Calibrating and Updating the Global Forest Products Model (GFPM version 2014 with BPMPD)

by

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1 Introduction

1.1 Terms of use

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

1.2 Outline

The Global Forest Products Model (GFPM) is an economic model of global production, consumption, and trade of forest products. An earlier version of the model is described in Buongiorno et al. (2003). The GFPM 2014 has data and parameters to simulate changes of the forest sector from 2010 to 2030. Buongiorno and Zhu (2014) describe how to use the model for simulation. Like the simulation procedures, the base-year calibration procedure described here uses the BPMPD optimizer (Mészáros 1999) to represent market equilibria.

All the data needed to run the GFPM are in the WORLD in the C:\GFPM directory. One part of the data describes the world forest sector in the base year. The other data refer to the exogenous changes, such as GDP growth, that drive the forest sector over time. The GFPM can be used with the included WORLD successfully without recalibration. This manual is meant only for users who want to recalibrate the model with new data.

The calibration creates most of the base year data in WORLD. The exogenous changes must be entered directly in WORLD. The GFPM User Manual (Buongiorno and Zhu 2014), which should be read first, describes the WORLD file.

The present manual describes the steps in calibrating and updating the GFPM:

--Updating data from the Food and Agriculture Organization (FAO), World Bank, and other sources.

--Calibrating the base year data so that they satisfy economic equilibrium in each country, given prior knowledge on technology and other constraints.

--Checking the data consistency

--Validating the base year solution

--(Optional) adding bilateral trade flows

--(Optional) adding/removing countries and commodities

2 FAO and World Bank data

2.1 Pre-downloaded FAO and World Bank data

The GFPM (version 2014) includes pre-downloaded FAO and World Bank data for all countries and selected commodities from 1992 to 2011 in the folder C:\GFPM\input\InputFiles (Table 1). They are sufficient to calibrate GFPM models with base years from 1992 to 2011 and with the default 180 countries and 14 commodities (Tables 1 and 2 in GFPM User Manual (Buongiorno and Zhu 2014). If the FAO and World Bank data have already been downloaded, you can go directly to part 3.

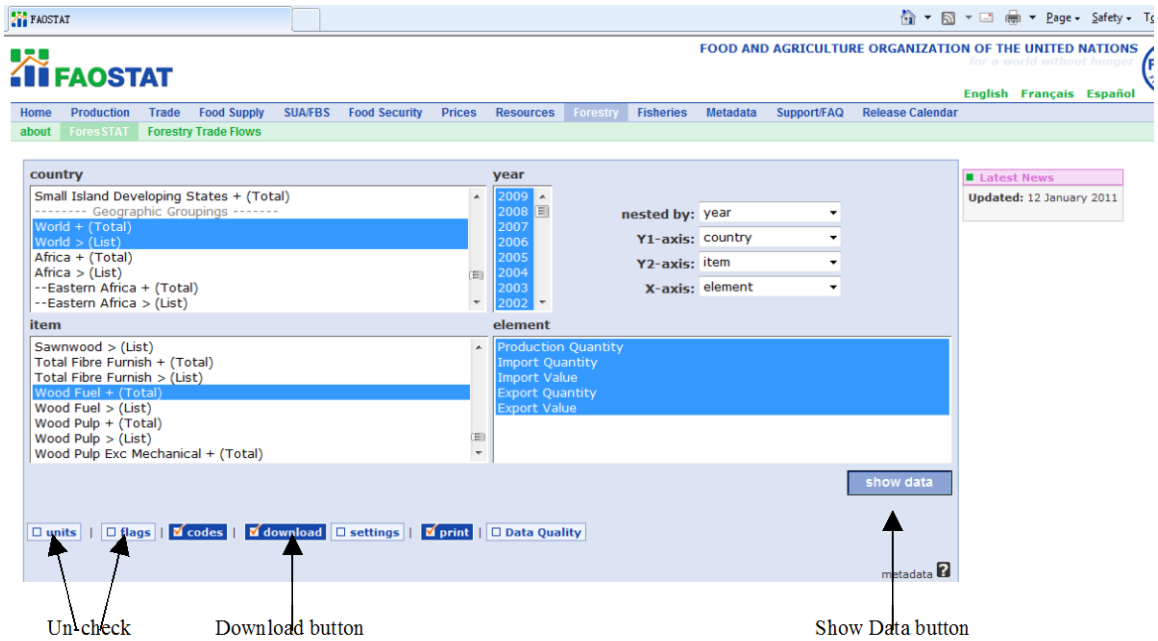
Updating may be desirable as newer FAO and World Bank data become available. To add or remove countries or commodities, see part 8.

Table 1: Names of files in C:\GFPM\input\InputFiles.

GFPM names	Item Name	File Name
	FAO	
Fuelwood	WOOD FUEL+	Fuelwood.csv
Chips and Particles	Chips and Particles	Chips.csv
Wood Residues	Wood Residues	WdResidue.csv
Industrial Roundwood	INDUSTRIAL ROUNDWOOD+	IndRound.csv
Other Industrial Roundwood	OTHER INDUST ROUNDWD+	OthIndRound.csv
Sawnwood	SAWNWOOD+	Sawnwood.csv
Plywood	Plywood	Plywood.csv
Veneer Sheets	Veneer Sheets	Veneer.csv
Particleboard	Particle Board	ParticleB.csv
Fiberboard	FIBREBOARD+	FiberB.csv
Mechanic Pulp	Mechanical Wood Pulp	MechPlp.csv
Chemical Pulp	Chemical Wood Pulp	ChemPlp.csv
Semi-chemical Pulp	Semi-Chemical Pulp	SemiChemPlp.csv
Other Fiber Pulp	Other Fibre Pulp	OthFbrPlp.csv
Newsprint	Newsprint	Newsprint.csv
Printing and Writing Paper	Printing+Writing Paper	PWPaper.csv
Other Paper and Paperboard	Other Paper+Paperboard	OthPaper.csv
Waste Paper	Recovered Paper	WastePaper.csv
Forest Stock and Area	Forest Stock and Area	Forest.csv
	World Bank	
GDP, Population	GDP, Population	GDPPopulation
GDP Deflator	GDP deflator for United States	GDPDeflatorUS

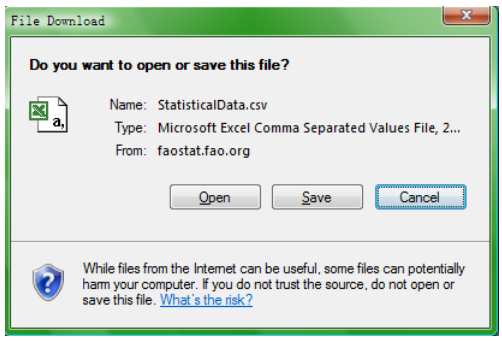
2.2 Updating FAO forest commodity data

Go to the FAOSTAT (forestry data) web site. The current address http://faostat.fao.org/site/626/default.aspx#ancor is subject to change. The following screen appears:

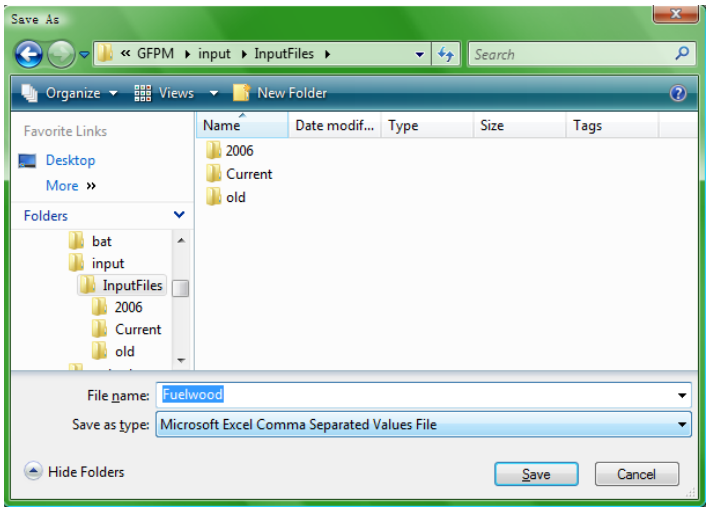


- Select *WORLD>* and *WORLD+* from the **Country** list, by clicking on the names while holding down the *Ctrl* key.
- Select *WOODFUEL+* from the **Item** list.
- Select *Production Quantity*, *Imports Quantity*, *Import Value ExportsQuantity* and *Exports Value* from the **Element** list, by clicking on the element while holding down the *Ctrl* key.
- Select the desired years from the **year** list. The GFPM2014 uses data from 1992 to 2011. For the current FAOSTAT web site, there may be a limit to the number of years that can be downloaded. If this is the case, you could first download 2000 to 2011 data, then download 1992 to 1999 data, and combine them in one file, giving it the name in Table 1.
- Select *year* from the nested-by list.
- Select *country* from the **Y1-axis** list.
- Select *item* from the **Y2-axis** list.
- Select *elements* from the **X-axis** list.
- Un-check options *units*, *flags*, *settings*, and *data quality*.

Click on "show data". The selected data will appear on the web page. Click on "download". The following box appears:



Click on **Save.** The **Save As…** box appears:



To save the downloaded data:

- Select the C:\GFPM\INPUT\INPUTFILES directory.
- Specify the file name in the **File name** (you must use the names in Table 1).
- Click **Save**.

Repeat the above steps for all the FAO data in Table 1 except forest area and forest stock.

Each downloaded cvs file contains the FAO country name and its code, the item (commodity) name and its code, the year, production, import quantity, import value, export quantity, and export value.

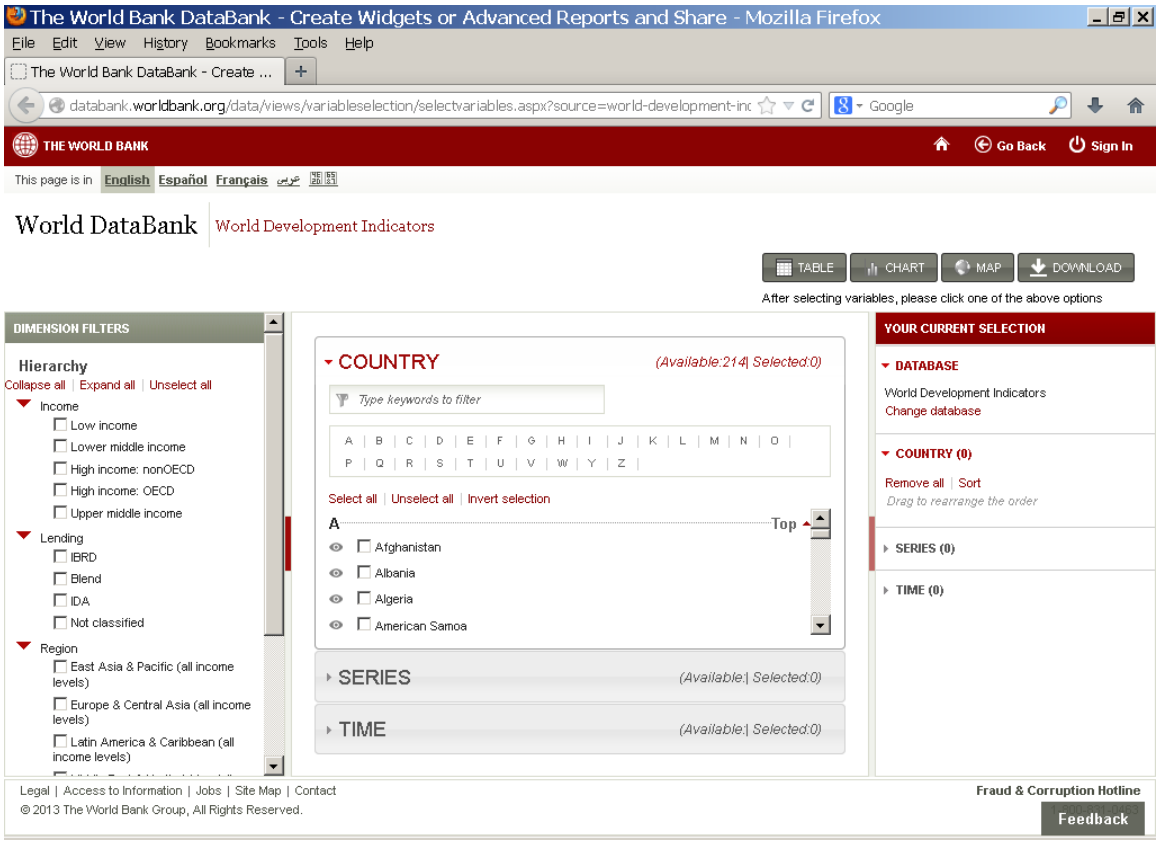
2.3 Updating forest stock and area data

The data on forest stock and area are not available for every year. The FAO "Global Forest Resources Assessment 2010" (http://www.fao.org/forestry/fra/fra2010/en/) was used to prepare the Forest.csv input file in GFPM 2014. The Forest.csv file contains estimated data on forest stock, forest stock growth rate on a given area without harvest, forest area, and forest area growth rate, in the same format as the other input data such as Fuelwood.csv. Users may modify or update the data by directly editing this file.

2.4 Updating World Bank GDP and population data

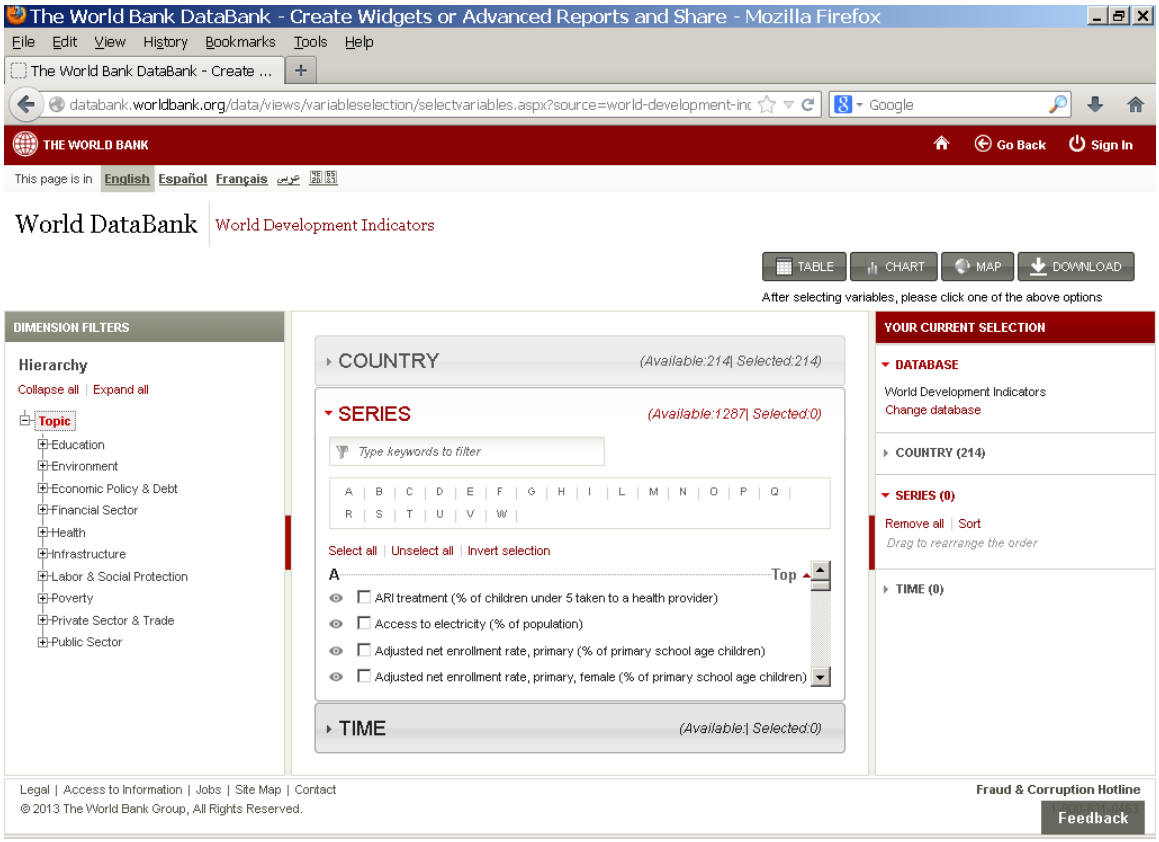
Go to the World Bank Development Indicators web page. The current address of the World Development Indicators online database (subject to change) is:
http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=world-development-indicators#s_g

The WDI browser country, series, and time selection window appears:



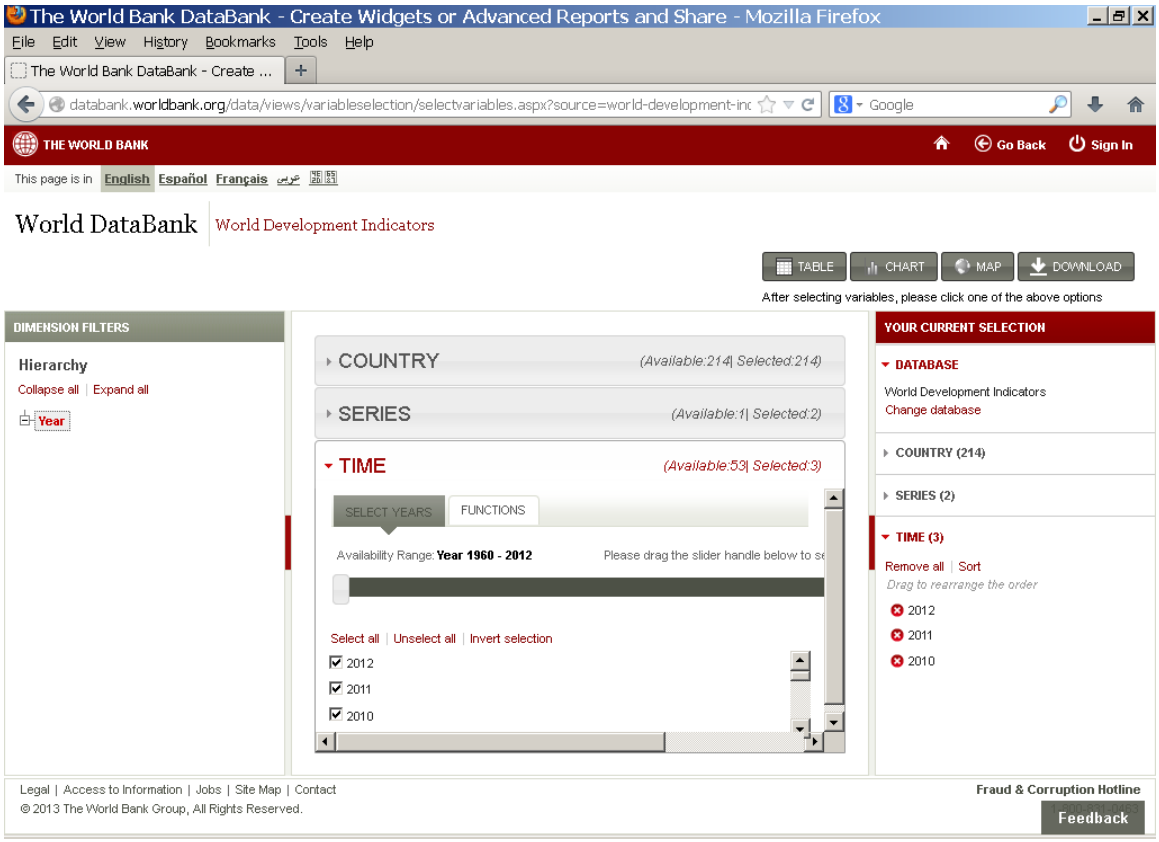
- Click on **Select all** to select all countries.
- Click **Series**.

The Series Selection panel appears:



- To add the *GDP (current US$)* series, use the filter on top of the panel to jump to the series name in the panel, click on the checkbox corresponding to the series name to select it.
- In the same way, select the *Population, total* series.
- Click **Time**.

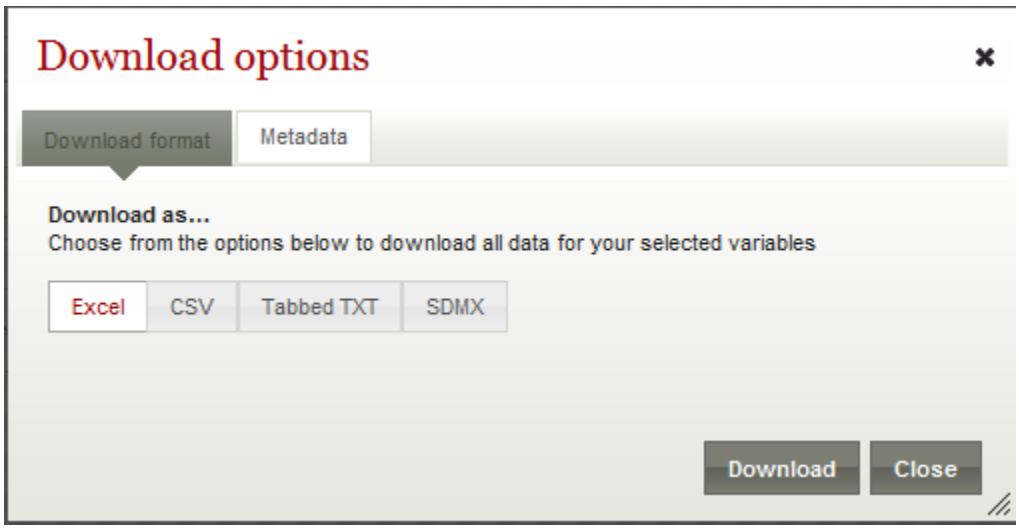
The Years Selection panel appears:



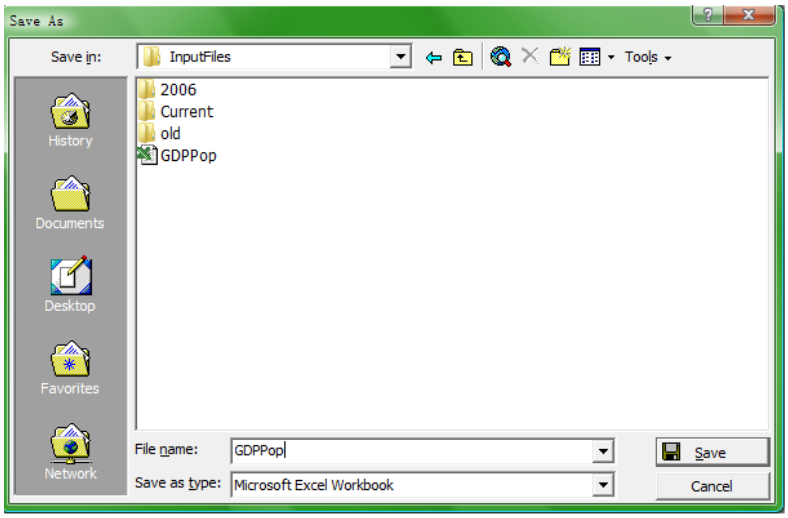
- To download data for a specific year use the scroll bar to move down to the year in the panel, click on the year to select it. Multiple years can be selected.

- Click on **DOWNLOAD** at the upper right corner of the page.

The following dialogue appears:



Choose the "Excel" option then click the Download button and save the file as an Excel file, like:



To save the downloaded data:

- select the C:\GFPM\INPUT\INPUTFILES directory.
- Specify the file name, GDPPopulation, in the **File name** box.
- Click **Save.**

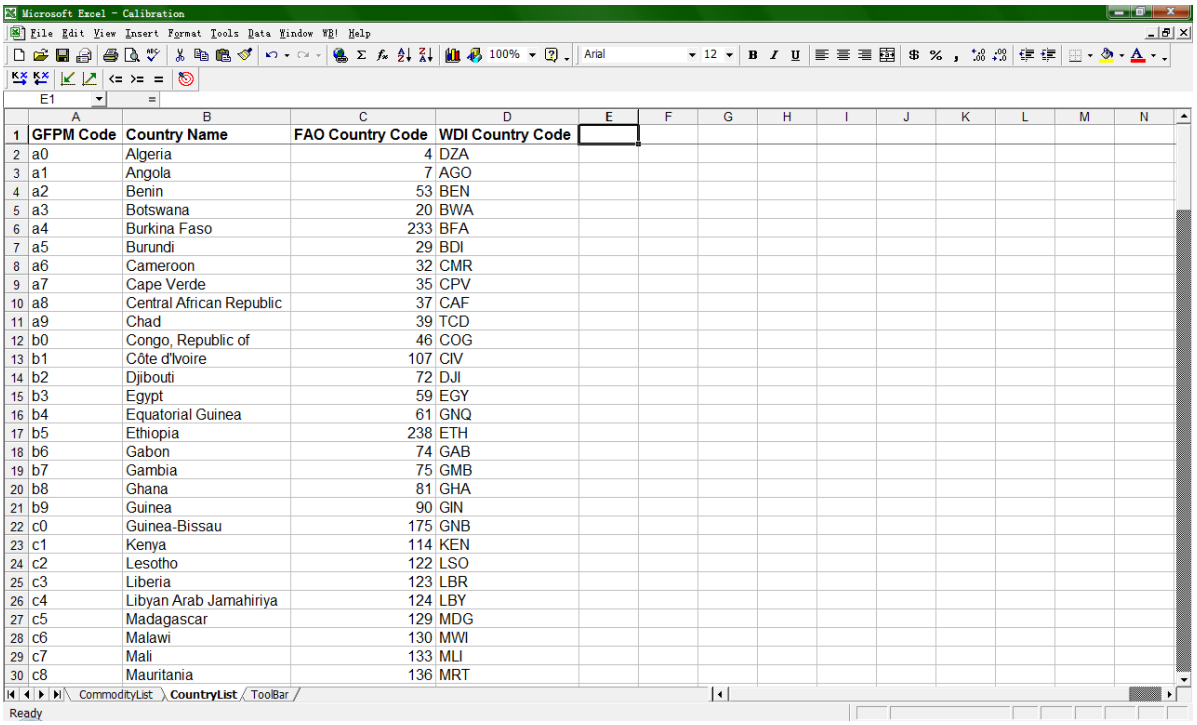
The format of the World Bank GDP and population database may change over time. Download the data as they are, and then process them into the format of the GDPPopulation file. The first column contains the year, followed by the country name and abbreviation, the GDP, and the population.

Repeat this procedure to download the data for the US GDP deflator *GDP deflator (base year varies by country)*. The US GDP deflator is used to express all price series in US dollars of the base year. As for GDP and population some processing may be required to cast the US deflator data in the format of GDPDeflatorUS.

3 Calibrating the base year

The calibration of the GFPM for the base year can be static, using only data for the base year, say 2010, or dynamic, using three years of smoothed or unsmoothed data. The GFPM 2014 used a static calibration with a three year data average (2010, 2011, 2012), for a base year of 2011.

Calibration is done for the countries listed in CALIBRATION, shown below, which defines the correspondence between the GFPM country code and name, and the codes of the country in FAOSTAT and in the World Bank database. Refer to section 8.3 to change the country list.



GFPM Code	Country Name	FAO Country Code	WDI Country Code
a0	Algeria	4	DZA
a1	Angola	7	AGO
a2	Benin	53	BEN
a3	Botswana	20	BWA
a4	Burkina Faso	233	BFA
a5	Burundi	29	BDI
a6	Cameroon	32	CMR
a7	Cape Verde	35	CPV
a8	Central African Republic	37	CAF
a9	Chad	39	TCD
b0	Congo, Republic of	46	COG
b1	Côte d'Ivoire	107	CIV
b2	Djibouti	72	DJI
b3	Egypt	59	EGY
b4	Equatorial Guinea	61	GNQ
b5	Ethiopia	238	ETH
b6	Gabon	74	GAB
b7	Gambia	75	GMB
b8	Ghana	81	GHA
b9	Guinea	90	GIN
c0	Guinea-Bissau	175	GNB
c1	Kenya	114	KEN
c2	Lesotho	122	LSO
c3	Liberia	123	LBR
c4	Libyan Arab Jamahiriya	124	LBY
c5	Madagascar	129	MDG
c6	Malawi	130	MWI
c7	Mali	133	MLI
c8	Mauritania	136	MRT

3.1 Calibration data

The files containing downloaded FAO and World Bank data, from 1992 to 2012 are in C:\GFPM\INPUT\INPUTFILES (see Table 1 above). The calibration procedure merges these files into a single file in C:\GFPM\INPUT\RAWDATA.

A permanent version of RAWDATA is also stored in C:\GFPM\INPUT\INPUTFILES\PROCESSEDRAWDATA, also contains user-supplied data on forest stock and area. If raw data files in INPUTFILES are updated, the calibration retrieves the raw data from INPUTFILES, and creates a new PROCESSEDRAWDATA. With the PROCESSEDRAWDATA, users can extrapolate the forest stock and area data to approximate a new year's raw data to calibrate a more recent base year before all the new data become available.

The data smoothing option uses PROCESSEDRAWDATA to produce 3 year averaged data around the base year, stored in C:\GFPM\INPUT\SMOOTHEDDATA

In addition the calibration uses user-specified data on tariff, freight factor, and bounds on input-output coefficients (Table 2). These data must be entered manually by users in INPUTDATA_BLANK.

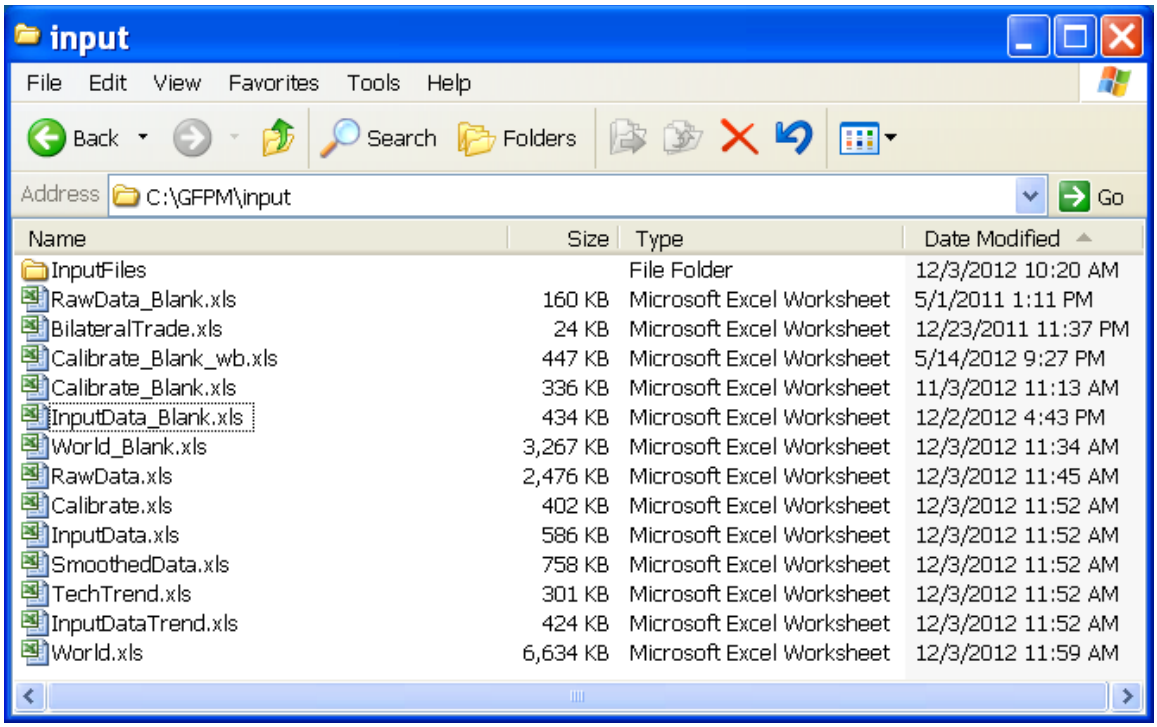


Figure 1. Files used by the calibration procedure.

3.2 Calibration results

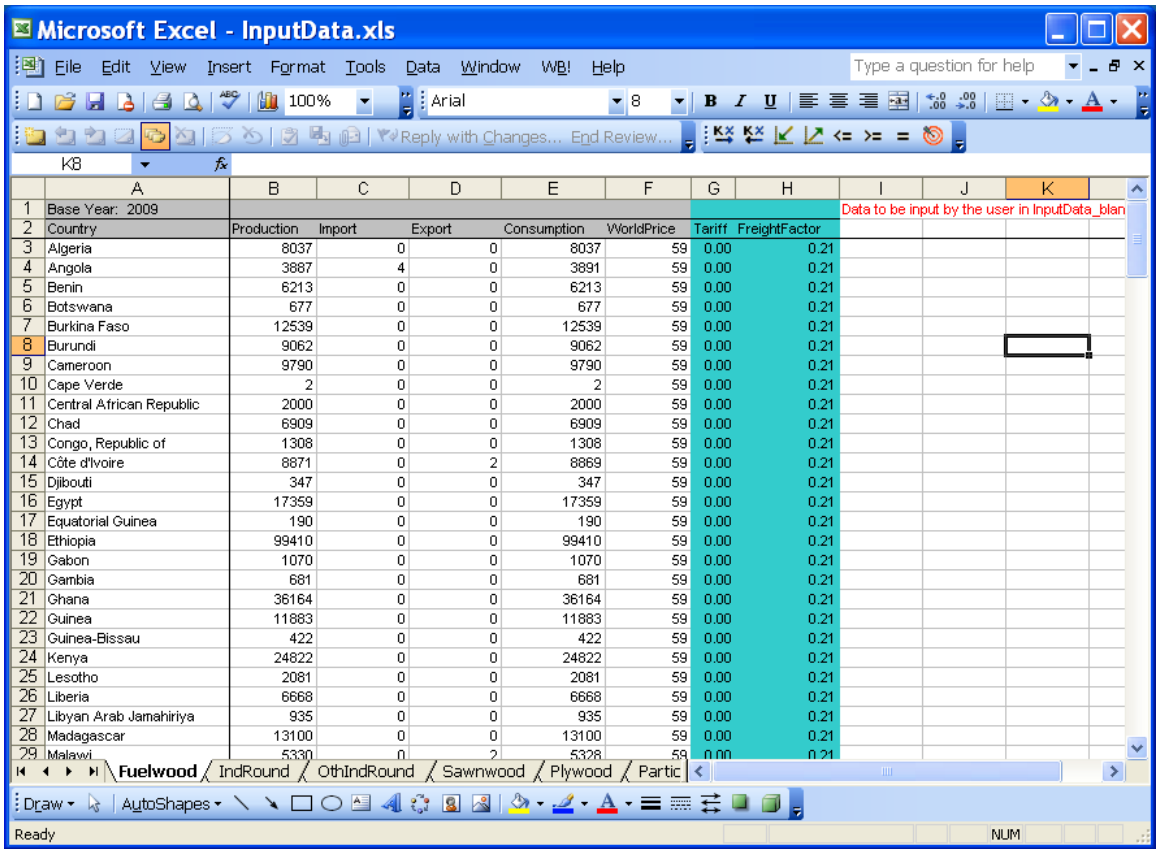
The calibration results are in INPUTDATA (Figure 2 and Table 2). The calibration computes for each country I-O coefficients and manufacturing costs consistent with observed quantities and prices, assuming competitive world markets. The manufacturing cost is the value of the output minus the cost of the input explicitly recognized in the model (wood and fiber). Thus, the manufacturing cost covers labor, energy, other material input, and a normal return to capital.

The calibrationprocedure keeps the data on imports and exports equal to the FAO data, but may alter the data on production.

The calibration determines production levels, I-O coefficients, and manufacturing costs that minimize the sum of the weighted deviations between the observed and calibrated productions (see section 10.2). The I-O coefficients are constrained to stay within user-specified bounds and the manufacturing cost must be non-negative.

If there is no feasible solution, the procedure widens all the bounds gradually until it finds a feasible solution. However, this automatic adjustment may give unlikely estimates of production (see warning option in the calibration menu, below), in which case the bounds should be adjusted manually.

After calibration, the I-O coefficients and the manufacturing cost for the current base year are stored in TECHTREND. Users can produce time series of I-O coefficients and manufacturing cost in TECHTREND by redoing the calibration for several base years. INPUTDATA and TECHTREND are in the C:\GFPM\INPUT folder (Figure 1).



	A	B	C	D	E	F	G	H	I	J	K
1	Base Year: 2009								Data to be input by the user in InputData_blan		
2	Country	Production	Import	Export	Consumption	WorldPrice	Tariff	FreightFactor			
3	Algeria	8037	0	0	8037	59	0.00	0.21			
4	Angola	3887	4	0	3891	59	0.00	0.21			
5	Benin	6213	0	0	6213	59	0.00	0.21			
6	Botswana	677	0	0	677	59	0.00	0.21			
7	Burkina Faso	12539	0	0	12539	59	0.00	0.21			
8	Burundi	9062	0	0	9062	59	0.00	0.21			
9	Cameroon	9790	0	0	9790	59	0.00	0.21			
10	Cape Verde	2	0	0	2	59	0.00	0.21			
11	Central African Republic	2000	0	0	2000	59	0.00	0.21			
12	Chad	6909	0	0	6909	59	0.00	0.21			
13	Congo, Republic of	1308	0	0	1308	59	0.00	0.21			
14	Côte d'Ivoire	8871	0	2	8869	59	0.00	0.21			
15	Djibouti	347	0	0	347	59	0.00	0.21			
16	Egypt	17359	0	0	17359	59	0.00	0.21			
17	Equatorial Guinea	190	0	0	190	59	0.00	0.21			
18	Ethiopia	99410	0	0	99410	59	0.00	0.21			
19	Gabon	1070	0	0	1070	59	0.00	0.21			
20	Gambia	681	0	0	681	59	0.00	0.21			
21	Ghana	36164	0	0	36164	59	0.00	0.21			
22	Guinea	11883	0	0	11883	59	0.00	0.21			
23	Guinea-Bissau	422	0	0	422	59	0.00	0.21			
24	Kenya	24822	0	0	24822	59	0.00	0.21			
25	Lesotho	2081	0	0	2081	59	0.00	0.21			
26	Liberia	6668	0	0	6668	59	0.00	0.21			
27	Libyan Arab Jamahiriya	935	0	0	935	59	0.00	0.21			
28	Madagascar	13100	0	0	13100	59	0.00	0.21			
29	Malawi	5330	0	2	5328	59	0.00	0.21			

Figure 2: Example of INPUTDATA file. The data supplied by users in INPUTDATA_BLANK are highlighted.

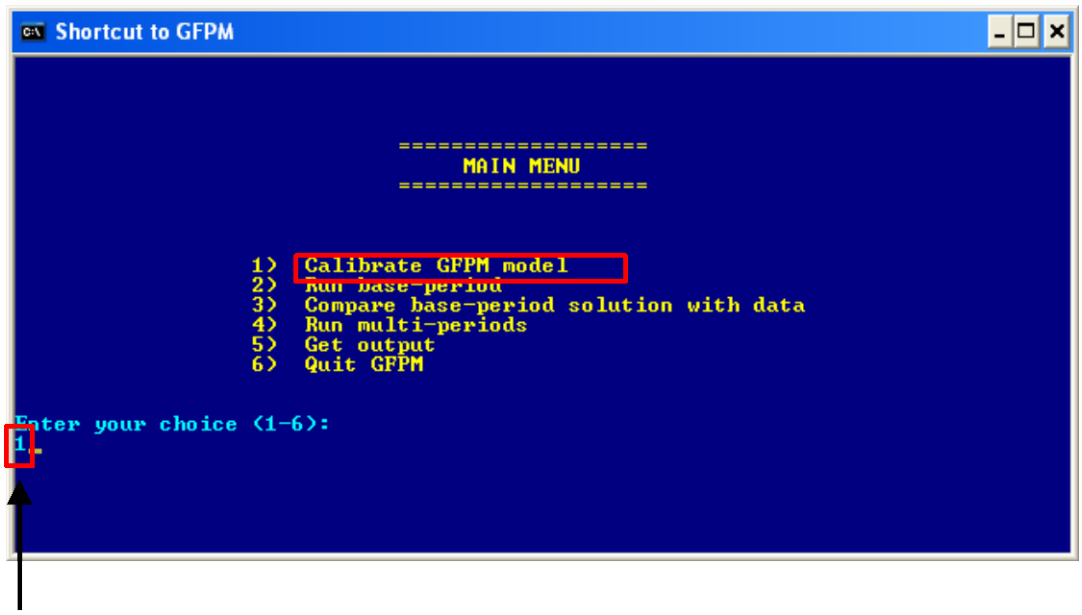
Table 2: Data in INPUTDATA, by product.

Data	Description	Source
Country	Country name as in the GFPM	GFPM
Production	Production (000 m^3 or 000 tonne)	Calculated
Import	Import volume (000 m^3 or 000 tonne)	FAOStat
Export	Export volume (000 m^3 or 000 tonne)	FAOStat
Consumption	Consumption volume (000 m^3 or 000 tonne)	Calculated
WorldPrice	World export unit value ($US/ m^3 or tonne)	Calculated
Tariff	Ad valorem tax on imports or exports	User*
Freight Factor	Freight cost as proportion of export unit value	User
ManuCost	Manufacturing cost above cost of wood or fiber input	Calculated
Input	input per unit of output.	Calculated
Upper, Lower	Upper, lower bound on Input-output coefficient.	User
Initial	Initial estimated value of input-output coefficient.	Calculated

*All user-supplied data must be inserted in INPUTDATA_blank

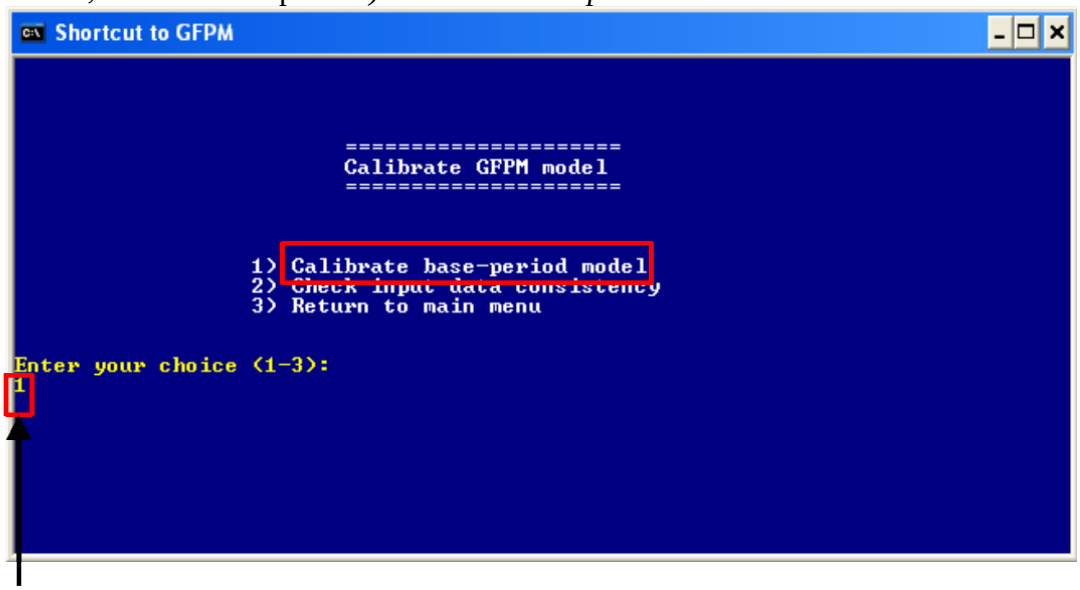
3.3 Calibration steps

To start calibration, select menu option *1) Calibrate GFPM model* from the GFPM Main Menu:



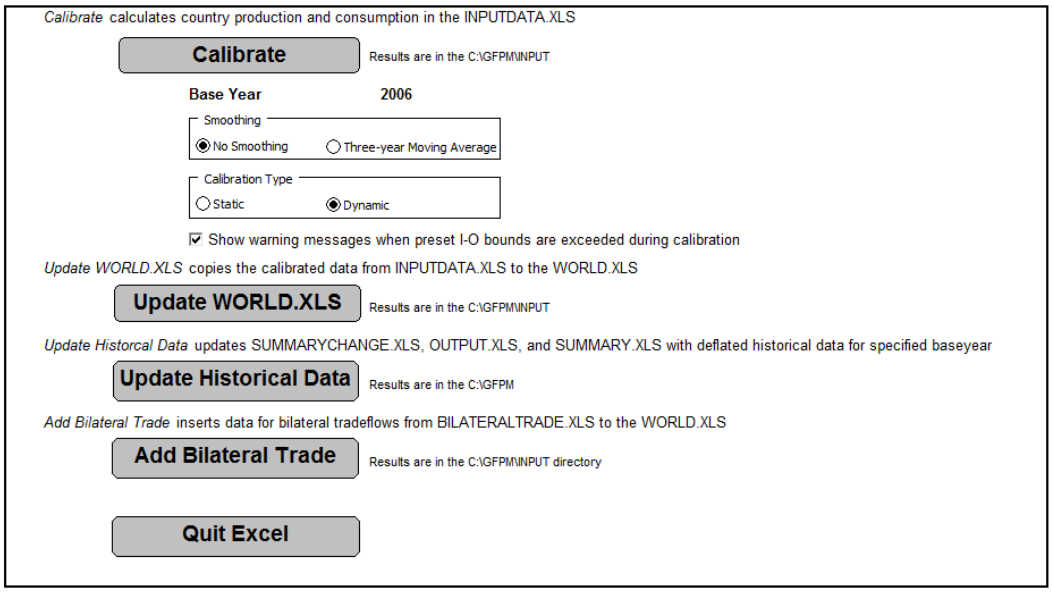
Type *1* here

Then, select menu option *1) Calibrate base-period model*:



Type *1* here

Click the **Enable the macros** button if the program asks you to do so. The following Calibration Menu appears:



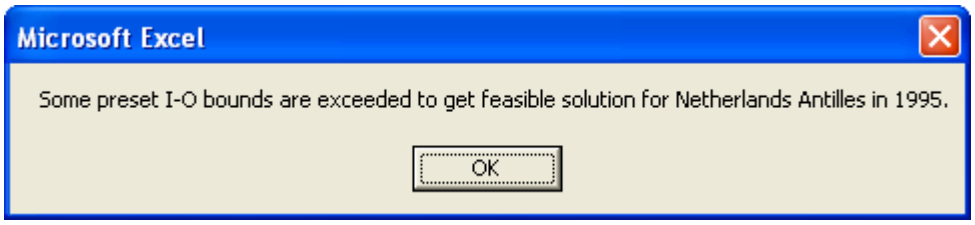
Click on **Calibrate**.

The **Base Year** is the year for which the GFPM is calibrated. With un-smoothed data, the base year can be the last year of historical data. With smoothed data it must be at least one year less.

Choosing **No Smoothing** keeps the historical data as is. **Three-year Moving Average** smoothes the data by for example averaging the historical data for 2005, 2006, and 2007 to produce the base year 2006. Thus, with smoothing and historical data from 1992 to 2011, the latest base year can be only 2011.

Choosing the **Static** calibration uses only the base-year data, while **Dynamic**, uses 3 years of data. The dynamic calibration mitigates excessive changes in the I-O coefficients and manufacturing costs when the base year is updated with new data.

Checking the "Show warning message" box, produces the following warning message if the calibration procedure had to extend the bounds of the I-O coefficients outside these preset bounds:

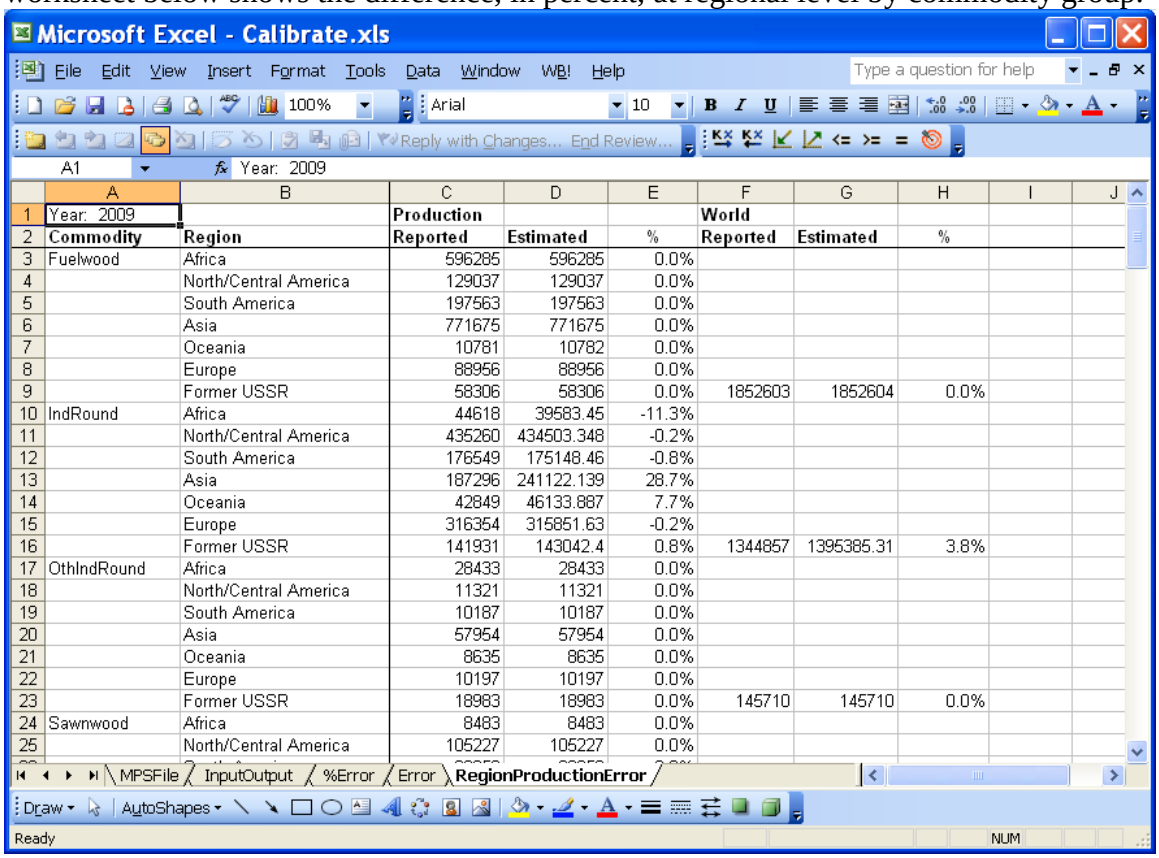


The results of the calibration, consisting of the input-output coefficients and of the manufacturing costs, are in file INPUTDATA in the INPUT folder.

3.4 Calibrated vs reported production

The differences between the calibrated production and the FAO reported production are in the CALIBRATE workbook in the INPUT folder. For example, the RegionProductionError

worksheet below shows the difference, in percent, at regional level by commodity group.



	A	B	C	D	E	F	G	H
1	Year: 2009		Production			World		
2	Commodity	Region	Reported	Estimated	%	Reported	Estimated	%
3	Fuelwood	Africa	596285	596285	0.0%			
4		North/Central America	129037	129037	0.0%			
5		South America	197563	197563	0.0%			
6		Asia	771675	771675	0.0%			
7		Oceania	10781	10782	0.0%			
8		Europe	88956	88956	0.0%			
9		Former USSR	58306	58306	0.0%	1852603	1852604	0.0%
10	IndRound	Africa	44618	39583.45	-11.3%			
11		North/Central America	435260	434503.348	-0.2%			
12		South America	176549	175148.46	-0.8%			
13		Asia	187296	241122.139	28.7%			
14		Oceania	42849	46133.887	7.7%			
15		Europe	316354	315851.63	-0.2%			
16		Former USSR	141931	143042.4	0.8%	1344857	1395385.31	3.8%
17	OthIndRound	Africa	28433	28433	0.0%			
18		North/Central America	11321	11321	0.0%			
19		South America	10187	10187	0.0%			
20		Asia	57954	57954	0.0%			
21		Oceania	8635	8635	0.0%			
22		Europe	10197	10197	0.0%			
23		Former USSR	18983	18983	0.0%	145710	145710	0.0%
24	Sawnwood	Africa	8483	8483	0.0%			
25		North/Central America	105227	105227	0.0%			

3.5 Updating WORLD

The WORLD file contains all the data needed to run the GFPM. Most of these data are computed by the base year calibration, such as consumption, production, prices, input-output coefficients, manufacturing cost, and transportation cost. The calibration also produces a template for the *ExogChange* sheet which must be completed by the user.

Default values of user-supplied parameters such as the demand and supply elasticities, and the parameters of the forest growth parameters are stored in WORLD_BLANK where they are highlighted in light blue.

Clicking on **Update WORLD** on the calibration menu (p. 16) merges the calibrated data in INPUTDATA and the default parameters in WORLD_BLANK into a new WORLD in the C:\GFPM\INPUT directory (Figure 3). The highlighted data in WORLD are the default parameters that were preset in WORLD_BLANK, the other data result from the calibration.

Copy or move this new WORLD to C:\GFPM before checking input data consistency, running the base period or validating the base period.

To make multi-period projections you must first enter the exogenous change data in the *ExogChange* sheet of WORLD described in "Using the GFPM 2014" (Buongiorno and Zhu 2014). The calibration procedure prepares an *ExogChange* template for the periods specified in WORLD_BLANK that must be completed by users.

The WORLD file has a "Specification" sheet with the list of countries and commodities, and the model base year. Other documentation of a particular run can also be recorded manually in the Specification sheet.

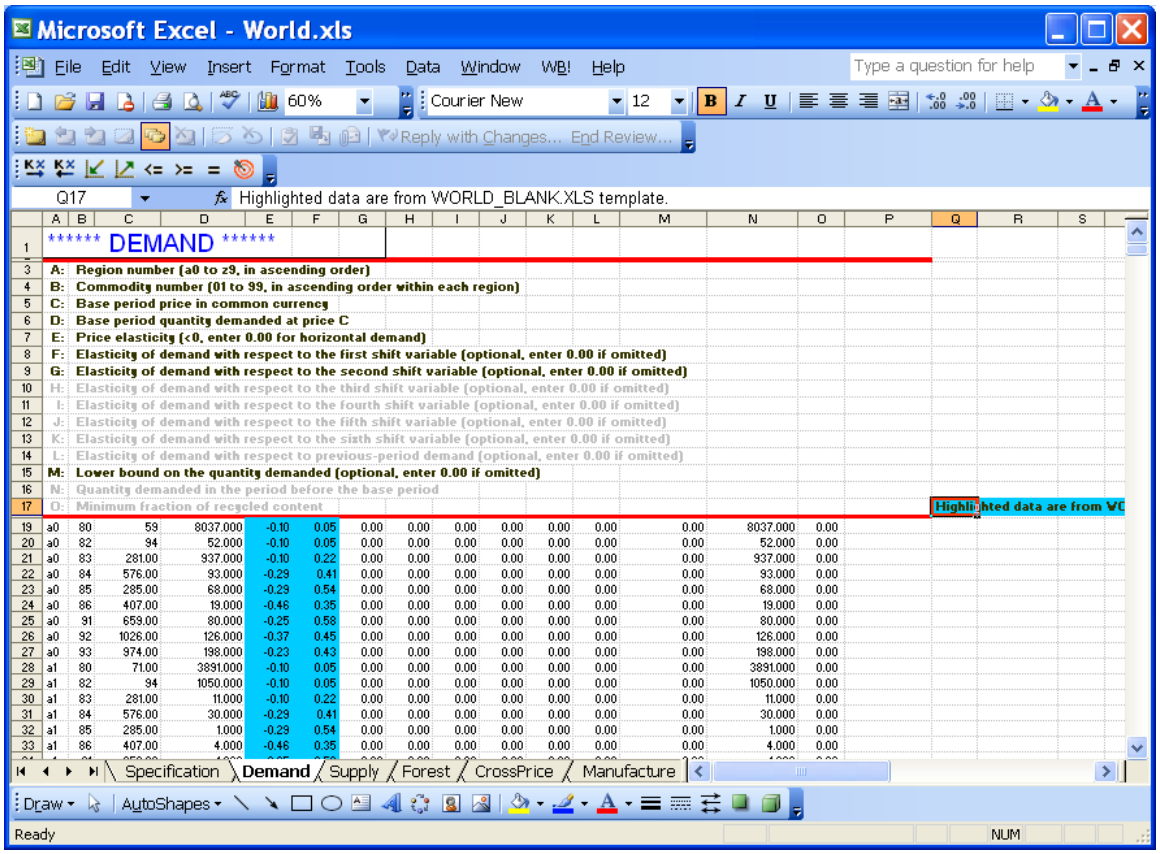


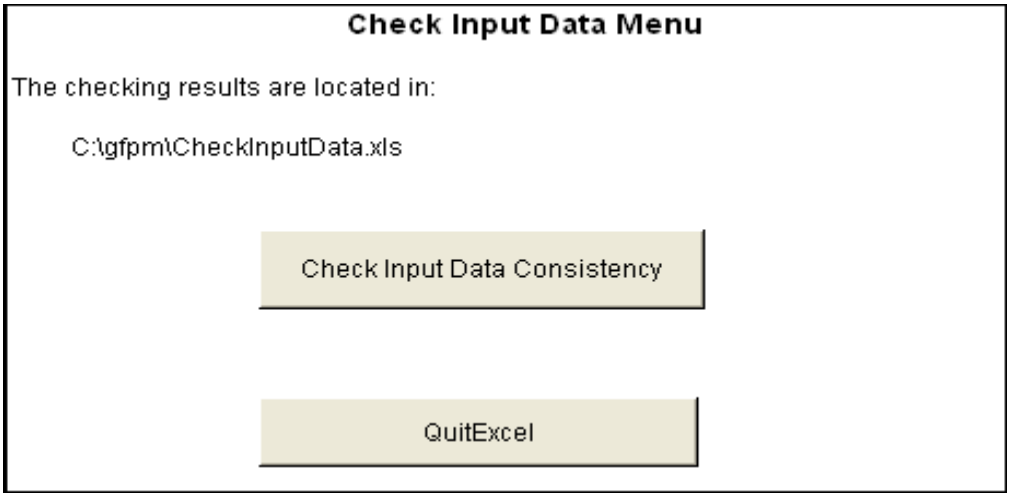
Figure 3. WORLD file produced by calibration. Highlighted data are default parameters read from the WORLD_BLANK template.

3.6 Other functions

For explanations of the "Update Historical Data" and "Add Bilateral Trade" buttons in the calibration menu, refer to sections 6 and 7. To exit the Calibration Menu and return to the Calibrate GFPM Model menu click the **Quit Excel** button on the Calibration menu (p. 15).

4 Checking input data consistency

Option *2) Check input data consistency* in the Calibrate GFPM model sub menu (p. 15) produces this menu



Make sure that the WORLD being checked is in C:\GFPM. Clicking on **Check Input Data Consistency** gives the results in the "Data Consistency" worksheet in C:\GFPM\CHECKINPUTDATA (Figure 4).

					Model Input												Combined			Derived				Check			
Country &					Local	Manuf	World X	Trans	Tariff	I/O coefficient				Paper	Max R	World X		Local		Local	Manuf		Local	Manuf	Max waste paper	
product	Consump	Producti	Export	Import	price	cost	price	cost	rate	81/87	88	89	90	consu	Rate	price	Consumpti	price	Consumpt	price	cost	Consum	price	cost	available	
s080	7425	7425			31											31	7425.00	31.00	7425.00	31		0.000	0.000			
s081		109.601		23	92.04		66	12	0.18							66	132.60	92.04	132.60	92.04		-0.001	0.000			
s082	110	110			66											66	110.00	66.00	110.00	66		0.000	0.000			
s083	778	13		765	241.5	83.19	207	23	0.05	1.72						207	778.00	241.50	778.00	241.5	83.191	0.000	0.000	0.000		
s084	270	25		245	539.72	259.9	396	16	0.31	3.04						396	270.00	539.72	270.00	539.7	259.92	0.000	0.000	0.000		
s085	60	23		37	278.75	142.5	214	9	0.25	1.48						214	60.00	278.75	60.00	278.8	142.53	0.000	0.000	0.000		
s086	19			19	386.25		297	12	0.25							297	19.00	386.25	19.00	386.3		0.000	0.000			
s087																305	0.00	305	0.00	305		0.000	0.000			
s088		0.056		15		156	431	34	0.05	3.61						431	15.06	488.25	15.06	488.3	155.93	0.000	0.000	0.000		
s089		5.958			864											864	5.96	864.00	5.96	864		0.000	0.000			
s090		7.549	6		108											108	1.55	108.00	1.55	108		0.000	0.000		33.63	OK
s091	45.153	8.153		37	535.5	1	486	24	0.05	0	0.61	0.25	0.19	45.15	0.13	486	45.15	535.50	45.15	535.5	1	0.000	0.000	0.000		
s092	76	14	2	64	391.3	397.8	813	49	0.15	0	0.72	0.28	0	76	0.13	813	76.00	391.30	76.00	391.3	397.84	0.000	0.000	0.000		
s093	138			138	880.9		723	43	0.15					138	0.13	723	138.00	880.90	138.00	880.9		0.000	0.000			
s180	3403	3403			31											31	3403.00	31.00	3403.00	31		0.000	0.000			
s181		46	1	1	66		66	12	0.18							66	46.00	66.00	46.00	66		-0.001	0.000			
s182	1050	1050			66											66	1050.00	66.00	1050.00	66		0.000	0.000			
s183	10	5		5	271.4	114.3	207	23	0.18	2.38						207	10.00	271.40	10.00	271.4	114.32	0.000	0.000	0.000		
s184	12	11		1	506.76	313.4	396	16	0.23	2.839						396	12.00	506.76	12.00	506.8	313.41	0.000	0.000	0.000		
s185	0				214											214	0.00	214.00	0.00	214		0.000	0.000			
s186	2			2	383.16		297	12	0.24							297	2.00	383.16	2.00	383.2		0.000	0.000			
s187																305	0.00	305	0.00	305		0.000	0.000			
s188		0.712				164.4				4.04						431	0.71	431	0.71	431	164.36	0.000	0.000	0.000		
s189		0.19			864											864	0.19	864.00	0.19	864		0.000	0.000			
s190		0.13			108											108	0.13	108.00	0.13	108		0.000	0.000		0.84	OK
s191	1	1			486	1				0	0.712	0.19	0.13	1	0.12	486	1.00	486.00	1.00	486	1	0.000	0.000	0.000		
s192	2			2	1034.4		813	49	0.2					2	0.12	813	2.00	1034.40	2.00	1034		0.000	0.000			
s193	4			4	888.56		723	43	0.16					4	0.12	723	4.00	888.56	4.00	888.6		0.000	0.000			

Figure 4. Checks of input data consistency.

The checks verify the following conditions for the base year data in the WORLD. After a static calibration the conditions should hold exactly. After a dynamic calibration the conditions should hold closely:

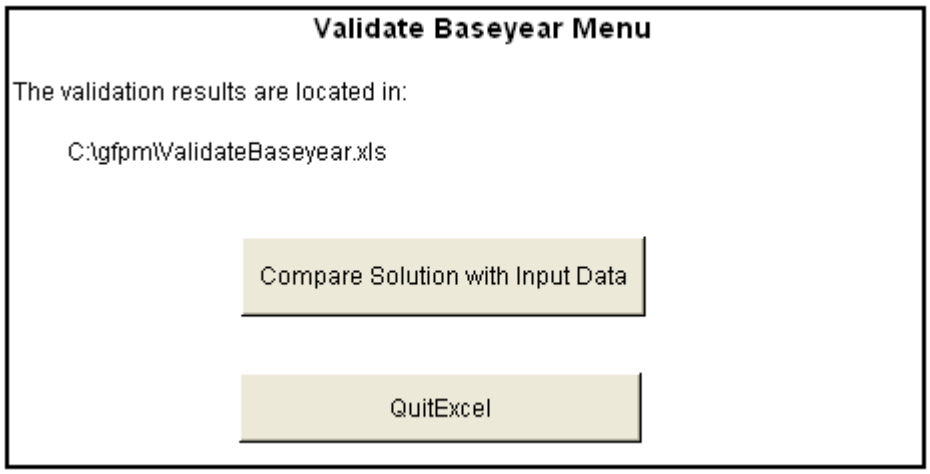
- Apparent consumption (production + import - export) = final demand, or intermediate demand (for an input used by other products).
- Local price = world price plus the transport cost to the country of interest (for net importers), or = world price (for net exporters).
- Manufacturing cost = price of the output minus cost of all inputs, given the price of inputs and the input-output coefficients.
- Waste paper production ≤ waste paper recoverable.

5 Validating the base year solution

After getting a base-year solution with option 2) in the Main menu (p. 14), you can compare the model solution with the base year input data in WORLD.

The base-year solution should be **with free trade**, i.e. without bound on exports and imports. In a well-calibrated model, imports and exports may differ from observed values, but net trade (exports minus imports) should be near the observed value. The input data and the solution should be nearly the same after a static model calibration. Some small differences are to be expected after a dynamic calibration.

To validate the base year solution, choose option "3) Compare base-period solution with data" in the Main menu (p. 14). The following sub-menu will appear:



Clicking on **Compare Solution with Input Data** produces the differences between base year input data and base year solution in the following spreadsheets in the workbook C:\GFPM\VALIDATEBASEYEAR.

The DEMAND sheet shows the difference between calculated and input demand and price of end products.

****** DEMAND ******

A: Region number (01 to 99, in ascending order)
B: Commodity number (01 to 99, in ascending order within each region)
C: Base period price in common currency
D: Base period quantity demanded at price C
E: Price elasticity (<0, enter 0.00 for horizontal demand)
F: Elasticity of demand with respect to the first shift variable (optional, enter 0.00 if omitted)
G: Elasticity of demand with respect to the second shift variable (optional, enter 0.00 if omitted)
H: Elasticity of demand with respect to the third shift variable (optional, enter 0.00 if omitted)
I: Elasticity of demand with respect to the fourth shift variable (optional, enter 0.00 if omitted)
J: Elasticity of demand with respect to the fifth shift variable (optional, enter 0.00 if omitted)
K: Elasticity of demand with respect to the sixth shift variable (optional, enter 0.00 if omitted)
L: Elasticity of demand with respect to previous-period demand (optional, enter 0.00 if omitted)
M: Lower bound on the quantity demanded (optional, enter 0.00 if omitted)
N: Quantity demanded in the period before the base period
O: Minimum fraction of recycled content

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
																Calculated by model, and difference with input data					
																Demand	Difference	%Diff	Price	Difference	%Diff
s0	80	30	7305	-0.10	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7305	0.00		7305	0	0	30	0	0
s0	82	66	182	-0.37	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	182	0.00		182	0	0	66	0	0
s0	83	223.65	348	-0.21	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	348	0.00		348	0	0	223.7	0	0
s0	84	539.72	145	-0.22	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	145	0.00		145	0	0	539.7	0	0
s0	85	220.00	31	-0.05	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31	0.00		31	0	0	220	0	0
s0	86	340.00	6	-0.52	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6	0.00		6	0	0	340	0	0
s0	91	520.80	29	-0.18	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29	0.00		29	0	0	520.8	0	0
s0	92	333.80	67	-0.37	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	67	0.00		67	0	0	333.8	0	0
s0	93	815.35	126	-0.14	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126	0.00		126	0	0	815.4	0	0
s1	80	30	3320	-0.10	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3320	0.00		3320	0	0	30	0	0
s1	82	66	1050	-0.37	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1050	0.00		1050	0	0	66	0	0
s1	83	192	5	-0.21	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5	0.00		5	0	0	192	0	0
s1	84	396	11	-0.22	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11	0.00		11	0	0	396	0	0

The SUPPLY sheet shows the difference between calculated and input supply and price of raw material.

****** SUPPLY ******

A: Region number (01 to 99, in ascending order)
B: Commodity Number (01 to 99, in ascending order within each region)
C: Base period price in common currency
D: Base period quantity supplied at price C
E: Price elasticity (>0)
F: Elasticity of supply with respect to the first shift variable (optional, enter 0.00 if omitted)
G: Elasticity of supply with respect to forest stock (optional, 0 if omitted)
H: Elasticity of supply with respect to forest area (optional, 0 if omitted)
I: Elasticity of supply with respect to GDP per capita (optional, 0 if omitted)
J: Elasticity of supply with respect to the fifth shift variable (optional, 0 if omitted)
K: Elasticity of supply with respect to the sixth shift variable (optional, 0 if omitted)
L: Elasticity of supply with respect to previous-period supply (optional, enter 0.00 if omitted)
M: Lower bound on the quantity supplied (optional, enter 0.00 if omitted)
N: Upper bound on the quantity supplied (optional, enter 0.00 if omitted)
O: Quantity supplied in the period before the base period

																Calculated by model, and difference with input data							
																Supply	Difference	%Diff	Price	Difference	%Diff		
s0	80	30	7305	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0	7305		7305	0	0	30	0	0		
s0	81	32.04	74	1.31	0.00	1.60	0.00	0.90	0.00	1.00	0.00	0.00	0	74		74.5	0	0	32	0	0		
s0	82	66	182	1.31	0.00	1.60	0.00	0.90	0.00	1.00	0.00	0.00	0	182		182	0	0	66	0	0		
s0	83	741	2	0.80	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	2		2	0	0	741	0	0		
s0	90	33	12	0.80	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	12		12.4	0	0	33	0	0		
s1	80	30	3320	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0	3320		3320	0	0	30	0	0		
s1	81	66	66	1.31	0.00	1.60	0.00	0.90	0.00	1.00	0.00	0.00	0	66		66	0	0	66	0	0		
s1	82	66	1050	1.31	0.00	1.60	0.00	0.90	0.00	1.00	0.00	0.00	0	1050		1050	0	0	66	0	0		
s1	83	741	0	0.80	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0		0	0		0	-741			
s1	90	33	0	0.80	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0		0	0		0	-33			
s2	80	30	5966	1.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0	5966		5966	0	0	30	0	0		
s2	81	32.04	23	1.31	0.00	1.60	0.00	0.90	0.00	1.00	0.00	0.00	0	23		23.5	0	0	32	0	0		
s2	82	66	237	1.31	0.00	1.60	0.00	0.90	0.00	1.00	0.00	0.00	0	237		237	0	0	66	0	0		

The MANUFACTURE sheet shows the difference between the computed and input manufacturing cost and quantity manufactured.

****** MANUFACTURE ******

A: Record type (two types of records are used, M and P)

-> Record type M (manufacturing cost) :
B: Region number (01 to 99, in ascending order)
D: Commodity (primary) number (01 to 99, in ascending order within each region)
E: Commodity (secondary) number (01 to 99, in ascending order within each region, and leave blank if not applicable)
F: Process number(01 to 99, in ascending order within each commodity)
G: Input mix number(1 to 9, in ascending order with each process)
H: Net manufacturing cost in common currency
I: Base period manufactured quantity
J: Output elasticity of manufacture cost, s >= 0

-> Record type P (manufacturing coefficients) :
B: Region number (01 to 99, in ascending order)
D: Input commodity number (01 to 99, in ascending order within each output commodity)
E: Output commodity number (01 to 99, in ascending order within each region)
F: Process number(01 to 99, in ascending order within each commodity)
H: Amount of input commodity per unit of output commodity

-> Record type B (by-product coefficients) :
B: Region number (01 to 99, in ascending order)
D: Primary commodity number (01 to 99, in ascending order within each output commodity)
E: Secondary commodity number (01 to 99, in ascending order within each region)
F: Process number(01 to 99, in ascending order within each commodity)
G: Input mix number(1 to 9, in ascending order w
H: Amount of secondary commodity per unit of

												Calculated from model solution								
												Manufacturing cost	Difference	%Diff	Quantity manufactured	Difference	%Diff	Price		
M	s0	83	10	1	123.3264	13	0.10					123.3	-0.0264	0	13.0000	0.0000	0	223.7		
M	s0	84	10	1	358.4012	25	0.10					358.4	-0.0012	0	25.0000	0.0000	0	539.7		
M	s0	85	10	1	122.4376	24	0.10					122.4	-0.0376	0	24.0000	0.0000	0	220		
M	s0	87	10	1	132.7360	1.35	0.10					132.7	-0.0360	0	1.4000	0.0500	5	280		
M	s0	88	10	1	280.6795	6.83	0.10					280.7	0.0205	0	6.8000	-0.0300	-3	448.4		
M	s0	92	10	1	488.4773	14	0.10					488.5	0.0221	0	14.0000	0.0000	0	933.8		
M	s0	93	10	1	536.1185	27	0.10					536.1	-0.0185	0	27.0000	0.0000	0	815.4		
M	s1	83	10	1	1.0000	5	0.10					1	0.0000	0	5.0000	0.0000	0	192		
M	s1	84	10	1	32.8182	11	0.10					32.8	-0.0182	0	11.0000	0.0000	0	396		

The TRANSPORTATION sheet shows the difference between the computed and input trade, and the difference between the calculated and input price (observed price= world price +

transport cost). To handle bilateral trade flows, another sheet "TransAggregated" shows total imports and exports from each country.

****** TRANSPORTATION COST AND TAX ******

A: Origin region number (01 to 99)
C: Destination region number (01 to 99, in ascending order within each origin)
E: Commodity number (01 to 99, in ascending order within each origin-destination)
F: Freight cost of shipping one unit of commodity from origin to destination
G: Import ad-valorem tax rate
H: Export ad-valorem tax rate
I: Base period quantity shipped from origin region to destination region
J: Mean elasticity of trade with respect to GDP (>=0; 0 for fixed trade, no trade, or free trade)
K: Trade inertia bounds as fraction of trade (>= 0; 0 for fixed trade; -1 for no trade; 1 for
L: Base period price of commodity in exporting country

Calculated by model, and difference with input data

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
													Trade	Difference	%Diff	Price	Difference	%Diff	
a1		aa		81	0.00	0.000	0.00	1	0	0.0001	66		1	0	0	66	0	0	
a2		aa		83	0.00	0.000	0.00	2	0	0.0001	192		2	0	0	192	0	0	
a4		aa		81	0.00	0.000	0.00	1	0	0.0001	66		1	0	0	66	0	0	
a5		aa		81	0.00	0.000	0.00	4	0	0.0001	66		4	0	0	66	0	0	
a6		aa		81	0.00	0.000	0.00	219	0	0.0001	66		219	0	0	66	0	0	
ay		aa		81	0	0.00	0.00	6171	0.00	0.0001	0		6171	0	0	0	0		
ay		aa		84	0	0.00	0.00	288	0.00	0.0001	0		288	0	0	0	0		
ay		aa		86	0	0.00	0.00	2030	0.00	0.0001	0		2030	0	0	0	0		
aa		a0		91	24	0.05	0.00	29	0.00	0.0001	472		29	0	0	520.8	-1.1E-13	0	
aa		a0		92	46	0.15	0.00	53	0.00	0.0001	766		53	0	0	933.8	0	0	
aa		a0		93	40	0.15	0.00	99	0.00	0.0001	663		99	0	0	815.4	0.05	0	
aa		a1		86	10	0.24	0.00	1	0.00	0.0001	262		1	0	0	337.3	0.02	0	
aa		ay		80	0.00	0.000	0.00	1144	0	0.0001	0		1144			0	0		
aa		ay		83	0.00	0.000	0.00	2736	0	0.0001	0		2736			0	0		
aa		ay		85	0.00	0.000	0.00	367	0	0.0001	0		367			0	0		
aa		ay		91	0.00	0.000	0.00	522	0	0.0001	0		522			0	0		
aa		ay		92	0.00	0.000	0.00	1755	0	0.0001	0		1755			0	0		

The NET TRADE sheet shows the difference between the input and calculated net trade. The country code, such as a0 for Algeria, is joined to the commodity code, such as 80 for fuelwood.

	A	B	C	D	E
1	Country code	Actual net trade	Calculated by model	Difference	% Diff
2	a080	0	0	0	
3	a081	-29	-29	0	0
4	a082	0	0	0	
5	a083	-935	-935	0	0
6	a084	-120	-120	0	0
7	a085	-7	-7	0	0
8	a086	-6	-6	0	0
9	a087	0	0	0	
10	a088	-17	-17	0	0
11	a089	0	0	0	
12	a090	0	0	0	
13	a091	-29	-29	0	0
14	a092	-53	-53	0	0
15	a093	-99	-99	0	0
16	a180	0	0	0	
17	a181	1	1	0	0

6 Updating historical data

Clicking *Update Historical Data* in the calibration menu (p. 15) updates the historical data from 1992 to the base year in the output workbooks SUMMARYCHANGE , OUTPUT, and SUMMARY with the latest data downloaded from the FAO and World Bank data bases.

All prices and values are expressed in constant US dollars of the base year specified in the calibration menu.

This updating may be done as soon as the FAO and World Bank data have been downloaded (see section 2). It can be done before or after base-year calibration.

7 Adding bilateral trade data to WORLD

The *Add Bilateral Trade* option of the calibration menu (p. 16) allows data on bilateral trade flows to be added to WORLD. The input data are in the BILATERALTRADE workbook in the C:\GFPM\INPUT\ directory (Figure 5).

GDP elasticity, tariff and freight factor, zero for trade to rest of world.

Bilateral trade volume for sawnwood exports from Canada to Australia

	A	B	C	D	E	F	G	H	I	J
1	Exporter	Code	Importer	Code	Import	GDPElas	Bound	Tariff	FreightFactor	ExporterPrice
2	Canada	f3	Mexico	g5	30	0.97	0.050	0.05	0.14	198.0
3	Canada	f3	USA	h1	45059	0.97	0.050	0	0.14	198.0
4	Canada	f3	Chile	h5	3	0.97	0.050	0.08	0.14	198.0
5	Canada	f3	China	j1	57	0.97	0.050	0.03	0.14	198.0
6	Canada	f3	Japan	j9	8007	0.97	0.050	0.002	0.14	198.0
7	Canada	f3	Australia	m4	399	0.97	0.050	0.05	0.14	198.0
8	Canada	f3	ROW	zz	2565	0	0.050	0	0	198.0
9	Mexico	g5	Canada	f3		0.97	0.050	0	0.14	237.0
10	Mexico	g5	USA	h1	260	0.97	0.050	0	0.14	237.0
11	Mexico	g5	Chile	h5		0.97	0.050	0.08	0.14	237.0
12	Mexico	g5	China	j1		0.97	0.050	0.03	0.14	237.0
13	Mexico	g5	Japan	j9	2	0.97	0.050	0.002	0.14	237.0
14	Mexico	g5	Australia	m4		0.97	0.050	0.05	0.14	237.0
15	Mexico	g5	ROW	zz	0	0	0.050	0	0	237.0
16	USA	h1	Canada	f3	1718	0.97	0.050	0	0.14	226.0
17	USA	h1	Mexico	g5	783	0.97	0.050	0.05	0.14	226.0
18	USA	h1	Chile	h5	3	0.97	0.050	0.08	0.14	226.0
19	USA	h1	China	j1	203	0.97	0.050	0.03	0.14	226.0
20	USA	h1	Japan	j9	1245	0.97	0.050	0.002	0.14	226.0
21	USA	h1	Australia	m4	70	0.97	0.050	0.05	0.14	226.0
22	USA	h1	ROW	zz	3757	0	0.050	0	0	226.0
23	Chile	h5	Canada	f3	12	0.97	0.050	0	0.14	198.0
24	Chile	h5	Mexico	g5	12	0.97	0.050	0.05	0.14	198.0
25	Chile	h5	USA	h1	774	0.97	0.050	0	0.14	198.0
26	Chile	h5	China	j1	4	0.97	0.050	0.03	0.14	198.0
27	Chile	h5	Japan	j9	478	0.97	0.050	0.002	0.14	198.0
28	Chile	h5	Australia	m4	1	0.97	0.050	0.05	0.14	198.0
29	Chile	h5	ROW	zz	654	0	0.050	0	0	198.0
30	China	j1	Canada	f3	2	0.97	0.050	0	0.14	233.0
31	China	j1	Mexico	g5		0.97	0.050	0.05	0.14	233.0
32	China	j1	USA	h1	51	0.97	0.050	0	0.14	233.0
33	China	j1	Chile	h5		0.97	0.050	0.08	0.14	233.0
34	China	j1	Japan	j9	494	0.97	0.050	0.002	0.14	233.0
35	China	j1	Australia	m4	1	0.97	0.050	0.05	0.14	233.0
36	China	j1	ROW	zz	199	0	0.050	0	0	233.0
37	Japan	j9	Canada	f3		0.97	0.050	0	0.14	230.0
38	Japan	j9	Mexico	g5		0.97	0.050	0.05	0.14	230.0
39	Japan	j9	USA	h1		0.97	0.050	0	0.14	230.0
40	Japan	j9	Chile	h5		0.97	0.050	0.08	0.14	230.0
41	Japan	j9	China	j1	3	0.97	0.050	0.03	0.14	230.0
42	Japan	j9	Australia	m4		0.97	0.050	0.05	0.14	230.0
43	Japan	j9	ROW	zz	12	0	0.050	0	0	230.0
44	Australia	m4	Canada	f3		0.97	0.050	0	0.14	237.0
45	Australia	m4	Mexico	g5		0.97	0.050	0.05	0.14	237.0
46	Australia	m4	USA	h1	9	0.97	0.050	0	0.14	237.0
47	Australia	m4	Chile	h5		0.97	0.050	0.08	0.14	237.0
48	Australia	m4	China	j1	9	0.97	0.050	0.03	0.14	237.0
49	Australia	m4	Japan	j9	25	0.97	0.050	0.002	0.14	237.0
50	Australia	m4	ROW	zz	236	0	0.050	0	0	237.0
51	ROW	zz	Canada	f3	114	0.97	0.050	0	0.14	198.0
52	ROW	zz	Mexico	g5	58	0.97	0.050	0.05	0.14	198.0
53	ROW	zz	USA	h1	4093	0.97	0.050	0	0.14	198.0
54	ROW	zz	Chile	h5	10	0.97	0.050	0.08	0.14	198.0
55	ROW	zz	China	j1	2267	0.97	0.050	0.03	0.14	198.0
56	ROW	zz	Japan	j9	8264	0.97	0.050	0.002	0.14	198.0

Fuelwood / IndRound / **Sawnwood** / Plywood / ParticleB / FiberB / Mech

Figure 5: Example of data stored in BILATERALTRADE.

The worksheets in BILATERALTRADE are similar to the *Transportation* worksheet in WORLD (see the GFPM User Manual (Buongiorno et al. 2014)). The data must be sorted by the code of the exporter, then by the code for the importer.

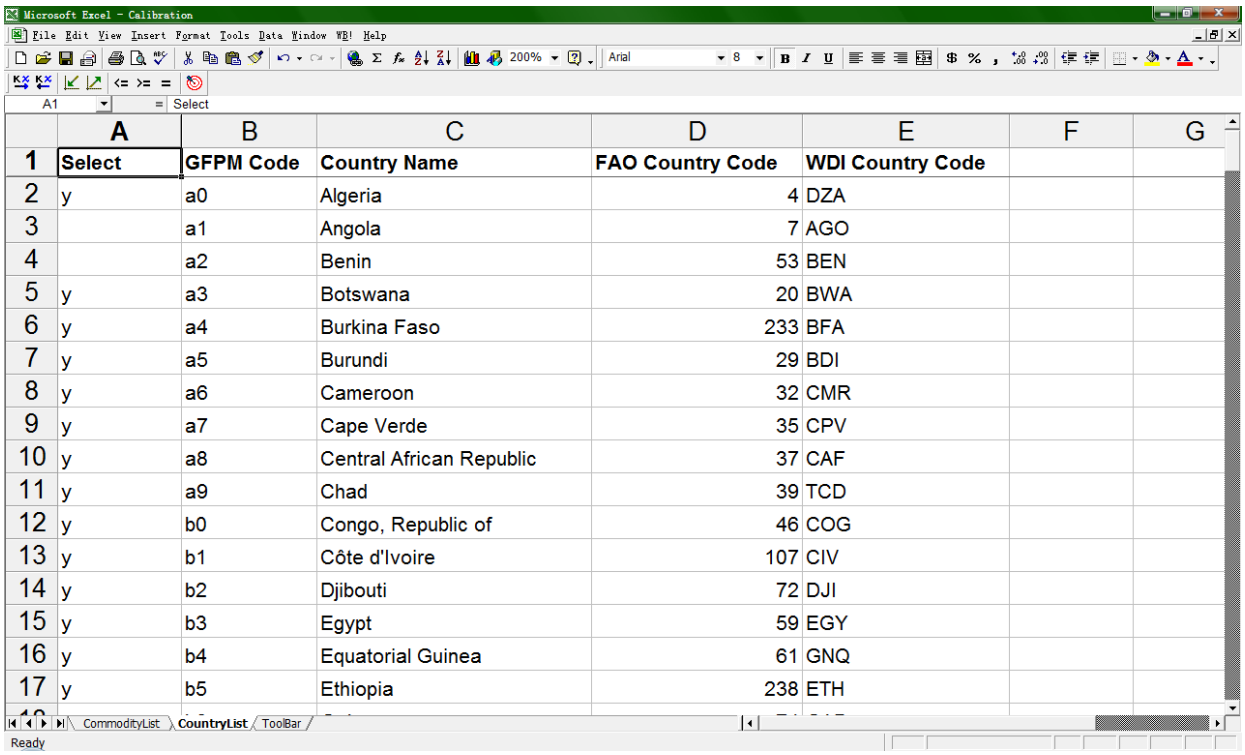
The sum of exports from each country in BILATERALTRADE must equal the total exports in WORLD. For example, the sum of Canadian exports to Mexico, USA, Chile, China,

Japan, Australia and the rest of the world (ROW) must equal total Canadian sawnwood exports; 5 6120 thousand m^3 in the example (Figure 5).

8 Adding/removing countries and commodities

8.1 Removing countries

To remove countries, delete “y” in the “Select” column of the “CountryList” sheet of C:\GFPM\CALIBRATION. For example, to remove Angola and Benin, delete the “y” in the “Select” column for these two countries. GFPM will not calibrate data for these two countries and the final WORLD will not include them.

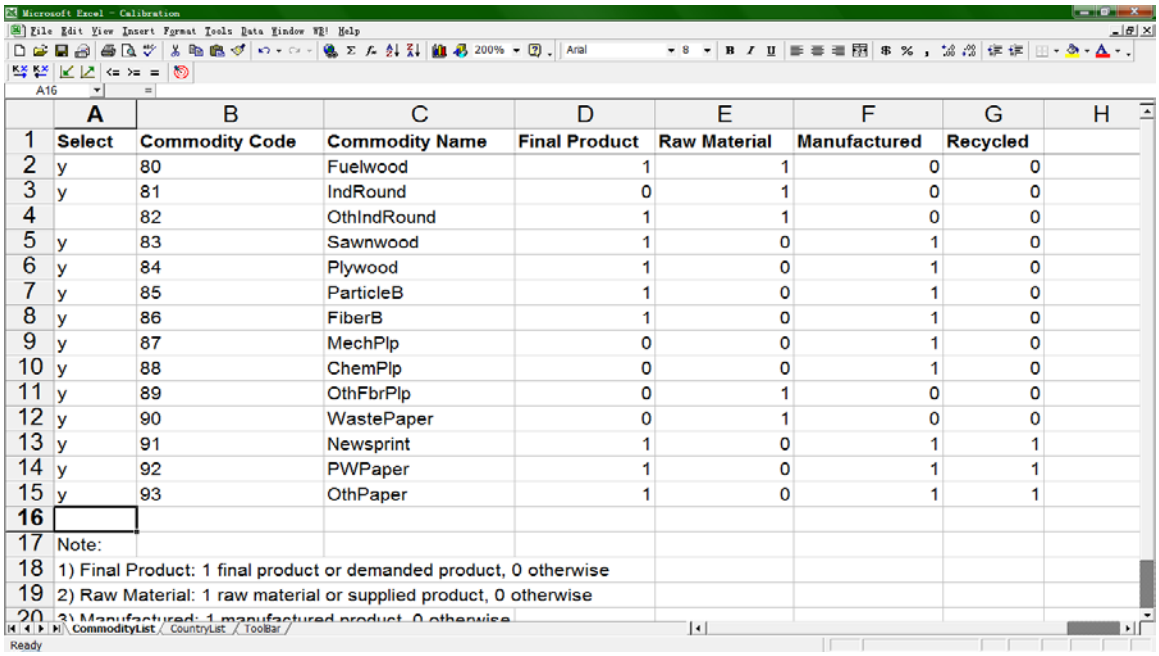


	A	B	C	D	E	F	G
1	Select	GFPM Code	Country Name	FAO Country Code	WDI Country Code		
2	y	a0	Algeria	4	DZA		
3		a1	Angola	7	AGO		
4		a2	Benin	53	BEN		
5	y	a3	Botswana	20	BWA		
6	y	a4	Burkina Faso	233	BFA		
7	y	a5	Burundi	29	BDI		
8	y	a6	Cameroon	32	CMR		
9	y	a7	Cape Verde	35	CPV		
10	y	a8	Central African Republic	37	CAF		
11	y	a9	Chad	39	TCD		
12	y	b0	Congo, Republic of	46	COG		
13	y	b1	Côte d'Ivoire	107	CIV		
14	y	b2	Djibouti	72	DJI		
15	y	b3	Egypt	59	EGY		
16	y	b4	Equatorial Guinea	61	GNQ		
17	y	b5	Ethiopia	238	ETH		

8.2 Removing commodities

To remove commodities, delete “y” in the “Select” column of the “commodityList” sheet in C:\GFPM\CALIBRATION. For example, to remove “othIndRound”, delete the “y” in the “Select” column for this commodity. GFPM will not calibrate data for this commodity in any country, and the final WORLD will totally exclude this commodity.

No commodity should be removed without full recognition of the effect on the representation of the entire forest sector.



	A	B	C	D	E	F	G	H
1	Select	Commodity Code	Commodity Name	Final Product	Raw Material	Manufactured	Recycled	
2	y	80	Fuelwood	1	1	0	0	
3	y	81	IndRound	0	1	0	0	
4		82	OthIndRound	1	1	0	0	
5	y	83	Sawnwood	1	0	1	0	
6	y	84	Plywood	1	0	1	0	
7	y	85	ParticleB	1	0	1	0	
8	y	86	FiberB	1	0	1	0	
9	y	87	MechPlp	0	0	1	0	
10	y	88	ChemPlp	0	0	1	0	
11	y	89	OthFbrPlp	0	1	0	0	
12	y	90	WastePaper	0	1	0	0	
13	y	91	Newsprint	1	0	1	1	
14	y	92	PWPaper	1	0	1	1	
15	y	93	OthPaper	1	0	1	1	
16								
17	Note:							
18	1) Final Product: 1 final product or demanded product, 0 otherwise							
19	2) Raw Material: 1 raw material or supplied product, 0 otherwise							
20	3) Manufactured: 1 manufactured product, 0 otherwise							

8.3 Replacing or adding countries

To replace a country by another, change the country name, its FAO country code, and its WDI (World Bank Indicator) country code in the “CountryList” sheet in C:\GFPM\CALIBRATION. Select this country with a “y”. Also modify the country name lists in all sheets of C:\GFPM\input\InputData_Blank to make them the same as in the “CountryList” sheet.

To add countries, modify the “CountryList” sheet of C:\GFPM\CALIBRATION by adding “y” in the “Select” column if the countries to be added already exist in the current list. Otherwise, add the countries to the list with their GFPM, FAO, and WDI county codes. The new GFPM country codes must be of the same form, but not duplicate the code of other countries, and the list of GFPM country codes after changing or adding countries must be in ascending order.

After modifying the “CountryList” sheet, also change all sheets of C:\GFPM\input\InputData_Blank to add model parameters for each replacing and added country. The country lists on these sheets should be the same as that of the selected countries in the “CountryList” sheet.

If the replaced or added countries are not within the default list of 180 countries in GFPM but are within the downloaded data files in C:\GFPM\input\inputFiles folder, delete the file C:\GFPM\input\inputFiles\ProcessedRawData, or save it with other name, to force GFPM to retrieve the raw data from the downloaded FAO and World Bank data files in the C:\GFPM\input\inputFiles folder. If these data files do not contain the required data, update them by re-downloading or directly modifying the downloaded file. In that case, GFPM will automatically produce a new ProcessedRawData.

8.4 Adding commodities

This requires several manual steps and an understanding of the relationship among GFPM commodities.

First, modify the "CommodityList" sheet of C:\GFPM\CALIBRATION. The new commodity must be inserted at the beginning of the list, before "Fuelwood" (code 80), with commodity code 79. Another commodity would be inserted above it with the code 78, and so on, down to commodity code 10. For each commodity, indicate if it is a final product, a raw material, a manufactured product, or a recycled product.

Second, add a sheet in C:\GFPM\input\InputData_Blank and give it the name of the new commodity. Insert for this new commodity the same data as for existing commodities such as sawnwood or newsprint.

Third, complete rows and columns in the "InputOutput" sheet of C:\GFPM\input\Calibrate_Blank as for existing commodities.

Fourth, download the required data from FAO or other sources and save the data in the same format as other files containing data for other commodities. The file name should be the same as the commodity name and is stored in the folder C:\GFPM\Input\InputFiles like the other data files. GFPM will detect the newly added data files and produce a new ProcessedRawData.

9 References

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10 Mathematical formulation

10.1 Data smoothing

When the optional smoothing is specified in the calibration menu, the raw data are smoothed with a 3-year moving average:

$$S_t = \frac{1}{3}(R_{t-1} + R_t + R_{t+1}) \qquad \text{for } t = t_{B-2} \text{ to } t_B$$

where S_t is the smoothed data in year t, R_t is the raw data, t_0 is the first year of data and t_B is the base year for which the GFPM is calibrated.

10.2 Static calibration

The static calibration calibrates the GFPM for a particular base year (or a three year average is the smoothing option is selected). Estimates of the I-O coefficients for a particular country and year are obtained with goal programming, conditional on the trade data and on prior bounds on the I-O coefficients. The method adjusts the production data if they are inconsistent with prior knowledge regarding the possible range of the input-output coefficients. The method minimizes the sum of the weighted difference between estimated and reported production, and of the sum of the weighted difference between estimated consumption and consumption implied by the prior I-O coefficients. In the following formulation all the variables refer to a specific country and year.

Objective function:

$$\min Z = \beta \sum_i (Y_i^+ + Y_i^-) w_i + (1-\beta) \sum_i \sum_j (Y_{ij}^+ + Y_{ij}^-)(w_i w_j)^{1/2} \qquad [1]$$

Deviation of estimated from reported production:

$$Y_i - q_i + Y_i^- - Y_i^+ = 0 \qquad \forall i \qquad [2]$$

Deviation of estimated from expected input:

$$Y_{ij} - a_{ij} Y_j + Y_{ij}^- - Y_{ij}^+ = 0 \qquad \forall i, j \qquad [3]$$

Material balance:

$$Y_i - \sum_j Y_{ij} + m_i - x_i = 0 \qquad \forall i \in R \qquad [4.1]$$

$$Y_i - \sum_j Y_{ij} + m_i - x_i \geq 0 \qquad \forall i \in F \qquad [4.2]$$

Feasible range of input *i* for output *j*:

$$Y_j a_{ij}^L \leq Y_{ij} \leq Y_j a_{ij}^U \qquad \forall i, j \qquad [5.1,5.2]$$

Feasible range of total inputs for output *j* (current inputs are 4 fibers):

$$Y_j a_j^L \leq \sum_i Y_{ij} \leq Y_j a_j^U \qquad \forall j \qquad [6.1,6.2]$$

Feasible post-consumer recovery:

$$\sum_j (Y_j + m_j - x_j) r_{ij}^L \leq Y_i \leq \sum_j (Y_j + m_j - x_j) r_{ij}^U \qquad \forall i \qquad [7.1,7.2]$$

Feasible total manufacturing cost:

$$c_j^L Y_j \leq w_j Y_j - \sum_i Y_{ij} w_i \leq c_j^U Y_j \qquad \forall j \qquad [8.1,8.2]$$

Input-output coefficient after solving [1] to [8]:

$$A_{ij} = \frac{Y_{ij}}{Y_j} \qquad \forall i, j \qquad [9]$$

Manufacturing cost:

$$M_j = p_j Y_j - \sum_i Y_{ij} p_i \qquad \forall j \qquad [10]$$

Sets and input data:

i,j : Products

` F : Set of final products
R : Set of raw materials or intermediate products
β : weight of official data vs. prior input-output data
w_i : weight of official data for product i.
q_i, m_i, x_i: reported data on production, imports, and exports.
p_i : local price.
a_{ij}^L, a_{ij}^U : lower, upper bound on input i per unit of output j.
$a_{ij} = (a_{ij}^L + a_{ij}^U)/2$: expected input i per unit of output j.
a_j^L, a_j^U : lower, upper bound on total input per unit of output j.
r_{ij}^L, r_{ij}^U : lower, upper bound on recycling of product j into product i.
c_j^L, c_j^U : lower, upper bound on unit manufacturing cost of output j.

Choice variables, all non-negative:
Y_i : estimated production of product i.
Y_i^+, Y_i^- : estimated production above, or below, reported production of product i.
Y_{ij} : estimated input i in output j.
Y_{ij}^+, Y_{ij}^- : estimated input above, or below, input implied by prior input-output coefficients.

Other variables:
A_{ij} : computed I-O coefficient.
M_{ij} : manufacturing cost (excluding wood and fiber explicit in model).

10.3 Dynamic calibration

Dynamic calibration with smoothed or unsmoothed data (see data smoothing procedure above) follows the following steps:

1) A static calibration is performed for each year t_{B-2} to t_B to get preliminary I-O coefficients, A_{ijt}, with the method described in section 10.2.

2) Each final base-year I-O coefficient A_{ijtB} is the average of the preliminary I-O coefficients for the years from t_{B-2} to t_B if there is at least one preliminary coefficient. If all thee preliminary I-O coefficient are missing, then there is no I-O coefficient entry for this commodity of this country.

3) The corresponding calibrated production, imports, exports, and prices data are also averaged over t_{B-2} to t_B.

4) The manufacturing costs are calculated based on the final I-O coefficients and the price data. If the manufacturing cost is negative, for wood products the I-O coefficient is reduced by 1% steps until the manufacturing cost is larger than 0.1, for paper products the I-O coefficient of the most expensive input is reduced and the coefficient of the cheapest input is increased by 1% steps until the manufacturing cost is larger than 0.1.

5) The intermediate and raw materials production are calculated based on the final I-O coefficients and the consumption of final products resulting from step 3).

6) The waste paper recovery rates are calculated based on the final I-O coefficients, and the consumption of waste paper and production of paper and paperboard resulting from step 3).