# Using the Global Forest Products Model (GFPM version 2012)

by

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**STAFF PAPER SERIES #74**

May 21, 2012

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## Acknowledgements

The research leading to this paper was supported in parts by the USDA Forest Service Southern Forest Experiment Station. We thank Jeff Prestemon for his support and collaboration. We also acknowledge with thanks the earlier contributions to the GFPM and PELPS by Ronald Raunikar, James Turner, Ruhong Li, Dali Zhang, Peter Ince, Patrice Calmels, and J. Keith Gilless.

## Contents

# 1 Introduction

The purpose of this manual is to enable users of the Global Forest Products Model to:

- Install and run the GFPM software
- Understand the input data
- Change the input data to explore different scenarios
- Interpret the output

The GFPM is an economic model of global production, consumption and trade of forest products (Buongiorno et al. 2003). The GFPM2012 has data and parameters to produce forecasts of forest resources and markets for 180 countries, and 14 forest product (commodity) categories, from 2009 to 2030. Zhu et al. (2008) describe how to update, calibrate, and validate the model with different data.

This manual describes how to install the GFPM (Section 2); interpret the base year (2009) input data (Section 3) and the exogenous change data (Section 4) which the GFPM uses to forecast production, consumption, imports, exports, prices, forest stock and forest area; run the GFPM (Section 5); interpret the projection output from the GFPM (Section 6) and analyze product value and value added (Section 7). Section 8 provides information on possible causes of common errors.

# 2 Installation and Configuration

## Hardware and Software Requirements

The GFPM requires a PC with a processor, at least 8MB of RAM, and a 32-bit Windows operating system, such as Windows NT, Windows 2000, Windows XP, Windows Vista, or Windows 7[1]. Nowadays, many personal computers run 64-bit Windows operating systems like Windows 7. On such computers, the easiest way to install GFPM is to order or upgrade the Windows 7 operating system to professional edition, create a virtual PC running 32-bit Windows XP operating system, then install GFPM in the virtual PC. For detailed instruction to create a virtual PC, search Microsoft website with key words like Windows 7 and Virtual PC.

The GFPM uses the QPELPS (Quadratic Price Endogenous Linear Programming System) software, a general economic modeling system. QPELPS uses the LINDOAPI solver to find the solution to each year's global equilibrium. Data input and output are handled with Microsoft Excel (Office 97 or higher). GFPM supports only Excel version Microsoft Office up to 2003.

[1] The GFPM uses the LINDOAPI mathematical programming solver. LINDOAPI is invoked by the GFPM from DOS, which can be done under the Windows NT, Windows 2000, Windows XP, or Windows Vista operating systems, but not under Windows 95 or Windows 98. The English Windows operating system is recommended since some GFPM users reported issues when using non-English Windows operating systems.

### Installing the GFPM

To install the GFPM (Figure 1) do the following, in order:

- In the root directory of your C: drive, install LINDOAPI.
  After installing LINDOAPI, verify the settings of environment variables related to LINDOAPI. Go to Windows control panel -> System -> Advanced (a tab) -> Environment Variables (a button at the bottom), verify the following environment variables are set correctly for LINDOAPI (for version 7.0):
  lindoapi_home: C:\Lindoapi\
  lindoapi_license_file: %LINDOAPI_HOME%license\lndapi70.lic
  classpath: %LINDOAPI_HOME%lib\lindo7_0.jar
  path: %LINDOAPI_HOME%bin\win32

- Unzip GFPM.ZIP into the C:\ root directory. This should end up with two folders: C:\GFPM and C:\PELPS, which contain GFPM application specific files and QPELPS generic files respectively. After installing the GFPM, verify that the top level directory structure is C:\GFPM and C:\PELPS.

- Copy the file SNJRT11.DLL from C:\PELPS\COPY-TO-C-DRIVE to the C:\WINDOWS\SYSTEM32[2] directory. This file is needed to run Java executable files.

- Copy the license key file obtained from Lindo Systems Inc. to C:\LINDOAPI\LICENSE to replace the original demo license key file (for example: the license key file for LINDOAPI 7.0 is lndapi70.lic).

### Testing Installation

The file C:\GFPM\WORLD.XLS contains a GFPM model that has already been calibrated by the authors. Running the base period of this model will test that PELPS/GFPM executables and LINDOAPI have been installed properly. Getting output for the base period will test that Microsoft Office works correctly with the GFPM. For detailed instruction to run GFPM, go to section 5 “Running the GFPM”. To perform this test, only two steps (in order) are necessary:

- 2) Run base-period
- 5) Get output

This test runs the default calibrated GFPM model for the base period, and then retrieves its results in Excel output files.

## 3 GFPM base year input

The GFPM uses Microsoft Excel (Office 97 or higher) to organize the input data. All the data are in the file WORLD.XLS, under the C:\GFPM directory. Only worksheets with names in bold in

[2] Under Windows NT and Windows 2000 this directory is C:\WINNT\SYSTEM32

the following list are used in the GFPM2012. All data sheets except the last are needed to calculate the solution for the base year, the year from which the projections start. The *ExogChange* data are needed for multi-period projections.

| Full name | Short name |
|---|---|
| **Specification** | |
| **Demand** | |
| **Supply** | |
| **Forest Resource** | *Forest* |
| Cross Price Elasticity | |
| **Manufacture** | |
| Capacity--1 | *Capacity1* |
| Capacity--2 | *Capacity2* |
| Recycling (Demand) | |
| **Recycling (Supply)** | *RecyclingS* |
| **Transportation Cost and Tax** | *Transportation* |
| Exchange Rate | |
| **Exogenous Change** | *ExogChange* |

You may find it useful to open the WORLD.XLS file and look at each of the worksheets discussed next.

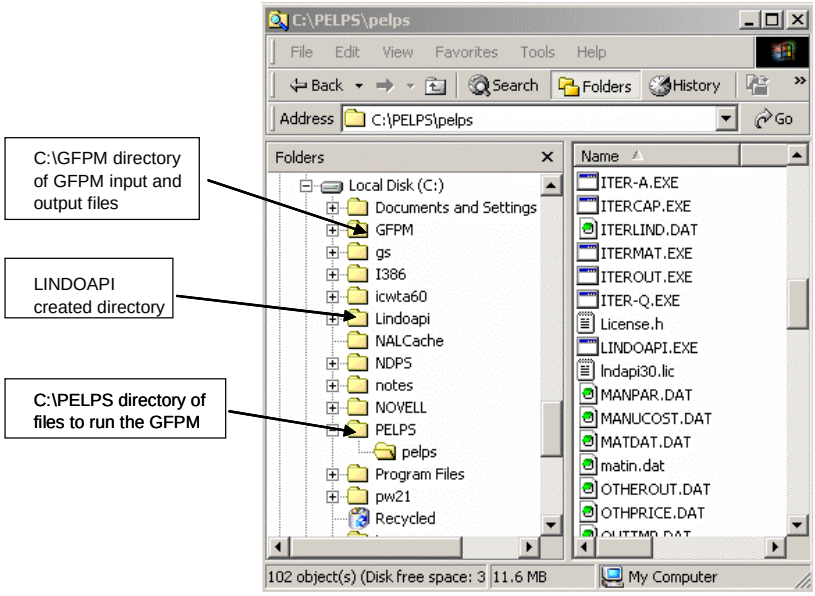


**Figure 1: Files and directories to install and run the GFPM, shown in Microsoft Windows Explorer.**

## Specification

The *Specification* sheet contains information on the data in the WORLD.XLS. Typically, it shows the codes of the commodities and regions, and information about the base year and model version. The region codes and names, commodity codes and names, and base year are generated automatically if the WORLD.XLS file is created with the calibration program (Buongiorno and Zhu, 2012). These region and commodity names, and base year are used in by GFPM to construct the output tables and charts. The other data on this sheet are informational only.

## Demand

The *Demand* worksheet (Figure 2) contains the data that define the demand equation for each region/country and end product in the base year: the quantity consumed, the price[3], the price elasticity of demand and the elasticity of demand with respect to the first shift variable (GDP in GFPM2012). Country and commodity codes are in Table 1 and Table 2 at the end of this paper. For net exporting countries, the price is equal to the world price, the average unit value of world exports. For net importing countries the price is equal to the world price plus freight cost and tariff.

The price elasticity is negative even if the quantity demanded is 0, unless the demand is horizontal as indicated by a zero (0) elasticity. If both the quantity demanded and the elasticity are zero, the upper bound on demand is set internally at 0.

The data in the Demand and other worksheets must follow the format indicated at the top of the worksheet. No dangling entry is permitted in the reserved columns A to O (i.e., no other data may be entered in these reserved columns below the model data. However, informational or calculated data may be recorded in non-reserved columns, which are ignored by GFPM). The information in grayed-out text are not used in the GFPM2012.

[3] All prices and costs in the GFPM2012 are in $US of 2009.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** DEMAND ****** | | | | | | | | | | | | | | | |
| 3 | A: | Region number (01 to 99, in ascending order) | | | | | | | | | | | | | | |
| 4 | B: | Commodity number (01 to 99, in ascending order within each region) | | | | | | | | | | | | | | |
| 5 | C: | Base period price in common currency | | | | | | | | | | | | | | |
| 6 | D: | Base period quantity demanded at price C | | | | | | | | | | | | | | |
| 7 | E: | Price elasticity (<0, enter 0.00 for horizontal demand) | | | | | | | | | | | | | | |
| 8 | F: | Elasticity of demand with respect to the first shift variable (optional, enter 0.00 if omitted) | | | | | | | | | | | | | | |
| 9 | G: | Elasticity of demand with respect to the second shift variable (optional, enter 0.00 if omitted) | | | | | | | | | | | | | | |
| 10 | H: | Elasticity of demand with respect to the third shift variable (optional, enter 0.00 if omitted) | | | | | | | | | | | | | | |
| 11 | I: | Elasticity of demand with respect to the fourth shift variable (optional, enter 0.00 if omitted) | | | | | | | | | | | | | | |
| 12 | J: | Elasticity of demand with respect to the fifth shift variable (optional, enter 0.00 if omitted) | | | | | | | | | | | | | | |
| 13 | K: | Elasticity of demand with respect to the sixth shift variable (optional, enter 0.00 if omitted) | | | | | | | | | | | | | | |
| 14 | L: | Elasticity of demand with respect to previous-period demand (optional, enter 0.00 if omitted) | | | | | | | | | | | | | | |
| 15 | M: | Lower bound on the quantity demanded (optional, enter 0.00 if omitted) | | | | | | | | | | | | | | |
| 16 | N: | Quantity demanded in the period before the base period | | | | | | | | | | | | | | |
| 17 | O: | Minimum fraction of recycled content | | | | | | | | | | | | | | |
| 19 | a0 | 80 | 41 | 7658.000 | -0.50 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7658.000 | 0.00 | |
| 20 | a0 | 82 | 80 | 63.000 | -0.37 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 63.000 | 0.00 | |
| 21 | a0 | 83 | 271.95 | 1169.000 | -0.10 | 0.22 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1169.000 | 0.00 | |
| 22 | a0 | 84 | 551.51 | 84.000 | -0.29 | 0.41 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 84.000 | 0.00 | |
| 23 | a0 | 85 | 320.00 | 86.000 | -0.29 | 0.54 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 86.000 | 0.00 | |
| 24 | a0 | 86 | 441.25 | 16.000 | -0.46 | 0.35 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 16.000 | 0.00 | |
| 25 | a0 | 91 | 616.35 | 52.000 | -0.25 | 0.58 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 52.000 | 0.00 | |
| 26 | a0 | 92 | 1044.20 | 112.000 | -0.37 | 0.45 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 112.000 | 0.00 | |
| 27 | a0 | 93 | 980.95 | 223.000 | -0.23 | 0.43 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 223.000 | 0.00 | |
| 28 | a1 | 80 | 41 | 3573.000 | -0.50 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3573.000 | 0.00 | |
| 29 | a1 | 82 | 80 | 1050.000 | -0.37 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1050.000 | 0.00 | |
| 30 | a1 | 83 | 305.62 | 8.000 | -0.10 | 0.22 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.000 | 0.00 | |

**Figure 2: *Demand* worksheet with data for demand equations.**

## Supply

The GFPM has a supply equation for each country and primary product (wood, recycled paper, other fiber pulp). The *Supply* worksheet (Figure 3) contains the data that define the supply equations: the quantity supplied in the base year, the price, the price elasticity, the elasticity with respect to the supply shifters, and the optional upper bound on supply.

As for demand, the price is equal to the world price for net exporters of the commodity, or to the world price plus freight costs and tariffs for net importers.

The price elasticity is positive even if supply is zero, unless the supply is horizontal which is indicated by a zero (0) elasticity. If the quantity supplied and the elasticity are both 0, the upper bound on supply is set internally to 0.

The wood supply (fuelwood, industrial roundwood, or other industrial roundwood) can be shifted exogenously or endogenously. Either way, the *Supply* data must agree with the exogenous change data in the *ExogChange* sheet described below. The *Supply* sheet sets the elasticities of supply with respect to the shifters, while the *ExogChange* sheet sets the changes in the shifters.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** SUPPLY ****** | | | | | | | | | | | | | | |
| 3 | A: | Region number (01 to 99, in ascending order) | | | | | | | | | | | | | |
| 4 | B: | Commodity Number (01 to 99, in ascending order within each region) | | | | | | | | | | | | | |
| 5 | C: | Base period price in common currency | | | | | | | | | | | | | |
| 6 | D: | Base period quantity supplied at price C | | | | | | | | | | | | | |
| 7 | E: | Price elasticity (>0, enter 0.00 for horizontal supply) | | | | | | | | | | | | | |
| 8 | F: | Elasticity of supply with respect to the first shift variable (optional, enter 0.00 if omitted) | | | | | | | | | | | | | |
| 9 | G: | Elasticity of supply with respect to forest stock (optional, 0 if omitted) | | | | | | | | | | | | | |
| 10 | H: | Elasticity of supply with respect to forest area (optional, 0 if omitted) | | | | | | | | | | | | | |
| 11 | I: | Elasticity of supply with respect to fourth shift variable (optional, 0 if omitted) | | | | | | | | | | | | | |
| 12 | J: | Elasticity of supply with respect to the fifth shift variable (optional, 0 if omitted) | | | | | | | | | | | | | |
| 13 | K: | Elasticity of supply with respect to the sixth shift variable (optional, 0 if omitted) | | | | | | | | | | | | | |
| 14 | L: | Elasticity of supply with respect to previous-period supply (optional, enter 0.00 if omitted) | | | | | | | | | | | | | |
| 15 | M: | Lower bound on the quantity supplied (optional, enter 0.00 if omitted) | | | | | | | | | | | | | |
| 16 | N: | Upper bound on the quantity supplied (optional, enter 0.00 if omitted) | | | | | | | | | | | | | |
| 17 | O: | Quantity supplied in the period before the base period | | | | | | | | | | | | | |
| 19 | a0 | 80 | 41 | 7658.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 7658.000 |
| 20 | a0 | 81 | 110.92 | 54.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 54.000 |
| 21 | a0 | 82 | 80 | 63.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 63.000 |
| 22 | a0 | 89 | 1114.05 | 2.000 | 0.75 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 2.000 |
| 23 | a0 | 90 | 123 | 20.000 | 1.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 20.000 |
| 24 | a1 | 80 | 41 | 3573.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 3573.000 |
| 25 | a1 | 81 | 80 | 39.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 39.000 |
| 26 | a1 | 82 | 80 | 1050.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 1050.000 |
| 27 | a1 | 89 | 982 | 0.000 | 0.75 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 28 | a1 | 90 | 123.00 | 0.000 | 1.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 29 | a2 | 80 | 41 | 4113.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 4113.000 |
| 30 | a2 | 81 | 80 | 86.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 86.000 |
| 31 | a2 | 82 | 80 | 297.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 297.000 |
| 32 | a2 | 89 | 982 | 0.000 | 0.75 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 33 | a2 | 90 | 123.00 | 0.000 | 1.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 34 | a3 | 80 | 41 | 660.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 660.000 |
| 35 | a3 | 81 | 80 | 0.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 36 | a3 | 82 | 80 | 105.000 | 1.31 | 0.00 | 1.10 | -0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 105.000 |
| 37 | a3 | 89 | 982 | 0.000 | 0.75 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 38 | a3 | 90 | 123 | 0.000 | 1.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |

**Figure 3: *Supply* worksheet with data for supply equations.**

To shift wood supply exogenously, the elasticity with respect to the first shift variable in column F should be 1.00. This makes data in columns G to K irrelevant.

To shift wood supply endogenously, the elasticity with respect to the first shift variable in column F of the *Supply* sheet must be 0.00. This causes wood supply to depend on forest stock, forest area, and GDP per capita according to the elasticities in columns G, H, and I. Together with this endogenous shift, wood supply can also be shifted exogenously according to the sixth shift variable with the elasticity in column K.

## Forest Resource

The *Forest* worksheet (Figure 4) contains data on forest stock, forest area, GDP per capita, and attendant parameters to predict the rate of change in forest area and forest stock. Forest stock and area data are published infrequently (every 5 years or so). They can be obtained at FAO sites such as: www.fao.org/forestry/site/32033/en, www.fao.org/forestry/site/32042/en, www.fao.org/forestry/site/32043/en.

The forest resource sheet can be left blank if the supply represented in the Supply sheet described above is independent of the forest resources,

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** FOREST RESOURCE ****** | | | | | | | | | | | | | |
| 3 | A: | Region number (01 to 99, in ascending order) | | | | | | | | | | | | |
| 4 | B: | Base period GDP per capita (US$) | | | | | | | | | | | | |
| 5 | C: | Base period forest stock (million $m^3$) | | | | | | | | | | | | |
| 6 | D: | Base period annual growth rate of forest stock, without harvest | | | | | | | | | | | | |
| 7 | E: | Elasticity of annual growth rate of forest stock, without harvest, with respect to stock per unit area | | | | | | | | | | | | |
| 8 | F: | Base period forest area (000 ha) | | | | | | | | | | | | |
| 9 | G: | Base period forest area annual growth rate | | | | | | | | | | | | |
| 10 | H: | Effect of GDP per capita (1000 US$) on forest area annual growth rate | | | | | | | | | | | | |
| 11 | I: | Effect of squared GDP per capita (1000 US$) on forest area annual growth rate | | | | | | | | | | | | |
| 12 | J: | Fraction of fuelwood that comes from forest | | | | | | | | | | | | |
| 13 | K: | Ratio of inventory drain to harvest | | | | | | | | | | | | |
| 14 | L: | Maximum ratio of inventory drain to growth of inventory without harvest (>0, -1 if unlimited) | | | | | | | | | | | | |
| 15 | M: | CO2 sequestered by wood (tonne per CUM) | | | | | | | | | | | | |
| 16 | N: | Price of CO2 (US$ per tonne) | | | | | | | | | | | | |
| 18 | a0 | 2935 | 174.000 | 0.005 | -0.48 | 2277 | 0.002 | 0.15 | -0.0032 | 0.75 | 1.20 | -1 | 1.5 | 0 |
| 19 | a1 | 1503 | 2291.000 | 0.005 | -0.48 | 59104 | -0.007 | 0.15 | -0.0032 | 0.75 | 1.20 | -1 | 1.5 | 0 |
| 20 | a2 | 596 | 480.490 | 0.037 | -0.48 | 2349 | -0.025 | 0.15 | -0.0032 | 0.75 | 1.20 | -1 | 1.5 | 0 |
| 21 | a3 | 4395 | 197.000 | 0.005 | -0.48 | 11942 | -0.010 | 0.15 | -0.0032 | 0.75 | 1.20 | -1 | 1.5 | 0 |
| 22 | a4 | 431 | 238.000 | 0.014 | -0.48 | 6794 | -0.003 | 0.15 | -0.0032 | 0.75 | 1.20 | -1 | 1.5 | 0 |
| 23 | a5 | 254 | 11.420 | 0.012 | -0.48 | 151 | -0.020 | 0.15 | -0.0032 | 0.10 | 1.20 | -1 | 1.5 | 0 |

**Figure 4: *Forest* worksheet with data for modeling country forest area and stock.**

## Manufacture

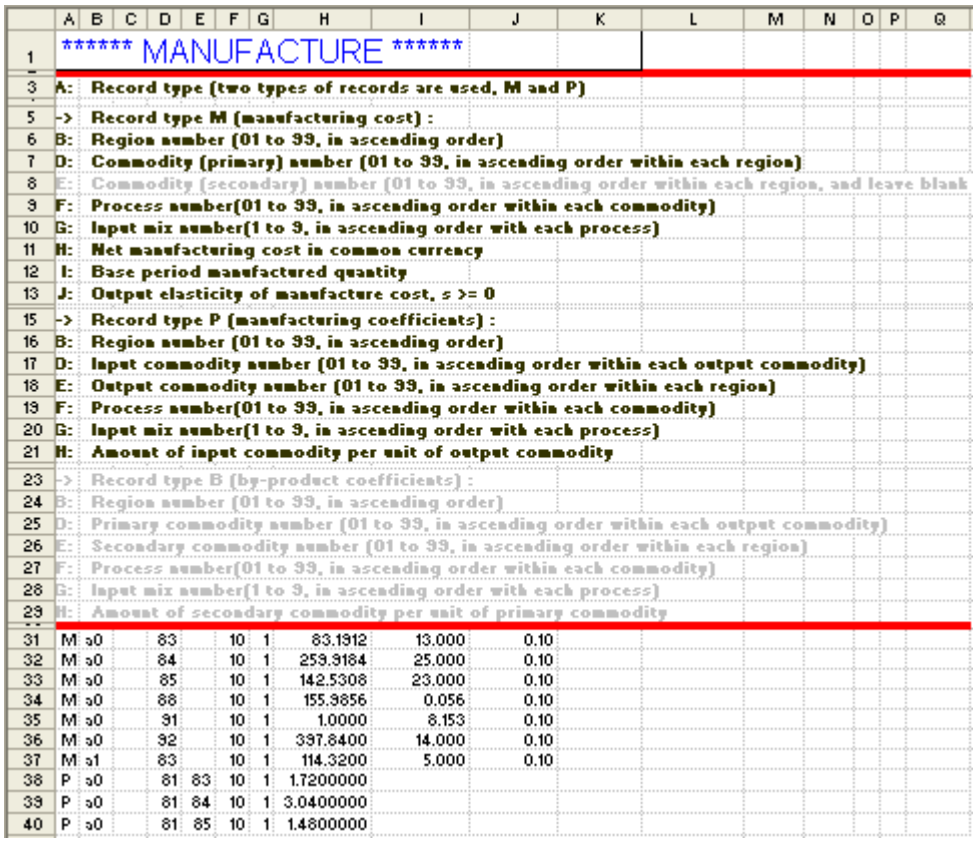
The *Manufacture* worksheet (Figure 5) contains data on the manufacturing costs and manufacturing or input-output (IO) coefficients in the base year for commodities that are manufactured to and from other commodities. Manufacturing costs and related data are in type M records, manufacturing coefficients are in type P records, data referring to secondary commodities, or byproducts are in type B records. All the M records must precede the P records, which must precede the B records.

The manufacturing cost is the cost of labor, capital, energy, and other non-wood or fiber input. The manufacturing cost depends on the level of production, according to the elasticity of manufacturing cost with respect to output quantity.

The manufacturing coefficients are the quantity of input per unit of output. The GFPM uses only one process and one input mix for each output.

Secondary commodities, or byproducts, result from the manufacture of other (primary) products. For example, sawnwood residues is a byproduct of sawnwood manufacturing. The primary commodity is specified with an M and a P record. The secondary product is specified with an M record with the commodity code in column E (instead of column D for a primary product), and with a B record (instead of a P record for a primary product). The B record indicates how much byproduct is obtained per unit of primary product.

The manufacture sheet can be left blank if the model does not involve manufactured commodities, for example if the demand and supply are entirely represented by the data in the Demand and Supply sheets described above.



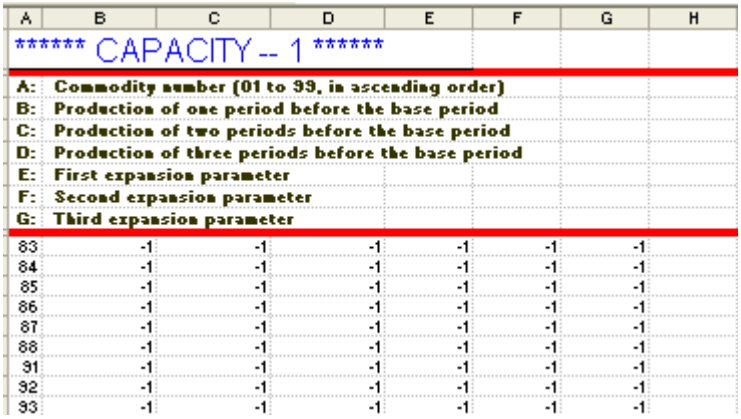
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** MANUFACTURE ****** | | | | | | | | | | | | | | | | |
| 3 | A: | Record type (two types of records are used, M and P) | | | | | | | | | | | | | | | |
| 5 | -> | Record type M (manufacturing cost) : | | | | | | | | | | | | | | | |
| 6 | B: | Region number (01 to 99, in ascending order) | | | | | | | | | | | | | | | |
| 7 | D: | Commodity (primary) number (01 to 99, in ascending order within each region) | | | | | | | | | | | | | | | |
| 8 | E: | Commodity (secondary) number (01 to 99, in ascending order within each region, and leave blank | | | | | | | | | | | | | | | |
| 9 | F: | Process number(01 to 99, in ascending order within each commodity) | | | | | | | | | | | | | | | |
| 10 | G: | Input mix number(1 to 9, in ascending order with each process) | | | | | | | | | | | | | | | |
| 11 | H: | Net manufacturing cost in common currency | | | | | | | | | | | | | | | |
| 12 | I: | Base period manufactured quantity | | | | | | | | | | | | | | | |
| 13 | J: | Output elasticity of manufacture cost, *s* >= 0 | | | | | | | | | | | | | | | |
| 15 | -> | Record type P (manufacturing coefficients) : | | | | | | | | | | | | | | | |
| 16 | B: | Region number (01 to 99, in ascending order) | | | | | | | | | | | | | | | |
| 17 | D: | Input commodity number (01 to 99, in ascending order within each output commodity) | | | | | | | | | | | | | | | |
| 18 | E: | Output commodity number (01 to 99, in ascending order within each region) | | | | | | | | | | | | | | | |
| 19 | F: | Process number(01 to 99, in ascending order within each commodity) | | | | | | | | | | | | | | | |
| 20 | G: | Input mix number(1 to 9, in ascending order with each process) | | | | | | | | | | | | | | | |
| 21 | H: | Amount of input commodity per unit of output commodity | | | | | | | | | | | | | | | |
| 23 | -> | Record type B (by-product coefficients) : | | | | | | | | | | | | | | | |
| 24 | B: | Region number (01 to 99, in ascending order) | | | | | | | | | | | | | | | |
| 25 | D: | Primary commodity number (01 to 99, in ascending order within each output commodity) | | | | | | | | | | | | | | | |
| 26 | E: | Secondary commodity number (01 to 99, in ascending order within each region) | | | | | | | | | | | | | | | |
| 27 | F: | Process number(01 to 99, in ascending order within each commodity) | | | | | | | | | | | | | | | |
| 28 | G: | Input mix number(1 to 9, in ascending order with each process) | | | | | | | | | | | | | | | |
| 29 | H: | Amount of secondary commodity per unit of primary commodity | | | | | | | | | | | | | | | |
| 31 | M | a0 | | 83 | | 10 | 1 | 83.1912 | 13.000 | 0.10 | | | | | | | |
| 32 | M | a0 | | 84 | | 10 | 1 | 253.9184 | 25.000 | 0.10 | | | | | | | |
| 33 | M | a0 | | 85 | | 10 | 1 | 142.5308 | 23.000 | 0.10 | | | | | | | |
| 34 | M | a0 | | 88 | | 10 | 1 | 155.3856 | 0.056 | 0.10 | | | | | | | |
| 35 | M | a0 | | 91 | | 10 | 1 | 1.0000 | 8.153 | 0.10 | | | | | | | |
| 36 | M | a0 | | 92 | | 10 | 1 | 397.8400 | 14.000 | 0.10 | | | | | | | |
| 37 | M | a1 | | 83 | | 10 | 1 | 114.3200 | 5.000 | 0.10 | | | | | | | |
| 38 | P | a0 | | 81 | 83 | 10 | 1 | 1.7200000 | | | | | | | | | |
| 39 | P | a0 | | 81 | 84 | 10 | 1 | 3.0400000 | | | | | | | | | |
| 40 | P | a0 | | 81 | 85 | 10 | 1 | 1.4800000 | | | | | | | | | |

**Figure 5: *Manufacture* worksheet with data for manufacturing costs and input-output coefficients.**

## Capacity

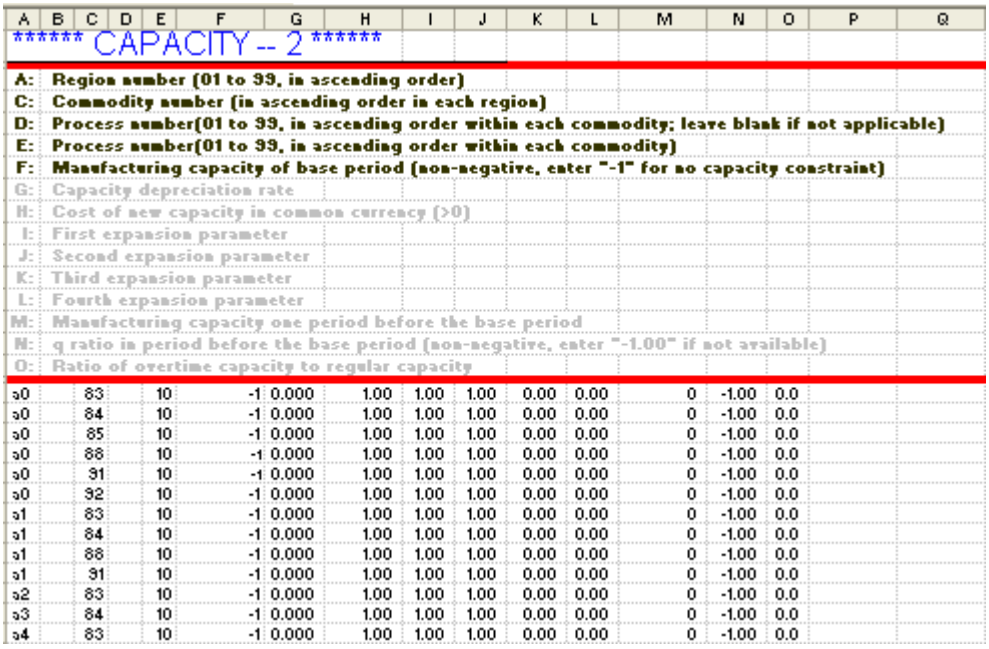
The *Capacity1* worksheet contains the data to predict world manufacturing capacity for each manufactured commodity (Figure 6). Capacity change is not modeled in GFPM2012. This is indicated by entering -1 for all input data in *Capacity1*. The *Capacity2* worksheet (Figure 7) contains data on base-year manufacturing capacity organized by country and commodity. In GFPM2012 base-year manufacturing capacity is set at -1 to mean that there is no capacity constraint. Instead, manufacturing cost increases with the level of production, according to the elasticity specified in the *Manufacture* sheet.

The *Capacity1* and *Capacity2* worksheet can be left blank for models that are completely defined by data in the Demand and Supply sheets described above, or if the model involves data in the Manufacture sheet but no manufacturing capacity needs to be specified.



| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | ****** CAPACITY -- 1 ****** | | | | | | | |
| 2 | A: | Commodity number (01 to 99, in ascending order) | | | | | | |
| 3 | B: | Production of one period before the base period | | | | | | |
| 4 | C: | Production of two periods before the base period | | | | | | |
| 5 | D: | Production of three periods before the base period | | | | | | |
| 6 | E: | First expansion parameter | | | | | | |
| 7 | F: | Second expansion parameter | | | | | | |
| 8 | G: | Third expansion parameter | | | | | | |
| 9 | 83 | -1 | -1 | -1 | -1 | -1 | -1 | |
| 10 | 84 | -1 | -1 | -1 | -1 | -1 | -1 | |
| 11 | 85 | -1 | -1 | -1 | -1 | -1 | -1 | |
| 12 | 86 | -1 | -1 | -1 | -1 | -1 | -1 | |
| 13 | 87 | -1 | -1 | -1 | -1 | -1 | -1 | |
| 14 | 88 | -1 | -1 | -1 | -1 | -1 | -1 | |
| 15 | 91 | -1 | -1 | -1 | -1 | -1 | -1 | |
| 16 | 92 | -1 | -1 | -1 | -1 | -1 | -1 | |
| 17 | 93 | -1 | -1 | -1 | -1 | -1 | -1 | |

**Figure 6: *Capacity1* worksheet with data for capacity expansion parameters.**



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** CAPACITY -- 2 ****** | | | | | | | | | | | | | | | | |
| 2 | A: | Region number (01 to 99, in ascending order) | | | | | | | | | | | | | | | |
| 3 | C: | Commodity number (in ascending order in each region) | | | | | | | | | | | | | | | |
| 4 | D: | Process number(01 to 99, in ascending order within each commodity; leave blank if not applicable) | | | | | | | | | | | | | | | |
| 5 | E: | Process number(01 to 99, in ascending order within each commodity) | | | | | | | | | | | | | | | |
| 6 | F: | Manufacturing capacity of base period (non-negative, enter "-1" for no capacity constraint) | | | | | | | | | | | | | | | |
| 7 | G: | Capacity depreciation rate | | | | | | | | | | | | | | | |
| 8 | H: | Cost of new capacity in common currency (>0) | | | | | | | | | | | | | | | |
| 9 | I: | First expansion parameter | | | | | | | | | | | | | | | |
| 10 | J: | Second expansion parameter | | | | | | | | | | | | | | | |
| 11 | K: | Third expansion parameter | | | | | | | | | | | | | | | |
| 12 | L: | Fourth expansion parameter | | | | | | | | | | | | | | | |
| 13 | M: | Manufacturing capacity one period before the base period | | | | | | | | | | | | | | | |
| 14 | N: | q ratio in period before the base period (non-negative, enter "-1.00" if not available) | | | | | | | | | | | | | | | |
| 15 | O: | Ratio of overtime capacity to regular capacity | | | | | | | | | | | | | | | |
| 16 | a0 | 83 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 17 | a0 | 84 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 18 | a0 | 85 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 19 | a0 | 88 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 20 | a0 | 91 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 21 | a0 | 92 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 22 | a1 | 83 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 23 | a1 | 84 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 24 | a1 | 88 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 25 | a1 | 91 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 26 | a2 | 83 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 27 | a3 | 84 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |
| 28 | a4 | 83 | 10 | -1 | 0.000 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0 | -1.00 | 0.0 | | | | |

**Figure 7: *Capacity2* worksheet with data on base-year capacity.**

## Recycling

The *RecyclingS* worksheet (Figure 8) contains the data that define the potential recovery of waste paper from consumed paper and paperboard. All parameters in Column H should be non-negative. For each paper type, this sheet specifies the potential recovery rate of waste paper in the base year. Within that range, supply of waste paper responds to price with the elasticity defined in the *Supply* worksheet (Figure 3). Absence of a record implies no constraint on recovery rate.

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** RECYCLING (SUPPLY) ****** | | | | | | | | | | | | |
| 3 | A: | Region number (01 to 99, in ascending order) | | | | | | | | | | | |
| 4 | C: | Recovered waste number (01 to 99, in ascending order within each region) | | | | | | | | | | | |
| 5 | E: | Consumed Commodity number (01 to 99, in ascending order within each recovered waste) | | | | | | | | | | | |
| 6 | F: | Fraction of the consumption in all regions which is consumed in this region (<1). | | | | | | | | | | | |
| 7 | G: | Minimum fraction of recovered waste from consumed commodity | | | | | | | | | | | |
| 8 | H: | Maximum fraction of recovered waste from consumed commodity (non-negative) | | | | | | | | | | | |
| 10 | a0 | | 90 | | 91 | 1.00 | 0.00 | 0.75 | | | | | |
| 11 | a0 | | 90 | | 92 | 1.00 | 0.00 | 0.75 | | | | | |
| 12 | a0 | | 90 | | 93 | 1.00 | 0.00 | 0.75 | | | | | |
| 13 | a1 | | 90 | | 91 | 1.00 | 0.00 | 0.75 | | | | | |
| 14 | a1 | | 90 | | 92 | 1.00 | 0.00 | 0.75 | | | | | |
| 15 | a1 | | 90 | | 93 | 1.00 | 0.00 | 0.75 | | | | | |
| 16 | a2 | | 90 | | 91 | 1.00 | 0.00 | 0.75 | | | | | |
| 17 | a2 | | 90 | | 92 | 1.00 | 0.00 | 0.75 | | | | | |
| 18 | a2 | | 90 | | 93 | 1.00 | 0.00 | 0.75 | | | | | |

**Figure 8: *RecyclingS* worksheet with data on waste paper recovery.**

## Transportation

The *Transportation* worksheet (Figure 9) contains data on the direction and quantity of international trade, freight costs, *ad-valorem* tariff rates, and trade inertia. In the GFPM all countries export to, and import from, the World market (region zz). Trade flows between countries can be added to the GFPM, as for example in Turner et al. (2001). Buongiorno and Zhu (2012) describes how to add bilateral trade flows to the *Transportation* worksheet.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** TRANSPORTATION COST AND TAX ****** | | | | | | | | | | | | | | |
| 3 | A: | Origin region number (01 to 99) | | | | | | | | | | | | | |
| 4 | C: | Destination region number (01 to 99, in ascending order within each origin) | | | | | | | | | | | | | |
| 5 | E: | Commodity number (01 to 99, in ascending order within each origin-destination) | | | | | | | | | | | | | |
| 6 | F: | Freight cost of shipping one unit of commodity from origin to destination | | | | | | | | | | | | | |
| 7 | G: | Import ad-valorem tax rate | | | | | | | | | | | | | |
| 8 | H: | Export ad-valorem tax rate | | | | | | | | | | | | | |
| 9 | I: | Base period quantity shipped from origin region to destination region | | | | | | | | | | | | | |
| 10 | J: | Mean elasticity of trade with respect to GDP (>=0; 0 for fixed trade, no trade, or free trade) | | | | | | | | | | | | | |
| 11 | K: | Trade inertia bounds as fraction of trade (>= 0; 0 for fixed trade; -1 for no trade; 1 for free trade) | | | | | | | | | | | | | |
| 12 | L: | Base period price of commodity in exporting country | | | | | | | | | | | | | |
| 13 | M: | Trade elasticity of transport cost, >=0, enter 0.00 for constant transport cost | | | | | | | | | | | | | |
| 15 | a0 | | zz | | 80 | 0 | 0.00 | 0.00 | 1 | 0 | 0.005 | 41 | 0.00 | | |
| 16 | a0 | | zz | | 81 | 0.00 | 0.000 | 0.00 | 1 | 0 | 0.005 | 80 | 0.00 | | |
| 17 | a0 | | zz | | 83 | 0.00 | 0.000 | 0.00 | 1 | 0 | 0.005 | 233 | 0.00 | | |
| 18 | a0 | | zz | | 90 | 0.00 | 0.000 | 0.00 | 7 | 0 | 0.005 | 123 | 0.00 | | |
| 19 | a0 | | zz | | 92 | 0.00 | 0.000 | 0.00 | 2 | 0 | 0.005 | 857 | 0.00 | | |
| 20 | a0 | | zz | | 93 | 0.00 | 0.000 | 0.00 | 1 | 0 | 0.005 | 805 | 0.00 | | |
| 21 | a1 | | zz | | 80 | 0 | 0.00 | 0.00 | 1 | 0 | 0.005 | 41 | 0.00 | | |
| 22 | zz | | r9 | | 92 | 51 | 0.13 | 0.00 | 23 | 0 | 0.005 | 857 | 0.00 | | |
| 23 | zz | | r9 | | 93 | 48 | 0.08 | 0.00 | 13 | 0 | 0.005 | 805 | 0.00 | | |
| 24 | zz | | zy | | 80 | 0 | 0.00 | 0.00 | 760 | 0 | 0 | 0 | 0 | | |
| 25 | zz | | zy | | 83 | 0 | 0.00 | 0.00 | 4071 | 0 | 0 | 0 | 0 | | |
| 26 | zz | | zy | | 84 | 0 | 0.00 | 0.00 | 1577 | 0 | 0 | 0 | 0 | | |
| 27 | zz | | zy | | 85 | 0 | 0.00 | 0.00 | 750 | 0 | 0 | 0 | 0 | | |
| 28 | zz | | zy | | 91 | 0 | 0.00 | 0.00 | 56 | 0 | 0 | 0 | 0 | | |
| 29 | zz | | zy | | 92 | 0 | 0.00 | 0.00 | 2148 | 0 | 0 | 0 | 0 | | |

**Figure 9: *Transportation* worksheet with data on transportation costs and tax rates.**

In calculating the base year solution, the trade inertia bounds in column K determine by how much trade can vary relative to the observed data in the base year.

Setting column K to 0 fixes imports and exports at their base year quantity in column I[4].

Setting column K to 1 removes the bounds on trade, allowing free trade. In a well-calibrated model this setting gives a calculated net trade (exports minus imports) equal to the observed, although imports and exports may differ from the observed.

Setting column K to -1 forces imports or exports to zero (this setting is mainly used to simulate trade-ban policy and is usually applied to one or a few regions to enforce zero trade for these regions and commodities).

# 4 Exogenous Change Data

The *ExogChange* worksheet (Figure 10) contains data that define the exogenous changes in demand, supply, etc., from year-to-year. Thus, the *ExogChange* worksheet is not needed when running the model for the base year only.

The *ExogChange* data are organized by period. The first record of a period has the form PERIOD*ixj*, where *i* is a one-digit or two-digit period number, and *j* is a one-digit or two-digit period length in years. For example PERIOD10x5 means that the following data refer to period 10, and that the length of period 10 and of every period up to the next PERIOD record is 5 years. This allows for a fine time scale at the beginning of the projections, and a rougher scale later.

The record PERIOD1x1 is needed to run the model for one period only, even if there is no exogenous change in period 1. This achieves the same thing as choosing option 2) run base period in the main menu (Figure 12).

All data in *ExogChange* such as the rate of GDP growth or the change in amount of input per unit of output are **per year**. They are transformed internally into periodic changes based on the period length (see the Appendix).

If all periods' data do not fit on the *ExogChange* sheet, additional periods can be added in *ExogChange2*. Within each period, the *ExogChange* holds data pertaining to **annual** changes of:

- Demand (record type D)
- Supply (record type S)
- Forest parameters (record type F)
- Manufacturing costs (record type M)
- Input-output coefficients (record type P)
- Freight cost, tariff rates, and trade inertia (record type T)

*ExogChange* data only need to be specified for periods when there is an exogenous change. For periods where a change occurs, the changes must be specified for all the model parameters. If *ExogChange* data are not specified for a period the previous period's exogenous changes apply.

The entries in the *ExogChange* worksheet must agree with those in the *Demand*, *Supply*, *Manufacture*, *Capacity*, *Recycling*, and *Transportation* worksheets. Check this especially after

[4] If the prices for the world region, zz, are desired, set all the trade inertia bounds in column K to an arbitrary small number, such as 0.0001, else the world prices will be zero although the individual country prices will be correct.

re-calibrating the model, since the calibration procedure (Zhu et al. 2008) may change the records in the *Manufacture* worksheet.

### Changes of demand

In the GFPM2012, demand shifts according to the GDP growth rate, specified in column J of record type D of the *ExogChange* sheet. For example 0.05 means an increase in GDP of 5 percent per year.

### Changes of supply

To shift supply of wood, waste paper, or other fiber pulp exogenously, enter the rate of shift in column J of record type S. For example -0.03 means a decrease in supply of 3 percent per year at constant price. When supply is shifted exogenously in this way the data in columns K to N are irrelevant.

To shift wood supply endogenously, enter -1 in column J. This ties wood supply to forest area and forest stock. To shift forest area and stock changes exogenously, set their growth rates in columns K and L, for example 0.05 means an increase of 5 percent per year.

For endogenous changes of forest area and stock, set columns K and L to -1. In this case, an adjustment in the rate of growth of forest stock can be specified in column N, for example to simulate a reduction in forest stock due to exotic forest pests (Prestemon et al. 2006).

Upper bounds on wood, waste paper, and other fiber pulp supply can shift exogenously or endogenously. If column P in record type S contains -1 the bound shifts endogenously at the same rate as the rest of the supply curve, else it shifts exogenously at the annual rate in column P. Upper bounds on waste paper supply are endogenous and equal to the maximum feasible recovery of waste paper.

### Changes in forest parameters

You can change periodically the elasticity of forest growth rate with respect to forest stock per unit area, the effect of GDP per capita and of its square on forest area growth rate, and fraction of fuelwood that comes from forest. The specified values replace the previous ones. Enter 0 (zero) if there is no change for the first three kinds of parameters. For the fraction of fuelwood coming from forest, enter –1 if there is no change since 0 (zero) is a regular entry for this column meaning there is no fuelwood coming from forest for the corresponding country.

### Changes in manufacturing cost

The manufacturing cost can be changed periodically with the rate of change in column H of record type M. For example, -0.02 means an annual decrease in manufacturing cost of 2 percent per year.

## Changes in manufacturing and byproduct coefficients

To change manufacturing (input-output) coefficients, enter the change in column H of record type P. For example if the amount of roundwood per unit of sawnwood is 2.3 in period 1, enter -0.1 in the appropriate record to reduce it to 2.2 in period 2.

To change by-product coefficients (amount of secondary commodity per unit of primary commodity) periodically, enter the annual change in column H of record type B. For example, if the amount of fiber residue per unit of sawnwood is 0.75 in period 1, enter -0.01 in the appropriate record to reduce it to 0.74 in period 2.

As for other periodical changes in GFPM, the input is an annual change, and the periodical change is the annual change multiplied by the length of the period.

Check that the cumulative changes lead to plausible manufacturing and byproduct coefficients at the end of the projection (2030 in GFPM2012).

## Changes in trade

Use record type T column I to change the import *ad-valorem* tax rate. For example, enter –0.02 if the tariff rate was 7 percent to reduce it to 5 percent.

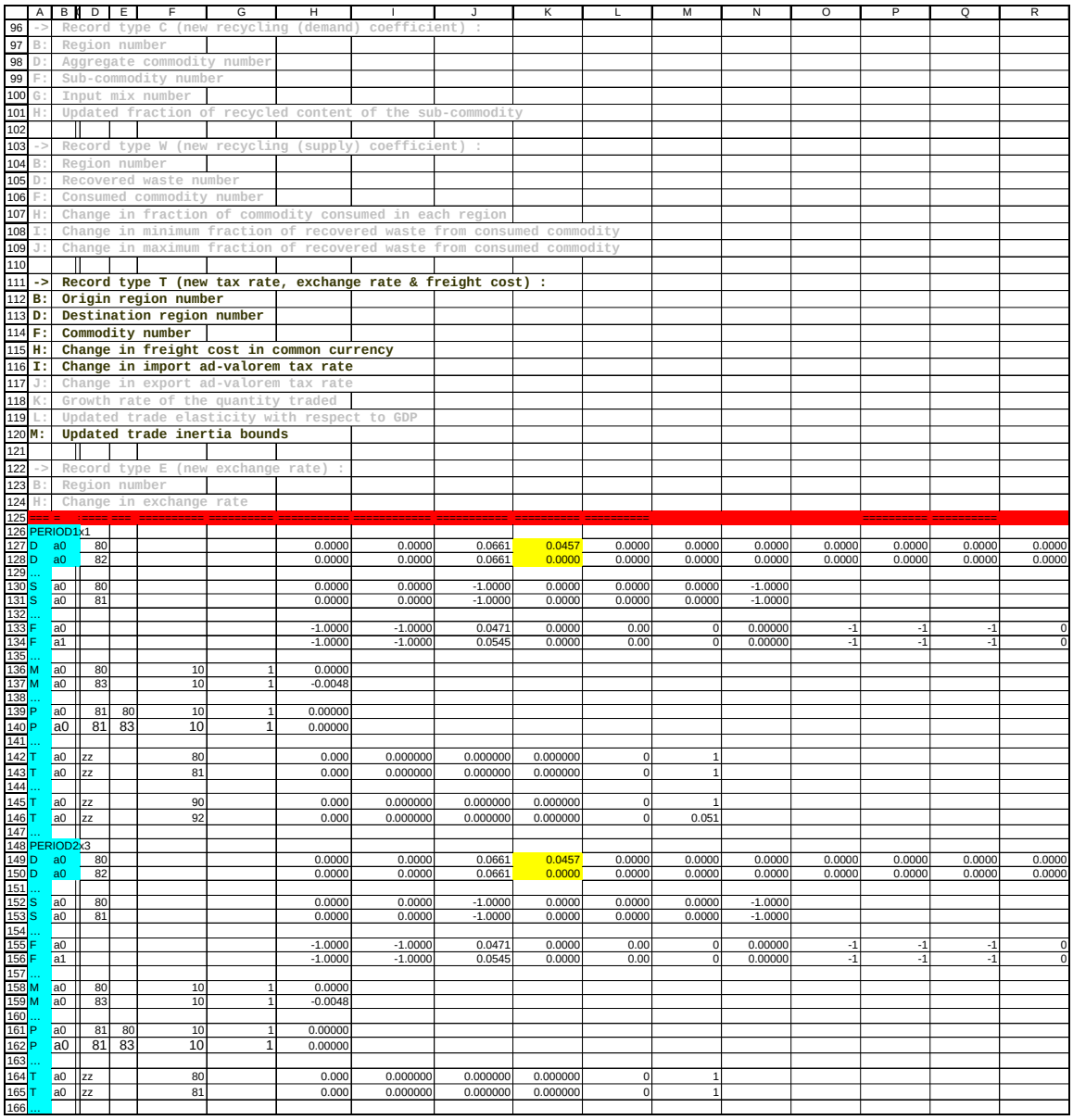
Change the trade inertia bounds with record type T column M. For example 0.05 means that the trade flow can increase or decrease by up to 5 percent per year. Enter 0 to maintain constant imports or exports. Enter 1 to remove the bounds on trade, allowing free trade. Enter -1 to force imports or exports to zero, simulating a trade ban.

| | A | B | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ****** EXOGENOUS CHANGE ****** | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | |
| 3 | A: | Data block name (the word "PERIOD" followed by the period number, "x", and the period length in years) | | | | | | | | | | | | | | |
| 4 | A: | Record type (twelve types of records are used: D,S,N,L,M,P,B,K,C,W,T,E) | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | |
| 6 | -> | Record type D (shift of the demand curve) : | | | | | | | | | | | | | | |
| 7 | B: | Region number | | | | | | | | | | | | | | |
| 8 | D: | Commodity number | | | | | | | | | | | | | | |
| 9 | H: | Updated price elasticity (< 0), enter 0.00 if unchanged | | | | | | | | | | | | | | |
| 10 | I: | Growth rate in value of currency | | | | | | | | | | | | | | |
| 11 | J: | Growth rate of the first demand shift variable | | | | | | | | | | | | | | |
| 12 | K: | Growth rate of the second demand shift variable | | | | | | | | | | | | | | |
| 13 | L: | Growth rate of the third demand shift variable | | | | | | | | | | | | | | |
| 14 | M: | Growth rate of the fourth demand shift variable | | | | | | | | | | | | | | |
| 15 | N: | Growth rate of the fifth demand shift variable | | | | | | | | | | | | | | |
| 16 | O: | Growth rate of the sixth demand shift variable | | | | | | | | | | | | | | |
| 17 | P: | Growth rate of the lower bound on the demanded commodity | | | | | | | | | | | | | | |
| 18 | Q: | Updated minimum fraction of recycled content | | | | | | | | | | | | | | |
| 19 | R: | Updated elasticity with respect to first demand shift variable, enter 0 if unchanged | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | |
| 21 | -> | Record type S (shift of the supply curve) : | | | | | | | | | | | | | | |
| 22 | B: | Region number | | | | | | | | | | | | | | |
| 23 | D: | Commodity number | | | | | | | | | | | | | | |
| 24 | H: | Updated price elasticity (> 0), enter 0.00 if unchanged | | | | | | | | | | | | | | |
| 25 | I: | Growth rate in value of currency | | | | | | | | | | | | | | |
| 26 | J: | Growth rate of the first supply shift variable (-1 for endogenous shifts) | | | | | | | | | | | | | | |
| 27 | K: | Growth rate of fourth supply shift variable | | | | | | | | | | | | | | |
| 28 | L: | Growth rate of the fifth supply shift variable | | | | | | | | | | | | | | |
| 29 | M: | Growth rate of the sixth supply shift variable | | | | | | | | | | | | | | |
| 30 | N: | Growth rate of the upper bound on the supplied commodity (-1 if endogenous) | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | |
| 32 | -> | Record type F (new forest data) : | | | | | | | | | | | | | | |
| 33 | B: | Region number | | | | | | | | | | | | | | |
| 34 | H: | Growth rate of forest stock on a given area, without harvest (-1 if endogenous) | | | | | | | | | | | | | | |
| 35 | I: | Growth rate of forest area (-1 if endogenous) | | | | | | | | | | | | | | |
| 36 | J: | Growth rate of GDP per capita | | | | | | | | | | | | | | |
| 37 | K: | Adjustment of endogenous growth rate of forest stock on a given area, without harvest (exogenous) | | | | | | | | | | | | | | |
| 38 | L: | Updated elasticity of forest growth rate with respect to forest stock per unit area, enter 0 if unchanged | | | | | | | | | | | | | | |
| 39 | M: | Updated effect of GDP per capita on forest area growth rate, enter 0 if unchanged | | | | | | | | | | | | | | |
| 40 | N: | Updated effect of squared GDP per capita on forest area growth rate, enter 0 if unchanged | | | | | | | | | | | | | | |
| 41 | O: | Updated fraction of fuelwood that comes from forest (-1 if unchanged) | | | | | | | | | | | | | | |
| 42 | P: | Updated ratio of inventory drain to harvest (-1 if unchanged) | | | | | | | | | | | | | | |
| 43 | Q: | Updated maximum ratio of inventory drain to growth of inventory without harvest (>0, 0 if unchanged, -1 if unlimited) | | | | | | | | | | | | | | |
| 44 | R: | Change in price of CO2, enter 0 if unchanged | | | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | | | | | |

**Figure 10: *ExogChange* worksheet with data on exogenous changes.**

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | -> | Record type N (new demand cross price elasticity) : | | | | | | | | | | | | | | | |
| 47 | B: | Region number | | | | | | | | | | | | | | | |
| 48 | D: | Commodity(1) number | | | | | | | | | | | | | | | |
| 49 | F: | Commodity(2) number | | | | | | | | | | | | | | | |
| 50 | H: | Updated elasticity of demand for commodity(1) with respect to the price of commodity(2) | | | | | | | | | | | | | | | |
| 51 | | | | | | | | | | | | | | | | | |
| 52 | -> | Record type L (new supply cross price elasticity) : | | | | | | | | | | | | | | | |
| 53 | B: | Region number | | | | | | | | | | | | | | | |
| 54 | D: | Commodity(1) number | | | | | | | | | | | | | | | |
| 55 | F: | Commodity(2) number | | | | | | | | | | | | | | | |
| 56 | H: | Updated elasticity of supply commodity(1) with respect to the price of commodity(2) | | | | | | | | | | | | | | | |
| 57 | | | | | | | | | | | | | | | | | |
| 58 | **->** | **Record type M (change of manufacturing cost) :** | | | | | | | | | | | | | | | |
| 59 | **B:** | **Region number** | | | | | | | | | | | | | | | |
| 60 | **D:** | **Primary commodity number** | | | | | | | | | | | | | | | |
| 61 | **E:** | **Secondary commodity number** | | | | | | | | | | | | | | | |
| 62 | **F:** | **Process number** | | | | | | | | | | | | | | | |
| 63 | **G:** | **Input mix number** | | | | | | | | | | | | | | | |
| 64 | **H:** | **Growth rate of real net manufacturing cost in domestic currency** | | | | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | | | | | | |
| 66 | **->** | **Record type P (new manufacturing coefficients) :** | | | | | | | | | | | | | | | |
| 67 | **B:** | **Region number** | | | | | | | | | | | | | | | |
| 68 | **D:** | **Input commodity number** | | | | | | | | | | | | | | | |
| 69 | **E:** | **Output commodity number** | | | | | | | | | | | | | | | |
| 70 | **F:** | **Process number** | | | | | | | | | | | | | | | |
| 71 | **G:** | **Input mix number** | | | | | | | | | | | | | | | |
| 72 | **H:** | **Change in amount of input per unit of output** | | | | | | | | | | | | | | | |
| 73 | | | | | | | | | | | | | | | | | |
| 74 | -> | Record type B (new by-product coefficients) : | | | | | | | | | | | | | | | |
| 75 | B: | Region number | | | | | | | | | | | | | | | |
| 76 | D: | Primary commodity number | | | | | | | | | | | | | | | |
| 77 | E: | Secondary commodity number | | | | | | | | | | | | | | | |
| 78 | F: | Process number | | | | | | | | | | | | | | | |
| 79 | G: | Input mix number | | | | | | | | | | | | | | | |
| 80 | H: | Updated amount of secondary per unit of primary | | | | | | | | | | | | | | | |
| 81 | | | | | | | | | | | | | | | | | |
| 82 | -> | Record type K (new capacity, depreciation rate, and cost of capacity) : | | | | | | | | | | | | | | | |
| 83 | B: | Region number | | | | | | | | | | | | | | | |
| 84 | D: | Commodity number | | | | | | | | | | | | | | | |
| 85 | E: | Overtime process number | | | | | | | | | | | | | | | |
| 86 | F: | Process number | | | | | | | | | | | | | | | |
| 87 | H: | Updated manufacturing capacity, enter " -1.00" if unchanged | | | | | | | | | | | | | | | |
| 88 | I: | Updated depreciation rate, enter 0.00 if unchanged | | | | | | | | | | | | | | | |
| 89 | J: | Updated capacity cost (>0), enter 0.00 if unchanged | | | | | | | | | | | | | | | |
| 90 | K: | Updated first expansion parameter, enter 0.00 if unchanged | | | | | | | | | | | | | | | |
| 91 | L: | Updated second expansion parameter, enter 0.00 if unchanged | | | | | | | | | | | | | | | |
| 92 | M: | Updated third expansion parameter, enter 0.00 if unchanged | | | | | | | | | | | | | | | |
| 93 | N: | Updated fourth expansion parameter, enter 0.00 if unchanged | | | | | | | | | | | | | | | |
| 94 | O: | Updated ratio of overtime capacity to regular capacity, enter 0.00 if unchanged | | | | | | | | | | | | | | | |
| 95 | | | | | | | | | | | | | | | | | |

**Figure 10 (contd): *ExogChange* worksheet with data on exogenous changes.**



| | A | B | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 96 | -> | Record type C (new recycling (demand) coefficient) : | | | | | | | | | | | | | | | |
| 97 | B: | Region number | | | | | | | | | | | | | | | |
| 98 | D: | Aggregate commodity number | | | | | | | | | | | | | | | |
| 99 | F: | Sub-commodity number | | | | | | | | | | | | | | | |
| 100 | G: | Input mix number | | | | | | | | | | | | | | | |
| 101 | H: | Updated fraction of recycled content of the sub-commodity | | | | | | | | | | | | | | | |
| 102 | | | | | | | | | | | | | | | | | |
| 103 | -> | Record type W (new recycling (supply) coefficient) : | | | | | | | | | | | | | | | |
| 104 | B: | Region number | | | | | | | | | | | | | | | |
| 105 | D: | Recovered waste number | | | | | | | | | | | | | | | |
| 106 | F: | Consumed commodity number | | | | | | | | | | | | | | | |
| 107 | H: | Change in fraction of commodity consumed in each region | | | | | | | | | | | | | | | |
| 108 | I: | Change in minimum fraction of recovered waste from consumed commodity | | | | | | | | | | | | | | | |
| 109 | J: | Change in maximum fraction of recovered waste from consumed commodity | | | | | | | | | | | | | | | |
| 110 | | | | | | | | | | | | | | | | | |
| 111 | -> | **Record type T (new tax rate, exchange rate & freight cost) :** | | | | | | | | | | | | | | | |
| 112 | B: | **Origin region number** | | | | | | | | | | | | | | | |
| 113 | D: | **Destination region number** | | | | | | | | | | | | | | | |
| 114 | F: | **Commodity number** | | | | | | | | | | | | | | | |
| 115 | H: | **Change in freight cost in common currency** | | | | | | | | | | | | | | | |
| 116 | I: | **Change in import ad-valorem tax rate** | | | | | | | | | | | | | | | |
| 117 | J: | Change in export ad-valorem tax rate | | | | | | | | | | | | | | | |
| 118 | K: | Growth rate of the quantity traded | | | | | | | | | | | | | | | |
| 119 | L: | Updated trade elasticity with respect to GDP | | | | | | | | | | | | | | | |
| 120 | M: | **Updated trade inertia bounds** | | | | | | | | | | | | | | | |
| 121 | | | | | | | | | | | | | | | | | |
| 122 | -> | Record type E (new exchange rate) : | | | | | | | | | | | | | | | |
| 123 | B: | Region number | | | | | | | | | | | | | | | |
| 124 | H: | Change in exchange rate | | | | | | | | | | | | | | | |
| 125 | == = | ==== === ========== ========== ========== ========== ========== ========== ========== | | | | | | | | | | | | | ========== ========== | | |
| 126 | PERIOD1x1 | | | | | | | | | | | | | | | | |
| 127 | D | a0 | 80 | | | | 0.0000 | 0.0000 | 0.0661 | 0.0457 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 128 | D | a0 | 82 | | | | 0.0000 | 0.0000 | 0.0661 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 129 | ... | | | | | | | | | | | | | | | | |
| 130 | S | a0 | 80 | | | | 0.0000 | 0.0000 | -1.0000 | 0.0000 | 0.0000 | 0.0000 | -1.0000 | | | | |
| 131 | S | a0 | 81 | | | | 0.0000 | 0.0000 | -1.0000 | 0.0000 | 0.0000 | 0.0000 | -1.0000 | | | | |
| 132 | ... | | | | | | | | | | | | | | | | |
| 133 | F | a0 | | | | | -1.0000 | -1.0000 | 0.0471 | 0.0000 | 0.00 | 0 | 0.00000 | -1 | -1 | -1 | 0 |
| 134 | F | a1 | | | | | -1.0000 | -1.0000 | 0.0545 | 0.0000 | 0.00 | 0 | 0.00000 | -1 | -1 | -1 | 0 |
| 135 | ... | | | | | | | | | | | | | | | | |
| 136 | M | a0 | 80 | | 10 | 1 | 0.0000 | | | | | | | | | | |
| 137 | M | a0 | 83 | | 10 | 1 | -0.0048 | | | | | | | | | | |
| 138 | ... | | | | | | | | | | | | | | | | |
| 139 | P | a0 | 81 | 80 | 10 | 1 | 0.00000 | | | | | | | | | | |
| 140 | P | a0 | 81 | 83 | 10 | 1 | 0.00000 | | | | | | | | | | |
| 141 | ... | | | | | | | | | | | | | | | | |
| 142 | T | a0 | zz | | 80 | | 0.000 | 0.000000 | 0.000000 | 0.000000 | 0 | 1 | | | | | |
| 143 | T | a0 | zz | | 81 | | 0.000 | 0.000000 | 0.000000 | 0.000000 | 0 | 1 | | | | | |
| 144 | ... | | | | | | | | | | | | | | | | |
| 145 | T | a0 | zz | | 90 | | 0.000 | 0.000000 | 0.000000 | 0.000000 | 0 | 1 | | | | | |
| 146 | T | a0 | zz | | 92 | | 0.000 | 0.000000 | 0.000000 | 0.000000 | 0 | 0.051 | | | | | |
| 147 | ... | | | | | | | | | | | | | | | | |
| 148 | PERIOD2x3 | | | | | | | | | | | | | | | | |
| 149 | D | a0 | 80 | | | | 0.0000 | 0.0000 | 0.0661 | 0.0457 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 150 | D | a0 | 82 | | | | 0.0000 | 0.0000 | 0.0661 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 151 | ... | | | | | | | | | | | | | | | | |
| 152 | S | a0 | 80 | | | | 0.0000 | 0.0000 | -1.0000 | 0.0000 | 0.0000 | 0.0000 | -1.0000 | | | | |
| 153 | S | a0 | 81 | | | | 0.0000 | 0.0000 | -1.0000 | 0.0000 | 0.0000 | 0.0000 | -1.0000 | | | | |
| 154 | ... | | | | | | | | | | | | | | | | |
| 155 | F | a0 | | | | | -1.0000 | -1.0000 | 0.0471 | 0.0000 | 0.00 | 0 | 0.00000 | -1 | -1 | -1 | 0 |
| 156 | F | a1 | | | | | -1.0000 | -1.0000 | 0.0545 | 0.0000 | 0.00 | 0 | 0.00000 | -1 | -1 | -1 | 0 |
| 157 | ... | | | | | | | | | | | | | | | | |
| 158 | M | a0 | 80 | | 10 | 1 | 0.0000 | | | | | | | | | | |
| 159 | M | a0 | 83 | | 10 | 1 | -0.0048 | | | | | | | | | | |
| 160 | ... | | | | | | | | | | | | | | | | |
| 161 | P | a0 | 81 | 80 | 10 | 1 | 0.00000 | | | | | | | | | | |
| 162 | P | a0 | 81 | 83 | 10 | 1 | 0.00000 | | | | | | | | | | |
| 163 | ... | | | | | | | | | | | | | | | | |
| 164 | T | a0 | zz | | 80 | | 0.000 | 0.000000 | 0.000000 | 0.000000 | 0 | 1 | | | | | |
| 165 | T | a0 | zz | | 81 | | 0.000 | 0.000000 | 0.000000 | 0.000000 | 0 | 1 | | | | | |
| 166 | ... | | | | | | | | | | | | | | | | |

**Figure 10 (end): *ExogChange* worksheet with data on exogenous changes.**

## 5 Running the GFPM

Before launching the GFPM, close any open Excel file, then, go to C:\GFPM and double-click on GFPM.BAT. This brings up the welcome screen (Figure 11).

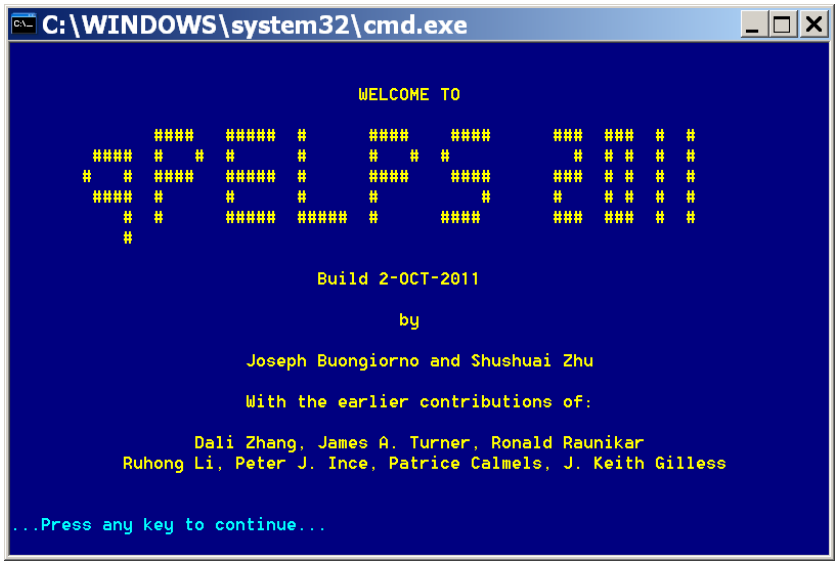



**Figure 11: The GFPM welcome screen.**

Pressing any key will bring up the GFPM main menu (Figure 12).

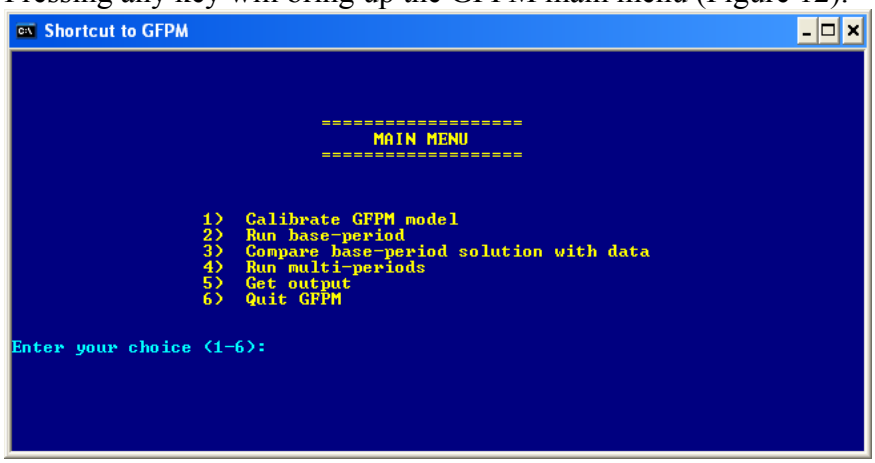



**Figure 12: The main menu of the GFPM.**

Users who want to run the model with the pre-calibrated data in C:\GFPM\WORLD.XLS can skip main menu options 1),2) and 3), and go directly to option 4).

MAIN MENU option **1) Calibrate GFPM model** brings up the Calibrate GFPM model menu (Figure 13). Its options are described in full in "Calibrating and Updating the GFPM 2009" (Zhu et al. 2008). You need not recalibrate the model if you use the world.xls file provided with GFPM2012.

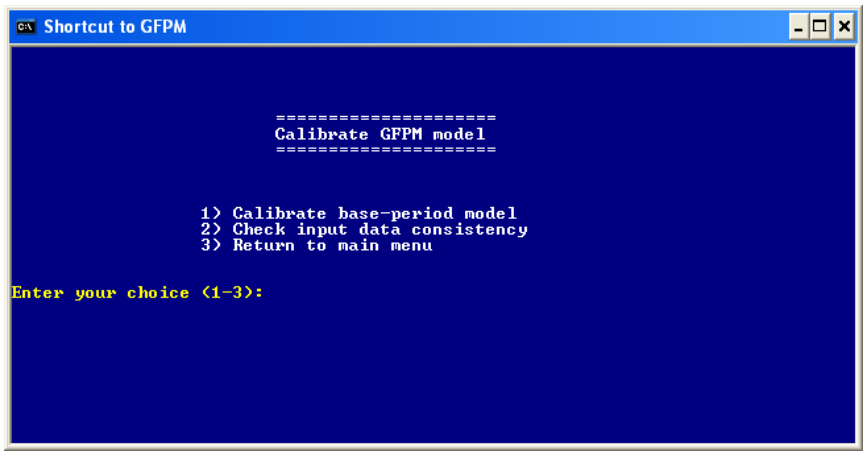



**Figure 13: The Calibrate GFPM model menu of the GFPM**

**1) Calibrate base-period model** calibrates the GFPM base year model with the FAO data. It produces WORLD.XLS. In GFPM 2012, the base year is 2009. The GFPM2012 was calibrated with smoothed data from 2008 to 2010 and a static calibration.

**2) Check input data consistency** verifies the following conditions for the base-year model. The results are in C:\GFPM\CHECKINPUTDATA.XLS. For a model calibrated with the static method (one year of data) the conditions should hold exactly. For a model calibrated with the dynamic method (several years of data) they should hold closely.

- Apparent consumption (production + import - export) equals final demand, or intermediate demand for input used by other products.
- Local price equals the world price plus the transport cost for net importers, or the world price for net exporters.
- Manufacturing cost equals the price of the output minus the cost of all inputs, given the price of inputs and the input-output coefficients.
- The waste paper used in paper manufacturing does not exceed the recovered waste paper, given the paper consumption and maximum recovery rate.

MAIN MENU option **2) Run base-period** produces the menu in Figure 14.

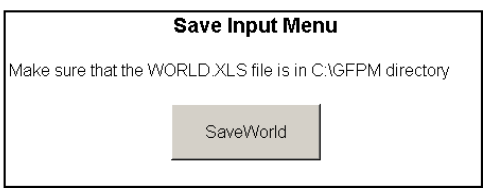


**Figure 14 The Save Input menu.**

Click on *SaveWorld* to prepare the input files and launch the base-year (2009) solution (Figure 15). Answer "yes" if the program asks whether you want to change existing files.

Solving the base year is a way to check if the model replicates the base-year data that are in the World file. This validation is best carried out with free trade (no bound on imports and exports). For a well calibrated model the predicted exports and imports may differ from the input data, but net trade (exports minus imports) should be close to the input data in the World file. The model solution should reproduce the input data almost exactly after a static calibration, and closely after a dynamic calibration. The base year may be run without data in the *ExogChange* worksheet since no projection beyond the base year is asked for.

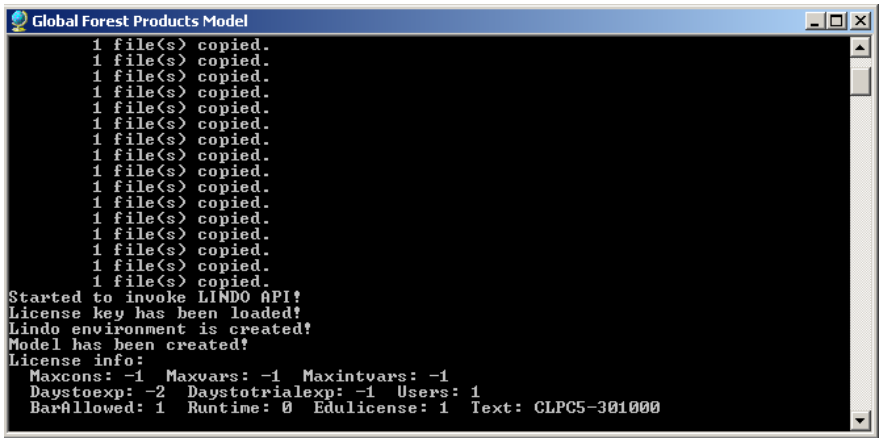



**Figure 15: GFPM base-year solution program running.**

To retrieve the base year solution, use MAIN MENU option **5) Get Output**, described below.

MAIN MENU option **3)Compare base-period solution with data** produces the Validate Baseyear menu (Figure 16) to compare the base-year calculated demand, supply, price, quantity manufactured, import, export, and net trade with the input data in the World file. The results of the comparisons are in VALIDATEBASEYEAR.XLS. The *Transportation* sheet shows the results for the trade flows specified in WORLD.XLS. The *TransAggregated* sheet shows the total imports and exports when a country exports or imports from several countries. In a well calibrated model and under free trade, the calculated net trade and prices should be the same as the input data in WORLD.XLS.

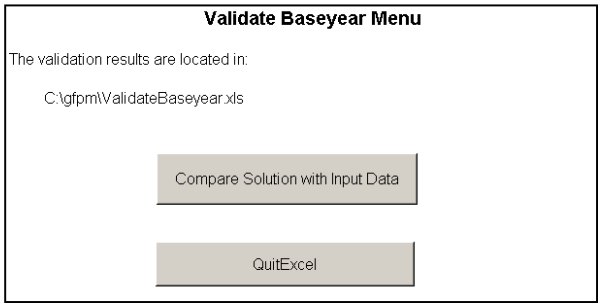



**Figure 16: The Validate Baseyear menu.**

MAIN MENU option **4) Run Multi-Periods** recalculates the base year (2009) solution and generates projections for future periods. Choosing this option leads to the prompt "**Enter number of projected periods:**" For example, enter "10" for a 10-period projection. The projected number of years depends on the length of each period in the *ExogChange* worksheet of the World.xls file. Entering the desired projection length produces the Save Input menu (Figure 14). Clicking on *SaveWorld* launches the multi-period projection.

The GFPM output options facilitate comparison of two scenarios: a "base" scenario and an "alternative" scenario. Typically, the scenarios could make different assumptions, such as GDP growth. You first run the base scenario and get its output. Then run the alternative scenario and get its output. Last, you can get changes between the two scenarios.

MAIN MENU option **5) Get Output** brings up the Get Output menu (Figure 17).

Option **1) For Base scenario** opens the sub menu[5] for the base scenario (Figure 18), with the following options:

*Detailed Output* retrieves the detailed projections for the base scenario. The results are in C:\GFPM\OUTPUT in files named *_base.xls, for example production_base.xls (Figure 19) contains data on predicted production.

You must run *Detailed Output* before *Trend Summary* or *Major Country Summary*. You cannot quit GFPM or Excel after running *Detailed Output* and run *Trend Summary* or *Major Country Summary* later. However, you can restart GFPM and run *Detailed Output* without redoing *Run multi-periods*.

*Trend Summary* retrieves results by region and product group. The results are in C:\GFPM\SUMMARY.XLS (Figures 20 and 21). The world prices are the shadow prices of the material balance constraints of the "World" region in the GFPM.

*Major Country Summary* gets projections for selected items (such as consumption), commodities (such as sawnwood), regions and countries. The results are in C:\GFPM\SUMMARYCHANGE.XLS. Each worksheet contains historical and projected data (Figure 22). By default, some items, commodities, and countries have already been selected in GFPM. You can select different items, commodities, countries and regions by marking "y" in the "Select" columns of the "Selection" sheet of SUMMARYCHANGE.XLS before running the *Major Country Summary* program.

[5] While opening the Get Output menu some harmless error messages may appear in the DOS box under the GFPM main menu. These error messages can be ignored.

Alternatively, you may select the main countries based on their base year quantities by entering the desired number of countries in the "Select" column for that region.

All aggregated regions are automatically selected even if they are not marked with "y" or no number is entered for them. If there is no "y" in the "Select" column, GFPM assumes users want to select the main countries for each region.

If there is no number of countries for a region, GFPM selects the top two to five countries based on their base year quantity (for Africa, top 3; North/Central America, top 3; South America, top 3, Asia, top 4; Oceania, top 2; Europe, top 5). To apply this default setting clear all y's and numbers in the "Select" column of the country/region section. Under the default setting prices are shown for the top producers.

The complete list of countries and regions in the Country section cannot be changed.

In the "Selection" sheet, an interface (Figure 23) allows users to view a particular projected trend and the historical data (from 1992 to 2007). Users can select the scenario (base and alternative), item (production, net trade, etc.), commodity (fuelwood, sawnwood, etc.), and country or aggregated region. These options are limited to the selections in the "Select" columns on this sheet. Clicking "View Selected Trend" shows both historical and projected trends.

*QuitExcel* returns to the Get Output sub menu.

Option **2) For Alternative scenario** opens a Get Output Menu analog to that of the base scenario.

*Detailed Output* retrieves the detailed GFPM projections for the alternative scenario. The results are in C:\GFPM\OUTPUT in files named *_.xls. For example imports.xls contains data on predicted imports. You must run *Detailed Output* before *Trend Summary* or *Major Country Summary*.

*Trend Summary* retrieves results by region and product groups. The results are in C:\GFPM\SUMMARY.XLS.

*Major Country Summary* gets projections for selected items, commodities, regions and countries analog to those of the base scenario.

Option **3) For changes between scenarios** opens a Get Output Menu with the following options (Figure 24):

*Detailed Changes* produces files of changes in all items, from AREA_CHANGE.XLS to VALUE_PROD_CHANGE.XLS. These files have the same format as the files in Base and Alternative scenarios. They contain detailed changes by country and region. The files, named *_change.xls, are in C:\GFPM\OUTPUT.

The interest rate specified in the Get Output Menu is used to calculate the differences in the total present value of production, consumption, trade, and value added (the corresponding file names start with "value_"). For example the file VALUE_CONS_CHANGE.XLS contains data and charts on the change in the net present value of value of consumption between the two scenarios (Figure 25).

*Major Country Changes* gives differences for selected items, commodities, regions and countries between base and alternative scenarios. The results are in

C:\GFPM\SUMMARYCHANGE.XLS. The *Diff* worksheet shows the differences in level. The *%Diff* worksheet shows the differences in percent.

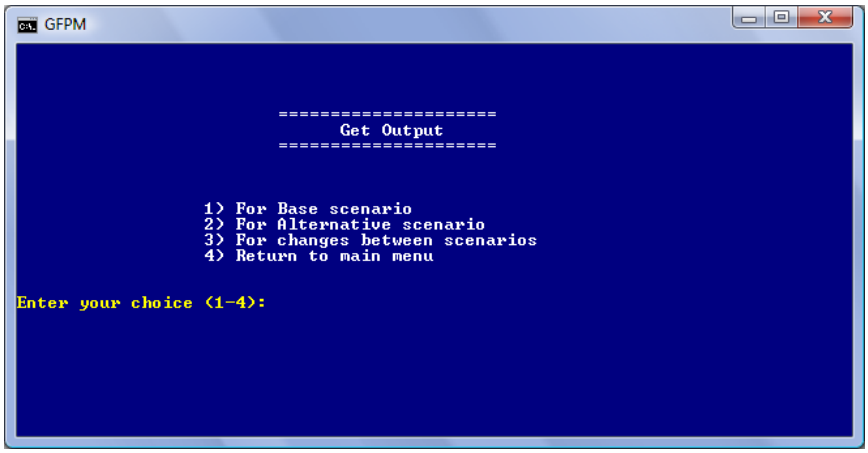



**Figure 17: The Get Output sub menu.**

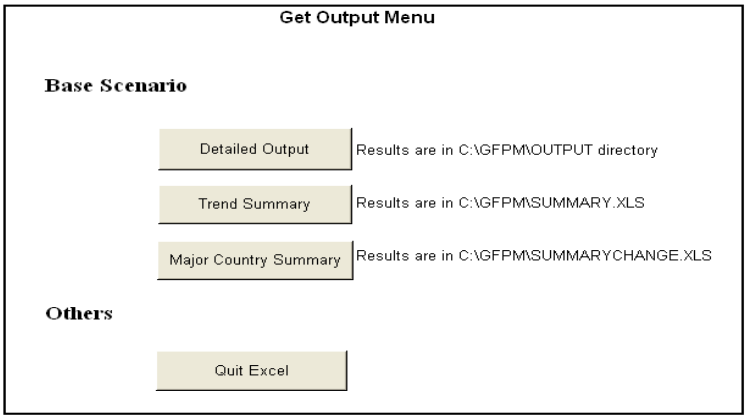



**Figure 18: The Get Output menu for Base Scenario.**

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **PRODUCTION OF TOTAL ROUNDWOOD** | | | | | | | |
| 2 | **Country** | **2006** | **2007** | **2010** | **2015** | **2020** | **2025** | **2030** |
| 3 | Algeria | 7817 | 8073.3 | 8903.2 | 10423.6 | 11981.9 | 13775.9 | 15865.4 |
| 4 | Angola | 4676 | 4778.3 | 5097.4 | 5650.2 | 6403.5 | 7265.4 | 8251.8 |
| 5 | Benin | 4063.4 | 4150.5 | 4422.7 | 4893.2 | 5541.9 | 6278.6 | 7115.3 |
| 6 | Botswana | 766 | 786.1 | 849.5 | 961.8 | 1112.7 | 1287.3 | 1489.4 |
| 7 | Burkina Faso | 13403.8 | 13723.8 | 14783.6 | 16662.8 | 19203 | 22117.8 | 25462.6 |
| 8 | Burundi | 8816.4 | 8994.8 | 9605.1 | 10676.8 | 12100.5 | 13662.9 | 15366 |
| 9 | Cameroon | 11103.2 | 11347.3 | 12096 | 13386 | 15115.7 | 17100.3 | 19417.2 |
| 10 | Cape Verde | 2 | 2.4 | 2.7 | 3.1 | 3.6 | 4.3 | 4.9 |
| 11 | Central African Republic | 2803.2 | 2864.8 | 3046.1 | 3348 | 3755.4 | 4246.2 | 4838.4 |
| 12 | Chad | 7247 | 7422.9 | 7994.1 | 9002.3 | 10361.4 | 11917.9 | 13700.9 |
| 13 | Congo, Republic of | 3208.4 | 3256.3 | 3384.3 | 3634.4 | 3930.5 | 4254.7 | 4633.8 |
| 14 | Côte d'Ivoire | 6056.7 | 6214 | 6707.3 | 7577.1 | 8730.7 | 10058.2 | 11612 |
| 15 | Djibouti | 0.2 | 0.5 | 0.6 | 0.6 | 0.7 | 0.8 | 0.9 |
| 16 | Egypt | 17168 | 17674 | 19375.1 | 22498 | 25698.6 | 29364.4 | 33590 |
| 17 | Equatorial Guinea | 1118.5 | 1121.9 | 1129.1 | 1142.3 | 1177.3 | 1228.5 | 1302.7 |
| 18 | Ethiopia | 97297.9 | 99818.3 | 107994.1 | 122479.7 | 141982.7 | 164344.7 | 190005.2 |
| 19 | Gabon | 3418.4 | 3482.3 | 3606.7 | 3770.2 | 4120 | 4616.7 | 5110.2 |
| 20 | Gambia | 655.8 | 674.3 | 733.5 | 838.8 | 980.7 | 1144.8 | 1334.8 |
| 21 | Ghana | 22076.4 | 22658.9 | 24628.5 | 28165.8 | 32748.1 | 37883.6 | 43743.9 |
| 22 | Guinea | 12285.9 | 12591.9 | 13572.5 | 15303.3 | 17656.1 | 20363.9 | 23479.8 |
| 23 | Guinea-Bissau | 598.1 | 611.1 | 650.5 | 718.3 | 812.6 | 921.7 | 1046.7 |
| 24 | Kenya | 22469.8 | 23131.3 | 25340.1 | 29306.6 | 34626.2 | 40878.3 | 48293.8 |
| 25 | Lesotho | 2053 | 2115.1 | 2310.7 | 2660 | 3134.9 | 3691.5 | 4344.4 |
| 26 | Liberia | 6494.5 | 6616 | 6984.3 | 7631.1 | 8591.4 | 9725.4 | 11052.7 |
| 27 | Libyan Arab Jamahiriya | 652 | 676.1 | 763.5 | 934.6 | 1126.2 | 1354.2 | 1628 |
| 28 | Madagascar | 11736.7 | 12026.1 | 12932.3 | 14526.4 | 16726.3 | 19268.4 | 22205 |
| 29 | Malawi | 5659 | 5792.4 | 6216 | 6957.4 | 7972.3 | 9137.8 | 10476.1 |
| 30 | Mali | 5460.5 | 5592.5 | 6018.3 | 6767.6 | 7783.1 | 8947.4 | 10281.3 |

**Figure 19: Example of *Detailed Output* table in production_base.xls.**

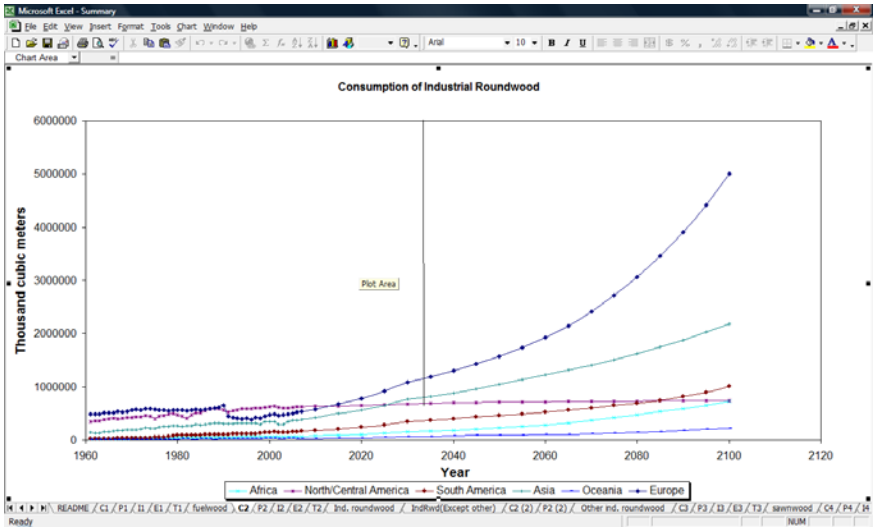



**Figure 20: Example of consumption chart in SUMMARY.XLS.**

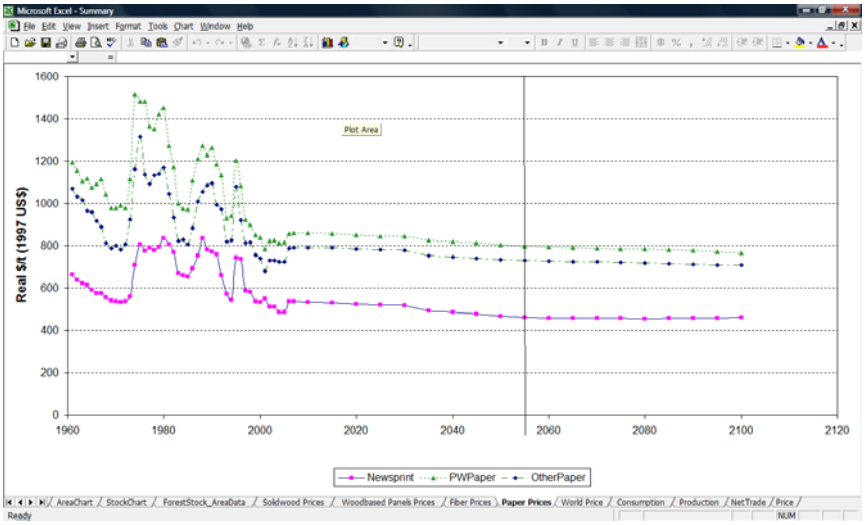



**Figure 21: Example of price chart in SUMMARY.XLS.**

Microsoft Excel - summaryChange

File Edit View Insert Format Tools Data Window Help

A2137 = OtherPaper

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | Table 52 Other paper and paperboard net trade by region and selected countries (thousand MT) | | | | | | | | | | | | | | | | | | |
| 1991 | | Actual | | | Projection | | | | | | | | | | | | | | |
| 1992 | | 1992 | 2006 | | 2006 | 2007 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | 2055 | 2060 | 2065 | 2070 |
| 1993 | **AFRICA** | **-517** | **-858** | | **-858** | **-880** | **-959** | **-1122** | **-1352** | **-1648** | **-2026** | **-2487** | **-3021** | **-3392** | **-3526** | **-3402** | **-3255** | **-3020** | **-2702** |
| 1994 | Egypt | -197 | -303 | | -303 | -318 | -370 | -471 | -595 | -747 | -935 | -1169 | -1455 | -1541 | -1418 | -1071 | -808 | -609 | -459 |
| 1995 | Nigeria | -22 | -106 | | -106 | -111 | -127 | -159 | -198 | -248 | -309 | -385 | -480 | -598 | -746 | -930 | -1159 | -1444 | -1799 |
| 1996 | South Afric | 40 | 391 | | 391 | 428 | 550 | 779 | 1040 | 1349 | 1721 | 2175 | 2733 | 3423 | 4278 | 5341 | 6663 | 8309 | 10359 |
| 1997 | **NORTH/CI** | **4181** | **2551** | | **2551** | **2845** | **3876** | **5777** | **7940** | **10476** | **13518** | **10686** | **8139** | **5763** | **3102** | **-619** | **-5729** | **-11977** | **-18500** |
| 1998 | Canada | 1135 | 804 | | 804 | 770 | 662 | 499 | 376 | 283 | 214 | 161 | 122 | 92 | 69 | 52 | 39 | 29 | 22 |
| 1999 | Mexico | -145 | -1227 | | -1227 | -1298 | -1530 | -1980 | -2522 | -3184 | -3999 | -5007 | -6258 | -7812 | -9745 | -12151 | -14852 | -17669 | -20678 |
| 2000 | United Sta | 3732 | 3876 | | 3876 | 4318 | 5835 | 8636 | 11789 | 15463 | 19853 | 18537 | 17690 | 17356 | 17155 | 16396 | 14581 | 11776 | 8878 |
| 2001 | **SOUTH AI** | **-51** | **-191** | | **-191** | **-256** | **-515** | **-976** | **-1390** | **-1861** | **-2415** | **-2944** | **-3579** | **-4233** | **-4998** | **-5874** | **-6768** | **-7756** | **-8890** |
| 2002 | Argentina | -163 | -215 | | -215 | -230 | -280 | -376 | -489 | -625 | -790 | -993 | -1244 | -1555 | -1942 | -2422 | -3021 | -3766 | -4694 |
| 2003 | Brazil | 494 | 508 | | 508 | 485 | 388 | 236 | 108 | -6 | -113 | -85 | -64 | -48 | -36 | -27 | -21 | -15 | -11 |
| 2004 | Chile | -61 | 16 | | 16 | 19 | 18 | 16 | 80 | 145 | 215 | 293 | 384 | 493 | 625 | 786 | 986 | 1232 | 1539 |
| 2005 | **ASIA** | **-2843** | **-6801** | | **-6801** | **-7442** | **-9560** | **-13603** | **-17996** | **-23210** | **-29509** | **-27381** | **-26253** | **-26483** | **-27707** | **-30035** | **-33451** | **-38030** | **-43938** |
| 2006 | China | -1626 | -3763 | | -3763 | -4217 | -5664 | -8334 | -11347 | -14866 | -19072 | -14377 | -10527 | -7548 | -5208 | -3325 | -1758 | -392 | 867 |
| 2007 | Indonesia | 75 | 213 | | 213 | 220 | 210 | 204 | 154 | 118 | 89 | 67 | 50 | 38 | 28 | 12 | -2 | -15 | -29 |
| 2008 | Japan | 302 | -280 | | -280 | -269 | -231 | -174 | -132 | -100 | -75 | -141 | -211 | -290 | -382 | -491 | -623 | -785 | -985 |
| 2009 | Korea, Re | 241 | 585 | | 585 | 560 | 481 | 186 | 140 | 105 | 79 | 60 | 45 | 34 | 25 | 19 | -7 | -34 | -61 |
| 2010 | Malaysia | -497 | -566 | | -566 | -606 | -741 | -998 | -1299 | -1661 | -2101 | -2642 | -3311 | -4139 | -5169 | -6449 | -8042 | -10026 | -12498 |
| 2011 | **OCEANIA** | **-34** | **383** | | **383** | **439** | **633** | **989** | **1383** | **1836** | **2374** | **3024** | **3817** | **4462** | **4996** | **5657** | **6476** | **6648** | **6753** |
| 2012 | Australia | 13 | 353 | | 353 | 390 | 514 | 744 | 1005 | 1311 | 1678 | 2124 | 2670 | 2994 | 3128 | 3290 | 3486 | 3680 | 3861 |
| 2013 | New Zeala | -43 | 79 | | 79 | 100 | 178 | 318 | 469 | 638 | 837 | 1074 | 1361 | 1714 | 2149 | 2687 | 3356 | 3387 | 3370 |
| 2014 | **EUROPE** | **420** | **5032** | | **5032** | **5410** | **6639** | **9051** | **11531** | **14523** | **18175** | **19217** | **21014** | **23998** | **28249** | **34389** | **42843** | **54250** | **67393** |
| 2015 | EU-25 | 5 | 4528 | | 4528 | 4828 | 5833 | 7796 | 9772 | 12164 | 15165 | 15700 | 16622 | 18461 | 21289 | 25603 | 32012 | 40891 | 51172 |
| 2016 | Austria | 431 | 476 | | 476 | 538 | 758 | 1174 | 1637 | 2171 | 2804 | 3568 | 4502 | 5653 | 7076 | 8841 | 11035 | 13764 | 15991 |
| 2017 | Finland | 2274 | 2754 | | 2754 | 2778 | 2894 | 3122 | 3481 | 4076 | 4891 | 5454 | 6073 | 6935 | 8100 | 9700 | 11854 | 14561 | 17977 |
| 2018 | France | -873 | 276 | | 276 | 374 | 607 | 1022 | 1216 | 1355 | 1502 | 1133 | 854 | 644 | 485 | 366 | 276 | 208 | 156 |
| 2019 | Germany | -1426 | 772 | | 772 | 738 | 634 | 478 | 360 | 272 | 205 | 80 | -100 | -331 | -613 | -915 | -1263 | -1687 | -2189 |
| 2020 | Italy | -864 | -669 | | -669 | -641 | -551 | -415 | -314 | -238 | -180 | -403 | -636 | -895 | -1191 | -1542 | -1965 | -2481 | -3116 |
| 2021 | Russian Fe | 146 | 367 | | 367 | 428 | 625 | 1011 | 1437 | 1925 | 2499 | 3191 | 4033 | 5069 | 6350 | 7937 | 9910 | 12363 | 15417 |
| 2022 | Spain | -487 | -686 | | -686 | -680 | -714 | -801 | -942 | -1122 | -1345 | -1817 | -2363 | -2809 | -3204 | -3541 | -3811 | -3991 | -4154 |
| 2023 | Sweden | 3302 | 4712 | | 4712 | 4800 | 5164 | 5905 | 6819 | 8054 | 9633 | 10873 | 12325 | 14147 | 16502 | 19736 | 24221 | 30189 | 37627 |
| 2024 | United Kin | -1806 | -1286 | | -1286 | -1230 | -1057 | -797 | -601 | -454 | -342 | -527 | -732 | -969 | -1250 | -1591 | -2006 | -2519 | -3153 |
| 2025 | **DEVELOP** | **5414** | **9925** | | **9925** | **10801** | **13747** | **19344** | **25439** | **32667** | **41401** | **41911** | **43934** | **47654** | **52819** | **59620** | **68063** | **78108** | **90085** |
| 2026 | **DEVELOP** | **-4258** | **-9809** | | **-9809** | **-10684** | **-13632** | **-19228** | **-25323** | **-32551** | **-41283** | **-41797** | **-43817** | **-47539** | **-52702** | **-59504** | **-67946** | **-77991** | **-89969** |

Base / Alternative / Diff / HistoricalPrices / AggregateTemplate / Scratch / BackupFixedCountryList

Ready Sum=17356.8 NUM

**Figure 22: Results for selected regions and countries, for base scenario, in SUMMARYCHANGE.XLS *Base* worksheet.**

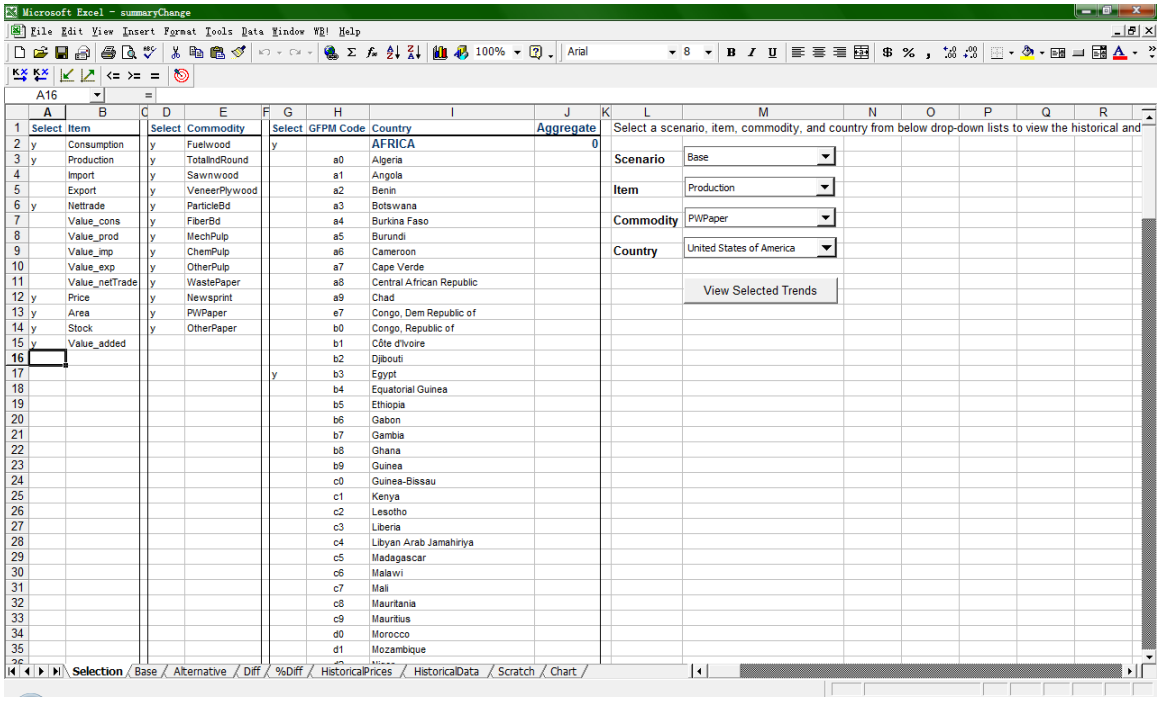



**Figure 23: Menu for view selected trends.**

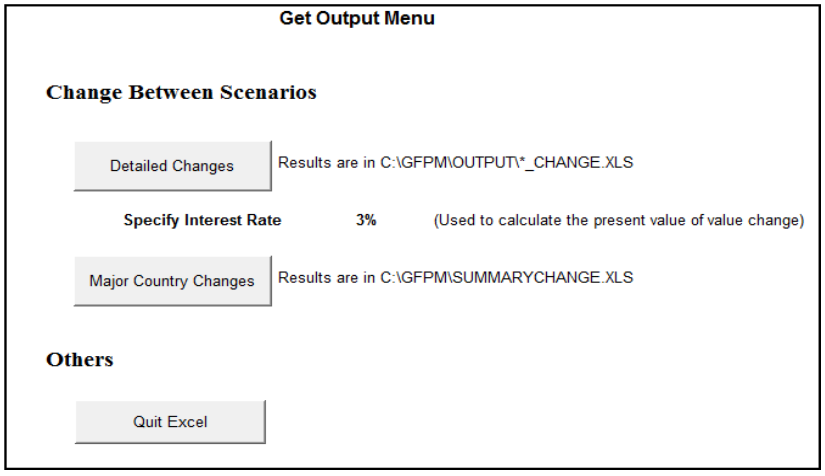



**Figure 24: Menu for changes between the base and alternative scenario.**

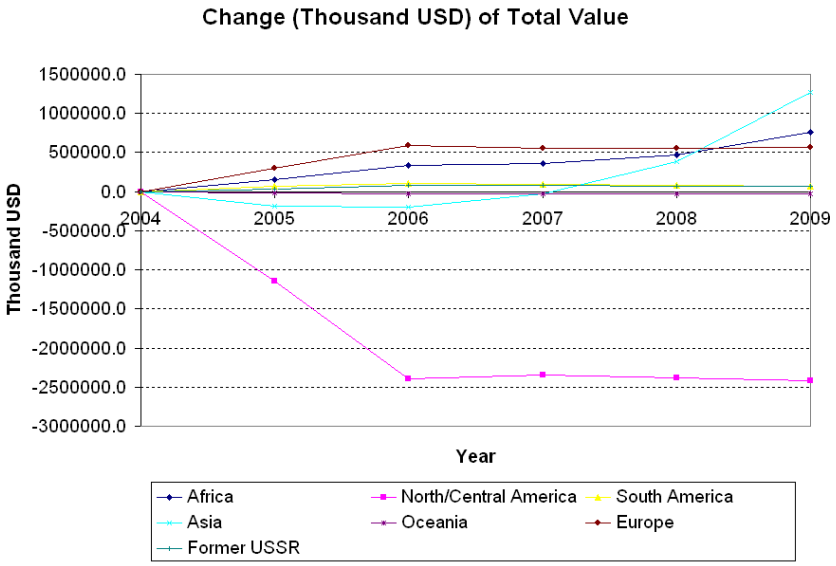



**Figure 25. Chart showing the difference in present value of forest product consumption between the base and alternative scenarios, in file Value_Cons_Change.xls**

# 6 Trouble Shooting GFPM Errors

## 6.1 Infeasibility

Infeasibility means that LINDOAPI cannot find a solution to the optimization problem described by the GFPM input data. When this occurs, GFPM pauses the batch file execution so users can review the LINDOAPI output on the screen. After that, users can close the GFPM program, or press any key to continue, but this will result in termination of the GFPM with several run-time errors.

For several applications of the GFPM, countries import from the world and export to the world without specification of countries of origin and destination. However, world import data are rarely equal to world export data in the base-year. To account for the difference, the GFPM has a dummy region, coded zy, which produces or demands the difference between world imports and exports. Infeasibility may then arise in the base year solution when trade is fixed to its input value. There should be no infeasibility with the free trade option. To ensure that the base year has a feasible solution, check that, for each commodity:

1) The imports of the dummy region are equal to its demand.
2) The exports of the dummy region are equal to its supply.
3) The total exports from all the countries and from the dummy region are equal to the total exports.

Theoretically, infeasibility should not occur during multi-period projections since GFPM allows trade flows to exceed the trade inertia bounds by imposing high cost penalties. However, when the bounds are too tight, the penalties could be so large that some prices explode, which results in numerical failure of the programs.

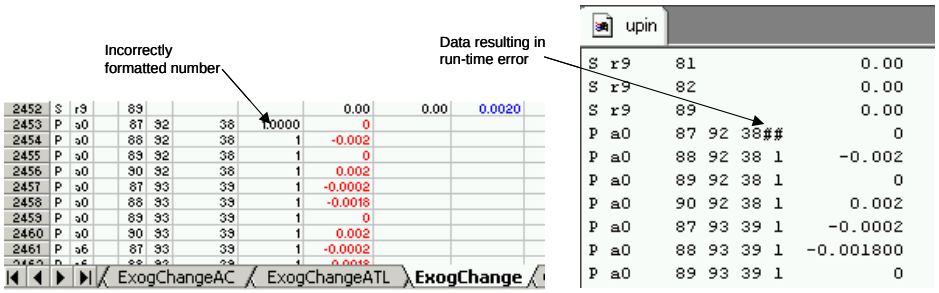
To avoid infeasibility during multi-period projections, check that the prices remain reasonable, else check the corresponding trade inertia parameters, demand growth rates, supply shift rates, and other exogenous parameters that may cause the undue price increase.

## 6.2 Run-time Error

Run-time errors are error messages generated by Pascal, one of the programming languages of the GFPM. Run-time errors cause the GFPM to terminate. Check the type of run-time error for the first error that occurs, because often an initial error will cause a chain of subsequent errors. One common run-time error is: **106 Invalid Numeric Formats.**

The format of the data for a variable or parameter differs from the format expected by the Pascal program. This error occurs when data in the WORLD.XLS worksheets have the wrong format or cells are erroneously empty. It is easiest to check for this kind of error in the QPELPS input files, such as UPIN.DAT (see Buongiorno et al. 2003, Chapter 12 for a description of these files).

For example, Figure 26 shows how entering a process number as "1.000" instead of "1" in the *ExogChange* worksheet leads to "##" in the file UPIN.DAT, causing a run-time error. In UPIN.DAT, users may enter some parameters calculated in other sheets by copying and pasting in *ExogChange* sheet, which may contain many digits after the decimal points. This could cause numbers in two columns to be clubbed together and results in invalid numbers in UPIN.DAT. To avoid this, users should make sure the column is wide enough or keep at most 5 or 6 digits




after the decimal points for all input parameters. This could be achieved by using the Excel "Decrease Decimal" menu button to format those cells.

**Figure 26. Incorrectly formatted data in the WORLD.XLS *ExogChange* worksheet and the corresponding data in UPIN.DAT resulting in a runtime error.**

In addition, each column of data in WORLD.XLS should be wide enough to show all the the digits of a particular number, to avoid clogging of data from adjacent columns when they contain long numbers.

# 7 References


Buongiorno, J., and S. Zhu. 2012. Calibrating and updating the Global Forest Products Model (GFPM version 2011). Staff paper #75, Department of Forest and Wildlife Ecology, University of Wisconsin, Madison. 29p.

Buongiorno, J., S. Zhu, D. Zhang, J.A. Turner, and J. Tomberlin. 2003. The Global Forest Products Model: Structure, Estimation and Applications. Academic Press, San Diego. 301 pp.

Prestemon, J.P., S. Zhu, J.A. Turner, J. Buongiorno, and R. Li. 2006. The forest product trade impacts of an invasive species: Modeling structure and intervention tradeoffs. *Agricultural and Resource Economics Review* 35(1): 128-143. http://www.treesearch.fs.fed.us/pubs/23572

Turner, J.A., J. Buongiorno, G.P. Horgan, and F.M. Maplesden. 2001. Liberalization of forest product trade and the New Zealand forest sector, 2000-2015: A global modelling approach. New Zealand Journal of Forestry Science 31(3): 320-338.


# 8 Appendix: GFPM Structure and Formulation

## SPATIAL GLOBAL EQUILIBRIUM

Objective Function

$$\max Z = \sum_i \sum_k \int_0^{D_{ik}} P_{ik}(D_{ik})dD_{ik} - \sum_i \sum_k \int_0^{S_{ik}} P_{ik}(S_{ik})dS_{ik} - \sum_i \sum_k \int_0^{Y_{ik}} m_{ik}(Y_{ik})dY_{ik} - \sum_i \sum_j \sum_k c_{ijk} T_{ijk} \quad [1]$$

where: $i,j$ = country, $k$ = product, $P$ = price in US dollars of constant value, $D$ = final product demand, $S$ = raw material supply, $Y$ = quantity manufactured, $m$ = manufacturing cost, $T$ = quantity transported, and $c$ = cost of transportation, including tariff. All variables refer to a specific year. In making predictions, the period between successive equilibria may be multiple years.

## End Product Demand

$$D_{ik} = D_{ik}^{*}(\frac{P_{ik}}{P_{ik,-1}})^{\delta_{ik}} \qquad [2]$$

where: $D^{*}$ = current demand at last period's price, $P_{-1}$ = last period's price, and $\delta$= price elasticity of demand.

As shown in the section on market dynamics, below, $D^{*}$ depends on last period's demand, and the growth of GDP in the country. In the base year, $D^{*}$ is equal to the observed base-year consumption, and $P_{-1}$ is equal to the observed base-year price.

## Primary Product Supply

$$S_{ik} = S_{ik}^{*}(\frac{P_{ik}}{P_{ik,-1}})^{\lambda_{ik}} \qquad [3]$$

where: $S^{*}$ = current supply at last period's price, and $\lambda$ = price elasticity of supply. As shown in the section on market dynamics, below, $S^{*}$ depend on last period's supply, and on exogenous or endogenous supply shifters. In the base year, $S^{*}$ is equal to the base-year supply, and $P_{-1}$ is equal to the observed base year price.

Total wood drain from the forest:

$$S_i = (S_{ir} + S_{in} + \theta_i S_{if})\mu_I \qquad [4]$$

$r$ = industrial roundwood,
$n$ = other industrial roundwood,
$f$ = fuelwood,
$0 \le \theta \le 1$ = fraction of fuelwood that comes from the forest,
$\mu \ge 1$ = ratio of drain to harvest.
$S_i \le I_i$
$I_i$ = forest stock.

Optional constraints may also limit the harvest to a fraction of the growth of forest stock (see "Allowable cut constraints", below).

## Material Balance

$$\sum_j T_{jik} + S_{ik} + Y_{ik} - D_{ik} - \sum_n a_{ikn} Y_{in} - \sum_j T_{ijk} = 0 \qquad \forall i,k \qquad [5]$$

where: $a_{ikn}$ = input of product $k$ per unit of product $n$.

In addition, by-products, which result from the production of a manufactured commodity satisfy the constraint:

$$Y_{il} - b_{ikl} Y_{ik} = 0 \qquad \forall i,k,l$$

where $b_{ikl}$ is the amount of by-product $l$ that can be recovered per unit of production of manufactured commodity $k$.

### Trade Inertia

$$T_{ijk}^{L} \le T_{ijk} \le T_{ijk}^{U} \qquad [6]$$

where the superscripts $L$ and $U$ refer to a lower bound, and upper bound, respectively.

### Prices

The shadow prices of the material balance constraints [5] give the market-clearing prices for each commodity and country.

### Manufacturing Cost

Manufacturing is represented by activity analysis, with input-output coefficients and a manufacturing cost. The manufacturing cost is the marginal cost of the inputs not recognized explicitly by the model (labor, energy, capital, etc.);

$$m = m_{ik}^{*} \left(\frac{Y_{ik}}{Y_{ik,-1}}\right)^{s_{ik}} \qquad [7]$$

where: $m^*$ = current manufacturing cost, at last period's output, and $s$= elasticity of manufacturing cost with respect to output.

As shown in the next section, $m^*$ depend on last period's manufacturing cost, and on the exogenous rate of change of manufacturing cost. In the base year, $m^*$ is equal to the observed base-year manufacturing cost and $Y_{ik,-1}$ is equal to the observed base-year quantity manufactured.

### Transport Cost

The transport cost per unit of volume for commodity $k$ from country $i$ to country $j$ in any given year is given by:

$$c_{ijk} = c_{ijk}^{*} \left(\frac{T_{ijk}}{T_{ijk,-1}}\right)^{\tau_{iijk}} \qquad [8]$$

Where: c*=current transport cost at last period's trade, and τ=elasticity of transport cost with respect to trade. As shown in the next section, c* depends on last period's transport cost, and on the exogenous changes of freight rates and taxes. In the base year, c* is computed as:

$$c_{ijk} = f_{ijk} + t_{jk}^{X}\left(P_{ik,-1}\right) + t_{jk}^{I}\left(f_{ijk} + P_{ik,-1}\right) \qquad [9]$$

where: $c$ = transport cost, per unit of volume, $f$ = freight cost, per unit of volume, $t^X$ =export tax, $t^I$ = import ad-valorem tariff, and $P_{-1}$ is equal to the observed base-year world export price.

## MARKET DYNAMICS[6]

All periodic exponential rates of change, $r_p$, are defined by the annual exponential rate of change, $r_a$, as:

$$r_p = (1 + r_a)^p - 1 \quad \text{where } p \text{ is the length of a period, in years.} \qquad [10]$$

All periodic linear changes, $\Delta v_p$ are defined by the corresponding annual linear change, $\Delta v_a$, as:

$$\Delta v_p = p \Delta v_a \qquad [11]$$

### Shifts of Demand

$$D^* = D_{-1}(1 + \alpha_y g_y + \alpha_0) \qquad [12]$$

$g_y$ = GDP periodic growth rate, $\alpha_y$= elasticity with respect to GDP, $\alpha_0$=periodic trend.

### Shifts of Supply

*Industrial roundwood and fuelwood:*

$$S^* = S_{-1}(1 + \beta_I g_I + \beta_a g_a) \text{ for } k=r, n, f \qquad [13]$$

where: $g_I$ = periodic rate of change of forest stock (endogenous, see below), $g_a$ = periodic rate of change of forest area, and $\beta$ = elasticity.

*Waste paper and other fiber pulp:*

$$S^* = S_{-1}(1 + \beta_y g_y) \qquad [14]$$

### Changes in forest area and forest stock

$$A = (1 + g_a) A_{-1} \qquad [15]$$

where: $A$ = forest area, and $g_a$ = periodic rate of forest area change based on the period length, $p$, equation [10] and the annual rate of forest area change, $g_{aa}$, defined by:

$$g_{aa} = \alpha_0 + \alpha_1 y' + \alpha_2 y'^2 \quad \text{for } y' <= y'^*, \text{ else } g_{aa} = 0 \qquad [16]$$

[6] Unless otherwise indicated, variables refer to one country, one commodity, and one year. Rates of change refer to a multi-year period.

Where, for each country, $\alpha_0$ is calibrated so that in the base year the observed $g_{aa}$ is equal to the $g_{aa}$ predicted by [16] given the income per capita $y'$.
$y'$= income per capita, predicted from:

$$y' = (1 + g_{y'})y'_{-1} \quad [17]$$

$y'^*$ is defined by $g_{aa} = \alpha_0 + \alpha_1 y'^* + \alpha_2 y'^{*2} = 0$ and $y'^* > -\alpha_1/2\alpha_2$ . [18]

Forest stock evolves over time according to a growth-drain equation:

$$I = I_{-1} + G_{-1} - pS_{-1} \quad [19]$$

Where $I$ is the forest stock at the beginning of the current period, $G_{-1} = (g_a + g_u + g_u^*)I_{-1}$ is the change of forest stock without harvest during the previous period, $g_u$= periodic rate of forest growth on a given area, without harvest, and $g_u$*=adjustment of periodic rate of forest growth on a given area, without harvest. The last is exogenous, for example to represent the effect of invasive species, or of climate change[7].

The periodic rate of forest growth, $g_u$, is based on the annual rate of forest growth, $g_{ua}$, defined by:

$$g_{ua} = \gamma_0 (\frac{I_{-1}}{A_{-1}})^{\sigma} \quad [20]$$

where $\sigma$ is negative, so that $g_{ua}$ decreases with stock per unit area. For each country, $\gamma_0$ is calibrated so that in the base year the observed $g_{ua}$ is equal to the $g_{ua}$ predicted by [20] given the stock per unit area, $I/A$.

The periodic rate of change of forest stock net of harvest, used in equation [13] is then:

$$g_I = \frac{I - I_{-1}}{I_{-1}} \quad [21]$$

## Changes in Manufacturing Coefficients and Costs

The input-output coefficients $a$ in equation [5], may change exogenously over time, for example to reflect increasing use of recycled paper in paper manufacturing:

$$a = a_{-1} + \Delta a \quad [22]$$

where $\Delta a$ = periodic change in input-output coefficient.

The manufacturing cost function shifts exogenously over time:

$$m^* = m_{-1}(1 + g_m) \quad [23]$$

---

[7] The forest stock $I$ is: $I_t = U_t A_t$ where $A_t$ is the area and $U_t$ is the stock per unit area (stock density). Without harvest, the stock annual ($p$=1) growth rate is $dI/I = dU/U + dA/A$ or $g_I = g_u + g_a$ . Thus, the level of stock, without harvest, changes according to $I_t = I_{t-1}(1 + g_I) = I_{t-1}(1 + g_u + g_a)$ . With a harvest $S_{t-1}$ from $t$-1 to $t$ this becomes $I_t = I_{t-1}(1 + g_u + g_a) - S_{t-1}$ . With the above notations $I_{t-1}(g_u + g_a) = G_{t-1}$ , the change in forest stock without harvest, which leads to equation [18] except for the additional exogenous change $g_u$*.

where $g_m$ = the exogenous rate of periodic change in manufacturing cost.

### Changes in transport cost

The transport cost function [8] shifts exogenously over time according to a recursion of equation [9]:

$$c^* = c_{-1} + \Delta f + t^x P_{-1} - t^x_{-1} P_{-2} + t^I (f + P_{-1}) - t^I_{-1} (f_{-1} + P_{-2})$$

with:

$$f = f_{-1} + \Delta f \ , \ t = t_{-1} + \Delta t \qquad [24]$$

where $\Delta f$ and $\Delta t$ are periodic changes in freight cost and taxes, respectively.

### Changes in Trade Inertia Bounds

$$T^L = T_{-1}(1-\varepsilon)^p$$

$$T^U = T_{-1}(1+\varepsilon)^p \qquad [25]$$

$\varepsilon$ = absolute value of maximum annual relative change in trade flow (exogenous).

## LINEAR APPROXIMATION OF DEMAND, SUPPLY, AND COST FUNCTIONS

*Demand and supply:*

For example, consider a demand equation such as [2]. Omitting the subscripts for region and product, the inverse demand equation in any given year is:

$$P = P_{-1}(\frac{D}{D^*})^{1/\sigma}$$

The linear approximation at ($P_{-1}$, $D^*$) is:

$P = a + bD$ ,

where:

if $\sigma \neq 0$ and $D^* \geq 1$, then $b = \frac{P_{-1}}{\sigma D^*}$, $a = P_{-1} - bD^*$,

else, by convention, if $\sigma \neq 0$ and $D^* < 1$, then $b = \frac{P_{-1}}{\sigma}$ and $a = P_{-1}$,

else, by convention, if $\sigma = 0$, then $b = 0$. and $a = P_{-1}$. [26]

The same method is used for the supply equations.

*Manufacturing and transport cost:*

For example, consider a manufacturing cost equation such as [7] for a given country, product and year:

$$m = m^*(\frac{Y}{Y_{-1}})^s$$

The linear approximation is:

$m = a + bY$,

where:

if $Y_{-1} \geq 1$, then $b = s\frac{m^*}{Y_{-1}}$ and $a = m^* - bY_{-1}$,

else, by convention, $b = 0$. and $a = P_{-1}$. [27]

The same method is used for the transport cost equation.

## TIMBER SUPPLY WITH CARBON MARKETS

The marginal cost of wood is the marginal cost of harvesting and local delivery represented above by equation [26], plus the opportunity cost per $m^3$ of not leaving the wood in the forest:

**Base year wood supply:**

$$P = a_0 + b_0 S + \varpi P_{c0} \quad [28]$$

Where if $S_{-1} \geq 1$ $b_0 = \frac{P_{-1}}{\sigma S_{-1}}$, $a_0 = P_{-1} - b_0 S_{-1}$, else $b_0 = \frac{P_{-1}}{\sigma}$ and $a_0 = P_{-1}$.

$\omega = CO_2$ content of wood (t/m3). $P_{c0}$= price of CO2 in base year ($/t).

With this wood supply the base year GFPM solution is $P_0$, $S_0$.

**Subsequent years' wood supply**

$S^*$= supply at price $P_0$ (i.e. after shift due to changes in stock, etc…)

$$P = a_1 + b_1 S + \varpi(P_{c1} - P_{c0}) \quad [29]$$

Where if $S^* \geq 1$ $b_1 = \frac{P_0}{\sigma S^*}$, $a_1 = P_0 - b_1 S^*$, else $b_1 = \frac{P_0}{\sigma}$ and $a_1 = P_0$.

$P_{c1}$= price of CO2 in period 1.

## ALLOWABLE CUT CONSTRAINTS

The optional allowable cut constraints specify that in any given year the total wood drain from the forest of a country must be less than a user-specified fraction of the current annual gross growth of the forest stock, i.e. the amount by which the forest stock would grow if there were no harvest.

The general form of the constraint is:

$$S \leq \max(aG / p, 0) \quad [30]$$

Where:

$S$ = total wood drain from the forest defined by equation [4],

$G$= periodic change of growing stock without harvest, with $G = (g_a + g_u + g_u^*)I_{-1}$ as in equation [19].
$a$=user-defined maximum ratio of inventory drain to the growth of growing stock.
In the base year $I_{-1}$ is set equal to the base-year level of growing stock.

## IMPLEMENTATION OF TRADE INERTIA BOUNDS

To avoid infeasibilities due to inconsistent bounds, the inertia constraints [6] are implemented as:

$$T_{ijk} + \Delta T_{ijk}^L \geq T_{ijk}^L$$
$$T_{ijk} - \Delta T_{ijk}^U \leq T_{ijk}^U \qquad [31]$$

where: $\Delta T^L$, $\Delta T^U$ = amount by which trade falls short of the lower bound, or exceeds the upper bound. These two variables appear in the objective function:

$$\max Z = ... - \sum_{i,j,k} W(\Delta T_{ijk}^L + \Delta T_{ijk}^U)... \qquad [32]$$

where $W$ is an arbitrarily large number.

**Table 1 Commodity codes in GFPM[8]**

| Code | Commodities | Units |
|---|---|---|
| 80 | Fuelwood and charcoal | $10^3$ $m^3$ |
| 81 | Industrial roundwood | $10^3$ $m^3$ |
| 82 | Other industrial roundwood | $10^3$ $m^3$ |
| 83 | Sawnwood | $10^3$ $m^3$ |
| 84 | Veneer and plywood | $10^3$ $m^3$ |
| 85 | Particleboard | $10^3$ $m^3$ |
| 86 | Fiberboard | $10^3$ $m^3$ |
| 87 | Mechanical wood pulp | $10^3$ t |
| 88 | Chemical and semi-chemical wood pulp | $10^3$ t |
| 89 | Other fiber pulp | $10^3$ t |
| 90 | Waste paper | $10^3$ t |
| 91 | Newsprint | $10^3$ t |
| 92 | Printing and writing paper | $10^3$ t |
| 93 | Other paper and paperboard | $10^3$ t |

[8] The listed commodities are default commodities in GFPM. To add/remove commodities, see Zhu et al. (2008).

## Table 2 Country codes in GFPM[9]

| Code | Country | Code | Country | Code | Country | Code | Country |
|---|---|---|---|---|---|---|---|
| | **AFRICA** | | **N/C AMERICA** | | **ASIA** | | **EUROPE** |
| A0 | Algeria | F0 | Bahamas | I5 | Afghanistan | N5 | Albania |
| A1 | Angola | F1 | Barbados | I6 | Bahrain | N6 | Austria |
| A2 | Benin | F2 | Belize | I7 | Bangladesh | N7 | Belgium |
| A3 | Botswana | F3 | Canada | I8 | Bhutan | N8 | Bosnia and Herzegovina |
| A4 | Burkina Faso | F4 | Saint Lucia | I9 | Brunei Darussalam | N9 | Bulgaria |
| A5 | Burundi | F5 | Costa Rica | J0 | Cambodia | O0 | Croatia |
| A6 | Cameroon | F6 | Cuba | J1 | China | O1 | Czech Republic |
| A7 | Cape Verde | F7 | Dominica | J2 | Cyprus | O2 | Denmark |
| A8 | Central African Republic | F8 | Dominican Republic | J3 | Maldives | O3 | Finland |
| A9 | Chad | F9 | El Salvador | J4 | India | O4 | France |
| B0 | Congo, Republic of | G0 | Guatemala | J5 | Indonesia | O5 | Germany |
| B1 | Côte d'Ivoire | G1 | Haiti | J6 | Iran, Islamic Rep of | O6 | Greece |
| B2 | Djibouti | G2 | Honduras | J7 | Iraq | O7 | Hungary |
| B3 | Egypt | G3 | Jamaica | J8 | Israel | O8 | Luxembourg |
| B4 | Equatorial Guinea | G4 | Martinique | J9 | Japan | O9 | Ireland |
| B5 | Ethiopia | G5 | Mexico | K0 | Jordan | P0 | Italy |
| B6 | Gabon | G6 | Netherlands Antilles | K1 | Korea, Dem People's Rep | P1 | Macedonia, The Fmr Yug Rp |
| B7 | Gambia | G7 | Nicaragua | K2 | Korea, Republic of | P2 | Montenegro |
| B8 | Ghana | G8 | Panama | K3 | Kuwait | P3 | Netherlands |
| B9 | Guinea | G9 | Saint Vincent/Grenadines | K4 | Laos | P4 | Norway |
| C0 | Guinea-Bissau | H0 | Trinidad and Tobago | K5 | Lebanon | P5 | Poland |
| C1 | Kenya | H1 | United States of America | K6 | Timor-Leste | P6 | Portugal |
| C2 | Lesotho | | **SOUTH AMERICA** | K7 | Malaysia | P7 | Romania |
| C3 | Liberia | H2 | Argentina | K8 | Mongolia | P8 | Slovakia |
| C4 | Libyan Arab Jamahiriya | H3 | Bolivia | K9 | Myanmar | P9 | Slovenia |
| C5 | Madagascar | H4 | Brazil | L0 | Nepal | Q0 | Spain |
| C6 | Malawi | H5 | Chile | L1 | Oman | Q1 | Sweden |
| C7 | Mali | H6 | Colombia | L2 | Pakistan | Q2 | Switzerland |
| C8 | Mauritania | H7 | Ecuador | L3 | Philippines | Q3 | United Kingdom |
| C9 | Mauritius | H8 | French Guiana | L4 | Qatar | Q4 | Serbia |
| D0 | Morocco | H9 | Guyana | L5 | Saudi Arabia | | **FORMER USSR** |
| D1 | Mozambique | I0 | Paraguay | L6 | Singapore | Q5 | Armenia |
| D2 | Niger | I1 | Peru | L7 | Sri Lanka | Q6 | Azerbaijan, Republic of |
| D3 | Nigeria | I2 | Suriname | L8 | Syrian Arab Republic | Q7 | Belarus |
| D4 | Réunion | I3 | Uruguay | L9 | Thailand | Q8 | Estonia |
| D5 | Rwanda | I4 | Venezuela, Boliv Rep of | M0 | Turkey | Q9 | Georgia |
| D6 | Sao Tome and Principe | | | M1 | United Arab Emirates | R0 | Kazakhstan |
| D7 | Senegal | | | M2 | Viet Nam | R1 | Kyrgyzstan |
| D8 | Sierra Leone | | | M3 | Yemen | R2 | Latvia |
| D9 | Somalia | | | | **OCEANIA** | R3 | Lithuania |
| E0 | South Africa | | | M4 | Australia | R4 | Moldova, Republic of |
| E1 | Sudan | | | M5 | Cook Islands | R5 | Russian Federation |
| E2 | Swaziland | | | M6 | Fiji Islands | R6 | Tajikistan |
| E3 | Tanzania, United Rep of | | | M7 | French Polynesia | R7 | Turkmenistan |
| E4 | Togo | | | M8 | New Caledonia | R8 | Ukraine |
| E5 | Tunisia | | | M9 | New Zealand | R9 | Uzbekistan |
| E6 | Uganda | | | N0 | Papua New Guinea | | |
| E7 | Congo, Dem Republic of | | | N1 | Samoa | ZY | Dummy Region |
| E8 | Zambia | | | N2 | Solomon Islands | ZZ | World |
| E9 | Zimbabwe | | | N3 | Tonga | | |
| | | | | N4 | Vanuatu | | |

[9] The listed countries are default countries in GFPM. To add or remove countries, see Zhu et al. (2008).