Using the Global Forest Products Model (GFPM version 2016 with BPMPD)

By:

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STAFF PAPER SERIES #85

July 8, 2016

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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 are especially grateful to Csaba Mészáros for permission to use the BPMPD optimizer in the GFPM. Patti Lebow made the critical upgrade of the software to Windows 7. 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

Terms of use

The GFPM is provided free of charge for academic research only. For any other use, please contact the authors.

Outline

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. The original formulation and several applications are described in Buongiorno et al. (2003). However, subsequent versions, including the GFPM 2016 reflect significant changes and extensions. The GFPM 2016 software uses the BPMPD optimizer (Mészáros 1999). The GFPM 2016 is packaged with a file, named World.xlsx, that has data and parameters to produce forecasts of forest resources and markets for 180 countries, and 14 forest product (commodity) categories, from 2012 to 2065. The GFPM 2016 can be run directly with this World.xlsx file. Alternatively, Buongiorno and Zhu (2015b) 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 (2012 in GFPM 2016) input data (Section 3),
--interpret the exogenous change data (Section 4) which the GFPM uses to make forecasts,
--run the GFPM (Section 5),
--interpret the output of the GFPM (Section 6)
--analyze product value and value added (Section 7).
--Deal with common errors (Section 8).

2 Installation and Configuration

Hardware and Software Requirements

The GFPM requires a PC with at least 2GB of RAM, and a 64-bit Windows operating system, such as Windows 7 or 8[1].

The GFPM uses the QPELPS (Quadratic Price Endogenous Linear Programming System) software, a general economic modeling system. The QPELPS version 2016 uses the BPMPD optimizer to find the solution to each year's global equilibrium. Data input and output are handled with Microsoft Excel (Office 2010 or higher). GFPM supports Excel versions in Microsoft Office from 2010.

[1] The English Windows operating system is recommended since some GFPM users reported issues with other operating systems.

Installing the GFPM

To install the GFPM do the following (Figure 1):

--Unzip GFPM.ZIP.This will give three folders, GFPM, PELPS and COPY-TO-C-DRIVE,
--Copy the GFPM folder and the PELPS folder into the C:\ directory,
--Copy the file SNJRT11.DLL from the folder COPY-TO-C-DRIVE to C:\Windows\System if the Windows 7 operating system is used[2]. This file is needed to run Java executable files.

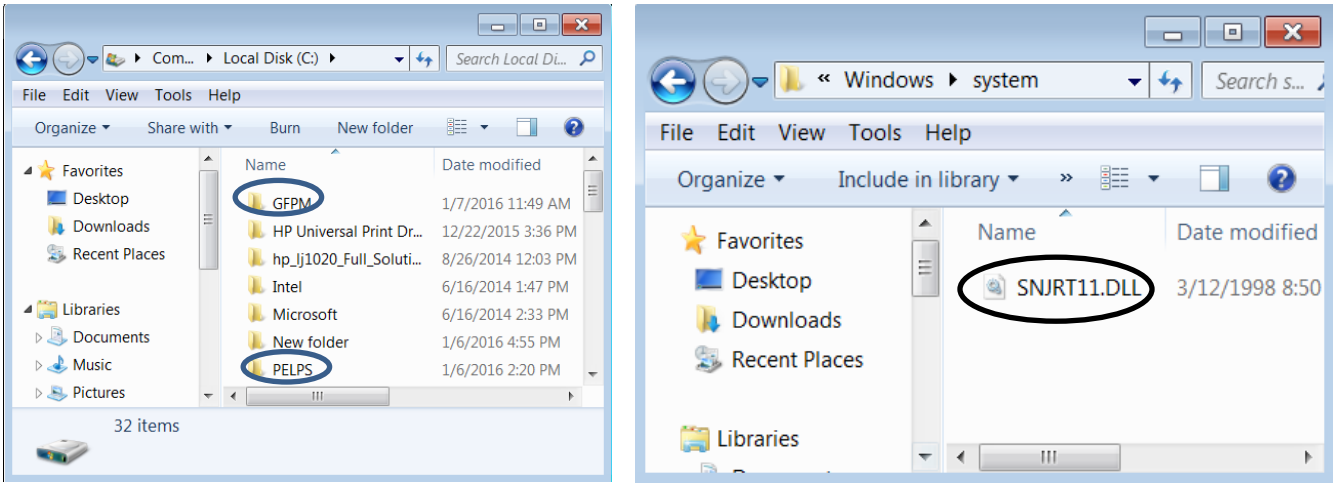


Figure 1: Files and directories to install and run the GFPM, shown in Microsoft Windows Explorer.

Testing Installation

The World.xlsx file in the GFPM folder contains the data for a model that has already been calibrated by the authors. Running the base period of this model will test that the GFPM has 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 (2012 for GFPM 2016), and then retrieves its results in Excel output files.

3 GFPM base year input

[2] The system folder name may differ depending on the version of the Windows operating system.

The GFPM uses Microsoft Excel (Office 2010 or higher) to organize the input data. All the data are in the World.xlsx file in the GFPM folder. Only worksheets with names in bold in the following list are used in the GFPM 2016.

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*

All data sheets except the last are needed to calculate the solution for the base year, the year from which the projections start, 2012 in GFPM 2016. The *ExogChange* data are needed for multi-period projections. You may find it useful to open the World.xlsx file and look at each of the worksheets discussed next.

Specification

The *Specification* sheet contains information on the data in the World.xlsx file. 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.xlsx file is created with the calibration program (Buongiorno and Zhu, 2015b). The region and commodity names, and the base year are used by the GFPM to construct the output tables and charts. The other data on this sheet are informational only, for example they may indicate modifications made by the user in creating a particular World.xlsx file.

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. In GFPM 2016 the end products are sawnwood, veneer & plywood, particleboard, fiberboard, newsprint), printing & writing paper, and other paper and paperboard. The commodity codes and country codes are in Table 1 and Table 2 at the end of this paper.

The *Demand* sheet contains data on the price[3], the quantity demanded at that price, the price elasticity of demand and the elasticity of demand with respect to shift variables (GDP is the only shift variable in GFPM 2016) in the base year. In GFPM 2016 the price in net exporting countries is equal

[3] All prices and costs in the GFPM 2016 are in $US of 2012.

to the world price, the average unit value of world exports, and the price in net importing countries 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 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 is not used in the GFPM 2016.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	****** DEMAND ******														
3	A:	Region number (a0 to z9, 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 (optional, enter 0.00 if omitted)													
17	O:	Minimum fraction of recycled content (optional, enter 0.00 if omitted)													
18	====	====	==========	==========	=======	=======	=======	=======					==========	==========	
19	a0	80	63.0000	8317.000	-0.12	-0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8317.000	0.00
20	a0	82	109.0000	52.000	-0.12	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.000	0.00
21	a0	83	352.3140	1992.000	-0.17	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1992.000	0.00
22	a0	84	721.1880	126.000	-0.33	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.000	0.00
23	a0	85	345.6440	43.000	-0.51	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.000	0.00
24	a0	86	521.4560	64.000	-0.54	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	64.000	0.00
25	a0	91	712.2150	69.000	-0.25	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	69.000	0.00
26	a0	92	1224.1988	192.000	-0.53	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	192.000	0.00
27	a0	93	1339.1687	276.000	-0.45	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	276.000	0.00
28	a1	80	63.0000	4195.000	-0.12	-0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4195.000	0.00
29	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
30	zy	92	0	0.000	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	2001	0.00	0.00

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

Supply

The GFPM has a supply equation for each country and primary product. In GFPM 2016 the primary products are fuelwood, industrial roundwood, other industrial roundwood, other fiber pulp, and recycled paper. 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, in GFPM 2016 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.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	****** SUPPLY ******														
3	A:	Region number (a0 to z9, 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 (optional, enter 0.00 if omitted)													
19	a0	80	63.0000	8317.000	1.31	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.000	8317.000
20	a0	81	135.0510	87.000	1.31	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.000	87.000
21	a0	82	109.0000	52.000	1.31	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.000	52.000
22	a0	89	1289.0000	2.000	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	2.000
23	a0	90	183.0000	39.700	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	39.700
24	a1	80	63.0000	4195.000	1.31	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.000	4195.000
25	a1	81	109.0000	92.000	1.31	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.000	92.000
26	a1	82	109.0000	1050.000	1.31	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.000	1050.000
27	a1	89	1289.0000	0.000	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000
28	a1	90	183.0000	0.585	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.585
29	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
30	zy	93	0	0.000	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	721	0.00

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

To shift the supply of wood (fuelwood, industrial roundwood, or other industrial roundwood) exogenously, the elasticity with respect to the first shift variable in column F should be 1.00. This makes data in columns G to L 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 changes 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. In GFPM 2016 the data in column M of the *Forest* sheet refer to the CO_2 sequestered in the total forest biomass per unit of growing stock, not just the CO_2 sequestered in the measured growing stock which typically includes only the stem.

	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$)												
5	C:	Base period forest stock (million m^3)												
6	D:	Base period annual growth rate of forest stock, without harvest												
7	E:	Elasticity of annual growth rate of forest stock, without harvest, with respect to stock per unit area												
8	F:	Base period forest area (000 ha)												
9	G:	Base period forest area annual growth rate												
10	H:	Linear effect of GDP per capita (1000 US$) on forest area annual growth rate												
11	I:	Exponential effect of GDP per capita (1000 US$) on forest area annual growth rate												
12	J:	Fraction of fuelwood that comes from forest												
13	K:	Ratio of inventory drain to harvest												
14	L:	Maximum ratio of inventory drain to growth of inventory without harvest (>0, -1 if unlimited)												
15	M:	CO2 sequestered in growing stock (tonne per CUM)												
16	N:	Price of CO2 (US$ per tonne)												
18	a0	5319	113	0.075	-0.41	1474	-0.006	0.0014000000	-0.0898000000	1.00	1.20	-1.00	2.00	0.00
19	a1	5501	2256	0.002	-0.41	58230	-0.002	0.0014000000	-0.0898000000	1.00	1.20	-1.00	2.00	0.00
20	a2	768	158	0.044	-0.41	4461	-0.011	0.0014000000	-0.0898000000	1.00	1.20	-1.00	2.00	0.00
21	a3	7443	756	0.008	-0.41	11114	-0.010	0.0014000000	-0.0898000000	1.00	1.20	-1.00	2.00	0.00
22	a4	663	232	0.050	-0.41	5529	-0.010	0.0014000000	-0.0898000000	1.00	1.20	-1.00	2.00	0.00
23	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	r9	1715	27	0.038	-0.41	3268	-0.001	0.0014000000	-0.0898000000	1.00	1.20	-1.00	2.00	0.00

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 input-output (I-O) coefficients in the base year for commodities that are transformed into other commodities. Manufacturing costs and related data are in type M records, manufacturing coefficients are in type P records, data referring to secondary commodities (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 (column J).

The manufacturing coefficients are the quantity of input per unit of output. A product can have multiple inputs, for example different pulps to make a paper product. The GFPM 2016 uses only one process and one input mix for each output. The calibration methods used in calculating the manufacturing costs and I-O coefficients are described in Buongiorno and Zhu (2015a), and the software, included in the GFPM 2016 package, is described in Buongiorno and Zhu (2015b).

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 record 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. There is no secondary commodity in GFPM 2016.

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 ******																
2	== = ==== ==== ==== ==== == ========== ========== ========== ========== ========== ========== ========== ========== === ========																
3	A:	Record type (two types of records are used, M and P)															
4																	
5	->	Record type M (manufacturing cost) :															
6	B:	Region number (a0 to z9, 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 blar															
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 manufacturing cost, >=0, enter 0.00 for constant manufacturing cost															
14																	
15	->	Record type P (manufacturing coefficients) :															
16	B:	Region number (a0 to z9, 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															
22																	
23	->	Record type B (by-product coefficients) :															
24	B:	Region number (a0 to z9, 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															
30	== = ==== ==== ==== ==== == ========== ========== ========== ========== ========== ========== ========== ========== === ========																
31	M	a0		83		10	1	128.7008	13.000	0.10							
32	M	a0		84		10	1	447.7097	25.000	0.10							
33	M	a0		85		10	1	217.3455	23.000	0.10							
34	…	…	…	…	…	…	…	…	…	…							
35	M	r9		93		10	1	291.2975	28.000	0.10							
36	P	a0		81	83	10	1	1.6557685									
37	P	a0		81	84	10	1	2.0250000									
38	P	a0		81	85	10	1	0.9500004									
39	…	…	…	…	…	…	…	…									
40	P	r9		90	93	10	1	0.2142857									

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

Capacity

The *Capacity1* worksheet (Figure 6) contains optional data to predict world manufacturing capacity for each manufactured commodity. Capacity change is not modeled in GFPM 2016. This is indicated by entering -1 for all input data in *Capacity1*. The *Capacity2* worksheet (Figure 7) contains optional data on base-year manufacturing capacity organized by country and commodity. In GFPM 2016 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
	****** CAPACITY -- 1 ******							
	A:	Commodity number (01 to 99, in ascending order)						
	B:	Production of one period before the base period						
	C:	Production of two periods before the base period						
	D:	Production of three periods before the base period						
	E:	First expansion parameter						
	F:	Second expansion parameter						
	G:	Third expansion parameter						
83		-1	-1	-1	-1	-1	-1	
84		-1	-1	-1	-1	-1	-1	
85		-1	-1	-1	-1	-1	-1	
86		-1	-1	-1	-1	-1	-1	
87		-1	-1	-1	-1	-1	-1	
88		-1	-1	-1	-1	-1	-1	
91		-1	-1	-1	-1	-1	-1	
92		-1	-1	-1	-1	-1	-1	
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	= ==== ==== ==== ==== ========== ======= ========== ====== ====== ======= ====== ========== ======= ==========																
3	A:	Region number (a0 to z9, in ascending order)															
4	C:	Commodity number (in ascending order in each region)															
5	D:	Process number(01 to 99, in ascending order within each commodity; leave blank if not applicable)															
6	E:	Process number(01 to 99, in ascending order within each commodity)															
7	F:	Manufacturing capacity of base period (non-negative, enter "-1" for no capacity constraint)															
8	G:	Capacity depreciation rate															
9	H:	Cost of new capacity in common currency (>0)															
10	I:	First expansion parameter															
11	J:	Second expansion parameter															
12	K:	Third expansion parameter															
13	L:	Fourth expansion parameter															
14	M:	Manufacturing capacity one period before the base period															
15	N:	q ratio in period before the base period (non-negative, enter "-1.00" if not available)															
16	O:	Ratio of overtime capacity to regular capacity															
18	a0		83		10	-1	0.000	1.00	1.00	1.00	0.00	0.00	0	-1.00	0.0		
19	a0		84		10	-1	0.000	1.00	1.00	1.00	0.00	0.00	0	-1.00	0.0		
20	a0		85		10	-1	0.000	1.00	1.00	1.00	0.00	0.00	0	-1.00	0.0		
21	a0		91		10	-1	0.000	1.00	1.00	1.00	0.00	0.00	0	-1.00	0.0		
22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		
23	r9		93		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 post-consumer recovery of products. In GFPM 2016 this is the waste paper recovered from the consumed paper and paperboard. For each paper type, the *RecyclingS* sheet specifies the potential recovery rate of waste paper in the base year, the parameters in Column H which must be non-negative. 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.
The *Recycling(Demand)* sheet is not used in GFPM 2016.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	****** RECYCLING (SUPPLY) ******												
3	A:	Region number (a0 to z9, 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). Use 1 if the region is both a consumption and a production region											
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	0.80					
11	a0		90		92	1.00	0.00	0.80					
12	a0		90		93	1.00	0.00	0.80					
13	a1		90		91	1.00	0.00	0.80					
14	a1		90		92	1.00	0.00	0.80					
15	...	...	...	...	...	...	...	...					
16	r9		90		93	1.00	0.00	0.80					

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 2016 all countries export to, and import from, the world market (region zz). Trade flows between specific countries can be added to the GFPM, as for example in Turner et al. (2001). This can be done manually directly on the *Transportation* sheet, or with the software as described in Buongiorno and Zhu (2015b).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	****** TRANSPORTATION COST AND TAX ******															
2	=	===	===	===	===	========	========	========	========	================	==========					
3	A: Origin region number (a0 to z9)															
4	C: Destination region number (a0 to z9, 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: Elasticity of trade with respect to **exporter** shift variable (set to 0 to enable column L for fixed trade, no trade, or free trade)															
11	K: Elasticity of trade with respect to **importer** shift variable (set to 0 to enable column L for fixed trade, no trade, or free trade)															
12	L: Trade inertia bounds as fraction of trade (>= 0; 0 for fixed trade; -1 for no trade; 1 for free trade)															
13	M: Base period price of commodity in exporting country															
14	N: Trade elasticity of transport cost, >=0, enter 0.00 for constant transport cost															
15	=	===	===	===	===	========	========	========	========	================	==========					
16	a0		zz		90	0.00	0.000	0.00	44	0.00	0.00	0.001	171	0.000		
17	a0		zz		91	0.00	0.000	0.00	5	0.00	0.00	0.001	622	0.000		
18	a0		zz		92	0.00	0.000	0.00	1	0.00	0.00	0.001	956	0.000		
19	a0		zz		93	0.00	0.000	0.00	2	0.00	0.00	0.001	993	0.000		
20	a1		zz		81	0.00	0.000	0.00	13	0.00	0.00	0.001	109	0.000		
21	…	…	…	…	…	…	…	…	…	…	…	…	…	…		
22	r9		zz		83	0.00	0.000	0.00	9	0.00	0.00	0.001	279	0.000		
23	r9		zz		84	0.00	0.000	0.00	3	0.00	0.00	0.001	580	0.000		
24	r9		zz		88	0.00	0.000	0.00	2	0.00	0.00	0.001	603	0.000		
25	r9		zz		92	0.00	0.000	0.00	1	0.00	0.00	0.001	956	0.000		
26	r9		zz		93	0.00	0.000	0.00	3	0.00	0.00	0.001	993	0.000		
27	zy		zz		87	0.00	0.000	0.00	173	0.00	0.00	0.001	0	0.000		
28	zy		zz		89	0.00	0.000	0.00	9	0.00	0.00	0.001	0	0.000		
29	zy		zz		90	0.00	0.000	0.00	251	0.00	0.00	0.001	0	0.000		
30	zz		a0		80	12.60	0.150	0.00	0	0.00	0.00	0.001	60	0.000		
31	zz		a0		81	19.62	0.050	0.00	14	0.00	0.00	0.001	109	0.000		
32	zz		a0		83	30.69	0.150	0.00	2105	0.00	0.00	0.001	279	0.000		
33	…	…	…	…	…	…	…	…	…	…	…	…	…	…		
34	zz		zy		93	0.00	0.000	0.00	492	0.00	0.00	0.001	0	0.000		

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 the free trade setting gives a calculated net trade (exports minus imports) equal to the observed net trade, 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 may be applied to one or a few regions/countries to simulate zero trade).

4 Exogenous Change Data

The *ExogChange* worksheet (Figure 10) contains data that define the periodic exogenous changes in demand, supply, etc., such as the changes induced by GDP growth. 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 or two-digit period number, and *j* is a one or two-digit period length in

[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.

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.

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 mathematical Appendix).

If all periods' data do not fit on the *ExogChange* sheet, additional periods can be added in *ExogChange2*. Within each period, the *ExogChange* sheet in the World.xlsx file of GFPM 2016 holds data pertaining to **annual** changes of:

- Demand (record type D)
- Supply (record type S)
- Forest resources (record type F)
- Manufacturing costs (record type M)
- Input-output coefficients (record type P)
- Capacity data (record type K)
- Recycling(Demand) data (record type C)
- Recycling(Supply) data (record type W)
- 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 there are no *ExogChange* data for a period the previous period's exogenous changes apply.

The records in the *ExogChange* worksheet must match those in the *Demand, Supply, Forest, Manufacture, Capacity, Recycling, Transportation,* worksheets. This must be checked especially if the model is re-calibrated, since the calibration procedure (Buongiorno and Zhu, 2015b) may change the records in the *Manufacture* worksheet. However, if there is no change in, say, the capacity worksheet, no capacity record (type K) is needed in *ExogChange*. There must be no dangling PERIOD record at the end of the *ExogChange* worksheet, as this will cause a run-time error. Figure 10 shows the parts of *ExogChange* used in GFPM 2016, as follows:

Changes in demand

In the GFPM 2016, 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 in supply

To shift supply of wood, waste paper, or other fiber pulp according to some shifter, enter the rate of change of the shift variable in column J of record type S. This rate acts in conjunction with the elasticity of supply with respect to the shift variable in column F of the *Supply* sheet.

To shift wood supply endogenously, enter -1 in column J. This ties wood supply to changes in forest stock, forest area, and GDP per capita.

Upper bounds on wood, waste paper, and other fiber pulp supply can shift exogenously or endogenously. If column N 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 N.

Changes in forest parameters

Most of the initial parameters specified in the *Forest Resource* sheet described above can be changed periodically with data in record type F in the *ExogChange* sheet, for example the exogenous growth rate of the forest area. If the growth rate of forest area is endogenous it varies with GDP per capita. If the growth rate of forest stock is endogenous it varies with the density of forest stock per unit area.

The data in column K are to adjust the endogenous growth rate of forest stock on a given area, for example to simulate a reduction in forest stock growth due to exotic forest pests (Prestemon et al. 2006).

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, 0.012 means an increase in manufacturing cost of 1.2 percent per year.

Changes in input-output 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 input per unit of sawnwood output is 1.8 in period 1, and the period length is 3 years, enter -0.1 in the appropriate record to reduce it to 1.5 in period 2.

To change byproduct coefficients (amount of secondary commodity per unit of primary commodity), enter the annual change in column H of record type B. For example, if the amount of fiber residues per unit of sawnwood is 0.75 in period 1, and period1 is 5 years long, enter -0.01 in the appropriate record to reduce it to 0.70 in period 2.

Check that the cumulative changes lead to plausible manufacturing and byproduct coefficients at the end of the projection (the year 2065 when GFPM 2016 is run for 11 periods with the packaged World.xlsx file).

Changes in trade

Use record type T, column I of the *ExogChange* sheet to change the import *ad-valorem* tax rate. For example, if the tax rate is 7 percent (0.07) in period 1, and the period length is 3 years, entering –0.01 in the proper record will reduce the tax rate to 4 percent (0.04) in period 2.

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	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	****** EXOGENOUS CHANGE ******																				
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 (> -1.0)																				
11	J: Growth rate of the first demand shift variable (> -1.0)																				
12	K: Growth rate of the second demand shift variable (> -1.0)																				
13	L: Growth rate of the third demand shift variable (> -1.0)																				
14	M: Growth rate of the fourth demand shift variable (> -1.0)																				
15	N: Growth rate of the fifth demand shift variable (> -1.0)																				
16	O: Growth rate of the sixth demand shift variable (> -1.0)																				
17	P: Growth rate of the lower bound on the demanded commodity (> -1.0)																				
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 (> -1.0)																				
26	J: Growth rate of the first supply shift variable (> -1.0, -1 for endogenous shifts)																				
27	K: Growth rate of fourth supply shift variable (> -1.0)																				
28	L: Growth rate of the fifth supply shift variable (> -1.0)																				
29	M: Growth rate of the sixth supply shift variable (> -1.0)																				
30	N: Growth rate of the upper bound on the supplied commodity (> -1.0, -1 if the same as supply shift)																				
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 (> -1.0, -1 if endogenous)																				
35	I: Growth rate of forest area (> -1.0, -1 if endogenous)																				
36	J: Growth rate of GDP per capita (> -1.0)																				
37	K: Adjustment of endogenous growth rate of forest stock on a given area, without harvest (exogenous) (> -1.0)																				
38	L: Updated elasticity of forest growth rate with respect to forest stock per unit area, enter 0 if unchanged																				
39	M: Updated linear effect of GDP per capita on forest area annual growth rate, enter 0 if unchanged																				
40	N: Updated exponential effect of GDP per capita on forest area annual 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																				

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
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 (> -1.0)																				
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: Change in amount of secondary per unit of primary																				

Figure 10: *ExogChange* worksheet definitions and sample data.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
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:	Exogenous growth rate of the exporter trade shi																
119	L:	Updated trade elasticity with respect to exporter shift variable																
120	M:	Exogenous growth rate of the importer trade shift variable (>-1.0)																
121	N:	Updated trade elasticity with respect to importer shift variable																
122	O:	Updated trade inertia bounds																
123																		
124	->	Record type E (new exchange rate) :																
125	B:	Region number																
126	H:	Change in exchange rate																
128	PERIOD1x2																	
129	D	a0		80				-0.1244	0.0000	0.0641	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.1445
130	D	a0		82				-0.1244	0.0000	0.0641	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0322
131	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
132	S	a0		80				0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	-1.0000				
133	S	a0		81				0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	-1.0000				
134	S	a0		82				0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	-1.0000				
135	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
136	S	a0		90				0.0000	0.0000	0.0320	0.0000	0.0000	0.0000	0.0000				
137	S	a1		80				0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	-1.0000				
138	S	a1		81				0.0000	0.0000	-1.0000	0.0000	0.0000	0.0000	-1.0000				
139	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
140	F	a0						-1.00	-1	0.0486	0	0	0	0	-1	-1	-1	0
141	F	a1						-1.00	-1	0.0570	0	0	0	0	-1	-1	-1	0
142	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
143	M	a0		83		10	1	0.0032										
144	M	a0		84		10	1	0.0120										
145	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
146	P	a0		81	83	10	1	0.00000										
147	P	a0		81	84	10	1	0.00000										
148	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
149	T	a0		zz		90		0.000	0.000000	0.000000	0.000000	0.000	0.000	0.000	0.135			
150	T	a0		zz		91		0.000	0.000000	0.000000	0.000000	0.000	0.000	0.000	0.029			
151	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
152	T	zz		a0		80		0.000	0.000000	0.000000	0.000000	0.000	0.000	0.000	0.071			
153	T	zz		a0		81		0.000	0.000000	0.000000	0.000000	0.000	0.000	0.000	0.040			
154	...	...	...	...	...	...	...	...	...	...	...	...	...	...				
155	PERIOD2x5																	
156	D	a0		80				-0.1244	0.0000	0.0614	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.1445
157	D	a0		82				-0.1244	0.0000	0.0614	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0322
158	...	...	...	...	...	...	...	...	...	...	...	...	...	...				

Figure 10 (continued): *ExogChange* worksheet definitions and sample data.

5 Running the GFPM

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

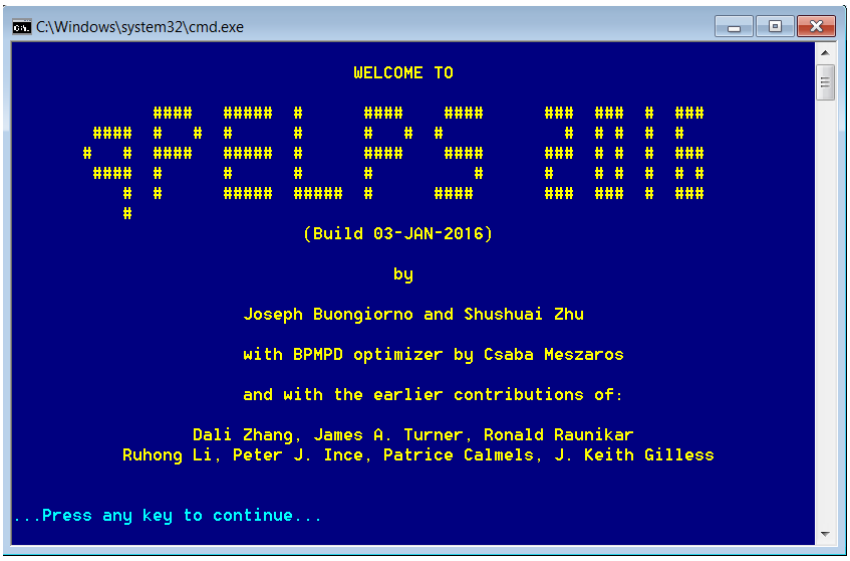


Figure 11: The GFPM welcome screen.

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

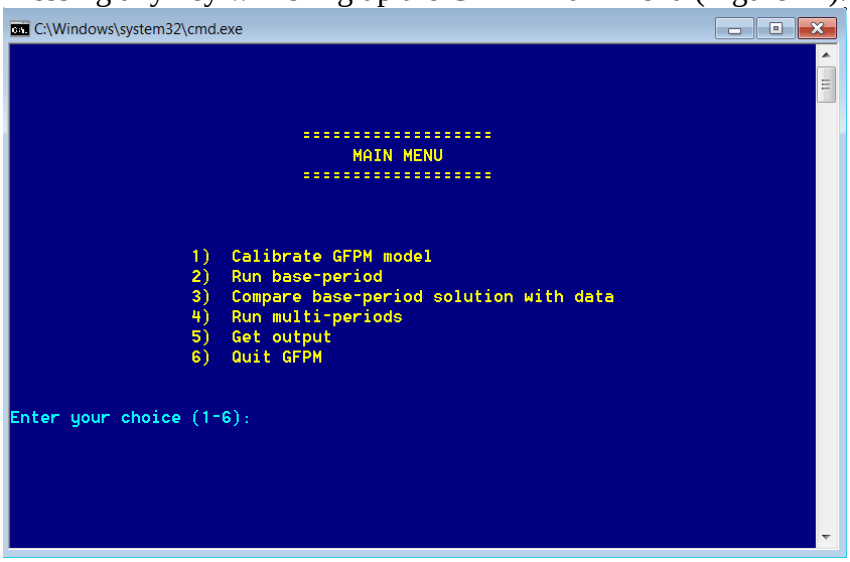


Figure 12: The main menu of the GFPM.

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

MAIN MENU option **1) Calibrate GFPM model** is optional. You need not recalibrate the model if you use the World.xlsx file provided with GFPM 2016. Choosing MAIN MENU option 1) brings up the menu in Figure 13. Its options are described in full in "Calibrating and updating the GFPM" (Zhu et al. 2015b).

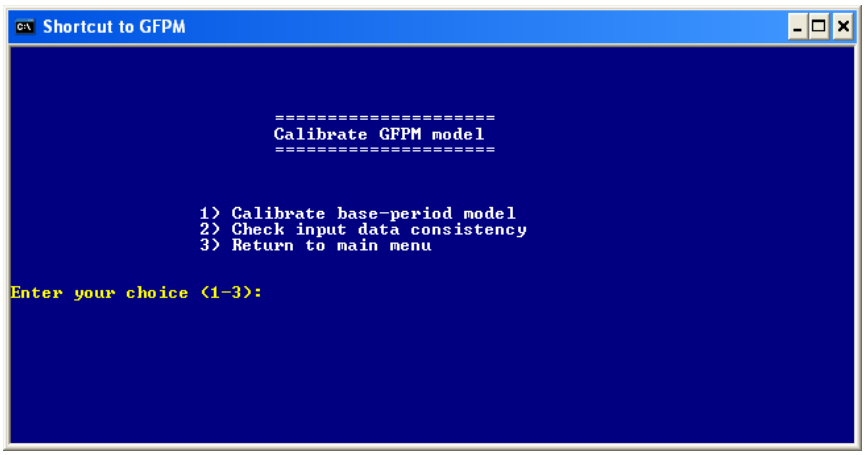


Figure 13: The Calibrate GFPM model menu.

1) Calibrate base-period model calibrates the GFPM base year model with the FAO data. It produces the World.xlsx file. In GFPM 2016, the base year is 2012. The World.xlsx file packaged with GFPM 2016 was calibrated with smoothed data from 2010 to 2013 and a static calibration.

2) Check input data consistency gives the results in C:\GFPM\CheckInputData.xlsm. The procedure verifies the following conditions for the base-year model:

- Apparent consumption (production + import - export) equals final demand for end products, 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 local input and output prices 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.

For a model calibrated with the static method (one year of data or three year average) the conditions should hold exactly. For a model calibrated with the dynamic method (several years of data) they should hold closely:

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

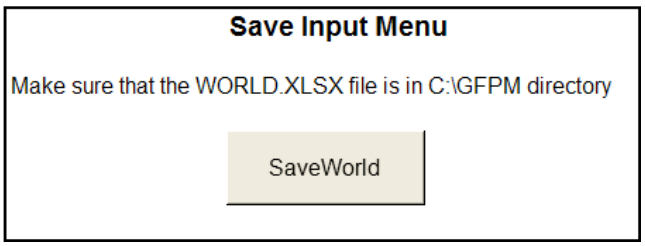


Figure 14 The Save Input menu.

Click on *SaveWorld* to prepare the input files and run the base year (2012 in GFPM 2016) solution (Figure 15). Answer “yes” if the program asks if you want to change existing files.

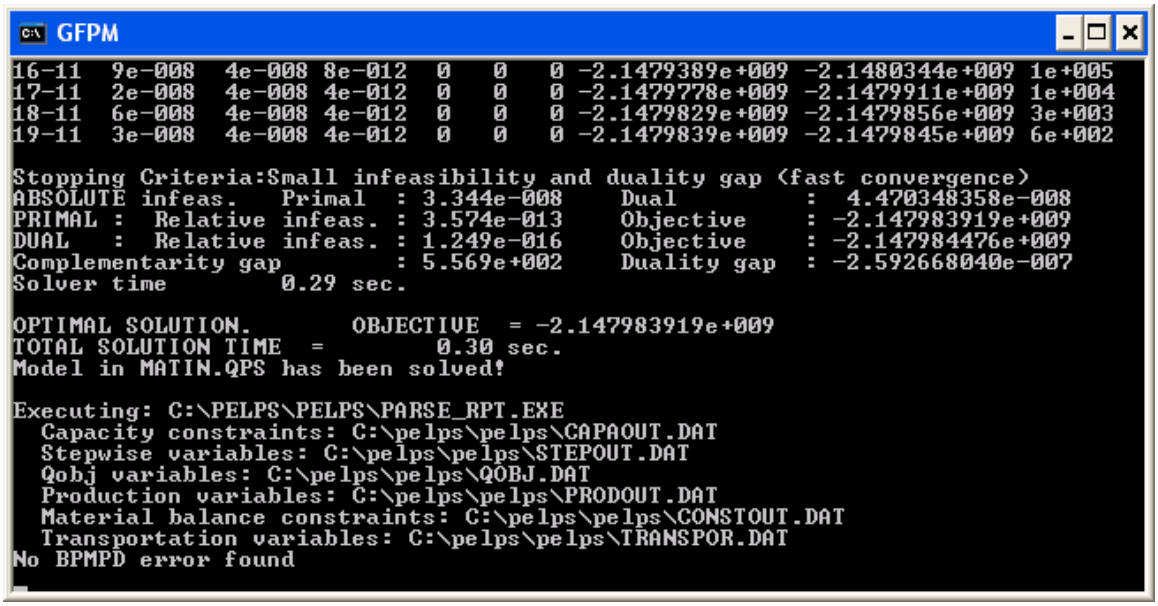


Figure 15: GFPM program running.

The base year may be run without data in the *ExogChange* worksheet since no projection beyond the base year is asked for. 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 menu in Figure 16. This procedure helps compare the base-year calculated demand, supply, price, quantity manufactured, import, export, and net trade with the input data in the World.xlsx file. The results of the comparisons are in the workbook in C:\GFPM\ValidateBaseYear.xlsm. This validation must be done with free trade (no bound on imports and exports). The *Transportation* sheet shows the results for the trade flows specified in World.xlsx. 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 (export minus imports) and prices should be very close to the input data in World.xlsx, but imports and exports may differ. The model solution should reproduce the input data almost exactly after a static calibration, and closely after a dynamic calibration.

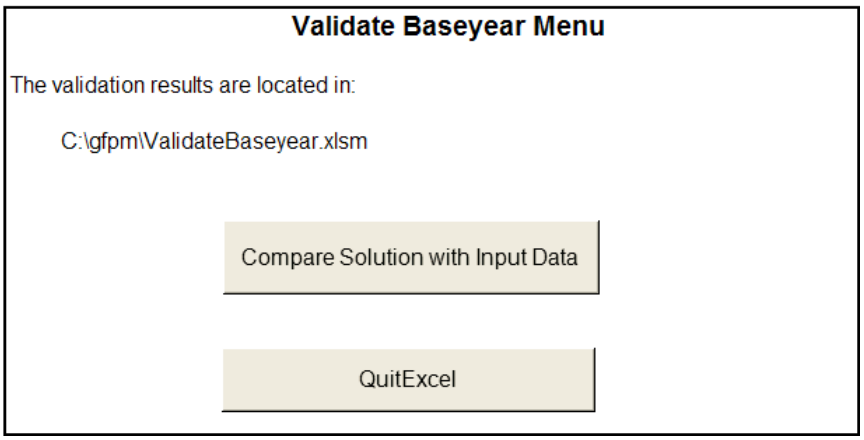


Figure 16: The Validate Baseyear menu.

MAIN MENU option **4) Run Multi-Periods** calculates the base year (2012) solution and projections for future periods. Choosing this option leads to the prompt "**Enter number of projected periods:**" For example, enter "11" for an 11-period projection. The projected number of years depends on the length of each period specified in the *ExogChange* worksheet of the World.xlsx file. Entering the desired projection length produces the **Save Input** menu (Figure 14). Clicking on *SaveWorld* launches the multi-period projection.

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

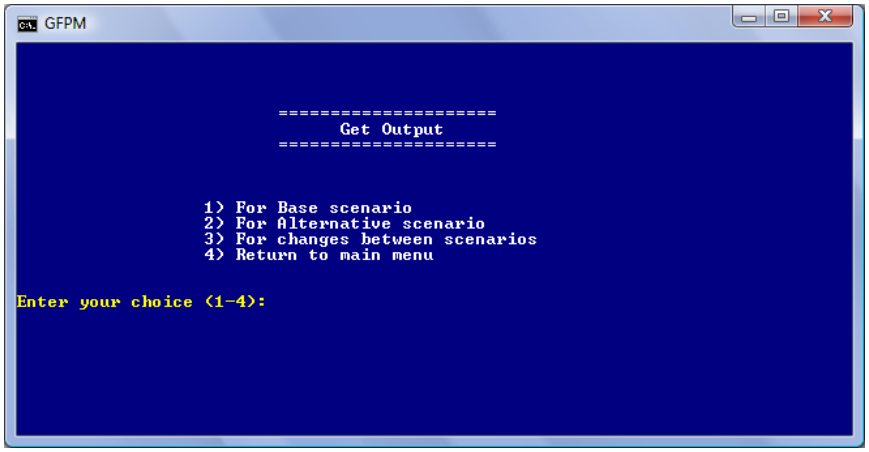


Figure 17: The Get Output menu.

The Get Output options facilitate comparison of a *base scenario* and an *alternative scenario*. The scenarios could make different assumptions, such as GDP growth, or use different parameters for sensitivity analysis. You first run the base scenario and get its output. Then run the alternative scenario and get its output. Last, you can get the changes between the two scenarios.

Get Output option **1) For Base scenario** opens the menu[5] in Figure 18.

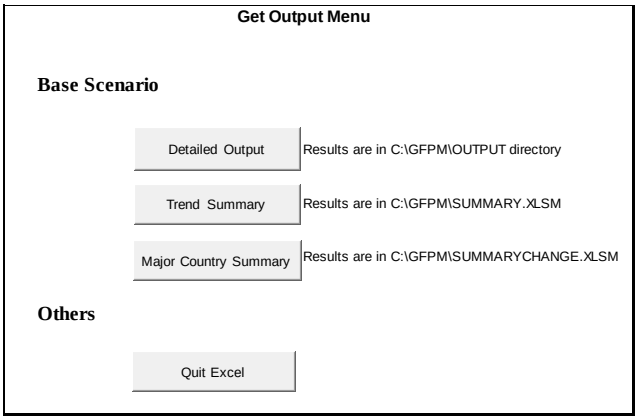


Figure 18: The Get Output menu for Base Scenario.

[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.

Detailed Output option retrieves the detailed projections for the base scenario. The results are in the folder C:\GFPM\output in files with names that end with _base. For example, the file area_base contains the projections of forest area according to the base scenario. The files with names that begin with value_ contain values at local prices. For example value_prod_base contains the projected values of production at local prices for the base scenario.

The Output workbook in the GFPM folder also contains tables of the same data together with their regional aggregates (Figure 19). *Detailed Output* must be run before *Trend Summary* or *Major Country Summary*. You can quit Excel after running *Detailed Output*, and then run *Trend Summary* or *Major Country Summary* later without redoing *Detailed Output*.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Table 1 Consumption of Total Roundwood (thousand CUM).														
2		Actual		Projection											
3	Country	1992	2012	2012	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065
4	**AFRICA**	**445741**	**683602**	**679350**	**655048**	**618621**	**583508**	**544842**	**479553**	**456089**	**427725**	**392471**	**377041**	**367998**	**359371**
5	Algeria	6371	8462	8463	8221.9	7880.9	7567.2	7281.1	7083.8	6907	6751.8	6892.1	7035.3	7185.5	7351.4
6	Angola	3379	5322	5330	5183.7	4964	4761.4	4574.2	4434.9	4308.7	4192.5	4241.5	4281.9	4319.2	4360.3
7	Benin	5972	6584	6820.5	6562.7	6198.6	5860.2	5546.9	5313.4	5096.8	4878.8	4702.5	4534.9	4371.5	4217.7
8	Botswana	692	805	806.1	790.1	766.6	744.8	724.6	731.1	738.4	746.2	753.5	761.3	768.9	776.9
9	Burkina Fa	10046	14299	14252.1	13613.5	12651.1	11730.7	10841.7	10070.8	9249.4	8245.4	5887.1	5.7	6.1	5.9
10	Burundi	6613	6356	7507.3	7263.2	6907.4	6570.3	6251.6	5999.7	5760.3	5533.8	5378.4	5231.6	5093.7	4965.1
11	Cameroon	10337	11447	11656	11406	11095.7	10838.1	10610.3	10462.9	10233.6	9952.9	9753	9596.8	9441	9325.4
12	Cape Verd	109	200	199	193.6	185.9	178.6	171.7	166.9	162.1	157.7	160.9	164.2	167.5	170.8
13	Central Afr	3692	2573	2449.1	2378.2	2273.4	2177.9	2091.4	2028.1	1970.9	1919.2	1879.3	1843.4	1811	1782.5
14	Chad	5423	8062	8054	7747.9	7291.3	6867.3	6474.2	6175.2	5896.3	5636.9	5455.2	5284.9	5124.4	4972.3
15	Congo, Re	1787	2809	2689.4	2681.8	2689.7	2728.5	2801.1	2875.2	2976.6	3105.6	3287.1	3484.9	3700	3939.4
16	Côte d'Ivoi	10672	10370	10318	10127.5	9902.2	9743.2	9640.3	9624.9	9552.7	9478	9475	9526.5	9634.9	9802.5
17	Djibouti	221	369	369	361.8	349.5	337.4	325.8	317.2	309.1	301.1	295.3	289.6	284.1	278.6

Figure 19: Part of a table in Output workbook showing detailed projections of total roundwood consumption by region and country.

Trend Summary option retrieves projections by world region and product group. The results are in the workbook C:\GFPM\Summary.xlsm (Figures 20 and 21). The world prices in Figure 21 are the shadow prices of the material balance constraints of the world region, coded “zz”.

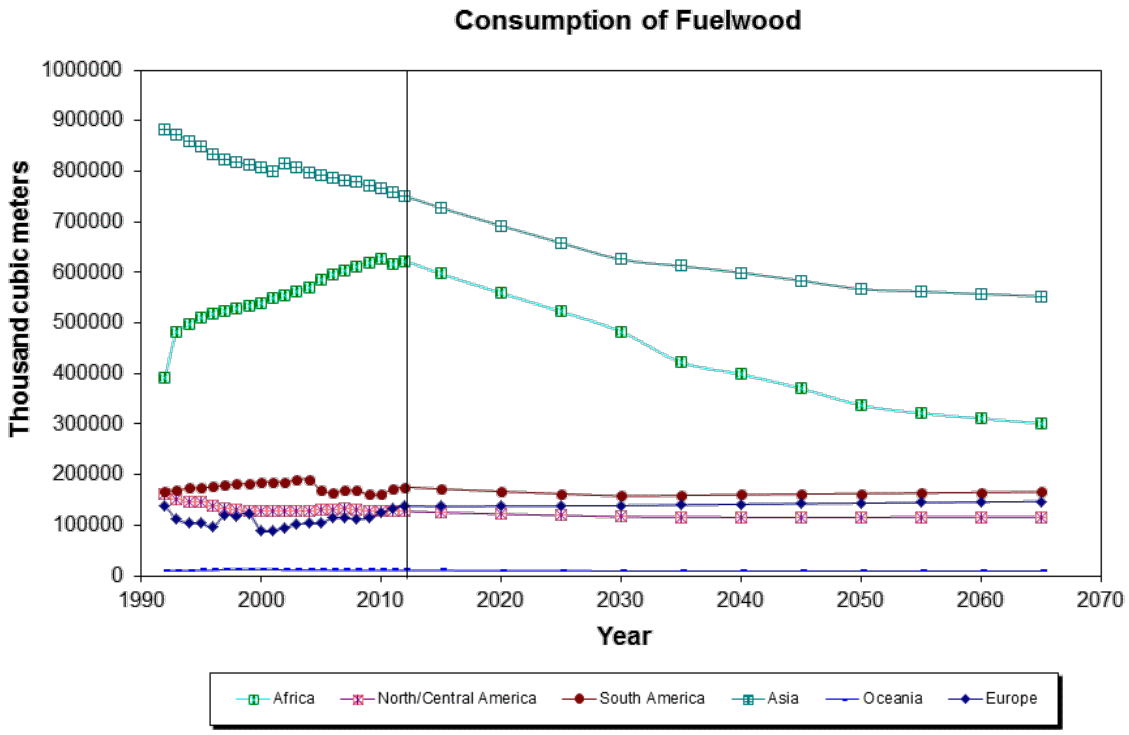


Figure 20: Example of consumption chart in Summary workbook.

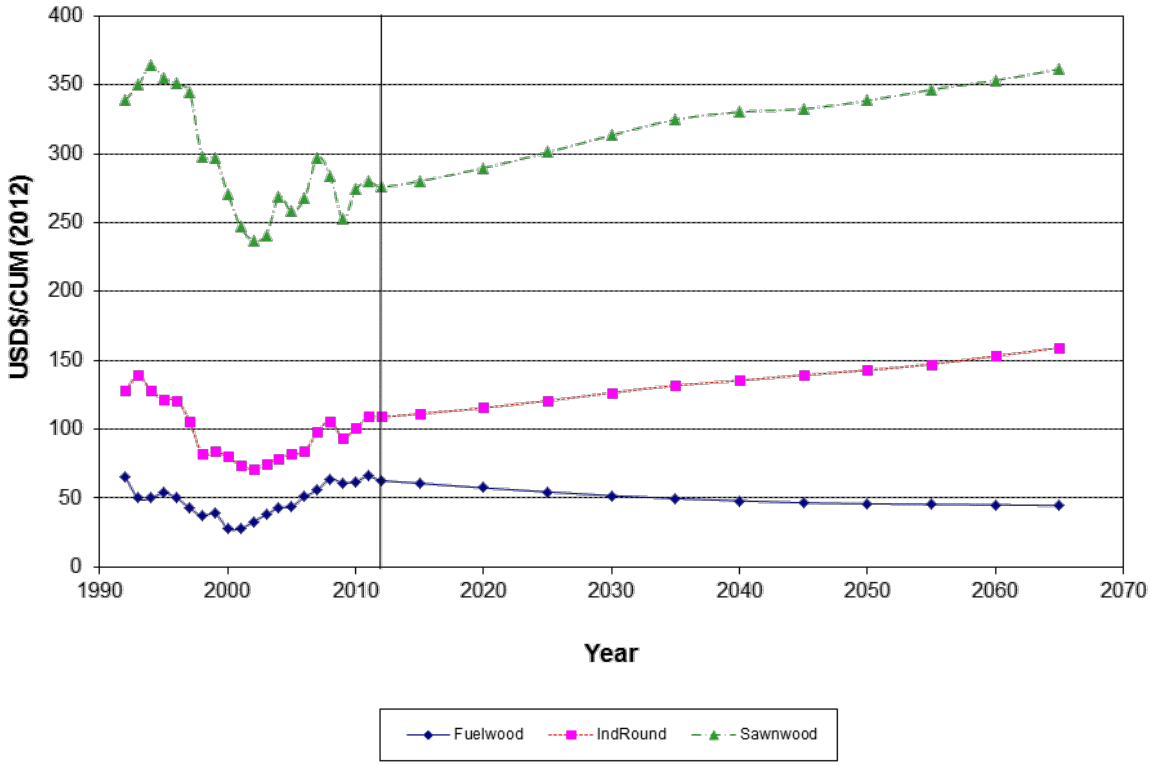
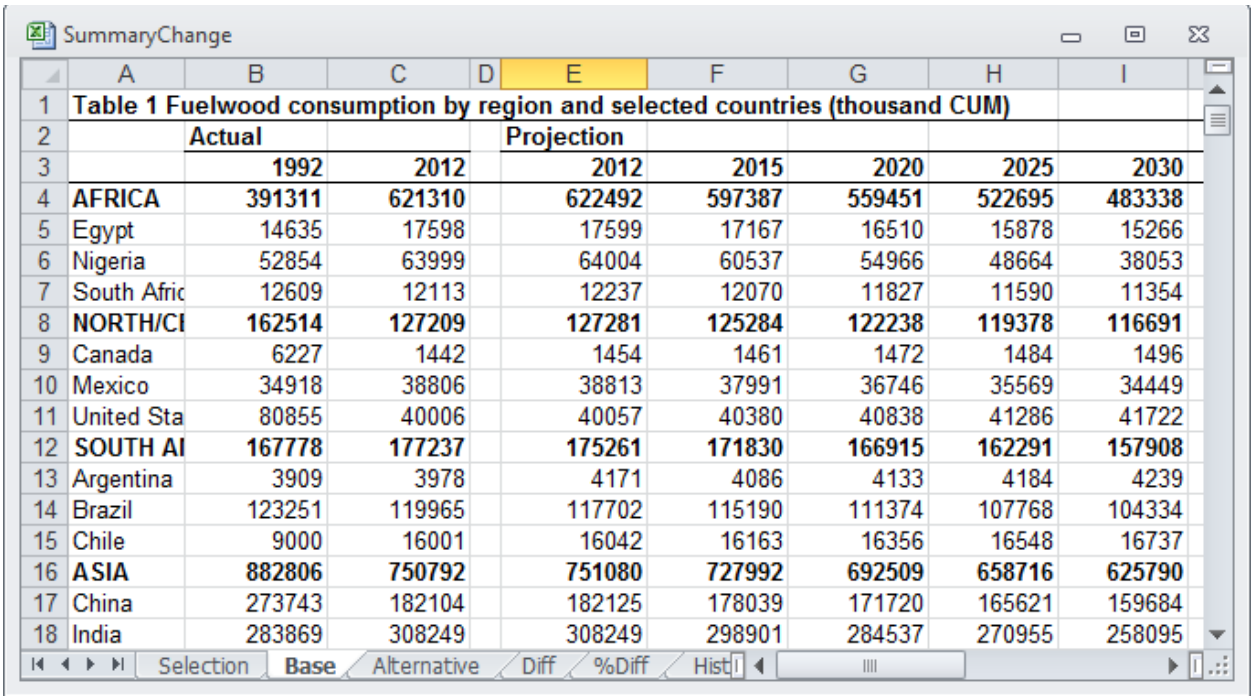


Figure 21: Example of price chart in Summary workbook.

Major Country Summary option tabulates projections for selected items (such as consumption), commodities (such as sawnwood), world regions and countries. The results are in the workbook SummaryChange.xlsm in the GFPM folder. Each worksheet contains historical and projected data (Figure 22).



SummaryChange

	A	B	C	D	E	F	G	H	I
1	Table 1 Fuelwood consumption by region and selected countries (thousand CUM)								
2		Actual			Projection				
3		1992	2012		2012	2015	2020	2025	2030
4	**AFRICA**	**391311**	**621310**		**622492**	**597387**	**559451**	**522695**	**483338**
5	Egypt	14635	17598		17599	17167	16510	15878	15266
6	Nigeria	52854	63999		64004	60537	54966	48664	38053
7	South Afric	12609	12113		12237	12070	11827	11590	11354
8	**NORTH/CI**	**162514**	**127209**		**127281**	**125284**	**122238**	**119378**	**116691**
9	Canada	6227	1442		1454	1461	1472	1484	1496
10	Mexico	34918	38806		38813	37991	36746	35569	34449
11	United Sta	80855	40006		40057	40380	40838	41286	41722
12	**SOUTH AI**	**167778**	**177237**		**175261**	**171830**	**166915**	**162291**	**157908**
13	Argentina	3909	3978		4171	4086	4133	4184	4239
14	Brazil	123251	119965		117702	115190	111374	107768	104334
15	Chile	9000	16001		16042	16163	16356	16548	16737
16	**ASIA**	**882806**	**750792**		**751080**	**727992**	**692509**	**658716**	**625790**
17	China	273743	182104		182125	178039	171720	165621	159684
18	India	283869	308249		308249	298901	284537	270955	258095

Selection | Base | Alternative | Diff | %Diff | Hist

Figure 22: Table of fuelwood consumption by region and selected countries, in SummaryChange.xlsm **workbook.**

By default, some items, commodities, and countries have already been selected in GFPM 2016. You can select different items, commodities, countries and regions by marking "y" in the "Select" columns of the "Selection" sheet of the SummaryChange.xlsm workbook before running *Major Country Summary* (Figure 23).

	A	B	C	D	E	F	G	H	I	J
1	**Select**	**Item**		**Select**	**Commodity**		**Select**	**GFPM Code**	**Country**	**Aggregate**
2	y	Consumption		y	Fuelwood		y		**AFRICA**	**0**
3	y	Production		y	TotalIndRound			a0	Algeria	
4	y	Import		y	Sawnwood			a1	Angola	
5	y	Export		y	Plywood			a2	Benin	
6	y	Nettrade		y	ParticleB			a3	Botswana	
7		Value_cons		y	FiberB			a4	Burkina Faso	
8		Value_prod		y	MechPlp			a5	Burundi	
9		Value_imp		y	ChemPlp			a6	Cameroon	
10		Value_exp		y	OthFbrPlp			a7	Cape Verde	
11		Value_netTrade		y	WastePaper			a8	Central African Republic	
12	y	Price		y	Newsprint			a9	Chad	
13	y	Area		y	PWPaper			e7	Congo, Dem Republic of	
14	y	Stock		y	OthPaper			b0	Congo, Republic of	
15	y	Value_added						b1	Côte d'Ivoire	
16								b2	Djibouti	
17							y	b3	Egypt	
18								b4	Equatorial Guinea	

Figure 23: Selection of items, commodities, and countries in Selection worksheet of SummaryChange.xlsm **workbook.**

Alternatively, you may select countries by entering the desired number of countries in the "Select" column for that region. The list of countries and regions cannot be changed.

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.

In the "Selection" sheet, an interface allows users to view the projected trend and the historical data (from 1992 to 2012). Users can select the scenario (base or 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** menu.

Get Output Option **2) For Alternative scenario** opens a menu analog to that of the base scenario (Figure 18).

Detailed Output retrieves the detailed projections for the alternative scenario. The results are in the folder C:\GFPM\output. For example the file named area contains detailed country data on predicted forest area for the alternative scenario. The file named value_prod contains the value of production at local prices under the alternative scenario.

The Output workbook in the GFPM folder contains tables (analog to Figure 19) of the same detailed country data supplemented with regional aggregates.

Trend Summary gives aggregated regional projections for the alternative scenario, in the workbook C:\GFPM\Summary.xlsm analog to Figures 20 and 21.

Major Country Summary gives projections for the alternative scenario for selected items, commodities, regions and countries, in the workbook SummaryChange.xlsm in the GFPM folder, analog to Figure 23.

As for the base scenario, you must run *Detailed Output* before *Trend Summary* or *Major Country Summary*.

Get Output Option **3) For changes between scenarios** opens the menu in Figure 24 with the following options:

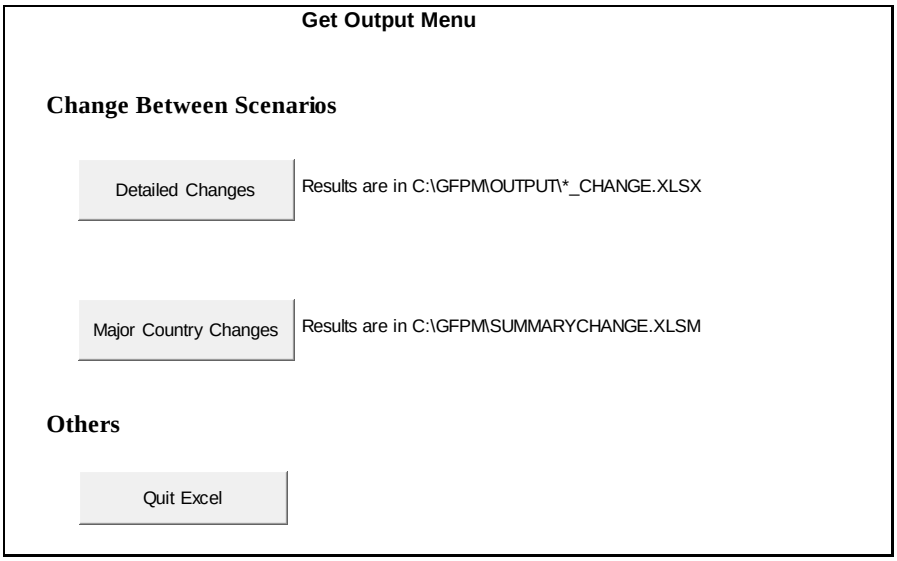


Figure 24: Menu for changes between the base scenario and the alternative scenario.

Detailed Changes produces detailed country data on changes between scenarios in each projected year. The files have the same format as those obtained for the Base and Alternative scenarios. The files are in the folder C:\GFPM\output. For example the file named area_change contains the changes in forest area by country and year between the base scenario and the alternative scenario.

The Get Output menu also gives the changes in value at local prices (in 2012 $US in GFPM 2016) of production, consumption, trade, and value added between scenarios in each projected year. For example the file value_cons_change contains tables and charts on the changes in the value of consumption between the two scenarios, in every projected year (Figure 25).

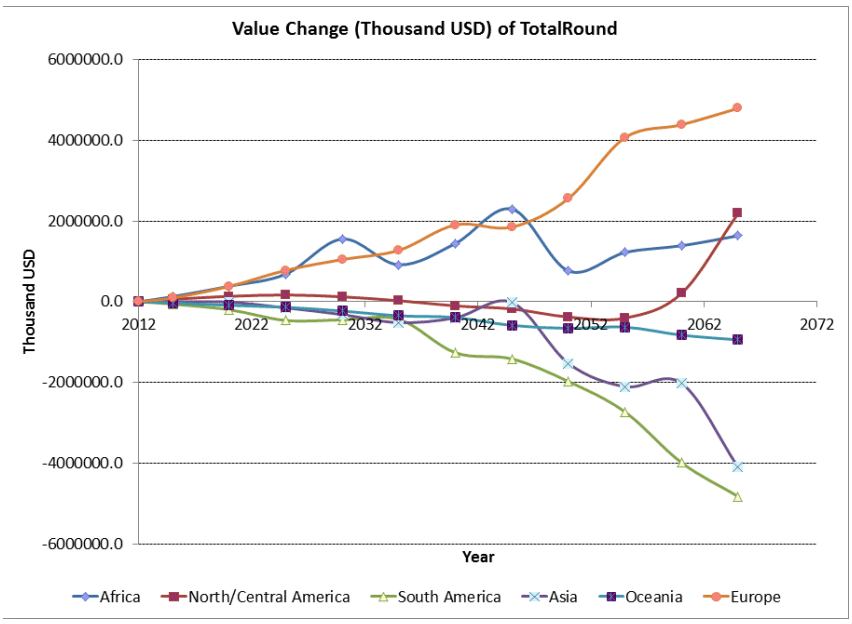


Figure 25: Chart of the change in value of total roundwood consumption between the alternative scenario and the base scenario.

Major Country Changes gives changes for selected items, commodities, regions and countries between base and alternative scenarios. The results are in C:\GFPM\SummaryChange.xlsm. The Diff worksheet shows the changes in level between scenarios. The %Diff worksheet shows the changes in percent.

6 Trouble Shooting GFPM Errors

6.1 Infeasibility

Infeasibility means that BPMPD cannot find a solution to the optimization problem defined by the GFPM input data. When this occurs, GFPM pauses the batch file execution so users can review the BPMPD 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 World.xlsx file of GFPM 2016 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 if 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 global exports from all the countries and from the dummy region are equal to the global imports.

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 Free 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, as it will often cause a chain of subsequent errors.

One common run-time error is: **106 Invalid Numeric Formats**, indicating that 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.xlsx 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 Zhu et al. (2014) 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. Copying and pasting data with many decimals from other worksheets into the *ExogChange* sheet may cause

numbers in two columns to be combined and result in invalid numbers in UPIN.DAT. To avoid this, make sure the column is wide enough or keep at most 5 or 6 digits after the decimal points for all input parameters.

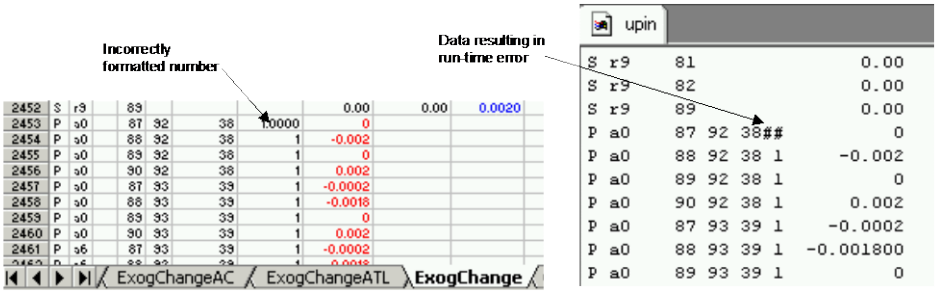


Figure 26. Incorrectly formatted data in the World *ExogChange* worksheet and the corresponding data in UPIN.DAT resulting in a runtime error.

All data columns in the World.xlsx **file should be wide enough to show all the digits of a particular number**.

In general, when preparing or editing the World.xlsx worksheets, follow the following guidelines to avoid run time errors:

1) Leave enough space in every column to see clearly every number, plus space for a couple of digits.

2) Left-justify the data in the first column of each sheet.

3) Right-justify the data in all the other columns.

Other causes of run-time error include:

--**Out of range data** (for example growth rates <= -1).
--A dangling PERIOD record at the end of the *ExogChange* worksheet in World.xlsx
--A dangling number of character at the end of any worksheet.

6.3 Checking local prices

As indicated in part 5 above, the base year solution should approximately match the data in the World.xlsx file. The validation procedure checks this. This validation should be done with free trade. It is only net trade (export – import) that must match the data, not exports or imports, since the model assumes perfect competition of homogenous products, so that at equilibrium countries can only import or export, but not both. Projections may be done with free trade, or with trade inertia constraints that limit the periodic change of imports and exports. In both cases, the best projections are of net trade, not of imports or exports. The trade inertia constraints may distort local prices. Too tight constraint on import variations may cause the local price to be too high compared to the world price. In particular, it is recommended to set free imports for countries and commodities that have zero consumption in the Demand sheet of the World.xlsx file.

7 References

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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 consumption at last period's price, P_{-1} = last period's price, and δ= 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 λ = 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).

For recycled commodities such as waste paper, the following constraints also apply:

$$S_{iw} \le \sum_k \rho_{iwk} D_{ik} \qquad \forall i, w \qquad [5]$$

Where w is the recycled commodity (e.g. waste paper) and k is the discarded commodity (e.g. newsprint, other paper and paperboard). ρ_{iwk} is the maximum fraction of commodity w that can be recovered from the consumption of commodity k in region i.

Material Balance

$$\sum_j T_{jik} + S_{ik} + Y_{ik} - D_{ik} - \sum_n a_{ikn} Y_{in} - \sum_j T_{ijk} = 0 \qquad \forall i, k \qquad [6]$$

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

In addition, byproducts (also named secondary commodities), which result from the production of a (primary) manufactured commodity, such as sawmill residues that result from the production of sawnwood, satisfy the constraint:

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

where b_{ikl} is the amount of byproduct l that can be recovered per unit of manufactured commodity k.

Trade Inertia

$$T_{ijk}^{L} \le T_{ijk} \le T_{ijk}^{U} \quad [7]$$

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

Prices

The shadow prices of the material balance constraints [6] 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.);

$$m = m_{ik}^{*}\left(\frac{Y_{ik}}{Y_{ik,-1}}\right)^{s_{ik}} \quad [8]$$

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:

$$c_{ijk} = c_{ijk}^{*}\left(\frac{T_{ijk}}{T_{ijk,-1}}\right)^{\tau_{ijk}} \quad [9]$$

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:

$$c_{ijk} = f_{ijk} + t_{jk}^{X}\left(P_{ik,-1}\right) + t_{jk}^{I}\left(f_{ijk} + P_{ik,-1}\right) \quad [10]$$

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:

$$r_p = (1 + r_a)^p - 1 \quad \text{where } p \text{ is the length of a period, in years.} \quad [11]$$

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

All periodic linear changes, Δv_p are defined by the corresponding annual linear change, Δv_a, as:

$$\Delta v_p = p\Delta v_a \quad [12]$$

Demand shifts

$$D^* = D_{-1}(1+\alpha_y g_y) \quad [13]$$

g_y = GDP periodic growth rate, α_y= elasticity with respect to GDP, α_0 =periodic trend.

Supply shifts

Industrial roundwood and fuelwood:

$$S^* = S_{-1}(1+\beta_I g_I + \beta_a g_a) \text{ for } k=r, n, f \quad [14]$$

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

Waste paper and other fiber pulp:

$$S^* = S_{-1}(1+\beta_y g_y) \quad [15]$$

Changes in forest area and forest stock

$$A = (1+g_a)A_{-1} \quad [16]$$

where: A = forest area, and g_a = periodic rate of forest area change based on the period length, p, equation [11] and the annual rate of forest area change, g_{aa}, defined by:

$$g_{aa} = (\alpha_0 + \alpha_1 y')e^{\alpha_2 y'} \quad [17]$$

Where y'= income per capita, predicted from:

$$y' = (1+g_{y'})y'_{-1} \quad [18]$$

For each country, α_0 is calibrated so that in the base year the observed g_{aa} is equal to the g_{aa} predicted by [17] given the income per capita y'.

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 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].

[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 eventual exogenous change g_u*.

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

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

where σ is negative, so that g_{ua} decreases with stock per unit area. For each country the GFPM calibrates γ_0 automatically 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 [14] is then:

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

Changes in Manufacturing Coefficients and Costs

The input-output coefficients a in equation [6], may change exogenously over time, for example to reflect increasing use of recycled paper in paper manufacturing:

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

where Δa = periodic change in input-output coefficient.

The manufacturing cost function shifts exogenously over time:

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

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

Changes in transport cost

The transport cost function [9] shifts exogenously over time according to a recursion of equation [10]:

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

with:

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

where Δf and Δt are periodic changes in freight cost and taxes, respectively.

Changes in Trade Inertia Bounds

$$T^L = T_{-1}(1 + g_T r_T - \varepsilon)$$

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

Where:

r_T=periodic rate of growth of trade shift variable (exogenous),

g_T=elasticity of trade with respect to trade shift variable,

ε = absolute value of maximum periodic deviation of trade flow from the trend.

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:

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

This constant elasticity inverse demand equations is approximated by the tangent at the point (D*, P_{-1}) where small changes of price and quantity are related by:

$dP/P = (1/\sigma)dD/D$ or approximately:

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

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

That is:

$P = a + bD$,

Where a and b are computed as follows:

If $\sigma \neq 0$ then $b = \dfrac{\max(P_{-1},1)}{\sigma \max(D^*,1)}$, $a = \max(P_{-1},1) - bD^*$,

If $\sigma = 0$ then $b = 0$, $a = \max(P_{-1},1)$ [26]

In the base year, D* is the consumption in the base year, and P_{-1} is the corresponding price.
The same method is used for the supply equations.

Manufacturing and transport cost:
For example, consider a manufacturing cost equation such as [8] for a given country, product and year:

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

The linear approximation is:

$m = a + bY$,

where:

$$b = s\frac{m^*}{\max(Y_{-1},1)} \text{ and } a = m^* - bY_{-1}, \quad [27]$$

In the base year, m* is the manufacturing cost and Y_{-1} is the manufactured quantity in that year.
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

$$P = a_0 + b_0 S \quad [28]$$

Where, as in [26]:

If $\sigma \neq 0$ then $b = \dfrac{\max(P_0,1)}{\sigma \max(S_0,1)}$, $a = \max(P_0,1) - bS_0$,

If $\sigma = 0$ then $b = 0$, $a = \max(P_0,1)$

Where P_0, and S_0 are respectively the observed price and production in the base year.
With this wood supply equation the base year GFPM solution is also P_0, S_0.

Subsequent years' wood supply

S^*= supply at price P_0 after shift due to changes in stock and other supply shifters, except the price of CO_2.

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

Where, as in [28]:

If $\sigma \neq 0$ then $b_1 = \dfrac{\max(P_0,1)}{\sigma \max(S^*,1)}$, $a = \max(P_0,1) - bS^*$,

If $\sigma = 0$ then $b = 0$, $a = \max(P_0,1)$

And ω = CO_2e content of the forest stock (t/m3), P_{c0}= price of CO_2 in base year ($/t), P_{c1}= price of CO_2 in period 1.

ALLOWABLE CUT CONSTRAINTS

In addition to the permanent constraints stating that in any given year the total wood drain from the forest of a country cannot exceed the stock (equation [4]), optional allowable cut constraints specify that the drain 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:

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

Where:

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

G= periodic change of growing stock without harvest, with $G = (g_a + g_u(1 + g_u^*))I_{-1}$ 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 trade bounds, the inertia constraints [7] are implemented as:

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

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

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

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. (2015b).

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. (2015b).