alpha(F, A));
```

5. In order to facilitate SAM-related computations, it is helpful to generate a global set, here named AC, including all elements in the sets for factors, activities, commodities, and households. Sets for the latter items are subsequently declared and defined as subsets of the global set.
6. When building CGE models, it is often useful to have identical sets with different names. In GAMS, the ALIAS command may be used to create a set that is identical to a set that already has been defined. (In the suggested answer, ALIAS is used to define sets identical to AC, C, and F.)
7. The models in this volume are formulated as a set of simultaneous equations and solved using a solver for nonlinear mixed-complementarity problems (PATH or MILES).⁶ Alternatively, simultaneous-equation models may be solved as nonlinear optimization problems. To follow this approach you may define an additional equation, OBJFN as:

```
OBJFN..      OBJ =E= DUMMY**2;
```

where OBJ is an unconstrained variable, and DUMMY is a non-negative variable. The solution statement should be changed to SOLVE CGE1 USING NLP MINIMIZING OBJ. In this setting, the other equations would define the constraint set with only one feasible solution (identical to the solution to the corresponding simultaneous-equation model). OBJ is minimized when DUMMY has a value of zero.

8. Do not input the row and column totals of the SAM. Instead, to remove one source of errors and model infeasibility, compute row and column totals and check that they are identical.
9. After entering the SAM, start using it to define the parameter values and initial variable levels. Initial variable levels are helpful for two reasons. First, they give the GAMS solver a good starting point, facilitating its search for the solution. Second, they make it easier to pinpoint the reasons why a model fails to generate the benchmark equilibrium. The latter issue is discussed further under point 12.
10. Note that parameters (in this model, ad_a , for example) may be defined using preceding definitions. If this approach is fol-

⁶In the general case, a mixed-complementarity problem consists of a set of simultaneous equations that are a mixture of strict equalities and inequalities, with the latter linked to bounded variables. The current model is a special case since all equations are strict equalities. For details and a mathematical definition, see Rutherford (1995).

lowed, it matters in which order the parameters and initial variable values are defined.

11. Assume that base-year factor and output prices are at unity and assign parameter and variable quantities on this basis. (This amounts to choosing the unit for each real flow so as to assure that its corresponding price is one.)
12. If you have implemented the model correctly, there should be no “significant” discrepancies between left-hand and right-hand sides of the equations when GAMS plugs in your parameter values and initial variable levels. You check this by looking for three asterisks (***) in the “equation listing.” If the left-hand side value (indicated as “LHS = <value>”) is “significantly” different (let’s say by more than 1.0E-5) from the right-hand side value in the preceding equation (after =E=), a problem exists with the definitions of the parameters and variables that appear in the equation in question. Errors may be caught by displaying the values of all parameters and variables in any problematic equation and checking whether the values are compatible with the SAM.
13. The number of (single) equations and (single) variables reported as part of the “model statistics” should be identical (at 24 for the proposed solution).⁷
14. A value of unity for all factor and commodity prices (that were initialized at this level) is a reliable indicator that the initial model solution replicates the initial equilibrium as captured by the initial SAM. To test that the model is robust, it is a good idea to solve it a couple of times with different values for selected parameters. To check that the model indeed is homogeneous, the initial value of *cpi* may be multiplied by some positive factor. Compared to the base, the prices of the model solution should all be changed by the value of the factor, while all quantities should stay unchanged.
15. In addition to model statement and base solution, the GAMS input file with the suggested answer includes a LOOP where two simulations are carried out: the BASE and a simulation for which the capital stock is increased by 10 percent. A set of report parameters are created. For each model solution they show (1) values for the factor supply parameter (which was changed in the experiment); (2) solution values for all model variables; (3) a SAM that is defined using data from each model solution; and (4) percentage changes from the base solution for

⁷By default, the GAMS variable count also includes variables that are fixed (have exogenous values) unless the model attribute *holdfixed* has been specified with a value of one, in which case only endogenous variables are included in the count (see Brooke et al. 1998, 74–76). If the model includes fixed variables, this attribute makes it straightforward to verify that the number of endogenous variables and equations is equal. In this manual, fixed variables and the *holdfixed* attribute appear in the proposed GAMS solutions to Exercises 3–5.

model variables and SAM cells. The SAM parameters provide data on the budgets of all agents and markets in the model in a concise format. For a more comprehensive set of report parameters, see the GAMS listing of the Cameroon CGE model in Chapter 3 of Devarajan, Lewis, and Robinson (1994).

16. This first exercise may be the toughest one; it is certainly the one requiring the largest amount of new GAMS code. It is important that you try to do it *before* checking the suggested answer, because “learning by doing” is the name of the game. However, keep in mind that although the suggested answer tries to embody good modeling practices, it is merely a *suggested* answer. Different formulations may seem preferable to other users. In many ways, “style” in modeling and language includes room for taste differences.

APPENDIX: EXERCISE A1

The notation of the model of Exercise 1 is set-driven, that is, reference is frequently made to sets and set indexes.⁸ The purpose of this exercise is to provide practice in interpreting what is hidden behind the veil of set notation and to demonstrate the gains from set notation in the form of more concise and more easily modified models. For example, the disaggregation of models based on set notation can be changed simply by varying the set definitions, the SAM, and other data, without any other changes in the input file.⁹ The starting point for this Exercise is the GAMS input file with your correct answer to Exercise 1.

TASK In the GAMS statement, rewrite two of the equations in Exercise 1, PRODFN and FACDEM, in “longhand,” that is, instead of making reference to sets and indexes, refer to specific set elements by name. Leave the rest of the model statement unchanged. Run the model and check that the solution is identical to Exercise 1.

HINTS

1. You have to declare and define a total of six equations. (In the suggested answer, they are named PRODFN1, PRODFN2, FACDEM1, FACDEM2, FACDEM3, and FACDEM4.) Put asterisks in the first character position of the lines where reference is made to the equations PRODFN and FACDEM (their definitions and declarations).¹⁰
2. Write the production function for the agricultural activity as follows:

```
PRODFN1.. QA('AGR-A')=E=
           ad('AGR-A')*QF('LAB','AGR-A')**alpha('LAB','AGR-A')
           *QF('CAP','AGR-A')**alpha('CAP','AGR-A').
```

⁸Recall that subscripts (but not superscripts) are set indexes.

⁹If one more production activity and commodity is added, the complete current model in longhand would require six new equations and modifications for five old equations. To add one more activity and commodity in the set-driven statement would merely require the addition of a couple of additional lines in the set definitions. Irrespective of approach, it would be necessary to further disaggregate the SAM.

¹⁰When an asterisk (*) is put in the first character position, GAMS ignores the rest of the line but reproduces it in the output file. This is a useful device for including short comments or excluding unused parts of a program without deleting them. (An alternative approach, preferable for longer comments, is to block off a section with \$ONTEXT and \$OFFTEXT before and after the section, respectively. The two “dollar” statements must start in the first character positions of their respective lines.)

EXERCISE 2

In this exercise, intermediate demands are added to the CGE model presented in Exercise 1.

DATA BASE The new SAM is shown in Table 3. New payment flows, representing payments for intermediate goods, have been added in the cells at commodity row and activity column intersections. The accounts in the SAM are unchanged.

TASKS

1. **Mathematical statement:** Modify the mathematical statement so that the model incorporates intermediate demands. For both sectors, assume Leontief technology, that is, that a fixed input quantity is needed per unit of output.
2. **GAMS:** After having assured yourself that the answer to Task 1 is without errors (compare it to the suggested answer), implement the model in GAMS. This involves all or parts of the following: modifying the SAM; adding/modifying declarations and definitions for sets, parameters, variables (for this the “definition” involves defining the initial levels), and equations; displaying (and checking) the results of new computations; solving the model without errors for the base case and for a simple experiment (the latter to check that the model is robust); and confirming that it replicates the base data. Make sure that for each new element (set, variable, parameter, or equation), you go through the same steps as for the corresponding elements already present in the initial model.

Table 3—Social accounting matrix for Exercise 2

	AGR-A	NAGR-A	AGR-C	NAGR-C	LAB	CAP	U-HHD	R-HHD	TOTAL
AGR-A			225						225
NAGR-A				250					250
AGR-C	60	40					50	75	225
NAGR-C	40	60					100	50	250
LAB	62	55							117
CAP	63	95							158
U-HHD					60	90			150
R-HHD					57	68			125
TOTAL	225	250	225	250	117	158	150	125	

Once the model is calibrated to the SAM, run the same experiment you did for Exercise 1.

HINTS AND SUGGESTIONS

1. Mathematical Statement

- When modifying the statement, check that the changes in the number of variables and equations are equal (so that the number of variables and independent equations remains equal). Compared to the Exercise 1 model, the suggested model in Exercise 2 has six additional equations and variables, the total number being 30.
- The suggested answer includes the following new elements:

Parameters

ica_{ca} quantity of c as intermediate input per unit of activity a

Variables

PVA_a value-added (or net) price of activity a

$QINT_{ca}$ quantity of commodity c as intermediate input in activity a

There are no new sets but two new equations for value-added prices and intermediate demands. Some changes in other equations are also needed.

2. GAMS

- Be systematic when you modify the model: for every parameter/variable you declare, make sure you don't forget to include it in the equations or to define and display its value/initial level. Check that the displayed values coincide with the values you expect.
- Note that both PVA_a and P_c cannot have initial (or equilibrium) levels of unity. The suggested answer follows the convention of keeping the initial value of P_c at unity and defining PVA_a at a level corresponding to the SAM payment to primary factors per unit of the activity.
- In the same way as in Exercise 1, define the parameter ad_a so that the production (or, more precisely, value-added) function for activity a on its own will generate the base level for QA_a .
- Pay special attention to Hint 12 in Exercise 1 for ways to track down the reasons why the model fails to replicate the base-year equilibrium.

EXERCISE 3

Few applied CGE models fall short of explicitly covering savings and investment. In our gradual process of constructing an applied model, we start by adding this aspect, using the CGE model of Exercise 2 as our starting point. Moreover, in the previous models, the wage (price) of each factor was assumed to be uniform across all activities that used that factor. In other words, every activity paid the average wage. In the real world, wages tend to be “distorted” in the broad sense that they differ across activities. A treatment that permits this variation (with no distortions as a special case) is also introduced in this exercise. We will assume that wages are distorted for labor but uniform across activities for capital, in a setting with full (or fixed) employment for both factors.

When doing the exercise, follow one general aspect of good modeling practice: introduce changes in different areas one at a time.

DATA BASE The SAM, displayed in Table 4, includes one new account called savings-investment (S-I).¹¹ Its row receives payments from the household (the only saver in this simple economy); its column shows spending on commodities used for investment. Note that investment is defined in terms of the commodities used in the production of the capital stock, not the activity of destination (the activity that receives the investment goods as an addition to its capital stock). This means that the model only applies to a period so short that there is not enough time for new investments to provide additional production capacity. For a model relevant to a longer time period (for example a multiperiod model), it would also be necessary to consider explicitly the resulting changes in capital stock.

For labor, the number of workers employed is 100 for agriculture and 50 for nonagriculture. For capital, quantities are assigned on the assumption that the wage is unity for both activities. There are no changes in the SAM associated with the change in the factor treatment.

TASKS Expand the mathematical statement so that savings-investment is included and each activity pays fixed shares of average base wages for labor and capital. Proceed in two steps, starting with the savings-investment aspect. Introduce the changes in the factor treatment when you have assured yourself that the first step was accomplished without error.

1. Mathematical Statement

¹¹The change in the assumption about the capital market is not linked to any change in the SAM since the SAM merely reports payment flows. That is, the SAM does not say anything about the behavioral rules of the economy, including the workings of the capital market.

Table 4—Social accounting matrix for Exercise 3

	AGR-A	NAGR-A	AGR-C	NAGR-C	LAB	CAP	U-HHD	R-HHD	S-I	TOTAL
AGR-A			250							250
NAGR-A				305						305
AGR-C	60	40					50	75	25	250
NAGR-C	40	60					100	50	55	305
LAB	72	80								152
CAP	78	125								203
U-HHD					80	120				200
R-HHD					72	83				155
S-I							50	30		80
TOTAL	250	305	250	305	152	203	200	155	80	

For savings-investment, assume the following: (a) household income is allocated in fixed shares to savings and consumption; (b) investment is savings-driven, that is, the value of total investment spending is determined by the value of savings; and (c) investment spending is allocated to the two commodities in a manner such that the ratio between the quantities is fixed. Together, assumptions (b) and (c) mean that when savings values and/or the prices of investment commodities change, there is a proportional adjustment in the quantities of investment demand for each commodity, generating an investment value equal to the savings value.

For the factor markets (both labor and capital), assume that each activity pays an endogenous wage expressed as the product of an endogenous (economywide) wage variable (for the base equal to the average wage) and an exogenous distortion factor. For the special case of no distortions, the distortion factor is equal to one for all activities. In each factor market, variations in the average wage clear the market.

The set of equilibrium conditions that is functionally dependent now includes not only the commodity market equilibrium conditions, but also the savings-investment balance. It would be possible to drop one of these equations. In the suggested answer, another approach is selected. Instead of dropping one of these equations, a variable called WALRAS is introduced in the savings-investment balance. This approach is commonly used for this class of models. The model still has an equal number of variables and equations. If the model works, the savings-investment balance should hold, that is, the value of WALRAS should be zero.

2. GAMS After having produced an error-free mathematical statement, implement the model in GAMS, using the same systematic approach that was developed for Exercise 2. Proceed in two steps, starting with the introduction of savings-investment. Once you have confirmed that the base solution is able to replicate the base data set (except for assumed labor employment levels), proceed with the changes for factors. When

the base solution also works well with this change, solve for the experiment with a 10 percent increase in the capital stock. Verify that the value for WALRAS remains (very close to) zero for this solution as well.

HINTS AND SUGGESTIONS

1. Mathematical Statement

- a. Introduce the changes in a stepwise manner, in each step keeping track of changes in the number of variables and equations.
- b. For the savings-investment modification, the following changes may accomplish the task:
 - (i) Parameters: Introduce new parameters for household savings shares (called mps_h) and base-year sectoral investment quantities (called \overline{qinv}_c);
 - (ii) Variables: Add new variables for quantities of investment demand and a factor introducing proportional changes in investment quantities (referred to as $QINV_c$ and $IADJ$, respectively).
 - (iii) Equations: Include new equations to define $QINV_c$ and to impose balance between savings and investment values. The investment equation may be written as $QINV_c = \overline{qinv}_c \cdot IADJ$.
- c. The change in the treatment of factor markets may involve the following:
 - (i) Parameters: Define and declare a new distortion factor (wf_{dist}_{fa}) that represents the ratio between the wage for factor f in activity a and the average wage for factor f .
 - (ii) Equations: To assure that payments for factors are made at distorted wages, multiply the average wage variable (WF_f) by the distortion factor in every equation where the wage variable appears. (The definition of the distortion factor implies that $WF_f \cdot wf_{dist}_{fa}$ indeed defines the wage for factor f in activity a .)

2. GAMS

Once again, proceed in two steps. Before introducing savings and investment, add S-I to elements in the set AC and use the new SAM. For factors quantities and wages, you may go through the following steps: (1) on the basis of the information in the data base and the stated assumptions, define initial levels for the activity-specific factor demand variable (QF_{fa}) and the factor supply parameter (qfs_f); (2) define initial levels for the average wage variable (WF_f) and activity-specific wages (an auxiliary parameter that only is used to facilitate calibration) in the proposed solution called wfa_{fa} ; (3) define the wage distortion parameter (wf_{dist}_{fa}) as the ratio between wfa_{fa} and WF_f ; and (4) for each activity-factor combination, verify that the product $Wf_f \cdot wf_{dist}_{fa} \cdot QF_{fa}$ equals the SAM payment from the activity to the factor.¹²

The suggested GAMS model has 34 equations and variables.

¹²The market-clearing economywide wage variable was initialized at the level of the average base wage. Generally speaking, it will not coincide with the economywide average wage for any experiment unless (1) wf_{dist}_{fa} equals one for all activities and/or (2) there is no change in the employment shares for the different activities. (This is confirmed by the results for Exercise 3.)

EXERCISE 4

Up to now, the modeled economy has not included a government, an essential actor in applied policy analysis. This defect is remedied in this exercise. The government of the model earns its revenues from income and sales taxes and spends it on consumption and transfers to households. Government savings is the difference between its revenues and spending.

In Exercise 3, we introduced activity-specific wage distortions. For both factors, we assumed full employment, free mobility across activities, and a flexible market-clearing wage. In this exercise, we will instead assume the following: (1) for labor: unemployment with fixed, activity-specific real wages and the quantity of labor supply as the market-clearing variable; and (2) for capital: full employment but no mobility between activities and a flexible market-clearing wage for each factor-activity combination.

DATA BASE The model is built around the SAM shown in Table 5. Labor employment quantities are the same as for Exercise 3 (100 for agriculture and 50 for nonagriculture). The introduction of the government is behind the changes in the SAM structure. (The changes for the factor markets require no changes in the SAM.) There are new accounts for the government (GOV) and the two tax types, taxes on incomes (YTAX) and sales (STAX). In the tax rows, income taxes are collected from the household and sales taxes from the commodity accounts (AGR-C and NAGR-C). In the tax columns, this income is passed on to the government. The government column shows that the government uses this revenue to cover the cost of government commodity consumption (payments to AGR-C and NAGR-C), transfers to the households (payments to U-HHD and R-HHD), and (negative) government savings (payment to S-I). Note that in the rows of the commodity accounts, the demanders buy commodities at market prices; in the columns of the commodity accounts, these payments are split between the sales tax account and the activities (paid for output valued at producer prices).

One important part of government consumption, government payment for the labor services of its administrators and other employees, does not appear explicitly in the SAM. These government employees may be viewed as working for a government service activity that produces a commodity that is purchased by the government (institution) account. The government-service activity-commodity pair in this SAM is part of the nonagricultural activity and its commodity. In more disaggregated, real-world SAMs, the government service activity and commodity typically have their own accounts.

Table 5—Social accounting matrix for Exercise 4

	AGR-A	NAGR-A	AGR-C	NAGR-C	LAB	CAP	
AGR-A			255				
NAGR-A				350			
AGR-C	66	44					
NAGR-C	44	66					
LAB	72	105					
CAP	73	135					
U-HHD					95	125	
R-HHD					82	83	
GOV							
S-I							
YTAX							
STAX			25	33			
TOTAL	255	350	280	383	177	208	
	U-HHD	R-HHD	GOV	S-I	YTAX	STAX	TOTAL
AGR-A							255
NAGR-A							350
AGR-C	55	77	11	27			280
NAGR-C	110	55	47	61			383
LAB							177
CAP							208
U-HHD			25				245
R-HHD			5				170
GOV					25	58	83
S-I	60	33	-5				88
YTAX	20	5					25
STAX							58
TOTAL	245	170	83	88	25	58	

TASKS**1. Mathematical Statement**

Present a statement for a model based on the above SAM that includes a government and has the proposed treatment for factor markets. Implement the changes in the two areas step by step, starting with the government. For the factors, the detailed assumptions were stated in the introduction to this exercise. For the government, assume the following:

- a. The income tax is a fixed share of the gross income of each household. A fixed share of post-tax income is saved and the rest is spent on consumption.

- b. Sales taxes are fixed shares of (mark-ups on) producer commodity prices.
- c. The government consumes fixed commodity quantities, paying market prices (including the sales tax). Government transfers to the households are CPI-indexed, that is, they can simply be fixed in nominal terms. (Indexation to the CPI is automatic since the CPI level is fixed via the price normalization equation.¹³)
- d. Government savings is a residual, assuring balance between government outlays (including savings) and revenues. It is computed as the difference between expenditures (excluding savings) and revenues.

2. GAMS Once you have produced a correct mathematical statement, implement the model in GAMS in two steps. Make sure that in each step the model can replicate the data base and solves for an experiment where the quantities of government consumption of each commodity are increased by 20 percent. Analyze the impact of this change.

HINTS AND SUGGESTIONS

1. Mathematical Statement

To model the government, go through the following steps:

- a. Sets: A new set, I (with an identical set named I'), defines institutions (currently the two households and the government; the rest of the world will be added in Exercise 5). It is referred to in the modeling of transfers between institutions.
- b. Parameters: The new parameters, with suggested notation parenthesized, define government commodity consumption (qg_c), sales and income tax rates (tq_c and ty_h , respectively), and transfers from institution i' to institution i ($tr_{ii'}$). The transfer parameter captures transfers from the government to the households. In the equations where the parameter appears, reference is made explicitly to the relevant subset (H) and elements (GOV).¹⁴
- c. Variables: The new variables, with the symbols in parenthesis, denote producer prices exclusive of the sales tax (PX_c), government revenue (YG), and government expenditures (EG). The sales tax introduces a wedge between the price received by the producers (PX_c) and that paid by the demanders. The latter

¹³If government transfers and/or the labor wage are fixed, the model is, strictly speaking, no longer homogeneous of degree zero in prices. If you would like to maintain homogeneity, multiply government transfer parameters and the labor wage (but not the capital wage) by cpi .

¹⁴Alternatively, it would have been possible to declare this as a government transfer parameter with only the receiving set of institutions, h , in its domain. However, in a more complex model with many paying institutions, this approach would be tedious, requiring the definition of a separate parameter for each paying institution. The advantage of defining it over broadly defined sets of paying and receiving institutions is increased flexibility—one single parameter can handle a wider variety of contexts and fewer changes are needed elsewhere in the model. This will be evident in Exercise 5, where the rest of the world is added to the set of paying institutions, transferring money to both households and the government.

price includes the sales tax (the old symbol P_c is used to define this price). Thus, one important task is to change the variable P_c in the Exercise 3 model to PX_c in the current model whenever reference is made to what the producer receives (and not to what the demander pays).

- d. Equations: New equations are needed to define government revenue and expenditures. Modifications are introduced in the equations for household income (government transfers are a new income source), household consumption demand (owing to the presence of income taxes), commodity market equilibrium (to account for government consumption), and the savings-investment balance (since the government represents a new source of savings).

For factors, a relatively flexible approach is suggested. The changes are

- a. The parameters $wfdist_{fa}$ and qfs_f are turned into variables, written as $WFDIST_{fa}$ and QFS_f , respectively.
- b. Among the factor wage and quantity variables, the following are fixed: $WFDIST_{lab,a}$, WF_{lab} , $QF_{cap,a}$ and WF_{cap} .

This approach is relatively flexible because, by selectively fixing factor wage and quantity variables, it can handle a variety of closure rules (including the one used in Exercise 3).

2. GAMS To model the government, the following hints may facilitate your task:

- a. Augment the set AC with accounts for the government and the two tax types. Declare and define the new set for institutions.
- b. Let the initial values be unity for all prices except PVA_a and P_c (that is, PX_c is among the prices with an initial value of unity). For any activity a , PVA_a may be defined using the initial activity price, PA_a , and data in the SAM activity column.
- c. Calibrate the rate of the sales tax (tq_c) as the ratio between the tax payment *and* output value excluding the sales tax.
- d. Given the values of tq_c and PX_c , you can compute the initial value of P_c .
- e. Given that the commodity market price (P_c) paid by the demanders is no longer at unity, it is now necessary to explicitly consider this price when computing values for parameters and variables linked to commodity quantities.
- f. Note that the household savings rate (mps_h) should now be computed as the ratio between household savings and household *disposable* (post-tax) income.

For the factor markets, the changes in GAMS follow from the changes in the mathematical statement in a straightforward manner. The suggested model has 38 variables and equations. The suggested GAMS solution illustrates the use of scalars and IF statements to facilitate shifts between alternative closures for the savings-investment balance and factor markets (see Brooke et al. 1998, 152–154).

EXERCISE 5

In this final exercise, we complete the model by adding the rest of the world (RoW). Interaction with the RoW takes place in the form of imports, exports, and transfers. Crucially, for demanders, imports and domestic output sold domestically are assumed to be imperfect substitutes. Similarly, for producers, imperfect transformability is assumed between exports and domestic output sold domestically.¹⁵ Compared to the alternative of perfect substitutability (which, for any given commodity, only permits one-way trade), this treatment tends to generate more realistic responses by domestic prices, production, and consumption to changes in international prices. The treatment of factor markets is the same as for Exercise 4.

In combination with an appropriately disaggregated SAM, and data for labor employment and elasticities, the model that is the output of this exercise may provide the starting point for real-world applied policy analysis. However, it is highly likely that changes are needed to better reflect the structure of the modeled economy. Such changes, may, for example, include the introduction of price controls and other features that invalidate the assumption that flexible prices clear perfectly competitive markets. In addition, available production and consumption elasticities would typically suggest that the Cobb-Douglas functions should be replaced by more flexible (and complex) functional forms.

The task of implementing the model from scratch on the basis of stated assumptions is quite complex. Hence, not only the SAM, but a complete mathematical statement with brief comments on new features, is provided.

DATA BASE

The data base for the model consists of the SAM found in Table 6, unchanged data for labor employment, and trade elasticities. The values used are 0.7 for the elasticity of substitution between imports and domestic sales of the nonagricultural commodity, and 2 for the elasticity of transformation between exports and domestic sales of the agricultural commodity.

The SAM itself includes two new accounts, for the rest of the world (ROW) and for import tariffs (TAR). The row of the ROW account shows that our spending on imported commodities is the only income source of the RoW in its dealings with our country; the column of the same account shows that the receipts of our country from ROW consist of

¹⁵Imperfect substitutability and transformability may arise from differences in physical quality, differences in time and place of availability, and from aggregation biases.

Table 6—Social accounting matrix for Exercise 5

	AGR-A	NAGR-A	AGR-C	NAGR-C	LAB	CAP	U-HHD	R-HHD
AGR-A			279					
NAGR-A				394				
AGR-C	84	55					30	49
NAGR-C	50	99					165	92
LAB	72	105						
CAP	73	135						
U-HHD					95	125		
R-HHD					82	83		
GOV								
S-I							70	40
YTAX							20	5
STAX			10	20				
TAR				39				
ROW				105				
TOTAL	279	394	289	558	177	208	285	186
	GOV	S-I	YTAX	STAX	TAR	ROW	TOTAL	
AGR-A								279
NAGR-A								394
AGR-C	13	28				30		289
NAGR-C	67	85						558
LAB								177
CAP								208
U-HHD	25					40		285
R-HHD	5					16		186
GOV			25	30	39	15		109
S-I	-1					4		113
YTAX								25
STAX								30
TAR								39
ROW								105
TOTAL	109	113	25	30	39	105		

export revenues and transfers to the households and the government.¹⁶ The payments from ROW to S-I is foreign savings or the current account deficit, that is, the difference between our country's current (noncapital) foreign exchange expenditures and earnings.

MATHEMATICAL STATEMENT

The bulk of this statement consists of the model equations (a total of 27), divided into “blocks” for prices, production and commodities, institutions, and system constraints. Explanatory boxes are provided below each equation. New equations and other changes from the model in Exercise 4 are explained. The statement starts with alphabetical lists of sets, parameters, and variables that should serve as a reference as the reader goes through the equations.

Notation

$a \in A$

activities

$c \in C$

commodities

Sets

$c \in CM (\subset C)$

imported commodities

$c \in CNM (\subset C)$

nonimported commodities

$c \in CE (\subset C)$

exported commodities

$c \in CNE (\subset C)$

nonexported commodities

$f \in F$

factors

$h \in H (\subset I)$

households

$i \in I$

institutions (households, government, and rest of world)

Parameters

ad_a

production function efficiency parameter

aq_c

shift parameter for composite supply (Armington) function

at_c

shift parameter for output transformation (CET) function¹⁷

cpi

consumer price index

$cwts_c$

commodity weight in CPI

ica_{ca}

quantity of c as intermediate input per unit of activity a

mps_h

share of disposable household income to savings

pwe_c

export price (foreign currency)

pwm_c

import price (foreign currency)

qg_c

government commodity demand

$qinv_c$

base-year investment demand

$shry_{hf}$

share of the income from factor f in household h

te_c

export tax rate

tm_c

import tariff rate

tq_c

sales tax rate

¹⁶Neither of the two commodities is both exported and imported. The phenomenon of two-way trade (“cross-hauling”) is nevertheless commonly observed in the real world at the level of commodity aggregation used in applied models. It can be handled by the proposed approach without any modifications in the model structure.

¹⁷The acronym CET stands for constant elasticity of transformation.

$tr_{ii'}$	transfer from institution i' to institution i
ty_h	rate of household income tax
α_{fa}	value-added share for factor f in activity a
β_{ch}	share of commodity c in the consumption of household h
δ_c^q	share parameter for composite supply (Armington) function
δ_c^t	share parameter for output transformation (CET) function
θ_{ac}	yield of commodity c per unit of activity a
ρ_c^q	exponent ($-1 < \rho_c^q < \infty$) for composite supply (Armington) function
ρ_c^t	exponent ($1 < \rho_c^t < \infty$) for output transformation (CET) function
σ_c^q	elasticity of substitution for composite supply (Armington) function
σ_c^t	elasticity of transformation for output transformation (CET) function

Variables

EG	government expenditure
EXR	foreign exchange rate (domestic currency per unit of foreign currency)
$FSAV$	foreign savings
$IADJ$	investment adjustment factor
PA_a	activity price
PD_c	domestic price of domestic output
PE_c	export price (domestic currency)
PM	import price (domestic currency)
PQ_c	composite commodity price
PVA_c	value-added price
PX_c	producer price
QA_a	activity level
QD_c	quantity of domestic output sold domestically
QE_c	quantity of exports
QF_{fa}	quantity demanded of factor f by activity a
QFS_f	supply of factor f
QH_{ch}	quantity of consumption of commodity c by household h
$QINT_c$	quantity of intermediate use of commodity c by activity a
$QINV_c$	quantity of investment demand
QM_c	quantity of imports
QQ_c	quantity supplied to domestic commodity demanders (composite supply)
QX_c	quantity of domestic output
$WALRAS$	dummy variable (zero at equilibrium)
WF_f	average wage (rental rate) of factor f
$WFDIST_{fa}$	wage distortion factor for factor f in activity a
YF_{hf}	transfer of income to household h from factor f
YG	government revenue
YH_h	household income

Equations The introduction of foreign trade with product differentiation drastically enriches the price system—out of the six equations in this block, four (Equations 1–4) are new.

Price Block

Import Price

$$PM_c = (1 + tm_c) \cdot EXR \cdot pwm_c \quad c \in CM$$

$$\begin{bmatrix} \text{import} \\ \text{price} \\ (\text{dom. cur.}) \end{bmatrix} = \begin{bmatrix} \text{tariff} \\ \text{adjust-} \\ \text{ment} \end{bmatrix} \cdot \begin{bmatrix} \text{exchange rate} \\ (\text{dom. cur. per} \\ \text{unit of for. cur.}) \end{bmatrix} \cdot \begin{bmatrix} \text{import} \\ \text{price} \\ (\text{for. cur.}) \end{bmatrix} \quad (1)$$

Export Price

$$PE_c = (1 - te_c) \cdot EXR \cdot pwe_c \quad c \in CE$$

$$\begin{bmatrix} \text{export} \\ \text{price} \\ (\text{dom. cur.}) \end{bmatrix} = \begin{bmatrix} \text{tariff} \\ \text{adjust-} \\ \text{ment} \end{bmatrix} \cdot \begin{bmatrix} \text{exchange rate} \\ (\text{dom. cur. per} \\ \text{unit of for. cur.}) \end{bmatrix} \cdot \begin{bmatrix} \text{export} \\ \text{price} \\ (\text{for. cur.}) \end{bmatrix} \quad (2)$$

The exogeneity of foreign-currency import and export prices indicates that we are modeling a country that is small relative to the relevant world markets (the “small-country” assumption). Note that Equations 1 and 2 only apply to imported and exported commodities, respectively.

Absorption

$$PQ_c \cdot QQ_c = [PD_c \in QD_c + (PM_c \cdot QM_c)_{c \in CM}] (1 + tq_c) \quad c \in C$$

$$\begin{aligned} [\text{absorption}] = & \left(\begin{bmatrix} \text{domestic sales price} \\ \text{times} \\ \text{domestic sales quantity} \end{bmatrix} \right. \\ & \left. + \begin{bmatrix} \text{import price} \\ \text{times} \\ \text{import quantity} \end{bmatrix} \right) \cdot \begin{bmatrix} \text{sales tax} \\ \text{adjustment} \end{bmatrix} \end{aligned} \quad (3)$$

For each commodity, absorption—total domestic spending on the commodity at domestic demander prices—is expressed as the sum of spending on domestic output and imports, including an upward adjustment for the sales tax. The fact that this condition holds follows from the linear homogeneity of the composite supply (Armington) function (Equation 11; the condition is referred to as Euler’s theorem). The import part only applies to imported commodities. The composite price, PQ_c , is paid by domestic demanders (households, the government, producers, and investors); hence it replaces P_c in all relevant equations. The composite price, implicitly defined by this equation, could easily be derived by dividing through by QQ_c . (See discussion of Equations 11 and 12 for further details.)

Domestic Output Value

$$PX_c \cdot QX_c = PD_c \cdot QD_c + (PE_c \cdot QE_c)_{|c \in CE} \quad c \in C$$

$$\begin{bmatrix} \text{producer} \\ \text{price} \\ \text{times} \\ \text{domestic} \\ \text{output quantity} \end{bmatrix} = \begin{bmatrix} \text{domestic} \\ \text{sales price} \\ \text{times} \\ \text{domestic} \\ \text{sales quantity} \end{bmatrix} + \begin{bmatrix} \text{export} \\ \text{price} \\ \text{times} \\ \text{export} \\ \text{quantity} \end{bmatrix} \quad (4)$$

For each commodity, domestic output value at producer prices is stated as the sum of the value of domestic output sold domestically and the export value (in domestic currency). This equation reflects the fact that the CET (constant-elasticity-of-transformation) function (Equation 14) is linearly homogeneous. The export part only applies to exported commodities. The producer price, PX_c , can be derived by dividing through by QX_c . Note that, in this model, the domestic output quantity is referred to as QX_c (as opposed to Q_c in earlier models). See discussion of Equations 14 and 15 for further details.

Activity Price

$$PA_a = \sum_{c \in C} PX_c \cdot \theta_{ac} \quad a \in A$$

$$\begin{bmatrix} \text{activity} \\ \text{price} \end{bmatrix} = \begin{bmatrix} \text{producer prices} \\ \text{times yields} \end{bmatrix} \quad (5)$$

Value-added Price

$$PVA_a = PA_a - \sum_{c \in C} PQ_c \cdot ica_{ca} \quad a \in A$$

$$\begin{bmatrix} \text{value-} \\ \text{added} \\ \text{price} \end{bmatrix} = \begin{bmatrix} \text{activity} \\ \text{price} \end{bmatrix} = \begin{bmatrix} \text{input cost} \\ \text{per activity} \\ \text{unit} \end{bmatrix} \quad (6)$$

Note that in this equation, there is a change in notation for the price applying to intermediate inputs (the composite supply price).

Production and Commodity Block

In this block, Equations 7–10 are unchanged compared to Exercise 4 (except for a minor notation change in Equation 10). Equations 11–16 are new. They allocate domestic supply of composite commodities between imports and domestic output, and transform domestic output to exports and domestic sales. Simpler expressions apply to commodities that are not imported and/or not exported.

Activity Production Function

$$QA_a = ad_a \cdot \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \quad a \in A$$

$$\begin{bmatrix} \text{activity} \\ \text{level} \end{bmatrix} = f \begin{bmatrix} \text{factor} \\ \text{inputs} \end{bmatrix} \quad (7)$$

Factor Demand

$$WF_f \cdot WFDIST_{fa} = \frac{a_{fa} \cdot PA_a \cdot QA_a}{QF_{fa}} \quad f \in F, a \in A$$

$$\begin{bmatrix} \text{marginal cost} \\ \text{of factor } f \\ \text{in activity } a \end{bmatrix} = \begin{bmatrix} \text{marginal revenue} \\ \text{product of factor} \\ \text{ } f \text{ in activity } a \end{bmatrix} \quad (8)$$

Intermediate demand

$$QINT_{ca} = ica_{ca} \cdot QA_a \quad c \in C, a \in A$$

$$\begin{bmatrix} \text{inter-} \\ \text{mediate} \\ \text{demand} \end{bmatrix} = f \begin{bmatrix} \text{activity} \\ \text{level} \end{bmatrix} \quad (9)$$

Output Function

$$QX_c = \sum_{a \in A} \theta_{ac} \cdot QA_a \quad c \in C$$

$$\begin{bmatrix} \text{domestic} \\ \text{output} \end{bmatrix} = f \begin{bmatrix} \text{activity} \\ \text{level} \end{bmatrix} \quad (10)$$

Composite Supply (Armington) Function

$$QQ_c = aq_c \cdot \left(\delta_c^q \cdot QM_c^{-\rho_c^q} + (1 - \delta_c^q) \cdot QD_c^{-\rho_c^q} \right)^{\frac{-1}{\rho_c^q}} \quad c \in CM$$

$$\begin{bmatrix} \text{composite} \\ \text{supply} \end{bmatrix} = f \begin{bmatrix} \text{import quantity, domestic} \\ \text{use of domestic output} \end{bmatrix} \quad (11)$$

The composite commodities are used by all domestic demanders. Imperfect substitutability between imports and domestic output sold domestically is captured by a CES (constant elasticity of substitution) aggregation function in which the composite commodity that is supplied domestically is “produced” by domestic and imported commodities, and enters this function as “inputs.” Economically, this means that demander preferences over imports and domestic output are expressed as a CES function. This function, with a domain that is limited to elements in CM , is often called an Armington function after the originator of the idea of using a CES function for this purpose. The restriction on the value of ρ_c^q ($-1 < \rho_c^q < \infty$) assures that the corresponding isoquant

is convex to the origin, in terms of production economics equivalent to a diminishing technical rate of substitution.

Import-Domestic Demand Ratio

$$\frac{QM_c}{QD_c} = \left(\frac{PD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \delta_c^q} \right)^{\frac{1}{1 + \rho_c^q}} \quad c \in CM$$

$$\begin{bmatrix} \text{import-} \\ \text{domestic} \\ \text{demand ratio} \end{bmatrix} = f \begin{bmatrix} \text{domestic-} \\ \text{import} \\ \text{price ratio} \end{bmatrix} \quad (12)$$

Equation 12 defines the optimal mix between imports and domestic output. Its domain is also limited to imported commodities. Together, Equations 3, 11, and 12 constitute the first-order conditions for cost-minimization given the two prices and subject to the Armington function and a fixed quantity of the composite commodity.

Composite Supply for Nonimported Commodities

$$QQ_c = QD_c \quad c \in CNM$$

$$\begin{bmatrix} \text{composite} \\ \text{supply} \end{bmatrix} = \begin{bmatrix} \text{domestic use of} \\ \text{domestic output} \end{bmatrix} \quad (13)$$

For commodities that are not imported, the Armington function is replaced by the above statement, which imposes equality between “composite” supply and domestic output used domestically.

Output Transformation (CET) Function

$$QX_c = at_c \cdot \left(\delta_c^t \cdot QE_c^{\rho_c^t} + (1 - \delta_c^t) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}} \quad c \in CE$$

$$\begin{bmatrix} \text{domestic} \\ \text{output} \end{bmatrix} = f \begin{bmatrix} \text{export quantity, domestic} \\ \text{use of domestic output} \end{bmatrix} \quad (14)$$

Imperfect substitutability between imports and domestic output sold domestically is paralleled by imperfect transformability between domestic output for exports and domestic sales. The latter is captured by Equation 14. The CET function, which applies to exported commodities, is identical to a CES function except for negative elasticities of substitution. The isoquant corresponding to the output transformation function will be concave to the origin given the restriction imposed on the value of ρ^t ($-1 < \rho_c^t < \infty$). In economic terms, the difference between the Armington and CET functions is that the arguments in the former are inputs, those in the latter are outputs.

Export-Domestic Supply Ratio

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PD_c} \cdot \frac{1 - \delta_c^t}{\delta_c^t} \right)^{\frac{1}{p_c^t - 1}} \quad c \in CE$$

$$\begin{bmatrix} \text{export-} \\ \text{domestic} \\ \text{supply ratio} \end{bmatrix} = f \begin{bmatrix} \text{export-} \\ \text{domestic} \\ \text{price ratio} \end{bmatrix} \quad (15)$$

Equation 15 defines the optimal mix between exports and domestic sales. Equations 4, 14, and 15 constitute the first-order conditions for maximization of producer revenues given the two prices (export and domestic) and subject to the CET function and a fixed quantity of domestic output.

One important difference between the equations for import demand (12) and export supply (15) is that the quantity demanded of the imported commodity (QM_c) is inversely related to the import price, whereas the quantity supplied of the exported commodity (QE_c) is directly related to the export price.

Output Transformation for Nonexported Commodities

$$QX_c = QD_c \quad c \in CNE$$

$$\begin{bmatrix} \text{domestic} \\ \text{output} \end{bmatrix} = \begin{bmatrix} \text{domestic sales of} \\ \text{domestic output} \end{bmatrix} \quad (16)$$

For commodities that are not exported, the CET function is replaced by a statement imposing equality between domestic output sold domestically and domestic output.

Institution Block This block is not changed compared to Exercise 4, except for the appearance of items related to interactions with the rest of the world (trade and transfers) in the definitions of household revenue and the revenue and expenditure of the government.

Factor Income

$$YF_{hf} = shry_{hf} \cdot \sum_{a \in A} WF_f \cdot WFDIST_{fa} \cdot QF_{fa} \quad h \in H, f \in F$$

$$\begin{bmatrix} \text{household} \\ \text{factor} \\ \text{income} \end{bmatrix} = \begin{bmatrix} \text{income} \\ \text{share to} \\ \text{household } h \end{bmatrix} \cdot \begin{bmatrix} \text{factor} \\ \text{income} \end{bmatrix} \quad (17)$$

Household Income

$$YH_h = \sum_{f \in F} YF_{hf} + tr_{h,gov} + EXR \cdot tr_{h,row} \quad h \in H$$

$$\begin{bmatrix} \text{household} \\ \text{income} \end{bmatrix} = \begin{bmatrix} \text{factor} \\ \text{incomes} \end{bmatrix} + \begin{bmatrix} \text{transfers from} \\ \text{government \&} \\ \text{rest of world} \end{bmatrix} \quad (18)$$

Household Consumption Demand

$$QH_{ch} = \frac{\beta_{ch} \cdot (1 - mps_h) \cdot (1 - ty_h) \cdot YH_h}{PQ_c} \quad c \in C, h \in H$$

$$\begin{bmatrix} \text{household} \\ \text{demand for} \\ \text{commodity } c \end{bmatrix} = f \begin{bmatrix} \text{household income,} \\ \text{composite price} \end{bmatrix} \quad (19)$$

Investment Demand

$$QINV_c = \overline{qinv_c} \cdot IADJ \quad c \in C$$

$$\begin{bmatrix} \text{investment} \\ \text{demand for} \\ \text{commodity } c \end{bmatrix} = \begin{bmatrix} \text{base-year investment} \\ \text{times} \\ \text{adjustment factor} \end{bmatrix} \quad (20)$$

Government Revenue

$$YG = \sum_{h \in H} ty_h \cdot YH_h + EXR \cdot tr_{gov,row} + \sum_{c \in C} tq_c \cdot (PD_c \cdot QD_c + (PM_c \cdot QM_c)_{|c \in CM})$$

$$+ \sum_{c \in CM} tm_c \cdot EXR \cdot pwm_c \cdot QM_c + \sum_{c \in CE} te_c \cdot EXR \cdot pwe_c \cdot QE_c \quad (21)$$

$$\begin{bmatrix} \text{govern-} \\ \text{ment} \\ \text{revenue} \end{bmatrix} = \begin{bmatrix} \text{direct} \\ \text{taxes} \end{bmatrix} + \begin{bmatrix} \text{transfers} \\ \text{from} \\ \text{RoW} \end{bmatrix} + \begin{bmatrix} \text{sales} \\ \text{tax} \end{bmatrix} + \begin{bmatrix} \text{import} \\ \text{tariffs} \end{bmatrix} + \begin{bmatrix} \text{export} \\ \text{taxes} \end{bmatrix}$$

Government Expenditures

$$EG = \sum_{h \in H} tr_{h,gov} + \sum_{c \in C} PQ_c \cdot qg_c$$

$$\begin{bmatrix} \text{government} \\ \text{spending} \end{bmatrix} = \begin{bmatrix} \text{household} \\ \text{transfers} \end{bmatrix} = \begin{bmatrix} \text{government} \\ \text{consumption} \end{bmatrix} \quad (22)$$

System Constraint Block

This block defines the constraints that are satisfied by the economy as a whole without being considered by its individual agents. The model's *micro* constraints apply to individual markets for factors and commodities. With the few exceptions discussed below (for labor, exports, and imports), it is assumed that flexible prices clear the markets for all commodities and factors. The *macro* constraints apply to the gov-

ernment, the savings-investment balance, and the rest of the world. For the government, savings clear the balance, whereas the investment value adjusts to changes in the value of total savings. For the rest of the world, the alternatives of a flexible exchange rate or flexible foreign savings are permitted in the current formulation.

In this block, the rest-of-world constraint (Equation 25) is new while the commodity market and savings-investment balance (Equations 24 and 26) have been modified (compared to Exercise 4). The treatment of factor markets (Equation 23) is unchanged.

Factor Markets

$$\sum_{a \in A} QF_{fa} = QFS_f \quad f \in F$$

$$\begin{bmatrix} \text{demand for} \\ \text{factor } f \end{bmatrix} = \begin{bmatrix} \text{supply of} \\ \text{factor } f \end{bmatrix} \quad (23)$$

For the two factors, the closure rules are the same as for Exercise 4: unemployment with fixed, activity-specific real wages for labor and fixed capital use for each activity. This is achieved by fixing the following variables at base values: $WFDIST_{lab,a}$, WF_{lab} , $QF_{cap,a}$, and WF_{cap} .

Composite Commodity Markets

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + qg_c + QINV_c \quad c \in C$$

$$\begin{bmatrix} \text{composite} \\ \text{supply} \end{bmatrix} = \begin{bmatrix} \text{composite demand;} \\ \text{sum of intermediate,} \\ \text{household, government,} \\ \text{\& investment demand} \end{bmatrix} \quad (24)$$

In the absence of foreign trade, the commodity market equilibrium condition in Exercises 1–4 equated output and domestic demand. This new equilibrium condition imposes equality in the composite commodity market with the demand side represented by all types of domestic commodity use while the supply comes from the Armington function (or its substitute for nonimported commodities) that aggregates imports and domestic output sold domestically. The variable PQ_c clears this market.

In addition to the composite commodity, the model includes quantity (and associated price) variables for the following commodities and activities: QM , QE , QX , QD , QA . These variables represent both the quantities supplied and demanded (that is, the equilibrium quantity has been substituted for the quantities supplied and demanded throughout the model). For exports and imports, the quantities demanded and supplied clear the markets (infinitely elastic world market demands and supplies at fixed foreign-currency prices). For the remaining three quantities, the associated price variables (PX , PD , and PA) serve the market-clearing role. (Exercise: Rewrite the model with separate supply and

demand variables replacing QM , QE , QX , QD , QA , and a full set of equilibrium conditions for the corresponding markets.)

Current Account Balance for RoW (in Foreign Currency)

$$\sum_{c \in C} pwe_c \cdot QE_c + \sum_{i \in I} tr_{i,row} + FSAV = \sum_{c \in CM} pwm_c \cdot QM_c$$

$$\begin{bmatrix} \text{export} \\ \text{revenue} \end{bmatrix} = \begin{bmatrix} \text{transfers} \\ \text{from RoW} \\ \text{to households} \\ \text{\& government} \end{bmatrix} = \begin{bmatrix} \text{foreign} \\ \text{savings} \end{bmatrix} = \begin{bmatrix} \text{import} \\ \text{spending} \end{bmatrix} \quad (25)$$

The current-account equation (which is expressed in foreign currency) imposes equality between the country's earning and spending of foreign exchange. Foreign savings is equal to the current-account deficit. Careful counting of equations and variables in the current model would indicate that the number of variables exceeds the number of equations by one. This is related to the fact that the model includes two variables that may serve the role of clearing the current-account balance—the foreign exchange rate (EXR) and foreign savings ($FSAV$). The experiment for this Exercise (see below), assumes that $FSAV$ is fixed.

Savings-Investment Balance

$$\sum_{h \in H} mps_h \cdot (1 - ty_h) \cdot YH_h + (YG - EG) + EXR \cdot FSAV$$

$$= \sum_{c \in C} PQ_c \cdot QINV_c + WALRAS \quad (26)$$

$$\begin{bmatrix} \text{household} \\ \text{savings} \end{bmatrix} + \begin{bmatrix} \text{government} \\ \text{savings} \end{bmatrix} + \begin{bmatrix} \text{foreign} \\ \text{savings} \end{bmatrix} = \begin{bmatrix} \text{invest-} \\ \text{ment} \\ \text{spending} \end{bmatrix} + \begin{bmatrix} \text{WALRAS} \\ \text{dummy} \\ \text{variable} \end{bmatrix}$$

Foreign savings, converted into domestic currency, appears as a new item in Equation 26. As long as either the exchange rate or foreign savings is fixed, their presence does not influence the savings-investment closure of the model, according to which the savings value determines the investment value.

Price Normalization

$$\sum_{c \in C} PQ_c \cdot cwtsc_c = cpi$$

$$\begin{bmatrix} \text{price times} \\ \text{weights} \end{bmatrix} = [CPI] \quad (27)$$

TASK Implement the model presented in the mathematical statement in GAMS, that is, calibrate it to the base, solve it to confirm that it calibrates, and implement a simple experiment where the world price (in foreign currency) of the agricultural commodity increases by 25 percent. Assume that the exchange rate is flexible. Analyze the impact.

As your starting point, use the file CGE4.GMS (the suggested answer to Exercise 4) and relevant parts of CGE5HLP.TXT. The latter includes the new SAM, as well as declarations and definitions for new parameters, variables, and equations. However, the numerous changes in definitions for old equations, parameters, and variables are not included.

HINTS It is suggested that you go through the following steps:

1. Carefully review the file CGE4.GMS, the mathematical statement for the Exercise 5 model, and the relevant part of CGEHLP.TXT
2. Make a copy of the file CGE4.GMS named CGE5.GMS
3. Carefully work through the file CGE5.GMS starting from the very beginning, introducing modifications when implied by the mathematical statement and the new SAM, and copying segments from CGE5HLP.TXT. In particular, copying and pasting the relatively complex definitions of parameters related to Armington and CET functions should be helpful.
4. When encountering problems, draw on suggestions in earlier exercises regarding how to debug the model. Rely on the GAMS user's guide as a reference.

Regarding initial values for price variables, it may be useful to note the following: In general, try to initialize as many prices as possible at unity. In the current model, this is the case for the capital wage and for the commodity prices PE_c , PM_c , PD_c , and PX_c . However, the possible presence of taxes and subsidies may impose divergence from this initialization rule for three other commodity prices: $tq_c > 0 \Rightarrow > 1$; $tm_c > 0 \Rightarrow < 1$; and $te_c > 0 \Rightarrow > 1$. (However, according to the current SAM, $te_c = 0$ for all commodities.)

The suggested GAMS model has 49 variables and equations. The GAMS solution uses an additional scalar and two IF statements to select closure for the foreign exchange market. Moreover, a new report parameter is used to compute GDP at market prices in two alternative ways (as total final demand for domestic output, value at market prices; and as GDP at factor cost plus net indirect taxes).

GOOD LUCK!

**KEY TO EXERCISES
IN CGE MODELING
USING GAMS**

HANS LÖFGREN

**(THE EXERCISES FOR THESE KEYS
ARE PUBLISHED SEPARATELY.)**

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EXERCISE 1: GAMS CODE

GAMS 2.50.094 DOS Extended/C
CGE1

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```
3
4 *INTRODUCTION=====

In this file, CGE1 is implemented in GAMS.

10
11 *SETS=====
12
13 SETS
14
15 AC global set (SAM accounts and other items)
16 /AGR-A agricultural activity
17 NAGR-A non-agricultural activity
18 AGR-C agricultural commodity
19 NAGR-C non-agricultural commodity
20 LAB labor
21 CAP capital
22 U-HHD urban household
23 R-HHD rural household
24 TOTAL total account in SAM /
25
26 ACNT(AC) all elements in AC except total
27
28 A(AC) activities
29 /AGR-A, NAGR-A/
30
31 C(AC) commodities
32 /AGR-C, NAGR-C/
33
34 F(AC) factors
35 /LAB, CAP/
36
37 H(AC) households
38 /U-HHD, R-HHD/
39 ;
40
41 ALIAS(AC,ACP); ALIAS(C,CP); ALIAS(F,FP);
42 ACNT(AC) = YES; ACNT('TOTAL') = NO; ALIAS(ACNT,ACNTP);
43
```

```

44
45 *PARAMETERS=====
46
47 PARAMETERS
48
49 ad(A)      efficiency parameter in the production fn for a
50 alpha(F,A) share of value-added to factor f in activity a
51 beta(C,H)  share of household consumption spending on commodity c
52 cpi        consumer price index
53 cwts(C)    weight of commodity c in the CPI
54 qfs(F)     supply of factor f
55 shry(H,F)  share for household h in the income of factor f
56 theta(A,C) yield of output c per unit of activity a
57 ;
58
59 *VARIABLES=====
60
61 VARIABLES
62
63 P(C)       price of commodity c
64 PA(A)      price of activity a
65 Q(C)       output level for commodity c
66 QA(A)      level of activity a
67 QF(F,A)    quantity demanded of factor f from activity a
68 QH(C,H)    quantity consumed of commodity c by household h
69 WF(F)      price of factor f
70 YF(H,F)    income of household h from factor f
71 YH(H)      income of household h
72 ;
73
74 *EQUATIONS=====
75
76 EQUATIONS
77
78 *PRODUCTION AND COMMODITY BLOCK+++++++
79 PRODFN(A)   Cobb-Douglas production function for activity a
80 FACDEM(F,A) demand for factor f from activity a
81 OUTPUTFN(C) output of commodity c
82 PADEF(A)    price for activity a
83
84 *INSTITUTION BLOCK+++++++
85 FACTTRNS(H,F) transfer of income from factor f to h-hold h
86 HHDINC(H)    income of household h
87 HHDEM(C,H)   consumption demand for household h & commodity c
88
89 *SYSTEM CONSTRAINT BLOCK+++++++
90 FACTEQ(F)    market equilibrium condition for factor f
91 COMEQ(C)     market equilibrium condition for commodity c
92 PNORM        price normalization
93 ;
94

```

```

95 *PRODUCTION AND COMMODITY BLOCK+++++++
96
97 PRODFN(A).. QA(A) =E= ad(A)*PROD(F, QF(F,A)**alpha(F,A));
98
99 FACDEM(F,A).. WF(F) =E= alpha(F,A)*PA(A)*QA(A) / QF(F,A);
100
101 OUTPUTFN(C).. Q(C) =E= SUM(A, theta(A,C)*QA(A));
102
103 PADEF(A).. PA(A) =E= SUM(C, theta(A,C)*P(C));
104
105
106 *INSTITUTION BLOCK+++++++
107
108 FACTTRNS(H,F).. YF(H,F) =E= shry(H,F)*WF(F)*SUM(A, QF(F,A));
109
110 HHDINC(H).. YH(H) =E= SUM(F, YF(H,F));
111
112 HHDEM(C,H).. QH(C,H) =E= beta(C,H)*YH(H)/P(C);
113
114
115 *SYSTEM CONSTRAINT BLOCK+++++++
116
117 FACTEQ(F).. SUM(A, QF(F,A)) =E= qfs(F);
118
119 COMEQ('AGR-C').. Q('AGR-C') =E= SUM(H, QH('AGR-C',H));
120
121 PNORM.. SUM(C, cwts(C)*P(C)) =E= cpi;
122
123
124 *MODEL=====
125
126 MODEL
127 CGE1 Simple CGE model /ALL/
128 ;
129
130 *SOCIAL ACCOUNTING MATRIX=====
131
132 TABLE SAM(AC,ACP) social accounting matrix
133
134          AGR-A  NAGR-A  AGR-C  NAGR-C  LAB  CAP  U-HHD  R-HHD
135 AGR-A                125
136 NAGR-A                150
137 AGR-C                    50   75
138 NAGR-C                    100  50
139 LAB          62      55
140 CAP          63      95
141 U-HHD                    60   90
142 R-HHD                    57   68
143 ;
144
145

```

```

146 PARAMETER
147   tdiff(AC)  column minus row total for account ac;
148 *This parameter is used to check that the above SAM is balanced.
149       SAM('TOTAL',ACNTP) = SUM(ACNT, SAM(ACNT,ACNTP));
150       SAM(ACNT,'TOTAL')  = SUM(ACNTP, SAM(ACNT,ACNTP));
151       tdiff(ACNT)       = SAM('TOTAL',ACNT)-SAM(ACNT,'TOTAL');
152
153 DISPLAY SAM, tdiff;
154
155
156 *ASSIGNMENTS FOR PARAMETERS AND VARIABLES=====
157
158 PARAMETERS
159 *The following parameters are used to define initial values of
160 *model variables.
161   P0(C), PA0(A), Q0(C), QA0(A), QF0(F,A), QH0(C,H), WF0(F), YF0(H,F),
162   YH0(H)
163   ;
164
165
166 *PRODUCTION AND COMMODITY BLOCK+++++++
167
168   P0(C)      = 1;
169   PA0(A)     = 1;
170   WF0(F)     = 1;
171
172   Q0(C)      = SAM('TOTAL',C)/P0(C);
173   QA0(A)     = SAM('TOTAL',A)/PA0(A);
174   QF0(F,A)   = SAM(F,A)/WF0(F);
175
176   alpha(F,A) = SAM(F,A) / SUM(FP, SAM(FP,A));
177   ad(A)      = QA0(A) / PROD(F, QF0(F,A)**alpha(F,A));
178   theta(A,C) = (SAM(A,C)/P0(C)) / QA0(A);
179
180
181 *INSTITUTION BLOCK+++++++
182
183   QH0(C,H)   = SAM(C,H)/P0(C);
184   YF0(H,F)   = SAM(H,F);
185   YH0(H)     = SAM('TOTAL',H);
186
187   beta(C,H)  = SAM(C,H)/SUM(CP, SAM(CP,H));
188   shry(H,F)  = SAM(H,F)/SAM('TOTAL',F);
189
190
191 *SYSTEM CONSTRAINT BLOCK+++++++
192
193   cwts(C)    = SUM(H, SAM(C,H)) / SUM((CP,H), SAM(CP,H));
194   cpi        = SUM(C, cwts(C)*P0(C));
195   qfs(F)     = SAM(F,'TOTAL')/WF0(F);
196

```

```

197
198 *INITIALIZING ALL VARIABLES+++++++
199
200 P.L(C)      = P0(C);
201 PA.L(A)     = PA0(A);
202 Q.L(C)      = Q0(C);
203 QA.L(A)     = QA0(A);
204 QF.L(F,A)   = QF0(F,A);
205 QH.L(C,H)   = QH0(C,H);
206 YF.L(H,F)   = YF0(H,F);
207 WF.L(F)     = WF0(F);
208 YH.L(H)     = YH0(H);
209
210
211 *DISPLAY+++++++
212
213 DISPLAY
214 ad, alpha, beta, cpi, cwts, qfs, shry, theta,
215
216 P.L, PA.L, Q.L, QA.L, QF.L, QH.L, WF.L, YF.L, YH.L
217 ;
218
219
220 *SOLVE STATEMENT FOR BASE=====
221
222 *SOLVE CGE1 USING MCP;
223
224
225 *REPORT SETUP AND BASE REPORT=====
226
227 *SET AND PARAMETERS FOR REPORTS+++++++
228
229 SET
230 SIM simulations
231     /BASE base simulation
232     CINCR increase in capital stock/
233
234 PARAMETERS
235
236 QFSCAPSIM(SIM) capital supply for sim'on sim (experiment parameter)
237 *Parameter is used to change the value for the capital stock
238 *parameter before solving the model for simulation sim
239
240 QFSREP(F,SIM)      supply of factor f for simulation sim (value used)
241 PREP(C,SIM)        demander price for commodity c
242 PAREP(A,SIM)       price of activity a
243 QREP(C,SIM)        output level for commodity c
244 QAREP(A,SIM)       level of activity a
245 QFREP(F,A,SIM)     demand for factor f from activity a
246 QHREP(C,H,SIM)     consumption of commodity c by household h
247 WFREP(F,SIM)       price of factor f

```

```

248 YFREP(H,F,SIM)      income of household h from factor f
249 YHREP(H,SIM)       income of household h
250 SAMREP(SIM,AC,ACP)  SAM computed from model solution
251 BALCHK(AC,SIM)     column minus row total for account ac in SAM
252 ;
253
254 QFSCAPSIM('BASE')   = qfs('CAP');
255 QFSCAPSIM('CINCR')  = 1.1*qfs('CAP');
256
257 DISPLAY QFSCAPSIM;
258
259
260 LOOP(SIM,
261
262   qfs('CAP') = QFSCAPSIM(SIM);
263
264 SOLVE CGE1 USING MCP;
265
266 QFSREP(F,SIM)       = qfs(F);
267
268 PREP(C,SIM)         = P.L(C);
269 PAREP(A,SIM)        = PA.L(A);
270 QREP(C,SIM)         = Q.L(C);
271 QAREP(A,SIM)        = QA.L(A);
272 QFREP(F,A,SIM)      = QF.L(F,A);
273 QHREP(C,H,SIM)      = QH.L(C,H);
274 WFREP(F,SIM)        = WF.L(F);
275 YFREP(H,F,SIM)      = YF.L(H,F);
276 YHREP(H,SIM)        = YH.L(H);
277
278 *Payments from activities
279 SAMREP(SIM,F,A)     = WF.L(F)*QF.L(F,A);
280 *Payments from commodities
281 SAMREP(SIM,A,C)     = P.L(C)*theta(A,C)*QA.L(A);
282 *Payments from factors
283 SAMREP(SIM,H,F)     = YF.L(H,F);
284 *Payments from households
285 SAMREP(SIM,C,H)     = P.L(C)*QH.L(C,H);
286
287 );
288
289
290 *Computing totals for SAMREP
291 SAMREP(SIM,'TOTAL',ACNTP) = SUM(ACNTP, SAMREP(SIM,ACNTP,ACNTP));
292 SAMREP(SIM,ACNTP,'TOTAL') = SUM(ACNTP, SAMREP(SIM,ACNTP,ACNTP));
293
294 *Check that SAMREP is balanced
295 BALCHK(ACNTP,SIM) = SAMREP(SIM,'TOTAL',ACNTP)-SAMREP(SIM,ACNTP,'TOTAL');
296
297
298 OPTION QFREP:3:1:1, QHREP:3:1:1, YFREP:3:1:1, SAMREP:3:1:1;

```

```

299
300 DISPLAY
301   QFSREP, PREP, PAREP, QREP, QAREP, QFREP, QHREP, WFREP, YFREP, YHREP,
302   SAMREP, BALCHK
303   ;
304
305
306 *Parameters reporting %-age change from BASE for model variables and
307 *for selected other data.
308 PARAMETERS
309   QFSREPP(F,SIM)      supply of factor f for simulation sim (%ch)
310   PREPP(C,SIM)        demander price for commodity c (%ch)
311   PAREPP(A,SIM)       price of activity a (%ch)
312   QREPP(C,SIM)        output level for commodity c (%ch)
313   QAREPP(A,SIM)       level of activity a (%ch)
314   QFREPP(F,A,SIM)     demand for factor f from activity a (%ch)
315   QHREPP(C,H,SIM)     consumption of commodity c by household h (%ch)
316   YFREPP(H,F,SIM)     income of household h from factor f (%ch)
317   WFREPP(F,SIM)       price of factor f (%ch)
318   YHREPP(H,SIM)       income of household h (%ch)
319   SAMREPP(SIM,AC,ACP) SAM computed from model solution (%ch by cell)
320   ;
321
322   QFSREPP(F,SIM)      = 100*(QFSREP(F,SIM)/QFSREP(F,'BASE')-1);
323   PREPP(C,SIM)        = 100*(PREP(C,SIM)/PREP(C,'BASE')-1);
324   PAREPP(A,SIM)       = 100*(PAREP(A,SIM)/PAREP(A,'BASE')-1);
325   QREPP(C,SIM)        = 100*(QREP(C,SIM)/QREP(C,'BASE')-1);
326   QAREPP(A,SIM)       = 100*(QAREP(A,SIM)/QAREP(A,'BASE')-1);
327   QFREPP(F,A,SIM)     = 100*(QFREP(F,A,SIM)/QFREP(F,A,'BASE')-1);
328   QHREPP(C,H,SIM)     = 100*(QHREP(C,H,SIM)/QHREP(C,H,'BASE')-1);
329   WFREPP(F,SIM)       = 100*(WFREP(F,SIM)/WFREP(F,'BASE')-1);
330   YFREPP(H,F,SIM)     = 100*(YFREP(H,F,SIM)/YFREP(H,F,'BASE')-1);
331   YHREPP(H,SIM)       = 100*(YHREP(H,SIM)/YHREP(H,'BASE')-1);
332   SAMREPP(SIM,AC,ACP)$SAMREP('BASE',AC,ACP)
333                       = 100*(SAMREP(SIM,AC,ACP)/SAMREP('BASE',AC,ACP)-1);
334
335 OPTION QFREPP:3:1:1, QHREPP:3:1:1, YFREPP:3:1:1, SAMREPP:3:1:1;
336
337
338 DISPLAY
339   QFSREPP, PREPP, PAREPP, QREPP, QAREPP, QFREPP, QHREPP, WFREPP,
340   YFREPP, YHREPP, SAMREPP
341   ;

```

EXERCISE A1: GAMS CODE

GAMS 2.50.094 DOS Extended/C
CGEA1

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```
3
4 *INTRODUCTION=====

In this file, the starting point is CGE1. The production function and
the factor demand functions have been rewritten in "longhand."

11
12 *SETS=====
13
14 SETS
15
16 AC global set (SAM accounts and other items)
17   /AGR-A  agricultural activity
18     NAGR-A non-agricultural activity
19     AGR-C  agricultural commodity
20     NAGR-C non-agricultural commodity
21     LAB    labor
22     CAP    capital
23     U-HHD  urban household
24     R-HHD  rural household
25     TOTAL  total account in SAM /
26
27 ACNT(AC) all elements in AC except total
28
29 A(AC)  activities
30       /AGR-A, NAGR-A/
31
32 C(AC)  commodities
33       /AGR-C, NAGR-C/
34
35 F(AC)  factors
36       /LAB, CAP/
37
38 H(AC)  households
39       /U-HHD, R-HHD/
40 ;
41
42 ALIAS(AC,ACP); ALIAS(C,CP); ALIAS(F,FP);
43 ACNT(AC) = YES; ACNT('TOTAL') = NO; ALIAS(ACNT,ACNTP);
```

```

44
45
46 *PARAMETERS=====
47
48 PARAMETERS
49
50 ad(A)      efficiency parameter in the production fn for a
51 alpha(F,A) share of value-added to factor f in activity a
52 beta(C,H)  share of household consumption spending on commodity c
53 cpi        consumer price index
54 cwts(C)    weight of commodity c in the CPI
55 qfs(F)     supply of factor f
56 shry(H,F)  share for household h in the income of factor f
57 theta(A,C) yield of output c per unit of activity a
58 ;
59
60 *VARIABLES=====
61
62 VARIABLES
63
64 P(C)       price of commodity c
65 PA(A)      price of activity a
66 Q(C)       output level for commodity c
67 QA(A)      level of activity a
68 QF(F,A)    quantity demanded of factor f from activity a
69 QH(C,H)    quantity consumed of commodity c by household h
70 WF(F)      price of factor f
71 YF(H,F)    income of household h from factor f
72 YH(H)      income of household h
73 ;
74
75 *EQUATIONS=====
76
77 EQUATIONS
78
79 *PRODUCTION AND COMMODITY BLOCK+++++++
80 PRODFN1    Cobb-Douglas production function for AGR-A
81 PRODFN2    Cobb-Douglas production function for NAGR-A
82 FACDEM1    demand for LAB from AGR-A
83 FACDEM2    demand for CAP from AGR-A
84 FACDEM3    demand for LAB from NAGR-A
85 FACDEM4    demand for CAP from NAGR-A
86 *PRODFN(A) Cobb-Douglas production function for activity a
87 *FACDEM(F,A) demand for factor f from activity a
88 OUTPUTFN(C) output of commodity c
89 PADEF(A)   price for activity a
90
91 *INSTITUTION BLOCK+++++++
92 FACTTRNS(H,F) transfer of income from factor f to h-hold h
93 HHINC(H)    income of household h
94 HHDEM(C,H)  consumption demand for household h & commodity c

```

```

95
96 *SYSTEM CONSTRAINT BLOCK+++++++
97  FACTEQ(F)  market equilibrium condition for factor f
98  COMEQ(C)  market equilibrium condition for commodity c
99  PNORM      price normalization
100           ;
101
102 *PRODUCTION AND COMMODITY BLOCK+++++++
103
104  PRODFN1..   QA('AGR-A') =E=
105              ad('AGR-A')*QF('LAB','AGR-A')**alpha('LAB','AGR-A')
106              *QF('CAP','AGR-A')**alpha('CAP','AGR-A');
107
108  PRODFN2..   QA('NAGR-A') =E=
109              ad('NAGR-A')*(QF('LAB','NAGR-A')**alpha('LAB','NAGR-A'))
110              *(QF('CAP','NAGR-A')**alpha('CAP','NAGR-A'));
111
112  FACDEM1..   WF('LAB') =E=
113              alpha('LAB','AGR-A')*PA('AGR-A')*QA('AGR-A')
114              / QF('LAB','AGR-A');
115
116  FACDEM2..   WF('CAP') =E=
117              alpha('CAP','AGR-A')*PA('AGR-A')*QA('AGR-A')
118              / QF('CAP','AGR-A');
119
120  FACDEM3..   WF('LAB') =E=
121              alpha('LAB','NAGR-A')*PA('NAGR-A')*QA('NAGR-A')
122              / QF('LAB','NAGR-A');
123
124  FACDEM4..   WF('CAP') =E=
125              alpha('CAP','NAGR-A')*PA('NAGR-A')*QA('NAGR-A')
126              / QF('CAP','NAGR-A');
127
128 *PRODFN(A).. QA(A) =E= ad(A)*PROD(F, QF(F,A)**alpha(F,A));
129 *FACDEM(F,A).. WF(F) =E= alpha(F,A)*PVA(A)*QA(A) / QF(F,A);
130
131  OUTPUTFN(C).. Q(C) =E= SUM(A, theta(A,C)*QA(A));
132
133  PADEF(A)..   PA(A) =E= SUM(C, theta(A,C)*P(C));
134
135
136 *INSTITUTION BLOCK+++++++
137
138  FACTTRNS(H,F).. YF(H,F) =E= shry(H,F)*WF(F)*SUM(A, QF(F,A));
139
140  HHDINC(H)..   YH(H) =E= SUM(F, YF(H,F));
141
142  HHDEM(C,H)..   QH(C,H) =E= beta(C,H)*YH(H)/P(C);
143
144
145 *SYSTEM CONSTRAINT BLOCK+++++++

```

```

146
147 FACTEQ(F)..      SUM(A, QF(F,A)) =E= qfs(F);
148
149 COMEQ('AGR-C').. Q('AGR-C') =E= SUM(H, QH('AGR-C',H));
150
151 PNORM..          SUM(C, cwts(C)*P(C)) =E= cpi;
152
153
154 *MODEL=====
155
156 MODEL
157 CGEAL Simple CGE model with selected equations in longhand /ALL/
158 ;
159
160 *SOCIAL ACCOUNTING MATRIX=====
161
162 TABLE SAM(AC,ACP) social accounting matrix
163
164           AGR-A  NAGR-A  AGR-C  NAGR-C  LAB  CAP  U-HHD  R-HHD
165 AGR-A                125
166 NAGR-A                150
167 AGR-C                50    75
168 NAGR-C                100   50
169 LAB           62    55
170 CAP           63    95
171 U-HHD                60   90
172 R-HHD                57   68
173 ;
174
175
176 PARAMETER
177   tdiff(AC) column minus row total for account ac;
178 *This parameter is used to check that the above SAM is balanced.
179           SAM('TOTAL',ACNTP) = SUM(ACNT, SAM(ACNT,ACNTP));
180           SAM(ACNT,'TOTAL') = SUM(ACNTP, SAM(ACNT,ACNTP));
181           tdiff(ACNT)        = SAM('TOTAL',ACNT)-SAM(ACNT,'TOTAL');
182
183 DISPLAY SAM, tdiff;
184
185
186 *ASSIGNMENTS FOR PARAMETERS AND VARIABLES=====
187
188 PARAMETERS
189 *The following parameters are used to define initial values of
190 *model variables.
191   P0(C), PA0(A), Q0(C), QA0(A), QF0(F,A), QH0(C,H), WF0(F), YF0(H,F),
192   YH0(H)
193 ;
194
195
196 *PRODUCTION AND COMMODITY BLOCK+++++++

```

```

197
198 P0(C)      = 1;
199 PA0(A)     = 1;
200 WF0(F)     = 1;
201
202 Q0(C)      = SAM('TOTAL',C)/P0(C);
203 QA0(A)     = SAM('TOTAL',A)/PA0(A);
204 QF0(F,A)   = SAM(F,A)/WF0(F);
205
206 alpha(F,A) = SAM(F,A) / SUM(FP, SAM(FP,A));
207 ad(A)      = QA0(A) / PROD(F, QF0(F,A)**alpha(F,A));
208 theta(A,C) = (SAM(A,C)/P0(C)) / QA0(A);
209
210
211 *INSTITUTION BLOCK+++++++
212
213 QH0(C,H)   = SAM(C,H)/P0(C);
214 YF0(H,F)   = SAM(H,F);
215 YH0(H)     = SAM('TOTAL',H);
216
217 beta(C,H)  = SAM(C,H)/SUM(CP, SAM(CP,H));
218 shry(H,F)  = SAM(H,F)/SAM('TOTAL',F);
219
220
221 *SYSTEM CONSTRAINT BLOCK+++++++
222
223 cwts(C)    = SUM(H, SAM(C,H)) / SUM((CP,H), SAM(CP,H));
224 cpi        = SUM(C, cwts(C)*P0(C));
225 qfs(F)     = SAM(F,'TOTAL')/WF0(F);
226
227
228 *INITIALIZING ALL VARIABLES+++++++
229
230 P.L(C)     = P0(C);
231 PA.L(A)    = PA0(A);
232 Q.L(C)     = Q0(C);
233 QA.L(A)    = QA0(A);
234 QF.L(F,A)  = QF0(F,A);
235 QH.L(C,H)  = QH0(C,H);
236 YF.L(H,F)  = YF0(H,F);
237 WF.L(F)    = WF0(F);
238 YH.L(H)    = YH0(H);
239
240
241 *DISPLAY+++++++
242
243 DISPLAY
244 ad, alpha, beta, cpi, cwts, qfs, shry, theta,
245
246 P.L, PA.L, Q.L, QA.L, QF.L, QH.L, WF.L, YF.L, YH.L
247 ;

```

```

248
249
250 *SOLVE STATEMENT FOR BASE=====
251
252 *SOLVE CGEAL USING MCP;
253
254
255 *REPORT SETUP AND BASE REPORT=====
256
257 *SET AND PARAMETERS FOR REPORTS+++++++
258
259 SET
260   SIM simulations
261     /BASE   base simulation
262     CINCR  increase in capital stock/
263
264 PARAMETERS
265
266   QFSCAPSIM(SIM) capital supply for sim'on sim (experiment parameter)
267 *Parameter is used to change the value for the capital stock parameter
268 *before solving the model for simulation sim
269
270   QFSREP(F,SIM)      supply of factor f for simulation sim (value used)
271   PREP(C,SIM)       demander price for commodity c
272   PAREP(A,SIM)      price of activity a
273   QREP(C,SIM)       output level for commodity c
274   QAREP(A,SIM)      level of activity a
275   QFREP(F,A,SIM)    demand for factor f from activity a
276   QHREP(C,H,SIM)    consumption of commodity c by household h
277   WFREP(F,SIM)      price of factor f
278   YFREP(H,F,SIM)    income of household h from factor f
279   YHREP(H,SIM)      income of household h
280   SAMREP(SIM,AC,ACP) SAM computed from model solution
281   BALCHK(AC,SIM)    column minus row total for account ac in SAM
282   ;
283
284   QFSCAPSIM('BASE') = qfs('CAP');
285   QFSCAPSIM('CINCR') = 1.1*qfs('CAP');
286
287   DISPLAY QFSCAPSIM;
288
289
290   LOOP(SIM,
291
292     qfs('CAP') = QFSCAPSIM(SIM);
293
294   SOLVE CGEAL USING MCP;
295
296   QFSREP(F,SIM) = qfs(F);
297
298   PREP(C,SIM) = P.L(C);

```

```

299  PAREP(A,SIM)      = PA.L(A);
300  QREP(C,SIM)       = Q.L(C);
301  QAREP(A,SIM)      = QA.L(A);
302  QFREP(F,A,SIM)    = QF.L(F,A);
303  QHREP(C,H,SIM)    = QH.L(C,H);
304  WFREP(F,SIM)      = WF.L(F);
305  YFREP(H,F,SIM)    = YF.L(H,F);
306  YHREP(H,SIM)      = YH.L(H);
307
308  *Payments from activities
309  SAMREP(SIM,F,A)    = WF.L(F)*QF.L(F,A);
310  *Payments from commodities
311  SAMREP(SIM,A,C)    = P.L(C)*theta(A,C)*QA.L(A);
312  *Payments from factors
313  SAMREP(SIM,H,F)    = YF.L(H,F);
314  *Payments from households
315  SAMREP(SIM,C,H)    = P.L(C)*QH.L(C,H);
316
317  );
318
319
320  *Computing totals for SAMREP
321  SAMREP(SIM,'TOTAL',ACNTP) = SUM(ACNT, SAMREP(SIM,ACNT,ACNTP));
322  SAMREP(SIM,ACNT,'TOTAL') = SUM(ACNTP, SAMREP(SIM,ACNT,ACNTP));
323
324  *Check that SAMREP is balanced
325  BALCHK(ACNT,SIM) = SAMREP(SIM,'TOTAL',ACNT)-SAMREP(SIM,ACNT,'TOTAL');
326
327
328  OPTION QFREP:3:1:1, QHREP:3:1:1, YFREP:3:1:1, SAMREP:3:1:1;
329
330  DISPLAY
331  QFSREP, PREP, PAREP, QREP, QAREP, QFREP, QHREP, WFREP, YFREP, YHREP,
332  SAMREP, BALCHK
333  ;

```

EXERCISE 2: MATHEMATICAL STATEMENT

NOTATION

Sets

$a \in A$	activities {AGR-A agricultural activity NAGR-A nonagricultural activity}
$c \in C$	commodities {AGR-C agricultural commodity NAGR-C nonagricultural commodity}
$f \in F$	factors {LAB labor CAP capital}
$h \in H$	households {U-HHD urban household R-HHD rural household}

Parameters

ad_a	efficiency parameter in the production function for activity a
cpi	consumer price index (CPI)
$cwts_c$	weight of commodity c in the CPI
ica_{ca}	qnty of c as intermed. input per unit of output in activity a
qfs_f	supply of factor f
$shry_{hf}$	share for household h in the income of factor f
α_{fa}	share of value-added for factor f in activity a
β_{ch}	share in household h consumption spending of commodity c
θ_{ac}	yield of output c per unit of activity a

Variables

P_c	market price of commodity c
PA_a	price of activity a
PVA_a	value-added (or net) price of activity a
Q_c	output level in commodity c
QA_a	level of activity a
QF_{fa}	demand for factor f from activity a
QH_{ch}	consumption of commodity c by household h
$QINT_{ca}$	qnty of commodity c as intermediate input in activity a
WF_f	price of factor f
YF_{hf}	income of household h from factor f
YH_h	income of household h

EQUATIONS

$$QA_a = ad_a \cdot \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \quad a \in A \quad (1)$$

Production and Commodity Block

$$WF_f = \frac{\alpha_{fa} \cdot PVA_a \cdot QA_a}{QF_{fa}} \quad f \in F, a \in A \quad (2)$$

$$QINT_{ca} = ica_{ca} \cdot QA_a \quad c \in C, a \in A \quad (3)$$

$$PA_a = \sum_{c \in C} \theta_{ac} \cdot P_c \quad a \in A \quad (4)$$

$$PVA_a = PA_a - \sum_{c \in C} P_c \cdot ica_{ca} \quad a \in A \quad (5)$$

$$Q_c = \sum_{a \in A} \theta_{ac} \cdot QA_a \quad c \in C \quad (6)$$

Institution Block

$$YF_{hf} = shry_{hf} \cdot WF_f \cdot \sum_{a \in A} QF_{fa} \quad h \in H, f \in F \quad (7)$$

$$YH_h = \sum_{f \in F} YF_{hf} \quad h \in H \quad (8)$$

$$QH_{ch} = \frac{\beta_{ch} \cdot YH_h}{P_c} \quad c \in C, h \in H \quad (9)$$

System Constraint Block

$$\sum_{a \in A} QF_{fa} = qfs_f \quad f \in F \quad (10)$$

$$Q_c = \sum_{h \in H} QH_{ch} + \sum_{a \in A} QINT_{ca} \quad c \in C \quad (11)$$

$$\sum_{c \in C} cwt_s_c \cdot P_c = cpi \quad (12)$$

EXERCISE 2: GAMS CODE

GAMS 2.50.094 DOS Extended/C
CGE2

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```
3
4 *INTRODUCTION=====

In this file, the starting point is CGE1.
Intermediate demands are added. A modified SAM is presented.

The line before any new feature or modification starts with
"***".

14
15 *SETS=====
16
17 SETS
18
19 AC global set (SAM accounts and other items)
20   /AGR-A   agricultural activity
21   NAGR-A   non-agricultural activity
22   AGR-C    agricultural commodity
23   NAGR-C   non-agricultural commodity
24   LAB      labor
25   CAP      capital
26   U-HHD    urban household
27   R-HHD    rural household
28   TOTAL    total account in SAM /
29
30 ACNT(AC) all elements in AC except total
31
32 A(AC) activities
33   /AGR-A, NAGR-A/
34
35 C(AC) commodities
36   /AGR-C, NAGR-C/
37
38 F(AC) factors
39   /LAB, CAP/
40
41 H(AC) households
42   /U-HHD, R-HHD/
43 ;
```

```

44
45 ALIAS(AC,ACP); ALIAS(C,CP); ALIAS(F,FP);
46 ACNT(AC) = YES; ACNT('TOTAL') = NO; ALIAS(ACNT,ACNTP);
47
48
49 *PARAMETERS=====
50
51 PARAMETERS
52
53 ad(A)          efficiency parameter in the production fn for a
54 alpha(F,A)    share of value-added to factor f in activity a
55 beta(C,H)     share of household consumption spending on commodity c
56 cpi           consumer price index
57 cwts(C)      weight of commodity c in the CPI
58 *++
59 ica(C,A)      qnty of c as intermediate input per unit of activity a
60 qfs(F)        supply of factor f
61 shry(H,F)     share for household h in the income of factor f
62 theta(A,C)   yield of output c per unit of activity a
63 ;
64
65 *VARIABLES=====
66
67 VARIABLES
68
69 P(C)          price of commodity c
70 PA(A)         price of activity a
71 *++
72 PVA(A)        value-added (or net) price for activity a
73 Q(C)          output level for commodity c
74 QA(A)         level of activity a
75 QF(F,A)       quantity demanded of factor f from activity a
76 QH(C,H)       quantity consumed of commodity c by household h
77 *++
78 QINT(C,A)     qnty of commodity c as intermediate input to activity a
79 WF(F)         price of factor f
80 YF(H,F)       income of household h from factor f
81 YH(H)         income of household h
82 ;
83
84 *EQUATIONS=====
85
86 EQUATIONS
87
88 *PRODUCTION AND COMMODITY BLOCK+++++++
89 PRODFN(A)     Cobb-Douglas production function for activity a
90 FACDEM(F,A)   demand for factor f from activity a
91 *++
92 INTDEM(C,A)   intermediate demand for commodity c from activity a
93 OUTPUTFN(C)  output of commodity c
94 PADEF(A)      price for activity a

```

```

95 ***
96 PVADEF(A)    value-added price for activity a
97
98 *INSTITUTION BLOCK+++++
99 FACTTRNS(H,F)  transfer of income from factor f to h-hold h
100 HHDINC(H)     income of household h
101 HHDEM(C,H)    consumption demand for household h & commodity c
102
103 *SYSTEM CONSTRAINT BLOCK+++++
104 FACTEQ(F)     market equilibrium condition for factor f
105 COMEQ(C)     market equilibrium condition for commodity c
106 PNORM        price normalization
107 ;
108
109 *PRODUCTION AND COMMODITY BLOCK+++++
110
111 PRODFN(A)..   QA(A) =E= ad(A)*PROD(F, QF(F,A)**alpha(F,A));
112 ***
113 FACDEM(F,A).. WF(F) =E= alpha(F,A)*PVA(A)*QA(A) / QF(F,A);
114 ***
115 INTDEM(C,A).. QINT(C,A) =E= ica(C,A)*QA(A);
116
117 OUTPUTFN(C).. Q(C) =E= SUM(A, theta(A,C)*QA(A));
118
119 PADEF(A)..   PA(A) =E= SUM(C, theta(A,C)*P(C));
120 ***
121 PVADEF(A)..  PVA(A) =E= PA(A)-SUM(C, P(C)*ica(C,A));
122
123
124 *INSTITUTION BLOCK+++++
125
126 FACTTRNS(H,F).. YF(H,F) =E= shry(H,F)*WF(F)*SUM(A, QF(F,A));
127
128 HHDINC(H)..   YH(H) =E= SUM(F, YF(H,F));
129
130 HHDEM(C,H)..  QH(C,H) =E= beta(C,H)*YH(H)/P(C);
131
132
133 *SYSTEM CONSTRAINT BLOCK+++++
134
135 FACTEQ(F)..   SUM(A, QF(F,A)) =E= qfs(F);
136 ***
137 COMEQ('AGR-C').. Q('AGR-C') =E=
138 SUM(H, QH('AGR-C',H)) + SUM(A, QINT('AGR-C',A));
139
140 PNORM..       SUM(C, cwts(C)*P(C)) =E= cpi;
141
142
143 *MODEL=====
144
145 MODEL

```

```

146 CGE2 Model with intermediate demand as new feature
147 /ALL/
148 ;
149
150 *SOCIAL ACCOUNTING MATRIX=====
151
152 TABLE SAM(AC,ACP) social accounting matrix
153
154          AGR-A  NAGR-A  AGR-C  NAGR-C  LAB  CAP  U-HHD  R-HHD
155 AGR-A                225
156 NAGR-A                250
157 AGR-C      60      40                50      75
158 NAGR-C      40      60                100     50
159 LAB         62      55
160 CAP         63      95
161 U-HHD                60     90
162 R-HHD                57     68
163 ;
164
165
166 PARAMETER
167 tdiff(AC) column minus row total for account ac;
168          SAM('TOTAL',ACNTP) = SUM(ACNT, SAM(ACNT,ACNTP));
169          SAM(ACNT,'TOTAL') = SUM(ACNTP, SAM(ACNT,ACNTP));
170          tdiff(ACNT)        = SAM('TOTAL',ACNT)-SAM(ACNT,'TOTAL');
171
172 DISPLAY SAM, tdiff;
173
174
175 *ASSIGNMENTS FOR PARAMETERS AND VARIABLES=====
176
177 PARAMETERS
178 *The following parameters are used to define initial values of
179 *model variables.
180 P0(C), PA0(A), PVA0(A), Q0(C), QA0(A), QF0(F,A), QH0(C,H), QINT0(C,A),
181 WF0(F), YF0(H,F), YH0(H)
182 ;
183
184
185 *PRODUCTION AND COMMODITY BLOCK+++++++
186
187 P0(C)      = 1;
188 PA0(A)     = 1;
189 WF0(F)     = 1;
190
191 *++
192 PVA0(A)    = SUM(F, SAM(F,A)) / (SAM(A,'TOTAL')/PA0(A));
193 Q0(C)      = SAM('TOTAL',C)/P0(C);
194 QA0(A)     = SAM('TOTAL',A)/PA0(A);
195 QF0(F,A)   = SAM(F,A)/WF0(F);
196 *++

```

```

197  QINT0(C,A) = SAM(C,A)/P0(C);
198
199  alpha(F,A) = SAM(F,A) / SUM(FP, SAM(FP,A));
200  ad(A)      = QA0(A) / PROD(F, QF0(F,A)**alpha(F,A));
201  ***
202  ica(C,A)   = (SAM(C,A)/P0(C)) / QA0(A);
203  theta(A,C) = (SAM(A,C)/P0(C)) / QA0(A);
204
205
206  *INSTITUTION BLOCK+++++++
207
208  QH0(C,H)   = SAM(C,H)/P0(C);
209  YF0(H,F)   = SAM(H,F);
210  YH0(H)     = SAM('TOTAL',H);
211
212  beta(C,H)  = SAM(C,H)/SUM(CP, SAM(CP,H));
213  shry(H,F)  = SAM(H,F)/SAM('TOTAL',F);
214
215
216  *SYSTEM CONSTRAINT BLOCK+++++++
217
218  cwts(C)    = SUM(H, SAM(C,H)) / SUM((CP,H), SAM(CP,H));
219  cpi        = SUM(C, cwts(C)*P0(C));
220  qfs(F)     = SAM(F,'TOTAL')/WF0(F);
221
222
223  *INITIALIZING ALL VARIABLES+++++++
224
225  P.L(C)     = P0(C);
226  PA.L(A)    = PA0(A);
227  ***
228  PVA.L(A)   = PVA0(A);
229  Q.L(C)     = Q0(C);
230  QA.L(A)    = QA0(A);
231  QF.L(F,A)  = QF0(F,A);
232  QH.L(C,H)  = QH0(C,H);
233  ***
234  QINT.L(C,A) = QINT0(C,A);
235  YF.L(H,F)  = YF0(H,F);
236  WF.L(F)    = WF0(F);
237  YH.L(H)    = YH0(H);
238  ;
239
240
241  *DISPLAY+++++++
242
243  DISPLAY
244  ad, alpha, beta, cpi, cwts, ica, qfs, shry, theta,
245
246  P.L, PA.L, PVA.L, Q.L, QA.L, QF.L, QH.L, QINT.L, WF.L, YF.L, YH.L
247  ;

```

```

248
249
250 *SOLVE STATEMENT FOR BASE=====
251
252 *SOLVE CGE2 USING MCP;
253
254
255 *REPORT SETUP AND BASE REPORT=====
256
257 *SET AND PARAMETERS FOR REPORTS+++++++
258
259
260 SET
261   SIM simulations
262     /BASE   base simulation
263     CINCR  increase in capital stock/
264
265
266
267 PARAMETERS
268
269   QFSCAPSIM(SIM)    capital supply for sim'on sim (experiment parameter)
270
271   QFSREP(F,SIM)    supply of factor f for simulation sim (value used)
272   PREP(C,SIM)     demander price for commodity c
273   PAREP(A,SIM)    price of activity a
274   PVAREP(A,SIM)   value-added price for activity a
275   QREP(C,SIM)     output level for commodity c
276   QAREP(A,SIM)    level of activity a
277   QFREP(F,A,SIM)  demand for factor f from activity a
278   QHREP(C,H,SIM)  consumption of commodity c by household h
279   QINTREP(C,A,SIM) qnty of commodity c as intermed. input for activity a
280   WFREP(F,SIM)    price of factor f
281   YFREP(H,F,SIM)  income of household h from factor f
282   YHREP(H,SIM)    income of household h
283   ;
284
285
286   QFSCAPSIM('BASE') = qfs('CAP');
287   QFSCAPSIM('CINCR') = 1.1*qfs('CAP');
288
289   DISPLAY QFSCAPSIM;
290
291
292
293   LOOP(SIM,
294
295     qfs('CAP') = QFSCAPSIM(SIM);
296
297   SOLVE CGE2 USING MCP;
298

```

```
299 QFSREP(F,SIM)      = qfs(F);
300 PREP(C,SIM)        = P.L(C);
301 PAREP(A,SIM)       = PA.L(A);
302 PVAREP(A,SIM)     = PVA.L(A);
303 QREP(C,SIM)        = Q.L(C);
304 QAREP(A,SIM)       = QA.L(A);
305 QFREP(F,A,SIM)     = QF.L(F,A);
306 QHREP(C,H,SIM)     = QH.L(C,H);
307 QINTREP(C,A,SIM)  = QINT.L(C,A);
308 WFREP(F,SIM)       = WF.L(F);
309 YFREP(H,F,SIM)    = YF.L(H,F);
310 YHREP(H,SIM)      = YH.L(H);
311
312 );
313
314 OPTION QFREP:3:1:1, QHREP:3:1:1, YFREP:3:1:1;
315
316 DISPLAY
317 QFSREP, PREP, PAREP, PVAREP, QREP, QAREP, QFREP, QHREP, QINTREP,
318 WFREP, YFREP, YHREP
319 ;
```

EXERCISE 3: MATHEMATICAL STATEMENT

NOTATION	$a \in A$	activities {AGR-A agricultural activity NAGR-A nonagricultural activity}
	Sets	
	$c \in C$	commodities {AGR-C agricultural commodity NAGR-C nonagricultural commodity}
	$f \in F$	factors {LAB labor CAP capital}
	$h \in H$	households {U-HHD urban household R-HHD rural household}
Parameters	ad_a	efficiency parameter in the production function for activity a
	cpi	consumer price index (CPI)
	$cwts_c$	weight of commodity c in the CPI
	ica_{ca}	qnty of c as intermed. input per unit of output in activity a
	mps_h	marginal (and average) propensity to save for household h
	qfs_f	supply of factor f
	\overline{pwm}_c	import price (foreign currency)
	\overline{qinv}_c	base-year qnty of investment demand for commodity c
	$shry_{hf}$	share for household h in the income of factor f
	$wfdist_{fa}$	wage distortion factor for factor f in activity a
	α_{fa}	share of value-added for factor f in activity a
	β_{ch}	share in household h consumption spending on commodity c
	θ_{ac}	yield of output c per unit of activity a
Variables	$IADJ$	investment adjustment factor
	P_c	market price of commodity c
	PA_a	price of activity a
	PVA_a	value-added (or net) price of activity a
	Q_c	output level in commodity c
	QA_a	level of activity a
	QF_{fa}	demand for factor f from activity a
	QH_{ch}	consumption of commodity c by household h
	$QINT_{ca}$	qnty of commodity c as intermediate input in activity a
	$QINV_c$	quantity of investment demand for commodity c
	$WALRAS$	$WALRAS$ dummy variable (zero at equilibrium)
WF_f	average wage (rental rate) for factor f	

YF_{hf} income of household h from factor f
 YH_h income of household h

EQUATIONS

Production and Commodity Block

$$QA_a = ad_a \cdot \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \quad a \in A \quad (1)$$

$$WF_f \cdot wfdist_{fa} = \frac{a_{fa} \cdot PVA_a \cdot QA_a}{QF_{fa}} \quad f \in F, a \in A \quad (2)$$

$$QINT_{ca} = ica_{ca} \cdot QA_a \quad c \in C, a \in A \quad (3)$$

$$PA_a = \sum_{c \in C} \theta_{ac} \cdot PX_c \quad a \in A \quad (4)$$

$$PVA_a = PA_a - \sum_{c \in C} P_c \cdot ica_{ca} \quad a \in A \quad (5)$$

$$Q_c = \sum_{a \in A} \theta_{ac} \cdot QA_a \quad c \in C \quad (6)$$

Institution Block

$$YF_{hf} = shry_{hf} \cdot \sum_{a \in A} WF_f \cdot wfdist_{fa} \cdot QF_{fa} \quad h \in H, f \in F \quad (7)$$

$$YH_h = \sum_{f \in F} YF_{hf} \quad h \in H \quad (8)$$

$$QH_{ch} = \frac{\beta_{ch} \cdot (1 - mps_h) \cdot (1 - ty_h) \cdot YH_h}{P_c} \quad c \in C, h \in H \quad (9)$$

$$QINV_c = \overline{qinv}_c \cdot IADJ \quad c \in C \quad (10)$$

System Constraint Block

$$\sum_{a \in A} QF_{fa} = qfs_f \quad f \in F \quad (11)$$

$$Q_c = \sum_{h \in H} QH_{ch} + \sum_{a \in A} QINT_{ca} + QINV_c \quad c \in C \quad (12)$$

$$\sum_{c \in C} P_c \cdot QINV_c + WALRAS = \sum_{h \in H} mps_h \cdot YH_h \quad (13)$$

$$\sum_{c \in C} cwts_c \cdot P_c = cpi \quad (14)$$

EXERCISE 3: GAMS CODE

GAMS 2.50.094 DOS Extended/C
CGE3

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```
3
4 *INTRODUCTION=====
```

In this file, the starting point is CGE2.

The new phenomena are

- (1) the assumption that, for labor, wages are "distorted" (wages are no longer uniform for both activities); and
- (2) the presence of savings and investment.

A modified SAM is presented (needed due to the addition of savings and investment).

The line before any new feature or modification starts with
"++".

Note that, in GAMS (as opposed to the mathematical statement), the household savings rate (mps) is declared as a variable that subsequently is fixed. (It was simply specified as a parameter in the mathematical statement.) Thus, investment remains savings-driven. However, with this specification, it is possible to change to making savings investment-driven by simply

- (1) fixing the variable for investment adjustment (IADJ); and
- (2) flexing the savings rate (mps) for one of the households.

In this setting, variations in a household savings rate would assure that the savings value is equal to the investment value. To see how this can be done, search for "SAV-INV++".

Given that the model now includes a fixed variable, the GAMS default variable count will now include an item that is not an endogenous variable. To overrule this default, the "holdfixed" model attribute is specified. As a result, only endogenous variables are included in the variable count. To see this, search "HOLDFIXED" (cf. Footnote 7 in Exercise manual).

```
39
40 *SETS=====
41
42 SETS
43
```

```

44 AC global set (SAM accounts and other items)
45   /AGR-A   agricultural activity
46   NAGR-A   non-agricultural activity
47   AGR-C    agricultural commodity
48   NAGR-C   non-agricultural commodity
49   LAB      labor
50   CAP      capital
51   U-HHD    urban household
52   R-HHD    rural household
53 *++
54   S-I      savings-investment
55   TOTAL    total account in SAM /
56
57 ACNT(AC) all elements in AC except total
58
59 A(AC) activities
60   /AGR-A, NAGR-A/
61
62 C(AC) commodities
63   /AGR-C, NAGR-C/
64
65 F(AC) factors
66   /LAB, CAP/
67
68 H(AC) households
69   /U-HHD, R-HHD/
70 ;
71
72 ALIAS(AC,ACP); ALIAS(C,CP); ALIAS(F,FP);
73 ACNT(AC) = YES; ACNT('TOTAL') = NO; ALIAS(ACNT,ACNTP);
74
75
76 *PARAMETERS=====
77
78 PARAMETERS
79
80 ad(A)          efficiency parameter in the production fn for a
81 alpha(F,A)     share of value-added to factor f in activity a
82 beta(C,H)      share of household consumption spending on commodity c
83 cpi            consumer price index
84 cwts(C)        weight of commodity c in the CPI
85 ica(C,A)       qnty of c as intermediate input per unit of activity a
86 qfs(F)         supply of factor f
87 *++
88 qinvbar(C)     base-year qnty of investment demand for commodity c
89 shry(H,F)      share for household h in the income of factor f
90 theta(A,C)     yield of output c per unit of activity a
91 *++
92 wfdist(F,A)    wage distortion factor for factor f in activity a
93 ;
94

```

```

95 *VARIABLES=====
96
97 VARIABLES
98 *++
99   IADJ      investment adjustment factor
100 *++
101  MPS(H)    marginal (and average) propensity to save for household h
102  P(C)      price of commodity c
103  PA(A)     price of activity a
104  PVA(A)    value-added (or net) price for activity a
105  Q(C)      output level for commodity c
106  QA(A)     level of activity a
107  QF(F,A)   quantity demanded of factor f from activity a
108  QH(C,H)   quantity consumed of commodity c by household h
109  QINT(C,A) qnty of commodity c as intermediate input to activity a
110 *++
111  QINV(C)   quantity of investment demand for commodity c
112 *++
113  WALRAS    dummy variable (zero at equilibrium)
114  WF(F)     average price of factor f
115  YF(H,F)   income of household h from factor f
116  YH(H)     income of household h
117 ;
118
119 *EQUATIONS=====
120
121 EQUATIONS
122
123 *PRODUCTION AND COMMODITY BLOCK+++++++
124  PRODFN(A)  Cobb-Douglas production function for activity a
125  FACDEM(F,A) demand for factor f from activity a
126  INTDEM(C,A) intermediate demand for commodity c from activity a
127  OUTPUTFN(C) output of commodity c
128  PADEF(A)   price for activity a
129  PVADEF(A)  value-added price for activity a
130
131 *INSTITUTION BLOCK+++++++
132  FACTTRNS(H,F) transfer of income from factor f to h-hold h
133  HHDINC(H)   income of household h
134  HHDEM(C,H)  consumption demand for household h & commodity c
135 *++
136  INVDEM(C)   investment demand for commodity c
137
138 *SYSTEM CONSTRAINT BLOCK+++++++
139  FACTEQ(F)   market equilibrium condition for factor f
140  COMEQ(C)    market equilibrium condition for commodity c
141 *++
142  SAVINV      savings-investment balance
143  PNORM       price normalization
144 ;
145

```

```

146
147 *PRODUCTION AND COMMODITY BLOCK+++++++
148
149   PRODFN(A)..   QA(A) =E= ad(A)*PROD(F, QF(F,A)**alpha(F,A));
150 *++
151   FACDEM(F,A).. WF(F)*wfdist(F,A) =E= alpha(F,A)*PVA(A)*QA(A) / QF(F,A);
152
153   INTDEM(C,A).. QINT(C,A) =E= ica(C,A)*QA(A);
154
155   OUTPUTFN(C).. Q(C) =E= SUM(A, theta(A,C)*QA(A));
156
157   PADEF(A)..   PA(A) =E= SUM(C, theta(A,C)*P(C));
158
159   PVADEF(A)..   PVA(A) =E= PA(A)-SUM(C, P(C)*ica(C,A));
160
161
162 *INSTITUTION BLOCK+++++++
163 *++
164   FACTTRNS(H,F).. YF(H,F)
165                   =E= shry(H,F)*SUM(A, WF(F)*wfdist(F,A)*QF(F,A));
166
167   HHDINC(H)..   YH(H) =E= SUM(F, YF(H,F));
168 *++
169   HHDEM(C,H)..   QH(C,H) =E= beta(C,H)*(1-MPS(H))*YH(H)/P(C);
170 *++
171   INVDEM(C)..   QINV(C) =E= qinvbar(C)*IADJ;
172
173
174 *SYSTEM CONSTRAINT BLOCK+++++++
175
176   FACTEQ(F)..   SUM(A, QF(F,A)) =E= qfs(F);
177 *++
178   COMEQ(C)..   Q(C) =E= SUM(H, QH(C,H)) + SUM(A, QINT(C,A)) + QINV(C)
179   ;
180   SAVINV..     SUM(C, P(C)*QINV(C)) + WALRAS =E= SUM(H, MPS(H)*YH(H))
181   ;
182   PNORM..     SUM(C, cwts(C)*P(C)) =E= cpi;
183
184
185 *MODEL=====
186
187 MODEL
188
189   CGE3 Model with savings-investment and wage distortions
190   /ALL/
191   ;
192
193 *SOCIAL ACCOUNTING MATRIX=====
194

```

```

195 TABLE SAM(AC,ACP) social accounting matrix
196
197           AGR-A  NAGR-A  AGR-C  NAGR-C  LAB  CAP  U-HHD  R-HHD  S-I
198 AGR-A                250
199 NAGR-A                305
200 AGR-C      60      40                50      75      25
201 NAGR-C      40      60                100     50      55
202 LAB          72      80
203 CAP          78     125
204 U-HHD                80     120
205 R-HHD                72     83
206 S-I                50      30
207 ;
208
209 PARAMETER
210   tdiff(AC) column minus row total for account AC;
211       SAM('TOTAL',ACNTP) = SUM(ACNT, SAM(ACNT,ACNTP));
212       SAM(ACNT,'TOTAL') = SUM(ACNTP, SAM(ACNT,ACNTP));
213       tdiff(ACNT)       = SAM('TOTAL',ACNT)-SAM(ACNT,'TOTAL');
214
215 DISPLAY SAM, tdiff;
216
217
218 *ASSIGNMENTS FOR PARAMETERS AND VARIABLES=====
219
220 PARAMETERS
221 *The following parameters are used to define initial values of
222 *model variables.
223   IADJ0, MPS0(H), P0(C), PA0(A), PVA0(A), Q0(C), QA0(A), QF0(F,A),
224   QH0(C,H), QINT0(C,A), QINV0(C), WF0(F), YF0(H,F), YH0(H)
225   ;
226
227
228 *++
229 *FACTOR EMPLOYMENT AND PRICES+++++++
230 *This section is new. It includes all items related to factor
231 *prices and quantities.
232
233
234 PARAMETERS
235   labor(A)      quantity of labor employed by activity (no. of workers)
236                 /AGR-A 100, NAGR-A 50/
237
238   wfa(F,A)      wage for factor f in activity a (only for calibration)
239   costgap(F,A)  gap calibrated factor cost-SAM value (should be zero)
240   ;
241
242 *Defining factor employment and supply
243   QF0('LAB',A) = labor(A);
244   QF0('CAP',A) = SAM('CAP',A);
245   qfs(F)       = SUM(A, QF0(F,A));

```

```

246
247 *Computing activity-specific wage
248   wfa(F,A)      = SAM(F,A)/QF0(F,A);
249
250 *Computing average wage
251   WF0(F)        = SUM(A, SAM(F,A))/SUM(A, QF0(F,A));
252
253 *Computing wage distortion factors
254   wfdist(F,A)   = wfa(F,A) / WF0(F);
255
256 *Checking calibration
257   costgap(F,A)  = WF0(F)*wfdist(F,A)*QF0(F,A)-SAM(F,A);
258
259 DISPLAY wfa, costgap;
260
261
262 *PRODUCTION AND COMMODITY BLOCK+++++++
263
264   P0(C)          = 1;
265   PA0(A)         = 1;
266
267   PVA0(A)        = SUM(F, SAM(F,A)) / (SAM(A,'TOTAL')/PA0(A));
268   Q0(C)          = SAM('TOTAL',C)/P0(C);
269   QA0(A)         = SAM('TOTAL',A)/PA0(A);
270   QINT0(C,A)     = SAM(C,A)/P0(C);
271
272   alpha(F,A)     = SAM(F,A) / SUM(FP, SAM(FP,A));
273   ad(A)          = QA0(A) / PROD(F, QF0(F,A)**alpha(F,A));
274   ica(C,A)       = (SAM(C,A)/P0(C)) / QA0(A);
275   theta(A,C)     = (SAM(A,C)/P0(C)) / QA0(A);
276
277
278 *INSTITUTION BLOCK+++++++
279
280 *++
281   IADJ0          = 1;
282 *++
283   MPS0(H)        = SAM('S-I',H)/SAM('TOTAL',H);
284   QH0(C,H)       = SAM(C,H)/P0(C);
285 *++
286   QINV0(C)       = SAM(C,'S-I')/P0(C);
287   YF0(H,F)       = SAM(H,F);
288   YH0(H)         = SAM('TOTAL',H);
289
290   beta(C,H)      = SAM(C,H)/SUM(CP, SAM(CP,H));
291 *++
292   qinvbar(C)     = SAM(C,'S-I')/P0(C);
293 *++
294   shry(H,F)      = SAM(H,F)/SAM('TOTAL',F);
295
296

```

```

297 *SYSTEM CONSTRAINT BLOCK+++++
298
299   cwts(C) = SUM(H, SAM(C,H))/SUM((CP,H), SAM(CP,H));
300   cpi      = SUM(C, cwts(C)*P0(C));
301
302
303 *INITIALIZATION=====
304
305 *++
306   IADJ.L      = IADJ0;
307 *++
308   MPS.L(H)    = MPS0(H);
309   P.L(C)      = P0(C);
310   PA.L(A)     = PA0(A);
311   PVA.L(A)    = PVA0(A);
312   Q.L(C)      = Q0(C);
313   QA.L(A)     = QA0(A);
314   QF.L(F,A)   = QF0(F,A);
315   QH.L(C,H)   = QH0(C,H);
316   QINT.L(C,A) = QINT0(C,A);
317 *++
318   QINV.L(C)   = QINV0(C);
319   WF.L(F)     = WF0(F);
320   YF.L(H,F)   = YF0(H,F);
321   YH.L(H)     = YH0(H);
322
323
324 *DISPLAY+++++
325
326 DISPLAY
327   ad, alpha, beta, cpi, cwts, ica, qfs, qinvbar, shry, theta, wfdist
328
329   IADJ.L, MPS.L, P.L, PA.L, PVA.L, Q.L, QA.L, QF.L, QH.L, QINT.L, QINV.L,
330   WF.L, YF.L, YH.L
331   ;
332
333
334 *SELECTING CLOSURE FOR SAVINGS-INVESTMENT BALANCE
335
336 *Savings-driven investment
337   MPS.FX(H) = MPS0(H);
338
339 *SAV-INV++
340 *If the ontext-offtext is removed from the following group of lines
341 *savings becomes investment-driven with the savings rate of the urban
342 *household as the adjusting variable.
   IADJ.FX      = IADJ0;
   MPS.LO('U-HHD') = -INF;
   MPS.UP('U-HHD') = +INF;
   MPS.L('U-HHD') = MPS0('U-HHD');
349

```

```

350 *SOLVE STATEMENT FOR BASE=====
351
352   CGE3.HOLDFIXED = 1;
353
354 *SOLVE CGE3 USING MCP;
355
356
357 *REPORT SETUP AND BASE REPORT=====
358
359 *SET AND PARAMETERS FOR REPORTS+++++++
360
361
362 SET
363   SIM  simulations
364       /BASE  base simulation
365       CINCR  increase in capital stock/
366
367
368 PARAMETERS
369
370   QFSCAPSIM(SIM)    supply of capital for simulation sim
371   QFSREP(F,SIM)    supply of factor f for sim (check)
372
373   IADJREP(SIM)     investment adjustment factor
374   MPSREP(H,SIM)   marginal (and avg) propensity to save for household h
375   PREP(C,SIM)     demander price for commodity c
376   PAREP(A,SIM)    price of activity a
377   PVAREP(A,SIM)   value-added price for activity a
378   QREP(C,SIM)     output level for commodity c
379   QAREP(A,SIM)    level of activity a
380   QFREP(F,A,SIM)  demand for factor f from activity a
381   QHREP(C,H,SIM)  consumption of commodity c by household h
382   QINTREP(C,A,SIM) qnty of commodity c as intermed. input for activity a
383   QINVREP(C,SIM)  quantity of investment by commodity of origin c
384   WFREP(F,SIM)    average price of factor f
385   WFAREP(F,A,SIM) price of factor f for activity a
386   YFREP(H,F,SIM)  income of household h from factor f
387   YHREP(H,SIM)    income of household h
388   WALRASREP(SIM)  dummy variable (zero at equilibrium)
389   ;
390
391   QFSCAPSIM('BASE') = qfs('CAP');
392   QFSCAPSIM('CINCR') = 1.1*qfs('CAP');
393
394 DISPLAY QFSCAPSIM;
395
396
397 LOOP(SIM,
398
399   qfs('CAP') = QFSCAPSIM(SIM);
400

```

```
401
402 SOLVE CGE3 USING MCP;
403
404
405 QFSREP(F,SIM)      = qfs(F);
406
407 MPSREP(H,SIM)      = MPS.L(H);
408 IADJREP(SIM)       = IADJ.L;
409 PREP(C,SIM)        = P.L(C);
410 PAREP(A,SIM)       = PA.L(A);
411 PVAREP(A,SIM)      = PVA.L(A);
412 QREP(C,SIM)        = Q.L(C);
413 QAREP(A,SIM)       = QA.L(A);
414 QFREP(F,A,SIM)     = QF.L(F,A);
415 QHREP(C,H,SIM)     = QH.L(C,H);
416 QINTREP(C,A,SIM)   = QINT.L(C,A);
417 QINVREP(C,SIM)     = QINV.L(C);
418 WFREP(F,SIM)       = WF.L(F);
419 WFAREP(F,A,SIM)    = WF.L(F)*wfdist(F,A);
420 YFREP(H,F,SIM)     = YF.L(H,F);
421 YHREP(H,SIM)       = YH.L(H);
422 WALRASREP(SIM)     = WALRAS.L;
423 );
424
425 OPTION QFREP:3:1:1, QHREP:3:1:1, WFAREP:3:1:1, YFREP:3:1:1;
426
427 DISPLAY
428 QFSREP, IADJREP, MPSREP, PREP, PAREP, PVAREP, QREP, QAREP, QFREP,
429 QHREP, QINTREP, QINVREP, WFREP, WFAREP, YFREP, YHREP, WALRASREP
430 ;
```

EXERCISE 4: MATHEMATICAL STATEMENT

NOTATION	$a \in A$	activities {AGR-A agricultural activity NAGR-A nonagricultural activity}	
	Sets	$c \in C$	commodities {AGR-C agricultural commodity NAGR-C nonagricultural commodity}
		$f \in F$	factors {LAB labor CAP capital}
	$i \in I$	institutions {U-HHD urban household R-HHD rural household GOV government}	
	$h \in H (\subset I)$	households {U-HHD urban household R-HHD rural household}	
	Parameters	ad_a	efficiency parameter in the production function for activity a
cpi		consumer price index (CPI)	
$cwts_c$		weight of commodity c in the CPI	
ica_{ca}		qnty of c as intermed. input per unit of output in activity a	
mps_h		marginal (and average) propensity to save for household h	
$\frac{qg_c}{qinv_c}$		government demand for commodity c base-year qnty of investment demand for commodity c	
$shry_{hf}$		share for household h in the income of factor f	
tq_c		rate of sales tax for commodity c	
$tr_{i'}$		transfers from institution i' to institution i	
ty_h		rate of income tax for household h	
α_{fa}		share of value-added for factor f in activity a	
β_{ch}		share in household h consumption spending on commodity c	
θ_{ac}		yield of output c per unit of activity a	
Variables		EG	government expenditure
	$IADJ$	investment adjustment factor	
	P_c	market price of commodity c	
	PA_a	price of activity a	
	PVA_c	value-added (or net) price of activity a	
	PX_c	producer price (excluding sales tax) of commodity c	

Q_c	output level in commodity c
QA_a	level of activity a
QF_{fa}	demand for factor f from activity a
QFS_f	supply of factor f
QH_{ch}	consumption of commodity c by household h
$QINT_{ca}$	qnty of commodity c as intermediate input in activity a
$QINV_c$	quantity of investment demand for commodity c
$WALRAS$	dummy variable (zero at equilibrium)
WF_f	average wage (rental rate) of factor f
$WFDIST_{fa}$	wage distortion factor for factor f in activity a
YF_{hf}	income of household h from factor f
YG	government revenue
YH_h	income of household h

EQUATIONS

Price, Production, and Commodity Block

$$QA_a = ad_a \cdot \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \quad a \in A \quad (1)$$

$$WF_f \cdot wfdist_{fa} = \frac{\alpha_{fa} \cdot PVA_a \cdot QA_a}{QF_{fa}} \quad f \in F, a \in A \quad (2)$$

$$QINT_{ca} = ica_{ca} \cdot QA_a \quad c \in C, a \in A \quad (3)$$

$$Q_c = \sum_{a \in A} \theta_{ac} \cdot QA_a \quad c \in C \quad (4)$$

$$P_c = (1 + tq_c) \cdot PX_c \quad c \in C \quad (5)$$

$$PA_a = \sum_{c \in C} \theta_{ac} \cdot P_c \quad a \in A \quad (6)$$

$$PVA_a = PA_a - \sum_{c \in C} P_c \cdot ica_{ca} \quad a \in A \quad (7)$$

Institution Block

$$YF_{hf} = shry_{hf} \cdot \sum_{a \in A} WF_f \cdot WFDIST_{fa} \cdot QF_{fa} \quad h \in H, f \in F \quad (8)$$

$$YH_h = \sum_{f \in F} YF_{hf} + tr_{h,gov} \quad h \in H \quad (9)$$

$$QH_{ch} = \frac{\beta_{ch} \cdot (1 - mps_h) \cdot (1 - ty_h) \cdot YH_h}{P_c} \quad c \in C, h \in H \quad (10)$$

$$QINV_c = \overline{qinv_c} \cdot IADJ \quad c \in C \quad (11)$$

$$YG = \sum_{h \in H} ty_h \cdot YH_h + \sum_{c \in C} tq_c \cdot PX_c \cdot Q_c \quad (12)$$

$$EG = \sum_{c \in C} P_c \cdot qg_c + \sum_{h \in H} tr_{h,gov} \quad (13)$$

**System Constraint
Block**

$$\sum_{a \in A} QF_{fa} = QFS_f \quad f \in F \quad (14)$$

$$Q_c = \sum_{h \in H} QH_{ch} + \sum_{a \in A} QINT_{ca} + QINV_c + qg_c \quad c \in C \quad (15)$$

$$\sum_{c \in C} P_c \cdot QINV_c + WALRAS = \sum_{h \in H} mps_h \cdot YH_h + (YG - EG) \quad (16)$$

$$\sum_{c \in C} cwt_s_c \cdot P_c = cpi \quad (17)$$

Given the assumption that labor is unemployed with a fixed wage while capital is fully employed and activity-specific, the following variables are fixed at base values:

$$WFDIST_{lab,a}, WF_{lab}, QF_{cap,a} \text{ and } WF_{cap}.$$

EXERCISE 4: GAMS CODE

GAMS 2.50.094 DOS Extended/C
CGE4

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```
3
4 *INTRODUCTION=====

In this file, the starting point is CGE3.
Additions: A government (and a new SAM), and labor unemployment with an
infinitely elastic supply of labor at a wage that is fixed in real
(and nominal) terms.

The line before any new feature or modification starts with
"***".

16
17 *SETS=====
18
19 SETS
20
21 AC global set (SAM accounts and other items)
22   /AGR-A   agricultural activity
23   NAGR-A   non-agricultural activity
24   AGR-C    agricultural commodity
25   NAGR-C   non-agricultural commodity
26   LAB      labor
27   CAP      capital
28   U-HHD    urban household
29   R-HHD    rural household
30 ***
31   GOV      government
32   S-I      savings-investment
33 ***
34   YTAX     income tax
35 ***
36   STAX     sales tax
37   TOTAL    total account in SAM /
38
39 ACNT(AC) all elements in AC except total
40
41 A(AC) activities
42   /AGR-A, NAGR-A/
43
```

```

44 C(AC) commodities
45     /AGR-C, NAGR-C/
46
47 F(AC) factors
48     /LAB, CAP/
49
50 *++
51 I(AC) institutions
52     /U-HHD, R-HHD, GOV/
53
54 H(I) households
55     /U-HHD, R-HHD/
56 ;
57
58 ALIAS(AC,ACP); ALIAS(C,CP); ALIAS(F,FP); ALIAS(I,IP);
59 ACNT(AC) = YES; ACNT('TOTAL') = NO; ALIAS(ACNT,ACNTP);
60
61
62 *PARAMETERS=====
63
64 PARAMETERS
65
66 ad(A)      efficiency parameter in the production fn for activity a
67 alpha(F,A) share of value-added to factor f in activity a
68 beta(C,H)  share of household consumption spending on commodity c
69 cpi        consumer price index
70 cwts(C)    weight of commodity c in the CPI
71 ica(C,A)   qnty of c as intermediate input per unit of activity a
72 *++
73 qg(C)      government demand for commodity c
74 qinvbar(C) base-year qnty of investment demand for commodity c
75 shry(H,F)  share for household h in the income of factor f
76 theta(A,C) yield of output c per unit of activity a
77 *++
78 tq(C)      rate of sales tax for commodity c
79 *++
80 tr(I,IP)   transfer from institution ip to institution i
81 *++
82 ty(H)      rate of income tax for household h
83 ;
84
85 *VARIABLES=====
86
87 VARIABLES
88 *++
89 EG         government expenditures
90 IADJ       investment adjustment factor
91 MPS(H)     marginal (and average) propensity to save for household h
92 P(C)       demander price for commodity c
93 PA(A)      price of activity a
94 PVA(A)     value-added (or net) price for activity a

```

```

95  ***
96  PX(C)      producer price for commodity c
97  Q(C)       output level for commodity c
98  QA(A)      level of activity a
99  QF(F,A)    quantity demanded of factor f from activity a
100 ***
101 QFS(F)     supply of factor f
102 QH(C,H)    quantity consumed of commodity c by household h
103 QINT(C,A)  qty of commodity c as intermediate input to activity a
104 QINV(C)    quantity of investment demand for commodity c
105 WALRAS     dummy variable (zero at equilibrium)
106 WF(F)     average price of factor f
107 ***
108 WFDIST(F,A) wage distortion factor for factor f in activity a
109
110 YF(H,F)    income of household h from factor f
111 ***
112 YG         government revenue
113 YH(H)     income of household h
114 ;
115
116 *EQUATIONS=====
117
118 EQUATIONS
119
120 *PRICE, PRODUCTION AND COMMODITY BLOCK+++++++
121 PRODFN(A)  Cobb-Douglas production function for activity a
122 FACDEM(F,A) demand for factor f from activity a
123 INTDEM(C,A) intermediate demand for commodity c from activity a
124 OUTPUTFN(C) output of commodity c
125 ***
126 PDEF(C)   demander price for commodity c
127 PADEF(A)  price for activity a
128 PVADEF(A) value-added price for activity a
129
130 *INSTITUTION BLOCK+++++++
131 FACTTRNS(H,F) transfer of income from factor f to h-hold h
132 HHDINC(H)   income of household h
133 HHDEM(C,H)  consumption demand for household h & commodity c
134 INVDEM(C)  investment demand for commodity c
135 ***
136 GOVREV     government revenue
137 ***
138 GOVEXP     government expenditures
139
140 *SYSTEM CONSTRAINT BLOCK+++++++
141 FACTEQ(F)  market equilibrium condition for factor f
142 COMEQ(C)  market equilibrium condition for commodity c
143 SAVINV     savings-investment balance
144 PNORM     price normalization
145 ;

```

```

146
147
148 *PRICE, PRODUCTION AND COMMODITY BLOCK+++++++
149
150 PRODFN(A).. QA(A) =E= ad(A)*PROD(F, QF(F,A)**alpha(F,A));
151
152 FACDEM(F,A).. WF(F)*WFDIST(F,A) =E= alpha(F,A)*PVA(A)*QA(A) / QF(F,A);
153
154 INTDEM(C,A).. QINT(C,A) =E= ica(C,A)*QA(A);
155
156 OUTPUTFN(C).. Q(C) =E= SUM(A, theta(A,C)*QA(A));
157 *++
158 PDEF(C).. P(C) =E= (1 + tq(C))*PX(C);
159 *++
160 PADEF(A).. PA(A) =E= SUM(C, theta(A,C)*PX(C));
161
162 PVADEF(A).. PVA(A) =E= PA(A)-SUM(C, P(C)*ica(C,A));
163
164
165 *INSTITUTION BLOCK+++++++
166
167 FACTTRNS(H,F).. YF(H,F)
168 =E= shry(H,F)*SUM(A, WF(F)*WFDIST(F,A)*QF(F,A));
169 *++
170 HHDINC(H).. YH(H) =E= SUM(F, YF(H,F)) + tr(H,'GOV');
171 *++
172 HHDEM(C,H).. QH(C,H) =E=
173 beta(C,H)*(1-MPS(H))*(1-ty(H))*YH(H)/P(C);
174
175 INVDEM(C).. QINV(C) =E= qinvbar(C)*IADJ;
176 *++
177 GOVREV.. YG =E= SUM(H, ty(H)*YH(H)) + SUM(C, tq(C)*PX(C)*Q(C));
178 *++
179 GOVEXP.. EG =E= SUM(C, P(C)*qg(C)) + SUM(H, tr(H,'GOV'));
180
181
182 *SYSTEM CONSTRAINT BLOCK+++++++
183 *++
184 FACTEQ(F).. SUM(A, QF(F,A)) =E= QFS(F);
185 *++
186 COMEQ(C).. Q(C) =E= SUM(H, QH(C,H)) + SUM(A, QINT(C,A))
187 + QINV(C) + qg(C);
188 *++
189 SAVINV.. SUM(C, P(C)*QINV(C)) + WALRAS =E=
190 SUM(H, MPS(H)*(1-ty(H))*YH(H)) + (YG-EG);
191
192 PNORM.. SUM(C, cwts(C)*P(C)) =E= cpi;
193
194
195 *MODEL=====
196

```

```

197 MODELS
198
199 CGE4 Model with gov't and flexible factor market treatment
200 /ALL/
201 ;
202
203 *SOCIAL ACCOUNTING MATRIX=====
204
205 TABLE SAM(AC,ACP) social accounting matrix
206
207          AGR-A  NAGR-A  AGR-C  NAGR-C  LAB  CAP
208 AGR-A                255
209 NAGR-A                    350
210 AGR-C      66      44
211 NAGR-C      44      66
212 LAB        72     105
213 CAP        73     135
214 U-HHD                95  125
215 R-HHD                82   83
216 GOV
217 S-I
218 YTAX
219 STAX                25    33
220
221
222 +          U-HHD  R-HHD  GOV  S-I  YTAX  STAX
223 AGR-A
224 NAGR-A
225 AGR-C      55     77    11   27
226 NAGR-C     110    55    47   61
227 LAB
228 CAP
229 U-HHD                25
230 R-HHD                5
231 GOV                    25    58
232 S-I      60     33    -5
233 YTAX     20     5
234 STAX
235 ;
236
237 PARAMETER
238   tdiff(AC) column minus row total for account AC;
239   SAM('TOTAL',ACNTP) = SUM(ACNT, SAM(ACNT,ACNTP));
240   SAM(ACNT,'TOTAL') = SUM(ACNTP, SAM(ACNT,ACNTP));
241   tdiff(ACNT)       = SAM('TOTAL',ACNT)-SAM(ACNT,'TOTAL');
242
243 DISPLAY SAM, tdiff;
244
245
246 *ASSIGNMENTS FOR PARAMETERS AND VARIABLES=====
247

```

```

248 PARAMETERS
249 *The following parameters are used to define initial values of
250 *model variables.
251 EGO, IADJO, MPS0(H), P0(C), PA0(A), PVA0(A), PX0(C), Q0(C), QA0(A),
252 QF0(F,A), QFS0(F), QH0(C,H), QINT0(C,A), QINV0(C), WF0(F),
253 WFDIST0(F,A), YF0(H,F), YG0, YH0(H)
254 ;
255
256
257 *FACTOR EMPLOYMENT AND PRICES+++++++
258
259
260 PARAMETERS
261 labor(A)      quantity of labor employed by activity (no. of workers)
262              /AGR-A 100, NAGR-A 50/
263
264 wfa(F,A)      wage for factor f in activity a (only for calibration)
265 costgap(F,A)  gap calibrated factor cost-SAM value (should be zero)
266 ;
267
268 *Defining factor employment and supply
269 QF0('LAB',A) = labor(A);
270 QF0('CAP',A) = SAM('CAP',A);
271 *++
272 QFS0(F)      = SUM(A, QF0(F,A));
273
274 *Computing activity-specific wage
275 wfa(F,A)     = SAM(F,A)/QF0(F,A);
276
277 *Computing average wage
278 WF0(F)       = SUM(A, SAM(F,A))/SUM(A, QF0(F,A));
279
280 *Computing wage distortion factors
281 WFDIST0(F,A) = wfa(F,A) / WF0(F);
282
283 *Checking calibration
284 costgap(F,A) = WF0(F)*WFDIST0(F,A)*QF0(F,A)-SAM(F,A);
285
286 DISPLAY wfa, costgap;
287
288
289 *PRICE, PRODUCTION AND COMMODITY BLOCK+++++++
290
291 PA0(A)       = 1;
292 *++
293 PX0(C)       = 1;
294 PVA0(A)      = SUM(F, SAM(F,A)) / (SAM(A,'TOTAL')/PA0(A));
295
296 *++
297 tq(C)        = SAM('STAX',C)/SUM(A, SAM(A,C) );
298 *++

```

```

299 P0(C)      = PX0(C)*(1 + tq(C));
300
301 Q0(C)      = SAM('TOTAL',C)/P0(C);
302 QA0(A)    = SAM('TOTAL',A)/PA0(A);
303 QINT0(C,A) = SAM(C,A)/P0(C);
304
305 alpha(F,A) = SAM(F,A) / SUM(FP, SAM(FP,A));
306 ad(A)      = QA0(A) / PROD(F, QF0(F,A)**alpha(F,A));
307 ica(C,A)   = (SAM(C,A)/P0(C)) / QA0(A);
308 *++
309 theta(A,C) = (SAM(A,C)/PX0(C)) / QA0(A);
310
311
312 *INSTITUTION BLOCK+++++++
313 *++
314 EG0        = SAM('TOTAL', 'GOV')-SAM('S-I', 'GOV');
315 IADJ0      = 1;
316 *++
317 MPS0(H)    = SAM('S-I', H) / (SAM('TOTAL', H)-SAM('YTAX', H));
318 QH0(C,H)   = SAM(C,H)/P0(C);
319 QINV0(C)   = SAM(C, 'S-I')/P0(C);
320 YF0(H,F)   = SAM(H,F);
321 *++
322 YG0        = SAM('GOV', 'TOTAL');
323 YH0(H)     = SAM('TOTAL', H);
324
325 beta(C,H)  = SAM(C,H)/SUM(CP, SAM(CP,H));
326 *++
327 qq(C)      = SAM(C, 'GOV')/P0(C);
328 qinvbar(C) = SAM(C, 'S-I')/P0(C);
329 shry(H,F)  = SAM(H,F)/SAM('TOTAL', F);
330 *++
331 tr(H, 'GOV') = SAM(H, 'GOV');
332 *++
333 ty(H)      = SAM('YTAX', H) / SAM('TOTAL', H);
334
335
336 *SYSTEM CONSTRAINT BLOCK+++++++
337
338 cwts(C)    = SUM(H, SAM(C,H)) / SUM((CP,H), SAM(CP,H));
339 cpi        = SUM(C, cwts(C)*P0(C));
340
341
342 *INITIALIZATION OF VARIABLES+++++++
343
344 EG.L       = EG0;
345 IADJ.L     = IADJ0;
346 MPS.L(H)   = MPS0(H);
347 P.L(C)     = P0(C);
348 PA.L(A)    = PA0(A);
349 PVA.L(A)   = PVA0(A);

```

```

350  PX.L(C)          = PX0(C);
351  Q.L(C)           = Q0(C);
352  QA.L(A)          = QA0(A);
353  QF.L(F,A)        = QF0(F,A);
354  QFS.L(F)         = QFS0(F);
355  QH.L(C,H)        = QH0(C,H);
356  QINT.L(C,A)      = QINT0(C,A);
357  QINV.L(C)        = QINV0(C);
358  WF.L(F)          = WF0(F);
359  WFDIST.L(F,A)    = WFDIST0(F,A);
360  YF.L(H,F)        = YF0(H,F);
361  YG.L             = YG0;
362  YH.L(H)          = YH0(H);
363
364
365  *DISPLAY+++++++
366
367  DISPLAY
368  ad, alpha, beta, cpi, cwts, ica, shry, qg, qinvbar, theta, tr, ty
369
370  EG.L, IADJ.L, MPS.L, P.L, PA.L, PVA.L, PX.L, Q.L, QA.L, QF.L, QFS.L,
371  QH.L, QINT.L, QINV.L, WF.L, WFDIST.L, YF.L, YG.L, YH.L
372  ;
373
374
375  *SELECTING CLOSURES+++++++
376
377  *SAVINGS-INVESTMENT BALANCE
378
379  SCALAR
380  SICLOS savings-investment closure /1/
381  *Select 1 or 2
382  *if SICLOS = 1, savings is investment-driven
383  *if SICLOS = 2, investment is savings-driven
384
385  IF(SICLOS EQ 1,
386  *Investment-driven savings-MPS('U-HHD') is flexible, permitting
387  *the savings value to adjust.
388  IADJ.FX          = IADJ0;
389  MPS.FX('R-HHD') = MPS0('R-HHD');
390  MPS.LO('U-HHD') = -INF;
391  MPS.UP('U-HHD') = +INF;
392  MPS.L('U-HHD')  = MPS0('U-HHD');
393  );
394
395  IF(SICLOS EQ 2,
396  *Savings-driven investment-IADJ is flexible, permitting
397  *investment quantities and the investment value to adjust.
398  MPS.FX(H)        = MPS0(H);
399  IADJ.LO          = -INF;
400  IADJ.UP          = +INF;

```

```

401 IADJ.L      = IADJ0;
402 );
403
404
405 *FACTOR MARKETS
406 *For each factor, fix (A + 1) quantity and-or price variables
407
408 SCALARS
409 CAPCLOS closure for capital market /2/
410 *Select 1 or 2
411 *if CAPCLOS = 1, capital is mobile and fully employed
412 *if CAPCLOS = 2, capital is activity-specific and fully employed
413
414 LABCLOS closure for labor market /2/
415 *Select 1 or 2
416 *if LABCLOS = 1, labor is mobile and fully employed
417 *if LABCLOS = 2, labor is mobile and unemployed (fixed wages)
418
419
420 IF(CAPCLOS EQ 1,
421 *Capital is fully employed and mobile. WF('CAP') is the market-clearing
422 *variable for the unified capital market.
423
424 WFDIST.FX('CAP',A) = WFDIST0('CAP',A);
425
426 WF.LO('CAP')      = -INF;
427 WF.UP('CAP')      = +INF;
428 WF.L('CAP')      = WF0('CAP');
429
430 QF.LO('CAP',A)    = -INF;
431 QF.UP('CAP',A)    = +INF;
432 QF.L('CAP',A)    = QF0('CAP',A);
433
434 QFS.FX('CAP')     = QFS0('CAP');
435 );
436
437 IF(CAPCLOS EQ 2,
438 *Capital is fully employed and activity-specific.
439 *WFDIST('CAP',A) is the market-clearing variable, one for
440 *each segment of the capital market.
441
442 WFDIST.LO('CAP',A) = -INF;
443 WFDIST.UP('CAP',A) = +INF;
444 WFDIST.L('CAP',A) = WFDIST0('CAP',A);
445
446 WF.FX('CAP')      = WF0('CAP');
447
448 QF.FX('CAP',A)    = QF0('CAP',A);
449
450 QFS.LO('CAP')     = -INF;
451 QFS.UP('CAP')     = +INF;

```

```

452  QFS.L('CAP')          = QFS0('CAP');
453  );
454
455  IF(LABCLOS EQ 1,
456  *Labor is fully employed and mobile. WF('LAB') is the market-clearing
457  *variable for the unified capital market.
458
459  WFDIST.FX('LAB',A) = WFDIST0('LAB',A);
460
461  WF.LO('LAB')          = -INF;
462  WF.UP('LAB')          = +INF;
463  WF.L('LAB')          = WF0('LAB');
464
465  QF.LO('LAB',A)        = -INF;
466  QF.UP('LAB',A)        = +INF;
467  QF.L('LAB',A)        = QF0('LAB',A);
468
469  QFS.FX('LAB')         = QFS0('LAB');
470  );
471
472  IF(LABCLOS EQ 2,
473  *Labor is unemployed and mobile. For each activity, the wage,
474  *WFDIST('LAB',A)*WF('LAB'), is fixed. QFS('LAB') is the market-clear-
475  *variable for the unified labor market.
476
477  WFDIST.FX('LAB',A) = WFDIST0('LAB',A);
478
479  WF.FX('LAB')         = WF0('LAB');
480
481  QF.LO('LAB',A)        = -INF;
482  QF.UP('LAB',A)        = +INF;
483  QF.L('LAB',A)        = QF0('LAB',A);
484
485  QFS.LO('LAB')         = -INF;
486  QFS.UP('LAB')         = +INF;
487  QFS.L('LAB')         = QFS0('LAB');
488  );
489
490  DISPLAY SICLOS, CAPCLOS, LABCLOS;
491
492
493  *SOLVE STATEMENT FOR BASE=====
494
495  CGE4.HOLDFIXED = 1;
496
497  *SOLVE CGE4 USING MCP;
498
499
500  *REPORT SETUP AND BASE REPORT=====
501

```

```

502 *SET AND PARAMETERS FOR REPORTS+++++++
503
504 ***
505 SET
506   SIM simulations
507     /BASE   base simulation
508     QGINCR  increase in government consumption /
509     ;
510
511 PARAMETERS
512 ***
513   QGSIM(C,SIM)      government consumption of c for sim
514 ***
515   QGREP(C,SIM)      government consumption of c for sim (check)
516
517   EGREP(SIM)        government expenditures
518   IADJREP(SIM)      investment adjustment factor
519   MPSREP(H,SIM)    marginal (and avg) propensity to save for household h
520   PREP(C,SIM)       demander price for commodity c
521   PAREP(A,SIM)      price of activity a
522   PVAREP(A,SIM)     value-added price for activity a
523   PXREP(C,SIM)      producer price (excl. sales tax) for commodity c
524   QREP(C,SIM)       output level for commodity c
525   QAREP(A,SIM)      level of activity a
526   QFREP(F,A,SIM)    demand for factor f from activity a
527   QFSREP(F,SIM)     supply of factor f for sim
528   QHREP(C,H,SIM)    consumption of commodity c by household h
529   QINTREP(C,A,SIM)  qty of commodity c as intermed. input for activity a
530   QINVREP(C,SIM)    quantity of investment by commodity of origin c
531   WFREP(F,SIM)      average price of factor f
532   WFAREP(F,A,SIM)   price of factor f for activity a
533   WFDISTREP(F,A,SIM) wage distortion factor for factor f in activity a
534   YFREP(H,F,SIM)    income of household h from factor f
535   YGREP(SIM)        government revenue
536   YHREP(H,SIM)      income of household h
537   WALRASREP(SIM)    dummy variable (zero at equilibrium)
538   ;
539
540 ***
541   QGSIM(C, 'BASE')  = qg(C);
542   QGSIM(C, 'QGINCR') = 1.2*qg(C);
543
544   DISPLAY QGSIM;
545
546
547   LOOP(SIM,
548     ***
549     qg(C) = QGSIM(C,SIM);
550
551   SOLVE CGE4 USING MCP;
552

```

```

553  ***
554  QGREP(C,SIM)      = qq(c);
555
556  EGREP(SIM)        = EG.L;
557  IADJREP(SIM)      = IADJ.L;
558  MPSREP(H,SIM)     = MPS.L(H);
559  PREP(C,SIM)       = P.L(C);
560  PAREP(A,SIM)      = PA.L(A);
561  PVAREP(A,SIM)     = PVA.L(A);
562  PXREP(C,SIM)      = PX.L(C);
563  QREP(C,SIM)       = Q.L(C);
564  QAREP(A,SIM)      = QA.L(A);
565  QFREP(F,A,SIM)    = QF.L(F,A);
566  QFSREP(F,SIM)     = QFS.L(F);
567  QHREP(C,H,SIM)    = QH.L(C,H);
568  QINTREP(C,A,SIM)  = QINT.L(C,A);
569  QINVREP(C,SIM)    = QINV.L(C);
570  WFREP(F,SIM)      = WF.L(F);
571  WFAREP(F,A,SIM)   = WF.L(F)*WFDIST.L(F,A);
572  WFDISTREP(F,A,SIM) = WFDIST.L(F,A);
573  YFREP(H,F,SIM)    = YF.L(H,F);
574  YGREP(SIM)        = YG.L;
575  YHREP(H,SIM)      = YH.L(H);
576  WALRASREP(SIM)    = WALRAS.L;
577  );
578
579  OPTION QFREP:3:1:1, QHREP:3:1:1, QINTREP:3:1:1, WFAREP:3:1:1,
580         WFDISTREP:3:1:1, YFREP:3:1:1
581  ;
582
583  DISPLAY
584  QGREP, EGREP, IADJREP, MPSREP, PREP, PAREP, PVAREP, PXREP, QREP,
585  QAREP, QFREP, QFSREP, QHREP, QINTREP, QINVREP, WFREP, WFAREP,
586  WFDISTREP, YFREP, YGREP, YHREP, WALRASREP
587  ;

```

EXERCISE 5: GAMS CODE

GAMS 2.50.094 DOS Extended/C
CGE5

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4 *INTRODUCTION=====

In this file, the starting point is CGE4.
The new feature is that the rest of the world has been added. A
CET-Armington specification is used for foreign trade.

The line before any new feature or modification starts with
"++". However, in the section where values are assigned
to variables and parameters, changes are not signalled.

In the experiment, the impact of a doubling of (initially positive)
foreign savings is explored.

19
20 *SETS=====

21	
22	SETS
23	
24	AC global set (SAM accounts and other items)
25	/AGR-A agricultural activity
26	NAGR-A non-agricultural activity
27	AGR-C agricultural commodity
28	NAGR-C non-agricultural commodity
29	LAB labor
30	CAP capital
31	U-HHD urban household
32	R-HHD rural household
33	GOV government
34	S-I savings-investment
35	YTAX income tax
36	STAX sales tax
37	*++
38	TAR import tariff
39	*++
40	ROW rest of world
41	TOTAL total account in SAM /
42	
43	ACNT(AC) all elements in AC except total

```

44
45  A(AC)  activities
46          /AGR-A, NAGR-A/
47
48  C(AC)  commodities
49          /AGR-C, NAGR-C/
50  *++
51  CE(C)  exported commodities
52          /AGR-C/
53  *++
54  CNE(C) non-exported commodities
55          /NAGR-C/
56  *++
57  CM(C)  imported commodities
58          /NAGR-C/
59  *++
60  CNM(C) non-imported commodities
61          /AGR-C/
62
63  F(AC)  factors
64          /LAB, CAP/
65
66  I(AC)  institutions
67          /U-HHD, R-HHD, GOV, ROW/
68
69  H(I)   households
70          /U-HHD, R-HHD/
71      ;
72
73  ALIAS(AC,ACP); ALIAS(C,CP); ALIAS(F,FP); ALIAS(I,IP);
74  ACNT(AC) = YES; ACNT('TOTAL') = NO; ALIAS(ACNT,ACNTP);
75
76
77  *PARAMETERS=====
78
79  PARAMETERS
80
81  ad(A)      efficiency parameter in the production fn for a
82  alpha(F,A) share of value-added to factor f in activity a
83  *++
84  aq(C)      Armington function shift parameter for commodity c
85  *++
86  at(C)      CET function shift parameter for commodity c
87  beta(C,H)  share of household consumption spending on commodity c
88  cpi        consumer price index
89  cwts(C)    weight of commodity c in the CPI
90  *++
91  deltaq(C)  Armington function share parameter for commodity c
92  *++
93  deltac(C)  CET function share parameter for commodity c
94  ica(C,A)   qty of c as intermediate input per unit of activity a

```

```

95  ***
96  pwe(C)      export price for c (foreign currency)
97  ***
98  pwm(C)      import price for c (foreign currency)
99  qg(C)       government demand for commodity c
100 qinvbar(C)  base-year qty of investment demand for commodity c
101 ***
102 rhoq(C)     Armington function exponent for commodity c
103 ***
104 rhot(C)     CET function exponent for commodity c
105 shry(H,F)   share for household h in the income of factor f
106 ***
107 te(C)       export subsidy rate for commodity c
108 theta(A,C)  yield of output c per unit of activity a
109 ***
110 tm(C)       import tariff rate for commodity c
111 tq(C)       rate of sales tax for commodity c
112 tr(I,IP)    transfer from institution ip to institution i
113 ty(H)       rate of income tax for household h
114 ;
115
116 *VARIABLES=====
117
118 VARIABLES
119
120 EG          government expenditures
121 ***
122 EXR        exchange rate (dom. currency per unit of for. currency)
123 ***
124 FSAV       foreign savings (foreign currency)
125 IADJ       investment adjustment factor
126 MPS(H)     marginal (and average) propensity to save for household h
127 PA(A)     price of activity a
128 ***
129 PD(C)     domestic price of domestic output c
130 ***
131 PE(C)     export price for c (domestic currency)
132 ***
133 PM(C)     import price for c (domestic currency)
134 ***
135 PQ(C)     composite commodity price for c
136 PVA(A)    value-added price for activity a
137 PX(C)     producer price for commodity c
138 QA(A)     level of activity a
139 ***
140 QD(C)     quantity sold domestically of domestic output c
141 ***
142 QE(C)     quantity of exports for commodity c
143 QF(F,A)   quantity demanded of factor f from activity a
144 QFS(F)    supply of factor f
145 QH(C,H)   quantity consumed of commodity c by household h

```

```

146  QINT(C,A)    qnty of commodity c as intermediate input to activity a
147  QINV(C)      quantity of investment demand for commodity c
148  *++
149  QM(C)        quantity of imports of commodity c
150  *++
151  QQ(C)        quantity of goods supplied domestically (composite supply)
152  *++
153  QX(C)        quantity of domestic output of commodity c
154  WALRAS       dummy variable (zero at equilibrium)
155  WF(F)        average price of factor f
156  WFDIST(F,A) wage distortion factor for factor f in activity a
157  YF(H,F)      transfer of income to household h from factor f
158  YG           government revenue
159  YH(H)        income of household h
160  ;
161
162  *EQUATIONS=====
163
164  EQUATIONS
165
166  *PRICE BLOCK+++++++
167  *++
168  PMDEF(C)     import price for commodity c (domestic currency)
169  *++
170  PEDEF(C)     export price for commodity c (domestic currency)
171  *++
172  ABSORB(C)    absorption for commodity c
173  *++
174  OUTVAL(C)    output value for commodity c
175  PADEF(A)     price for activity a
176  PVADEF(A)    value-added price for activity a
177
178  *PRODUCTION AND COMMODITY BLOCK+++++++
179  PRODFN(A)    Cobb-Douglas production function for activity a
180  FACDEM(F,A) demand for factor f from activity a
181  INTDEM(C,A) intermediate demand for commodity c from activity a
182  OUTPUTFN(C) output of commodity c
183  *++
184  ARMING(C)    composite supply (Armington) function for commodity c
185  *++
186  IMPDOMRAT(C) import-domestic demand ratio for commodity c
187  *++
188  ARMNM(C)     composite supply for non-imported commodity c
189  *++
190  CET(C)       output transformation (CET) function for commodity c
191  *++
192  EXPDOMRAT(C) export-domestic supply ratio for commodity c
193  *++
194  CETNE(C)     output transformation for non-exported commodity c
195
196

```

```

197 *INSTITUTION BLOCK+++++++
198 FACTTRNS(H,F) transfer of income from factor f to h-hold h
199 HHINC(H) income of household h
200 HHDEM(C,H) consumption demand for household h & commodity c
201 INVDEM(C) investment demand for commodity c
202 GOVREV government revenue
203 GOVEXP government expenditures
204
205 *SYSTEM CONSTRAINT BLOCK+++++++
206 FACTEQ(F) market equilibrium condition for factor f
207 COMEQ(C) market equilibrium condition for composite commodity c
208 ***
209 CURACC current account balance for RoW
210 SAVINV savings-investment balance
211 PNORM price normalization
212 ;
213
214 *PRICE BLOCK+++++++
215 ***
216 PMDEF(C)$CM(C).. PM(C) =E= (1 + tm(C))*EXR*pwm(C);
217 ***
218 PEDEF(C)$CE(C).. PE(C) =E= (1-te(C))*EXR*pwe(C);
219 ***
220 ABSORB(C).. PQ(C)*QQ(C)
221 =E= (PD(C)*QD(C) + (PM(C)*QM(C))$CM(C))*(1 + tq(C));
222 ***
223 OUTVAL(C).. PX(C)*QX(C) =E= PD(C)*QD(C) + (PE(C)*QE(C))$CE(C);
224
225 PADEF(A).. PA(A) =E= SUM(C, PX(C)*theta(A,C));
226 ***
227 PVADEF(A).. PVA(A) =E= PA(A)-SUM(C, PQ(C)*ica(C,A));
228
229
230 *PRODUCTION AND COMMODITY BLOCK+++++++
231
232 PRODFN(A).. QA(A) =E= ad(A)*PROD(F, QF(F,A)**alpha(F,A));
233
234 FACDEM(F,A).. WF(F)*WFDIST(F,A) =E= alpha(F,A)*PVA(A)*QA(A)
235 /QF(F,A);
236
237 INTDEM(C,A).. QINT(C,A) =E= ica(C,A)*QA(A);
238
239 OUTPUTFN(C).. QX(C) =E= SUM(A, theta(A,C)*QA(A));
240 ***
241 ARMING(C)$CM(C).. QQ(C) =E= aq(C)*(deltaq(C)*QM(C)**(-rhoq(C))
242 + (1-deltaq(C))*QD(C)**(-rhoq(C)))**(-1/rhoq(C));
243 ***
244 IMPDOMRAT(C)$CM(C).. QM(C)/QD(C) =E=
245 ( (PD(C)/PM(C))
246 *(deltaq(C)/(1-deltaq(C))) )**(1/(1 + rhoq(C)));
247 ***

```

```

248  ARMNM(C)$CNM(C)..      QQ(C) =E= QD(C);
249  ***
250  CET(C)$CE(C)..        QX(C) =E= at(C)*(deltat(C)*QE(C)**rhot(C)
251                        + (1-deltat(C))*QD(C)**rhot(C) )**(1/rhot(C));
252  ***
253  EXPDOMRAT(C)$CE(C)..  QE(C)/QD(C) =E= ( PE(C)/PD(C)
254                        *(1-deltat(C))/deltat(C) )**(1/(rhot(C)-1) );
255  ***
256  CETNE(C)$CNE(C)..     QX(C) =E= QD(C);
257
258
259  *INSTITUTION BLOCK+++++
260
261  FACTTRNS(H,F)..      YF(H,F)
262                        =E= shry(H,F)*SUM(A, WF(F)*WFDIST(F,A)*QF(F,A));
263
264  ***
265  HHDINC(H)..          YH(H) =E= SUM(F, YF(H,F)) + tr(H, 'GOV')
266                        + EXR*tr(H, 'ROW');
267
268  HHDEM(C,H)..         QH(C,H) =E=
269                        beta(C,H)*(1-MPS(H))*(1-ty(H))*YH(H)/PQ(C);
270
271  INVDEM(C)..          QINV(C) =E= qinvbar(C)*IADJ;
272  ***
273  GOVREV..            YG =E= SUM(H, ty(H)*YH(H))
274                        + EXR*tr('GOV', 'ROW')
275                        + SUM(C, tq(C)*(PD(C)*QD(C) + (PM(C)*QM(C))$CM(C)))
276                        + SUM(C$CM(C), tm(C)*EXR*pwm(C)*QM(C))
277                        + SUM(C$CE(C), te(C)*EXR*pwe(C)*QE(C))
278                        ;
279
280  GOVEXP..            EG =E= SUM(C, PQ(C)*qg(C)) + SUM(H, tr(H, 'GOV'));
281                        ;
282
283
284  *SYSTEM CONSTRAINT BLOCK+++++
285
286  FACTEQ(F)..          SUM(A, QF(F,A)) =E= QFS(F);
287  ***
288  COMEQ(C)..          QQ(C) =E= SUM(A, QINT(C,A)) + SUM(H, QH(C,H))
289                        + qg(C) + QINV(C);
290  ***
291  CURACC..            SUM(C$CE(C), pwe(C)*QE(C)) + SUM(I, tr(I, 'ROW'))
292                        + FSAV =E= SUM(C$CM(C), pwm(C)*QM(C));
293  ***
294  SAVINV..            SUM(H, MPS(H)*(1-ty(H))*YH(H)) + (YG-EG)
295                        + EXR*FSAV =E= SUM(C, PQ(C)*QINV(C)) + WALRAS;
296
297  PNORM..             SUM(C, PQ(C)*cwts(C)) =E= cpi;
298

```

```

299
300 *MODEL=====
301
302 MODELS
303
304   CGE5 Open-economy model
305   /ALL/
306   ;
307
308 *SOCIAL ACCOUNTING MATRIX=====
309
310 TABLE SAM(AC,ACP) social accounting matrix
311
312           AGR-A  NAGR-A  AGR-C  NAGR-C  LAB  CAP
313 AGR-A                279
314 NAGR-A                394
315 AGR-C      84      55
316 NAGR-C     50      99
317 LAB        72     105
318 CAP        73     135
319 U-HHD                95  125
320 R-HHD                82   83
321 GOV
322 S-I
323 YTAX
324 STAX                10    20
325 TAR                 39
326 ROW                 105
327
328 +           U-HHD  R-HHD  GOV  S-I  YTAX  STAX  TAR  ROW
329 AGR-A
330 NAGR-A
331 AGR-C      30    49    13   28                30
332 NAGR-C    165    92    67   85
333 LAB
334 CAP
335 U-HHD                25                40
336 R-HHD                5                16
337 GOV                 25    30    39    15
338 S-I      70    40    -1    4
339 YTAX     20    5
340 ;
341
342 PARAMETER
343   tdiff(AC) column minus row total for account AC;
344   SAM('TOTAL',ACNTP) = SUM(ACNT, SAM(ACNT,ACNTP));
345   SAM(ACNT,'TOTAL')  = SUM(ACNTP, SAM(ACNT,ACNTP));
346   tdiff(ACNT)       = SAM('TOTAL',ACNT)-SAM(ACNT,'TOTAL');
347
348 DISPLAY SAM, tdiff;
349

```

```

350
351 *ASSIGNMENTS FOR PARAMETERS AND VARIABLES=====
352
353 PARAMETERS
354 *The following parameters are used to define initial values of
355 *model variables.
356   EG0, EXR0, FSAV0, IADJ0, MPS0(H), PA0(A), PD0(C), PE0(C), PM0(C),
357   PQ0(C), PVA0(A), PX0(C), QA0(A), QD0(C), QE0(C), QF0(F,A), QFS0(F),
358   QH0(C,H), QINT0(C,A), QINV0(C), QM0(C), QQ0(C), QX0(C), WF0(F),
359   WFDIST0(F,A), YF0(H,F), YG0, YH0(H)
360   ;
361
362
363 *FACTOR EMPLOYMENT AND PRICES+++++++
364
365
366 PARAMETERS
367   labor(A)      quantity of labor employed by activity (no. of workers)
368                 /AGR-A 100, NAGR-A 50/
369
370   wfa(F,A)      wage for factor f in activity a (only for calibration)
371   costgap(F,A)  gap calibrated factor cost-SAM value (should be zero)
372   ;
373
374 *Defining factor employment and supply
375   QF0('LAB',A) = labor(A);
376   QF0('CAP',A) = SAM('CAP',A);
377   QFS0(F)      = SUM(A, QF0(F,A));
378
379 *Computing activity-specific wage
380   wfa(F,A)     = SAM(F,A)/QF0(F,A);
381
382 *Computing average wage
383   WF0(F)       = SUM(A, SAM(F,A))/SUM(A, QF0(F,A));
384
385 *Computing wage distortion factors
386   WFDIST0(F,A) = wfa(F,A) / WF0(F);
387
388 *Checking calibration
389   costgap(F,A) = WF0(F)*WFDIST0(F,A)*QF0(F,A)-SAM(F,A);
390
391 DISPLAY wfa, costgap;
392
393
394
395 *PRICE BLOCK+++++++
396
397 PARAMETERS
398   sigmaq(C)    elasticity of substitution bt. dom goods and imports for c
399   sigmat(C)    elasticity of transformation bt. dom sales and exports for c
400   ;

```

```

401
402 EXR0          = 1;
403 PA0(A)        = 1;
404 PD0(C)        = 1;
405 PE0(C)        = 1;
406 PM0(C)        = 1;
407 PX0(C)        = 1;
408
409 PVA0(A)        = SUM(F, SAM(F,A)) / (SAM(A, 'TOTAL')/PA0(A));
410
411 tq(C)          = SAM('STAX',C)
412                /((SAM('TAR',C) + SAM('ROW',C) + SUM(A, SAM(A,C))
413                  - SAM(C, 'ROW')));
414 PQ0(C)        = 1 + tq(C);
415
416 QA0(A)        = SAM('TOTAL',A)/PA0(A);
417 QD0(C)        = (SUM(A, SAM(A,C))-SAM(C, 'ROW'))/PD0(C);
418 QE0(C)        = SAM(C, 'ROW')/PE0(C);
419 QM0(C)        = (SAM('ROW',C) + SAM('TAR',C))/PM0(C);
420 QQ0(C)        = (SAM('TOTAL',C)-SAM(C, 'ROW'))/PQ0(C);
421 QX0(C)        = SUM(A, SAM(A,C))/PX0(C);
422
423 ica(C,A)      = (SAM(C,A)/PQ0(C)) / QA0(A);
424 theta(A,C)   = (SAM(A,C)/PX0(C)) / QA0(A);
425
426 te(C)        = 0;
427 pwe(C)       = PE0(C)/((1 + te(C))*EXR0);
428
429 tm(C)$CM(C)  = SAM('TAR',C)/SAM('ROW',C);
430 pwm(C)$CM(C) = PM0(C) / ( EXR0*(1 + tm(C)) );
431
432
433 *PRODUCTION AND COMMODITY BLOCK+++++++
434
435 QINT0(C,A)   = SAM(C,A)/PQ0(C);
436
437 alpha(F,A)   = SAM(F,A) / SUM(FP, SAM(FP,A));
438 ad(A)        = QA0(A) / PROD(F, QF0(F,A)**alpha(F,A));
439
440 sigmat(C)    = 2.0;
441 sigmaq(C)    = 0.7;
442 rhot(C)      = 1/sigmat(C) + 1;
443 rhoq(C)      = 1/sigmaq(C)-1;
444
445 deltat(C)$CE(C) = 1/(1 + (PD0(C)/PE0(C))*(QE0(C)/QD0(C))**(rhot(C)-
446 1));
447
448 at(C)$CE(C)   = QX0(C) / ( deltat(C)*QE0(C)**rhot(C)
449   + (1-deltat(C))*QD0(C)**rhot(C) )**(1/rhot(C));
450
451 deltaq(C)$CM(C) = 1/(1 + (PD0(C)/PM0(C))*(QD0(C)/QM0(C))**(1+rhoq(C)));

```

```

451
452  aq(C)$CM(C)      = QQ0(C) / (deltaq(C)*QM0(C)**(-rhoq(C))
453                    + (1-deltaq(C))*QD0(C)**(-rhoq(C))**(-1/rhoq(C)));
454
455
456 *INSTITUTION BLOCK+++++
457
458  EG0              = SAM('TOTAL', 'GOV')-SAM('S-I', 'GOV');
459  FSAV0           = SAM('S-I', 'ROW')/EXR0;
460  IADJ0           = 1;
461  MPS0(H)         = SAM('S-I', H) / (SAM('TOTAL', H)-SAM('YTAX', H));
462  QH0(C, H)       = SAM(C, H)/PQ0(C);
463  QINV0(C)        = SAM(C, 'S-I')/PQ0(C);
464  YF0(H, F)       = SAM(H, F);
465  YG0             = SAM('GOV', 'TOTAL');
466  YH0(H)          = SAM('TOTAL', H);
467
468  beta(C, H)      = SAM(C, H)/SUM(CP, SAM(CP, H));
469  qg(C)           = SAM(C, 'GOV')/PQ0(C);
470  qinvbar(C)      = SAM(C, 'S-I')/PQ0(C);
471  shry(H, F)      = SAM(H, F) / SAM('TOTAL', F);
472  tr(H, 'GOV')    = SAM(H, 'GOV');
473  tr(I, 'ROW')    = SAM(I, 'ROW')/EXR0;
474  ty(H)           = SAM('YTAX', H) / SAM('TOTAL', H);
475
476
477 *SYSTEM CONSTRAINT BLOCK+++++
478
479  cwts(C) = SUM(H, SAM(C, H)) / SUM((CP, H), SAM(CP, H));
480  cpi     = SUM(C, cwts(C)*PQ0(C));
481
482
483 *INITIALIZATION=====
484
485  EG.L           = EG0;
486  EXR.L          = EXR0;
487  FSAV.L         = FSAV0;
488  IADJ.L         = IADJ0;
489  MPS.L(H)       = MPS0(H);
490  PA.L(A)        = PA0(A);
491  PD.L(C)        = PD0(C);
492  PE.L(C)        = PE0(C);
493  PM.L(C)        = PM0(C);
494  PQ.L(C)        = PQ0(C);
495  PVA.L(A)       = PVA0(A);
496  PX.L(C)        = PX0(C);
497  QA.L(A)        = QA0(A);
498  QD.L(C)        = QD0(C);
499  QE.L(C)        = QE0(C);
500  QF.L(F, A)     = QF0(F, A);
501  QFS.L(F)       = QFS0(F);

```

```

502 QH.L(C,H)      = QH0(C,H);
503 QINT.L(C,A)    = QINT0(C,A);
504 QINV.L(C)      = QINV0(C);
505 QM.L(C)        = QM0(C);
506 QQ.L(C)       = QQ0(C);
507 QX.L(C)       = QX0(C);
508 WF.L(F)       = WF0(F);
509 WFDIST.L(F,A)  = WFDIST0(F,A);
510 YF.L(H,F)     = YF0(H,F);
511 YG.L          = YG0;
512 YH.L(H)       = YH0(H);
513
514 *DISPLAY+++++
515
516
517 DISPLAY
518 ad, alpha, aq, at, beta, deltaq, deltat, cpi, cwts, ica,
519 pwe, pwm, shry, theta, gg, qinvbar, rhoq,
520 rhot, te, sigmaq, sigmat, tm, tq, tr, ty,
521
522 EG.L, EXR.L, FSAV.L, IADJ.L, MPS.L, PA.L, PD.L, PE.L, PM.L,
523 PQ.L, PVA.L, PX.L, QA.L, QD.L, QE.L, QF.L, QFS.L, QH.L, QINT.L,
524 QINV.L, QM.L, QQ.L, QX.L, WF.L, WFDIST.L, YF.L, YG.L, YH.L
525 ;
526
527
528 *SELECTING CLOSURES+++++
529
530 *SAVINGS-INVESTMENT BALANCE
531
532 SCALAR
533 SICLOS savings-investment closure /1/
534 *Select 1 or 2
535 *if SICLOS = 1, savings is investment-driven
536 *if SICLOS = 2, investment is savings-driven
537
538 IF(SICLOS EQ 1,
539 *Investment-driven savings-MPS('U-HHD') is flexible, permitting
540 *the savings value to adjust.
541 IADJ.FX      = IADJ0;
542 MPS.FX('R-HHD') = MPS0('R-HHD');
543 MPS.LO('U-HHD') = -INF;
544 MPS.UP('U-HHD') = +INF;
545 MPS.L('U-HHD') = MPS0('U-HHD');
546 );
547
548 IF(SICLOS EQ 2,
549 *Savings-driven investment-IADJ is flexible, permitting
550 *investment quantities and the investment value to adjust.
551 MPS.FX(H) = MPS0(H);
552 IADJ.LO = -INF;

```

```

553 IADJ.UP      = +INF;
554 IADJ.L      = IADJ0;
555 );
556
557
558 *FACTOR MARKETS
559 *For each factor, fix (A + 1) quantity and-or price variables
560
561 SCALARS
562 CAPCLOS      closure for capital market /2/
563 *Select 1 or 2
564 *if CAPCLOS = 1, capital is mobile and fully employed
565 *if CAPCLOS = 2, capital is activity-specific and fully employed
566
567 LABCLOS      closure for labor market /2/
568 *Select 1 or 2
569 *if LABCLOS = 1, labor is mobile and fully employed
570 *if LABCLOS = 2, labor is mobile and unemployed (fixed wages)
571
572
573 IF(CAPCLOS EQ 1,
574 *Capital is fully employed and mobile. WF('CAP') is the market-clear-
575 ing
576 *variable for the unified capital market.
577 WFDIST.FX('CAP',A) = WFDIST0('CAP',A);
578
579 WF.LO('CAP')      = -INF;
580 WF.UP('CAP')      = +INF;
581 WF.L('CAP')       = WF0('CAP');
582
583 QF.LO('CAP',A)    = -INF;
584 QF.UP('CAP',A)    = +INF;
585 QF.L('CAP',A)    = QF0('CAP',A);
586
587 QFS.FX('CAP')     = QFS0('CAP');
588 );
589
590 IF(CAPCLOS EQ 2,
591 *Capital is fully employed and activity-specific.
592 *WFDIST('CAP',A) is the market-clearing variable, one for
593 *each segment of the capital market.
594
595 WFDIST.LO('CAP',A) = -INF;
596 WFDIST.UP('CAP',A) = +INF;
597 WFDIST.L('CAP',A) = WFDIST0('CAP',A);
598
599 WF.FX('CAP')       = WF0('CAP');
600
601 QF.FX('CAP',A)     = QF0('CAP',A);
602

```

```

603  QFS.LO('CAP')      = -INF;
604  QFS.UP('CAP')      = +INF;
605  QFS.L('CAP')       = QFS0('CAP');
606  );
607
608  IF(LABCLOS EQ 1,
609  *Labor is fully employed and mobile. WF('LAB') is the market-clearing
610  *variable for the unified capital market.
611
612  WFDIST.FX('LAB',A) = WFDIST0('LAB',A);
613
614  WF.LO('LAB')        = -INF;
615  WF.UP('LAB')        = +INF;
616  WF.L('LAB')        = WF0('LAB');
617
618  QF.LO('LAB',A)      = -INF;
619  QF.UP('LAB',A)      = +INF;
620  QF.L('LAB',A)      = QF0('LAB',A);
621
622  QFS.FX('LAB')       = QFS0('LAB');
623  );
624
625  IF(LABCLOS EQ 2,
626  *Labor is unemployed and mobile. For each activity, the wage,
627  *WFDIST('LAB',A)*WF('LAB'), is fixed. QFS('LAB') is the market-clearing
628  *variable for the unified labor market.
629
630  WFDIST.FX('LAB',A) = WFDIST0('LAB',A);
631
632  WF.FX('LAB')        = WF0('LAB');
633
634  QF.LO('LAB',A)      = -INF;
635  QF.UP('LAB',A)      = +INF;
636  QF.L('LAB',A)      = QF0('LAB',A);
637
638  QFS.LO('LAB')       = -INF;
639  QFS.UP('LAB')       = +INF;
640  QFS.L('LAB')       = QFS0('LAB');
641  );
642
643
644  *THE FOREIGN EXCHANGE MARKET
645
646  SCALAR
647  ROWCLOS rest-of-world closure /1/
648  *Select 1 or 2
649  *if ROWCLOS = 1, exchange rate is flexible
650  *if ROWCLOS = 2, foreign savings is flexible
651  ;
652
653  IF(ROWCLOS EQ 1,

```

```

654 *Foreign savings is fixed. A flexible exchange rate clears
655 *the current account of the balance of payments.
656   FSAV.FX = FSAV0;
657   EXR.LO  = -INF;
658   EXR.UP  = +INF;
659   EXR.L   = EXR0;
660 );
661
662 IF(ROWCLOS EQ 2,
663 *The exchange rate is fixed. Flexible foreign savings clears
664 *the current account of the balance of payments.
665   EXR.FX  = EXR0;
666   FSAV.LO = -INF;
667   FSAV.UP = +INF;
668   FSAV.L  = FSAV0;
669 );
670
671
672 DISPLAY SICLOS, CAPCLOS, LABCLOS, ROWCLOS;
673
674
675 *SOLVE STATEMENT FOR BASE=====
676
677   CGE5.HOLDFIXED = 1;
678
679 *SOLVE CGE5 USING MCP;
680
681
682 *REPORT SETUP AND BASE REPORT=====
683
684 *SET AND PARAMETERS FOR REPORTS+++++++
685
686
687 SET
688   SIM simulations
689     /BASE      base simulation
690     PWEINCR   increase in agricultural export price/
691
692   ACGDP GDP items
693   /
694   GDPMP1    GDP at market prices (from spending side)
695   PRVCON    private consumption
696   GOVCON    government consumption
697   INVEST    investment
698   EXP       exports of goods and services
699   IMP       imports of goods and services
700   NITAX     net indirect taxes
701   GDPFC     GDP at factor prices
702   GDPMP2    GDP at market prices (from income side)
703   GDPGAP    gap bt alternative calculations for GDP at market prices
704   /

```

```

705
706 ACGDP1(ACGDP) components of GDP at market prices
707 /
708 PRVCON private consumption
709 GOVCON government consumption
710 INVEST investment
711 EXP exports of goods and services
712 IMP imports of goods and services
713 /
714
715
716 PARAMETERS
717
718 PWEAGRSIM(SIM) agr'al export price (for curr) (experiment par.)
719 PWEREP(C,SIM) export price for commodity c (value used)
720
721 EGREP(SIM) government expenditures
722 EXRREP(SIM) exchange rate (dom. cur. per unit of for. cur.)
723 FSAVREP(SIM) foreign savings (foreign currency)
724 IADJREP(SIM) investment adjustment factor
725 MPSREP(H,SIM) marginal (and avg) propensity to save for household h
726 PAREP(A,SIM) price of activity a
727 PDREP(C,SIM) domestic price of domestic output c
728 PEREP(C,SIM) export price for c (domestic currency)
729 PMREP(C,SIM) import price for c (domestic currency)
730 PQREP(C,SIM) composite commodity price for c
731 PVAREP(A,SIM) value-added price for activity a
732 PXREP(C,SIM) producer price for commodity c
733 QAREP(A,SIM) level of activity a
734 QDREP(C,SIM) quantity sold domestically of domestic output c
735 QEREP(C,SIM) quantity of exports for commodity c
736 QFREP(F,A,SIM) demand for factor f from activity a
737 QFSREP(F,SIM) supply of factor f for sim
738 QHREP(C,H,SIM) consumption of commodity c by household h
739 QINTREP(C,A,SIM) qnty of commodity c as intermed. input for activity a
740 QINVREP(C,SIM) quantity of investment by commodity of origin c
741 QMREP(C,SIM) quantity of imports for commodity c
742 QQREP(C,SIM) quantity of goods supplied domestically ("composite
supply")
743 QXREP(C,SIM) quantity of domestic output of commodity c
744 WFREP(F,SIM) average price of factor f
745 WFAREP(F,A,SIM) price of factor f for activity a
746 WFDISTREP(F,A,SIM) wage distortion factor for factor f in activity a
747 YFREP(H,F,SIM) income of household h from factor f
748 YGREP(SIM) government revenue
749 YHREP(H,SIM) income of household h
750 WALRASREP(SIM) dummy variable (zero at equilibrium)
751
752 GDPREP(*,SIM) nominal GDP data
753 ;
754

```

```

755  PWEAGRSIM('BASE')      = pwe('AGR-C');
756  PWEAGRSIM('PWEINCR')   = 1.25*pwe('AGR-C');
757
758  DISPLAY PWEAGRSIM;
759
760
761  LOOP(SIM,
762
763    pwe('AGR-C') = PWEAGRSIM(SIM);
764
765
766    SOLVE CGE5 USING MCP;
767
768
769    PWEREP(CE,SIM)         = pwe(CE);
770
771    EGREP(SIM)             = EG.L;
772    EXRREP(SIM)           = EXR.L;
773    FSAVREP(SIM)          = FSAV.L;
774    IADJREP(SIM)          = IADJ.L;
775    MPSREP(H,SIM)         = MPS.L(H);
776    PAREP(A,SIM)          = PA.L(A);
777    PDREP(C,SIM)          = PD.L(C);
778    PEREP(CE,SIM)         = PE.L(CE);
779    PMREP(CM,SIM)         = PM.L(CM);
780    PQREP(C,SIM)          = PQ.L(C);
781    PVAREP(A,SIM)         = PVA.L(A);
782    PXREP(C,SIM)          = PX.L(C);
783    QAREP(A,SIM)          = QA.L(A);
784    QDREP(C,SIM)          = QD.L(C);
785    QEREP(CE,SIM)         = QE.L(CE);
786    QFREP(F,A,SIM)        = QF.L(F,A);
787    QFSREP(F,SIM)         = QFS.L(F);
788    QHREP(C,H,SIM)        = QH.L(C,H);
789    QINTREP(C,A,SIM)      = QINT.L(C,A);
790    QINVREP(C,SIM)        = QINV.L(C);
791    QMREP(CM,SIM)         = QM.L(CM);
792    QQREP(C,SIM)          = QQ.L(C);
793    QXREP(C,SIM)          = QX.L(C);
794    WFREP(F,SIM)          = WF.L(F);
795    WFAREP(F,A,SIM)       = WF.L(F)*WFDIST.L(F,A);
796    WFDISTREP(F,A,SIM)    = WFDIST.L(F,A);
797    YFREP(H,F,SIM)        = YF.L(H,F);
798    YGREP(SIM)            = YG.L;
799    YHREP(H,SIM)          = YH.L(H);
800
801    WALRASREP(SIM)        = WALRAS.L;
802
803    *GDP data
804    GDPREP('PRVCON',SIM)  = SUM((C,H), PQ.L(C)*QH.L(C,H)) ;
805    GDPREP('GOVCON',SIM)  = SUM(C, PQ.L(C)*qg(C));

```

```

806 GDPREP('INVEST',SIM) = SUM(C, PQ.L(C)*QINV.L(C));
807 GDPREP('EXP',SIM) = SUM(C, EXR.L*pwe(C)*QE.L(C));
808 GDPREP('IMP',SIM) = - SUM(C, EXR.L*pwm(C)*QM.L(C));
809 GDPREP('GDPFC',SIM) = SUM((F,A), WF.L(F)*WFDIST.L(F,A)*QF.L(F,A));
810 GDPREP('NITAX',SIM)
811 = SUM(C, tq(C)*(PD.L(C)*QD.L(C) + (PM.L(C)*QM.L(C))$CM(C)))
812 + SUM(C$CM(C), tm(C)*EXR.L*pwm(C)*QM.L(C))
813 + SUM(C$CE(C), te(C)*EXR.L*pwe(C)*QE.L(C));
814
815 );
816
817 *Processing GDP data
818 GDPREP('GDPMP1',SIM) = SUM(ACGDP1, GDPREP(ACGDP1,SIM));
819 GDPREP('GDPMP2',SIM) = GDPREP('GDPFC',SIM) + GDPREP('NITAX',SIM);
820 GDPREP('GDPGAP',SIM) = GDPREP('GDPMP1',SIM)-GDPREP('GDPMP2',SIM);
821
822
823 OPTION QFREP:3:1:1, QHREP:3:1:1, QINTREP:3:1:1, WFAREP:3:1:1,
824 WFAREP:3:1:1, WFDISTREP:3:1:1, YFREP:3:1:1
825 ;
826
827 DISPLAY
828 PWEREP, EGREP, EXRREP, FSAVREP, IADJREP, MPSREP, PAREP, PDREP, PEREP,
829 PMREP, PQREP, PVAREP, PXREP, QAREP, QDREP, QEREP, QFREP, QFSREP, QHREP,
830 QINTREP, QINVREP, QMREP, QQREP, QXREP, WFREP, WFAREP, WFDISTREP, YFREP,
831 YGREP, YHREP, WALRASREP, GDPREP
832 ;

```