GENERAL EQUILIBRIUM SIMULATION PROGRAM

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The general equilibrium simulation program follows the traditional Arrow-Debreu approach modified to include the possibility of taxes, a public good, and an externality. All households and firms act as price-takers. The simulation program has been coded in the Java language to provide a user-friendly interface. The program itself is very flexible and can accommodate an arbitrary number of goods, households, and firms. While the user can enter all the parameters of the economy (household endowments and utility functions; firm production functions; etc.), an alternative exists that most may find preferable. Alternatively, you can open an existing file and then modify any of the parameters if you wish.

Three sections follow:

- Setting up Java to run the program
- Parameters of the general equilibrium model
- Using the simulation program: "Nuts and bolts"

Section 1: Setting Up Java to Run the Program

NB: Chrome no longer supports Java; accordingly you must use a different browser (Firefox, Internet Explorer, etc.) that does.

Three steps are involved to set up Java:

- First, install the latest version of the Java Runtime Environment (JRE). It is available for free at the following url:

  http://java.com/en/download/index.jsp

- Second, you must give Java permission to run the program on your computer:
  - Click **Start**
  - Click **All Programs**.
  - Click the **Java icon folder icon** in the list that appears.
  - Click the **Configure Java icon**.
  - Click the **Security tab**.
  - Click the Edit Site List… button and type:
    http://www3.amherst.edu/~fwesthoff/
  - Click **OK**.
- Third, exit and reload your browser to activate the security change you just made.

Section 2: Parameters of the General Equilibrium Model

The parameters of the model specify the characteristics of households and firms. The model also incorporates a government sector that permits the possibility of taxes, transfer payments, a public good, and an externality.

Households

A constant elasticity of substitution utility function is used to specify each household's preferences:

$$u(x_1, x_2, \ldots, x_N) = \left[\sum_{i=1}^{N} \alpha_i x_i^{\rho_{Con}}\right]^{1/\rho_{Con}}$$

where N = Number of Private Goods

x_i = Quantity of Private Good g Consumed by the Household

α's = CES consumption "coefficients"

$\rho_{Con} = \dfrac{\sigma_{Con} - 1}{\sigma_{Con}}$ σ_{Con} = Elasticity of Substitution (Consumption)

If a good provides no (direct) utility, as may be the case of capital, the value of α is set to zero. Furthermore, in the case of labor, the household may have a positive α indicating a household's preference to consume its endowed labor as leisure. Note that for $\sigma_C = 1$, the production functions take a simple Cobb-Douglas form.

Every household must be provided with an endowment. Typically, a household is endowed with some non-produced goods (potential labor time and perhaps some capital) although any endowment scheme is permitted.

Each household is assumed to maximize its utility subject to a budget constraint that includes both consumer goods purchased and endowed resources sold.

Firms

Each firm can produce only a single good. A constant elasticity of substitution production function specifies the productive technology for each firm. The production function for a firm that produces good i is:

$$y_i = \beta_{ii}\left[\sum_{j \neq i} \beta_{ij} y_j^{\rho_{Pro}}\right]^{1/\rho_{Pro}}$$

where y_i = Quantity of Good i Produced

y_j = Quantity of Input j Used

β's = CES production "coefficients"

$\rho_{Pro} = \dfrac{\sigma_{Pro} - 1}{\sigma_{Pro}}$ σ_{Pro} = Elasticity of Substitution (Production)

Firms are assumed to maximize profits. Because of the constant returns nature of the production technology, in equilibrium all firms earn zero long-run profits. Hence, it is the ownership of productive input endowments that provides incomes to consumers – there is no distinct "income" of firms. Consequently specification of firm ownership is unnecessary in the simulation program. Note that for $\sigma_p = 1$, the production functions take a simple Cobb-Douglas form.

Price and Tax Conventions

All reported prices are the prices as seen by the households. For simplicity, the prices are normalized so as to sum to 1. *Ad valorem* taxes can be placed on any of the goods. Because the reported prices are those seen by households, it is perhaps easiest to think of taxes as being legally incident on the firms even though the legal incidence of the tax is irrelevant. To clarify how taxes are modeled, consider two examples.

***Ad valorem* tax on an input**: Suppose that the price of labor were .40, then $P_L = .40$. Consider imposition of an *ad valorem* tax of .25 on labor input ($t_L = .25$). In this case, each household would receive .40 of income for each unit of labor supplied. The firm would be spending .50 for each unit of labor hired. The difference would go to the government as tax revenue. More generally, for each unit of labor "traded" the:

- household receives P_L of income;
- firm incurs $P_L(1 + t_L)$ of costs;
- government receives $P_L t_L$ of tax revenue.

***Ad valorem* tax on a consumption good**: Suppose that the price of consumption good X is .50, ($P_X = .50$) and the *ad valorem* tax on consumption good X is .10 ($t_X = .10$). Each household would spend .50 for each unit of consumption good X purchased. The firm would receive .45 for each unit of consumption good X sold. The difference would go the government as tax revenue. More generally, for each unit of consumption good X traded the:

- household pays P_X;
- firm receives $P_X (1 - t_X)$ of revenues;
- government receives $P_X t_X$ of tax revenue.

Unit taxes can also be imposed. When unit taxes are specified, however, note that all prices are normalized so that they sum to 1. Your unit taxes should be "scaled" accordingly.

Government

A general equilibrium model allows us to explicitly account for the government's budget constraint. When the government collects tax revenue, something must be done with it. Broadly speaking, there are two choices:

- Redistribute it as transfer payments to households
- Finance the production of public goods.

The simulation program allows us to specify "redistribution factors" that determines the portion of the government's tax revenue that is redistributed to each households. To satisfy the budget constraint the sum of the redistribution factors across households cannot total more than 1. If the sum totals less than 1, the tax revenue will be used to finance the production of a public good.

Public Goods and Externalities

When a public is specified household by checking the Public Good checkbox, utility functions become:

$$u(x_1, x_2, \ldots, x_N, G) = \left[\sum_{i=1}^{N} \alpha_i x_i^{\rho_{Con}} + \alpha_P G^{\rho_{Con}}\right]^{1/\rho_{Con}}$$

where G = Quantity of Public Good

Public goods can be financed either from general (*ad valorem* and/or unit) tax revenue or a Lindahl "user tax" approach.

Similarly, when an externality is specified by checking the Externality checkbox, utility functions become:

$$u(x_1, x_2, \ldots, x_N, G, R-E) = \left[\sum_{i=1}^{N} \alpha_i x_i^{\rho_{Con}} + \alpha_P G^{\rho_{Con}} + \alpha_E (R-E)^{\rho_{Con}}\right]^{1/\rho_{Con}}$$

where R = Initial Quantity of "Common Resource"
E = Externality

The "externality term" requires explanation. Consider a negative externality in which we begin with a specified quantity of a common resource (the base quantity); subsequently, each firm's productive activities can deplete the common resource. For example, suppose there are 10 units of clean air available for the households to enjoy. Firms then pollute the atmosphere reducing the quantity of clean air available for households. In this case, R would equal 10.

Section 3: Using the Simulation Program: "Nuts and Bolts"

Two steps are involved in operating the simulation:

Step 1: Entering the model's parameters.

Step 2: Finding an equilibrium.

Step 1: Entering the model's parameters.

There are two ways to enter the parameters of your general equilibrium model. You can enter all the information yourself "from scratch." Alternatively, you can use an existing file that has been prepared beforehand and then modify the information as you wish. In many cases, the second method is generally preferred because it requires less data entry on your part.

Method 1: Enter All Information Yourself. In the menu bar at the top of the window, click File and then New. You will now be asked to specify the number of private goods, the number of households, and the number of private firms. After doing so, click the Set Constants button. Now, several radio buttons appear on the screen:

- ○ Good Names
- ○ Utility Functions
- ○ Endowments
- ○ Production Functions
- ○ Taxes Ad Val
- ○ Taxes Unit

By toggling through the radio buttons and entering the information in the appropriate spread sheet. You can specify the model's parameters by toggling through the radio buttons and entering the information a spread sheet that appears in the lower part of the window. While it is not required, you can provide names for the goods. You must, however, describe each household's utility function (the CES coefficients, the α's, and the elasticity of substitution, ρ_C), each household's endowments, and each firm's production function (the CES coefficients, the β's, and the elasticity of substitution, ρ_P). The standard general equilibrium notation for production function inputs and outputs is used; input coefficients are preceded by a negative sign and the output coefficient (for a firm producing good i, the input coefficients (β_{ig} $g \neq i$) must have negative signs and the output coefficient (β_{ii}) a positive sign, typically +1. Also, you can (but are not required to) include *ad valorem* and/or unit taxes to your model.

Note that you have the option of including a public good and/or an externality by checking the appropriate checkbox:

- □ Public Good
- □ Externality

When a public good is included, a Lindahl checkbox appears to permit the possibility of financing the public good with a Lindahl user tax. Do not forget that when a public good is specified, utility and production function parameters for the public good must be added by selecting the Utility Functions and Production Functions radio boxes.

When an externality is specified, a "Base" quantity text field appears below the Externality checkbox. You should enter the base quantity of the common resource in this field. Again note that when an externality is specified utility and production function parameters for the externality must be added by selecting the Utility Functions and Production Functions radio buttons. For each firm, the quantity of externality produced is proportional to the quantity of output produced. This proportionality factor is specified by selecting the Production Functions radio button. A negative externality is indicated by a negative sign, a positive externality by a positive sign.

Method 2: Use an Existing File. In the menu bar at the top of the window, click File and then Open. A new window appears; choose a file and then click the Open button. The radio buttons, checkboxes, and spread sheet window now appear immediately on the screen. You can accept parameters as is or modify them by selecting the appropriate radio buttons and entering new values in the spreadsheet. Also, you can change the public good and externality options by checking or unchecking the appropriate checkboxes.

Step 2: Finding an Equilibrium

After entering all the information, click the Find Equilibrium button. Merrill's refinement of Scarf's algorithm will now find a vector of prices that is an "approximate" equilibrium. You can halt the procedure at any time by clicking the Stop button. After doing so, the output will appear on the screen. To record the results, you can copy and paste the output in a word processor. Use Ctrl-A to select all the text and then Ctrl-C to copy the text. In your word processor, click the save button or type Ctrl-V.

What Next?

You can now return to the spreadsheet to run another simulation with modified parameters. To do so, click the Return to Spreadsheet button. Then, modified the desired parameters and click the Find Equilibrium button again.

When you finished with this particular model, click File in the menu bar. If you are running the program as an applet, click Close. Applet security will not permit you to save any changes you have made in the file. On the other hand, if you are running the program as an application, you will have the opportunity of saving the changes in the opened file or a new file.

After clicking Close, you can again repeat Steps 1 and 2.

Help Screens

The Basics Help Screen: This presents the basic "nuts and bolts" operation of the general equilibrium simulation program.

The Input/Output Help Screen: You may wish to increase or decrease the number of decimals reported in your input or output values. You can read how to do so in this screen.

The Advanced Help Screen: This program is a "work in progress." When you attempt to find an equilibrium (Step 2), the program may hang up. If you experience this problem, you should read the Advance Specs help screen for some advice.