INITIATIVE ON
Foresight

Introduction to SAMs and CGE Modeling

Using IFPRI's Dynamic CGE and Microsimulation Models

Overview

1. Why Do Economywide Analysis?

2. Social Accounting Matrices (SAMs)
3. SAM Multiplier Analysis

4. Simple CGE Model
5. IFPRI Standard CGE Model
6. Microsoft-Excel® Interface

7. Extending the Standard Model

IFPRI Modeling Systems

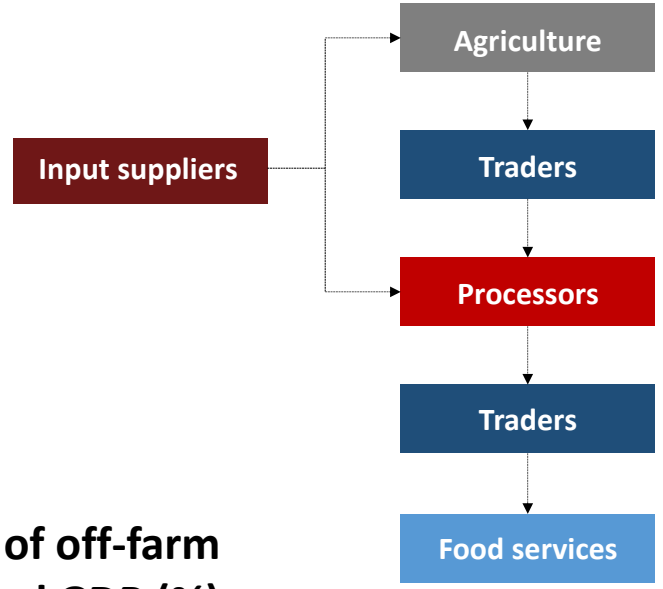
Informing future pathways and priorities

Part 1

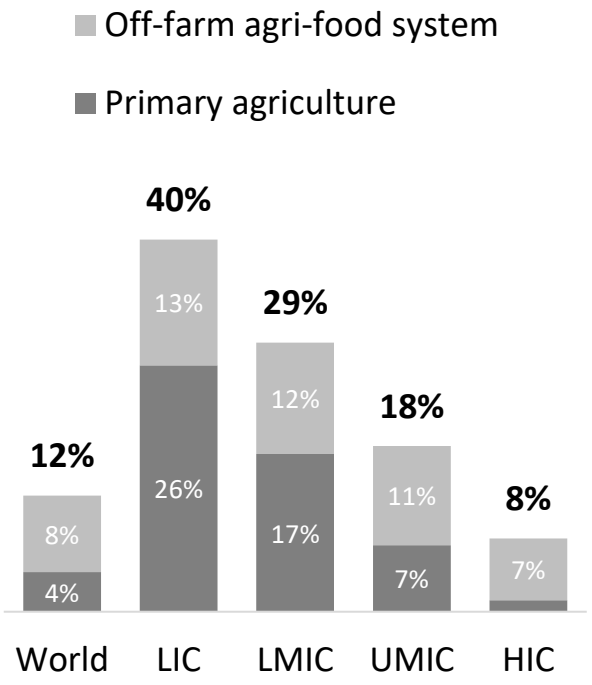
Why Do Economywide Analysis?

Agrifood Systems

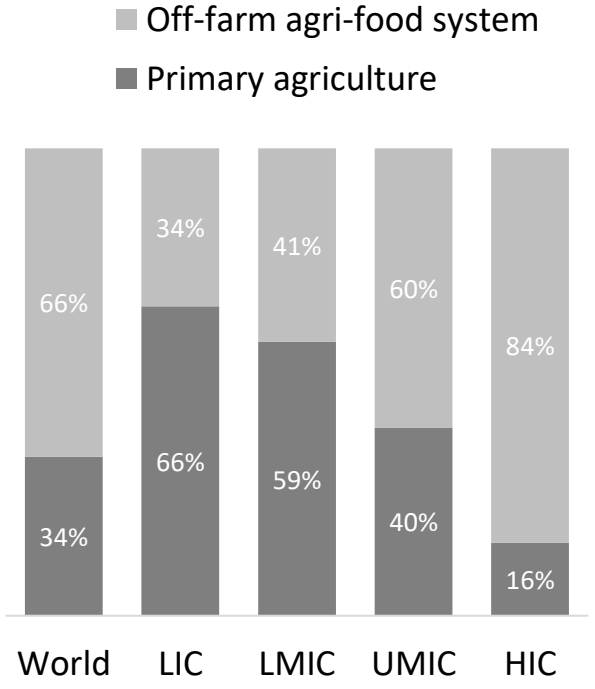
Off-farm components of the agrifood system are more important than on-farm components at higher-income levels.



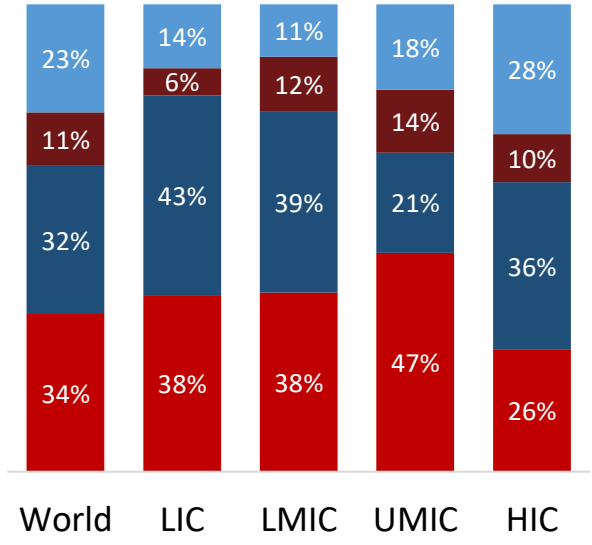
Share of national GDP (%)



Share of agrifood GDP (%)



Share of off-farm agrifood GDP (%)



Private Sector

Public-Sector-Driven Transformation

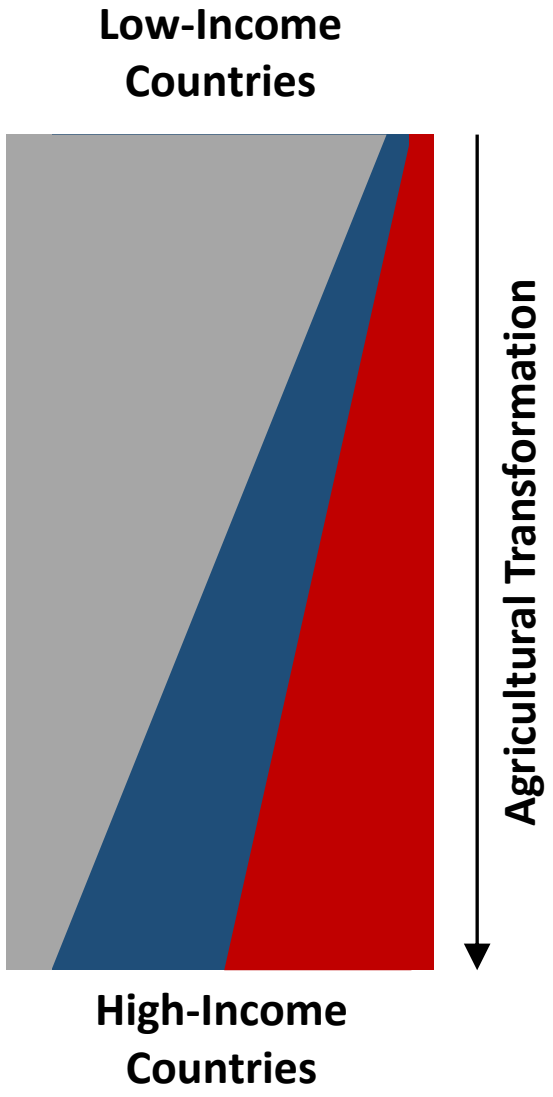
Actions government must undertake in most circumstances (e.g., infrastructure, education, R&D, extension services, etc.)

Public-Private Sector Coordination

Actions private sector will undertake if governments create an enabling environment (i.e., conducive policies & investments)

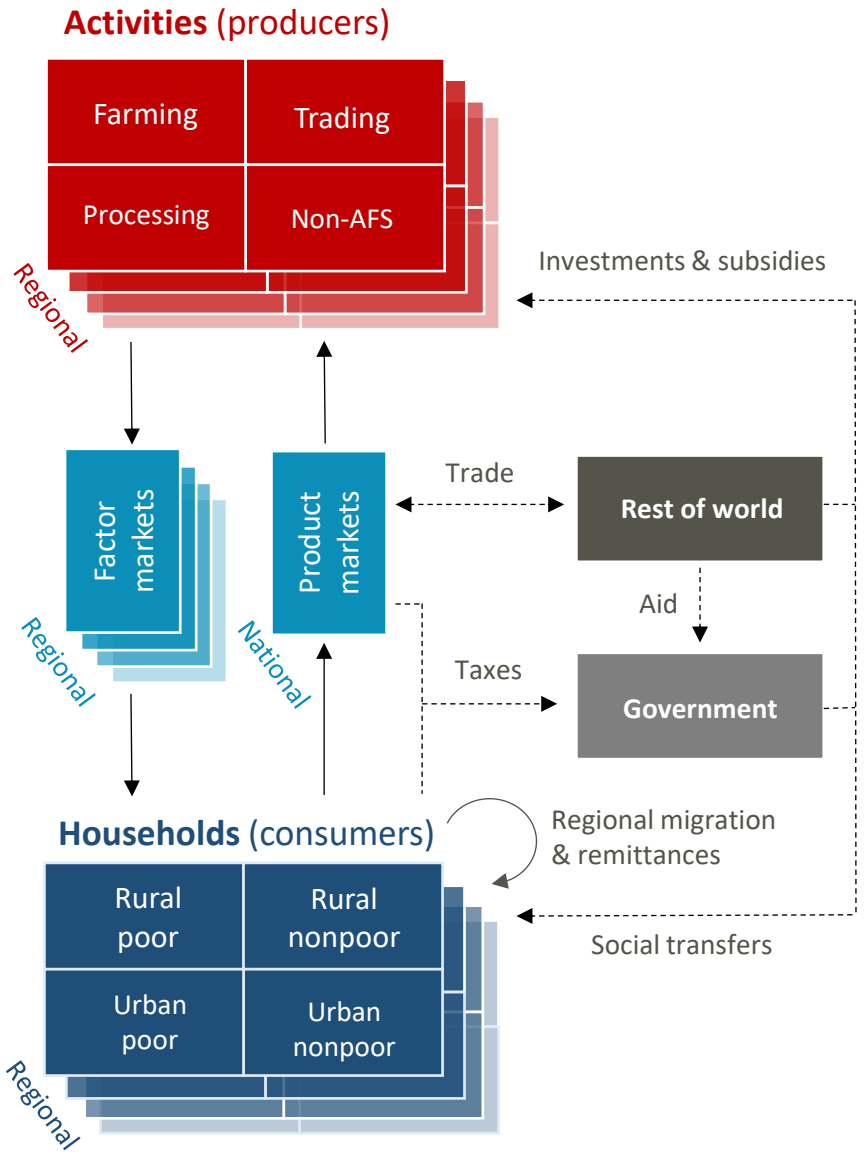
Private-Sector-Driven Transformation

Actions private sector will undertake on its own (e.g., supplying profitable input & output markets where demand is strong)



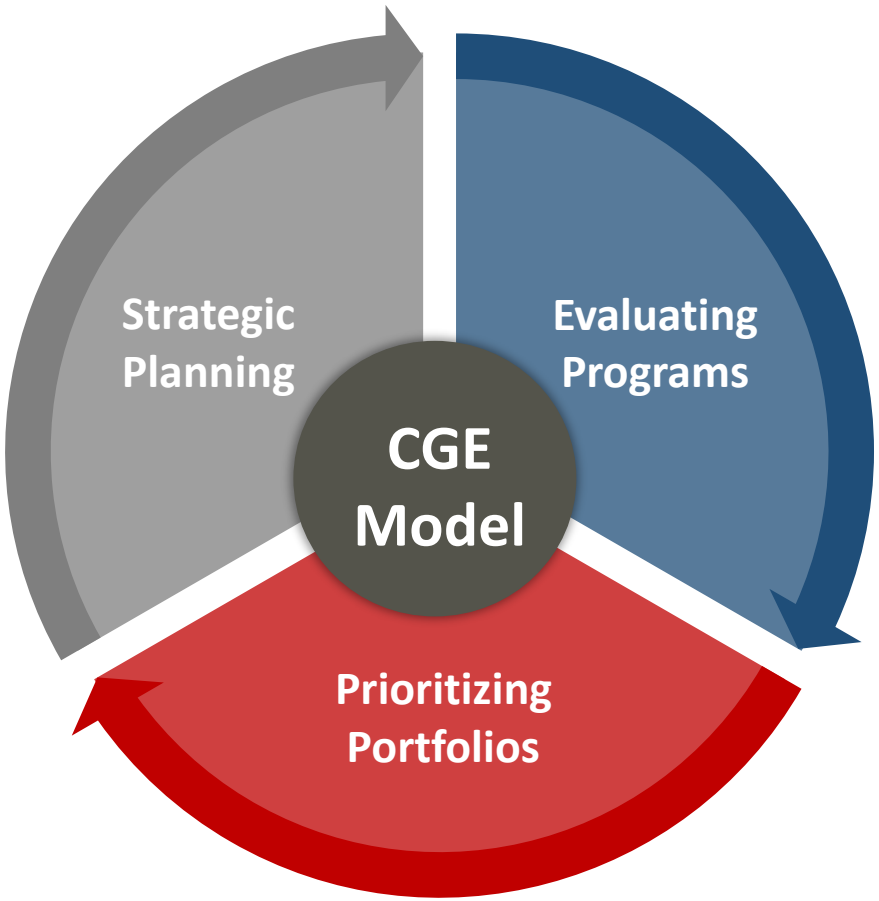
Economywide Models

- **Computable General Equilibrium**
- **Economic linkages**
  - Between sectors, households, government & rest of world
- **Resource competition**
  - Factor markets (land, labor, capital)
  - Product markets (supply, demand)
- **Macro consistency**
  - Government (revenues, spending)
  - Savings-investment
  - Current account (foreign exchange)



Types of Economywide Studies

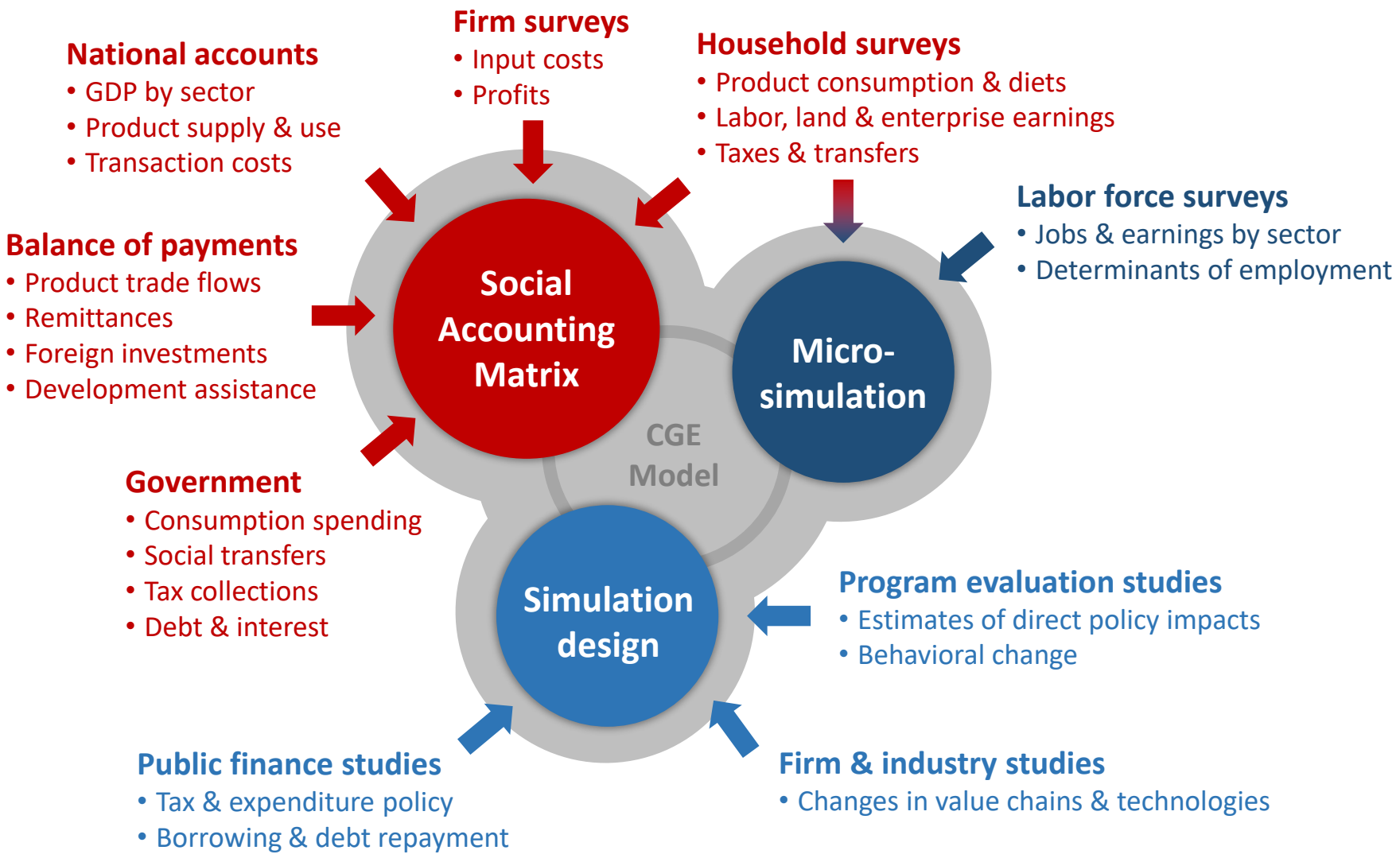
Foresight Analysis
Tracking progress
Setting targets & goals



Impact Evaluation
Capturing spillovers
Estimating benefits & costs

Policy & Investment Choices
Identifying priorities, Optimizing budgets

Data Reconciliation



IFPRI Modeling Systems

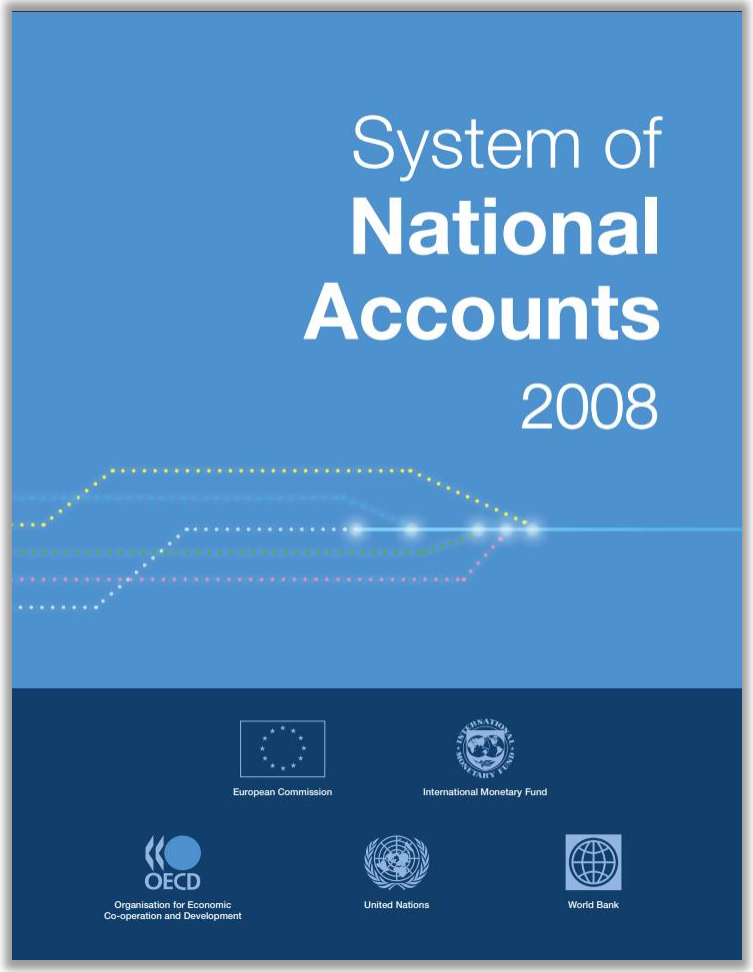
Informing future pathways and priorities

Part 2

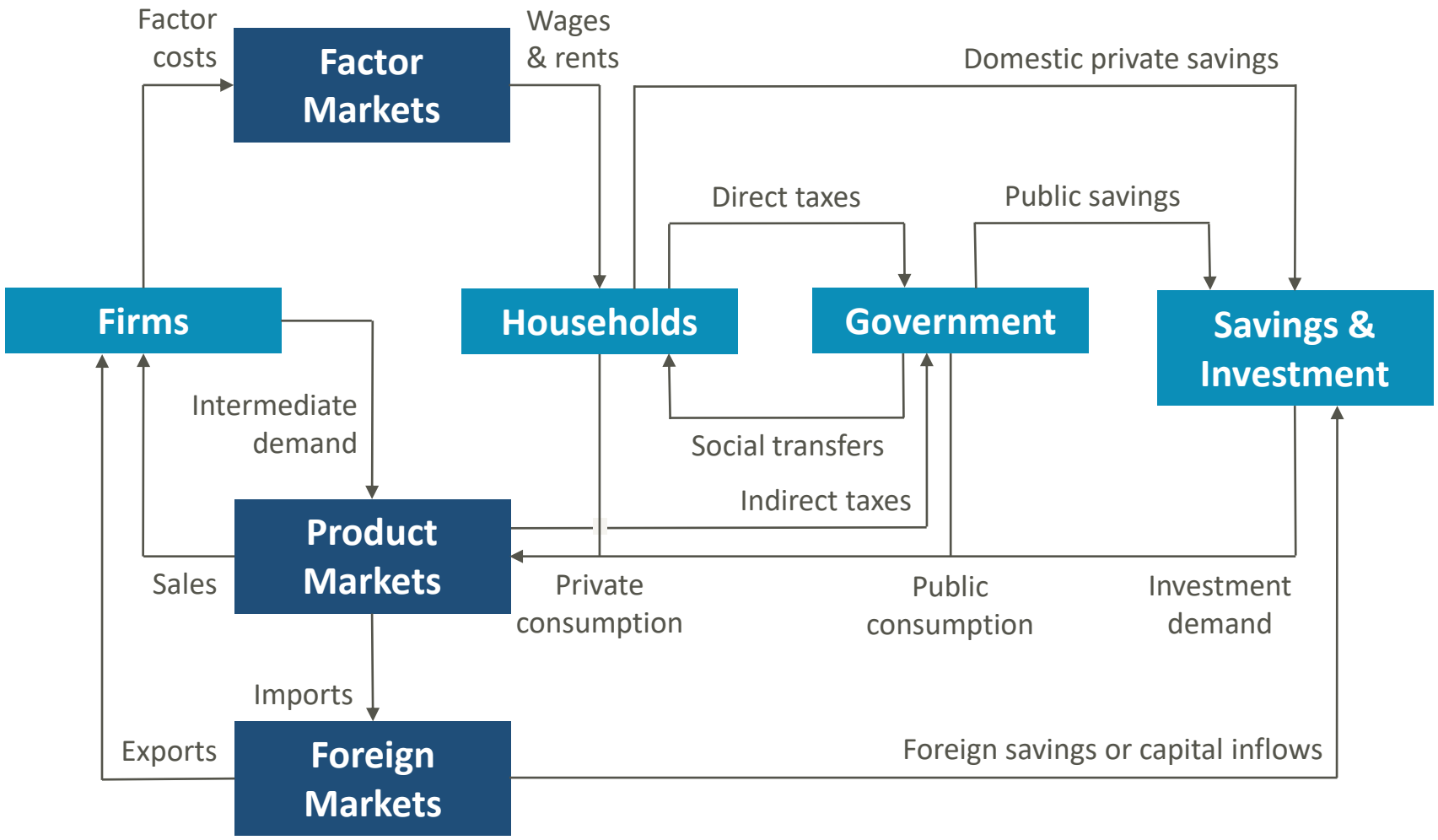
Social Accounting Matrices (SAMs)

What Is a SAM?

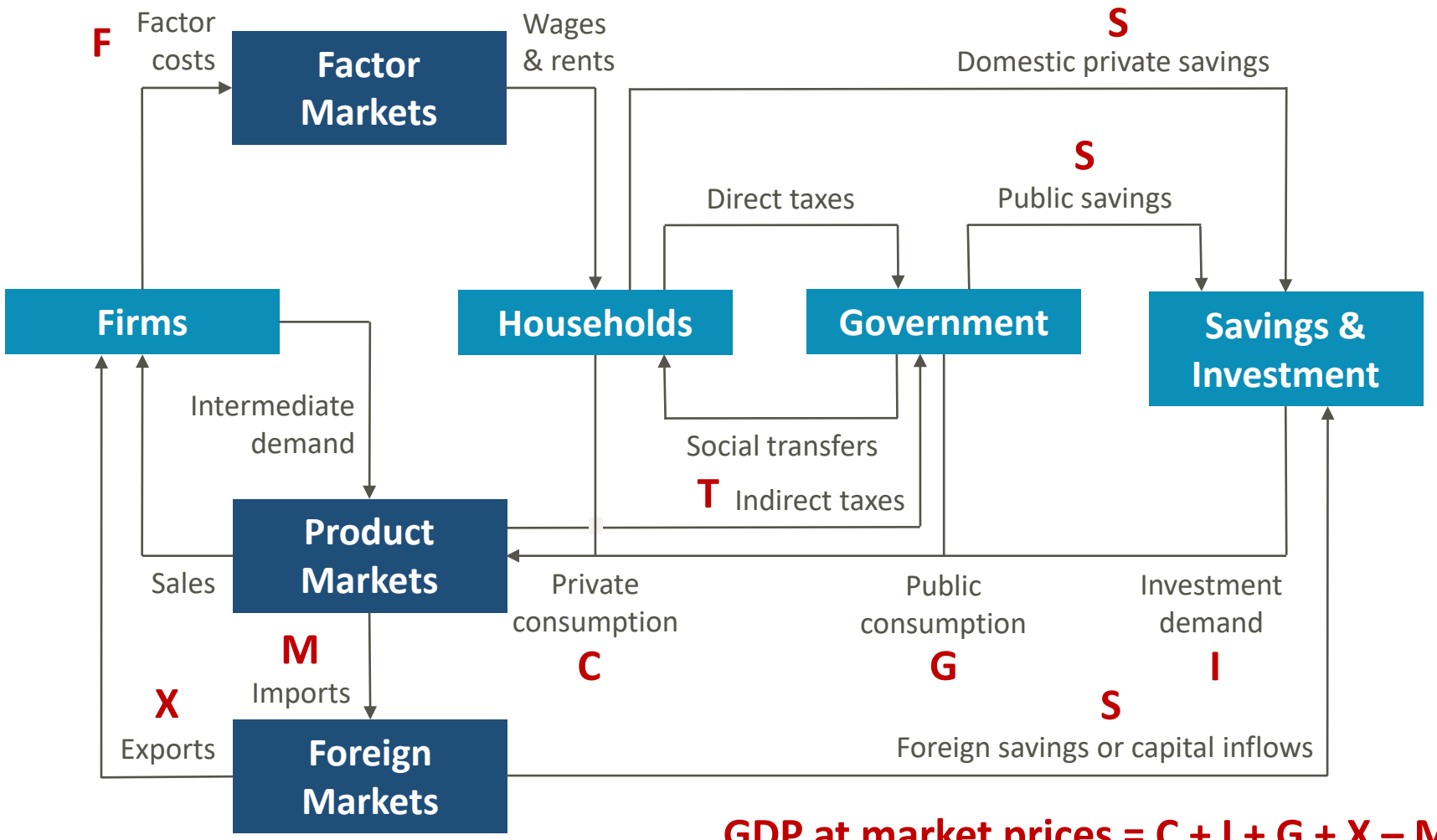
- SAMs are national accounting frameworks or databases
- SAMs capture the circular flow of receipts and payments between economic agents and markets during a given year
- SAMs include all sectors, factors, households, government and the rest of the world (i.e., economywide)
- Every payment becomes someone else's income (i.e., consistent double-entry accounting)



Circular Flow



Accounting Indenties



GDP at market prices = C + I + G + X – M

Total Investment I = Total Savings S

GDP at market prices = GDP at factor cost F + Indirect Taxes T

SAM Structure

Incomes across rows

Expenditures down columns

	ACT	COM	FAC	HHD	GOV	INV	ROW	TOT
ACT		Marketed output						Activity incomes
COM	Intermediate demand			Private consumption	Public consumption	Investment demand	Exports	Total demand
FAC	Value added							Factors incomes
HHD			Income distribution		Social transfers		Remittances	Household incomes
GOV	Producer taxes	Tariffs, VAT & excise taxes		Direct taxes			Foreign aid	Government revenues
SAV				Private savings	Public savings		Foreign savings	Total savings
ROW		Imports	Repatriated profits		Debt repayments			Foreign payments
TOT	Gross output	Total supply	Factor payments	Household expenditures	Government expenditures	Total investment	Foreign receipts	

Macro SAM | Data Sources

- **Three main data sources:**
  - National Accounts (activity and commodity accounts)
  - Government Financial Statistics (spending and tax accounts)
  - Balance of Payments (external account)

- **Standardized concordance between SAM and classification systems**
  - GFS2014 & BOP6 → SNA 2008 → Macro SAM accounts

- **Inconsistent values across sources requires reconciliation:**
  - Consistency with national accounts usually afforded highest priority, followed by BOPs and then GFS

Macro SAM | Entries

Incomes across rows

Expenditures down columns

	Act	Com	Fact	Ent	Hhd	Gov	Tax	S-I	Stk	Wld	Tot
Activities		NA									NA
Commodities	NA				NA	NA		NA	NA	NA	NA
Factors	NA									BOP	X
Enterprises			X			GFS				BOP	X
Households			X	X		GFS				BOP	X
Government			GFS	GFS	GFS		GFS			BOP	GFS
Taxes	NA	NA	GFS	GFS	GFS						GFS
Savings				?	X	GFS				BOP	X
Stock change								NA			X
Rest of world		NA	BOP	BOP	BOP	BOP					BOP
Total	NA	NA	X	X	X	GFS	GFS	NA	NA	BOP	

NA National Accounts
GFS Government Financial Statistics
BOP Balance of Payments
X Convention or residual

Macro SAM | Details

Incomes across rows

Expenditures down columns

	Act	Com	Fact	Ent	Hhd	Gov	Tax	S-I	Stk	Wld	Tot
Activities											
Commodities											
Factors											
Enterprises											
Households											
Government											
Taxes											
Savings											
Stock change											
Rest of world											
Total											

Factors

Labor | Land | Capital

Taxes

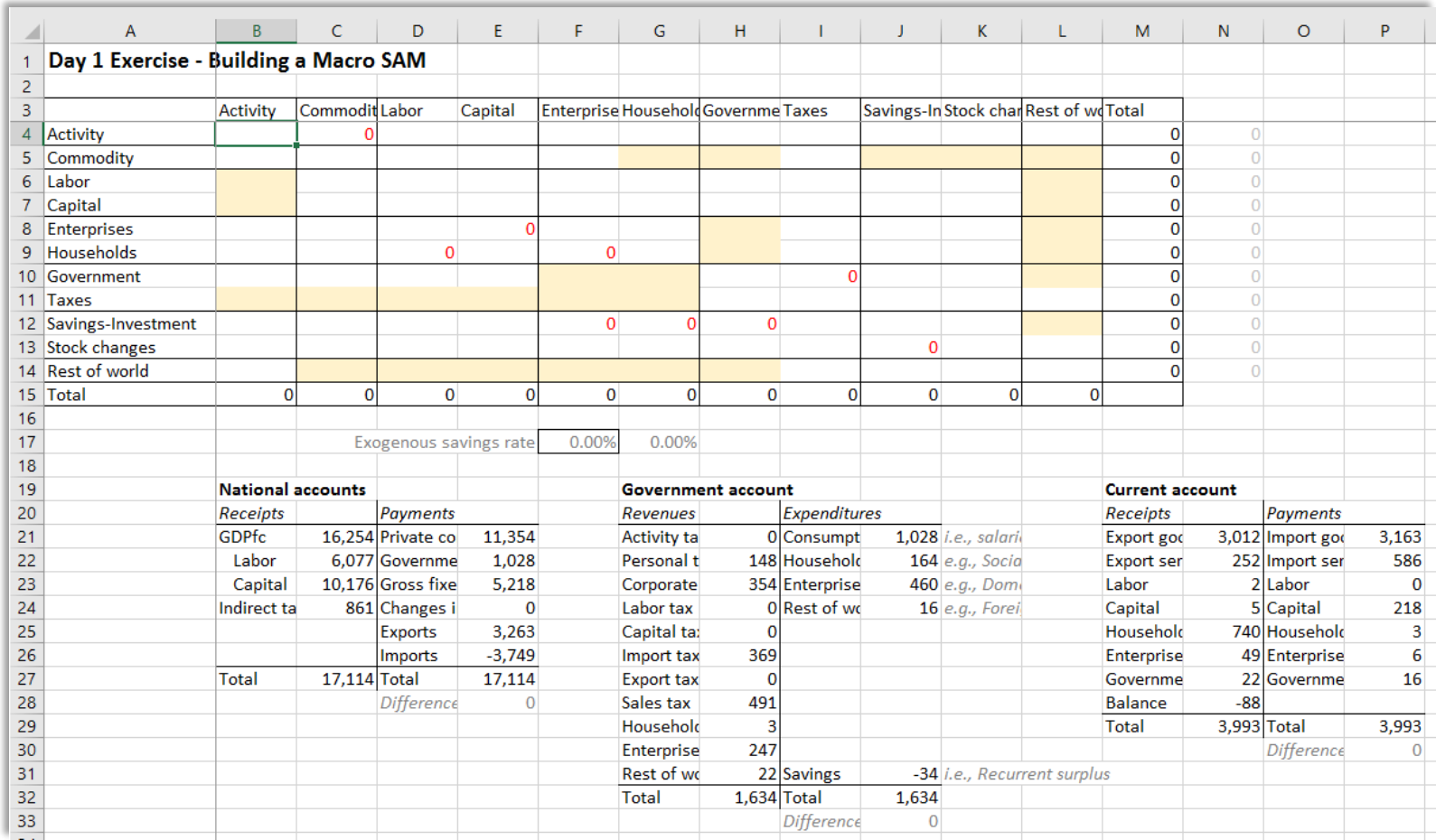
Activities (producer) | Export duties | Import duties | Sales or VAT | Factor | Direct

Exercise 1 | Building a Macro SAM

- **Complete the Macro SAM using the data provided below**
  - **Yellow cells** need data from the tables
  - **Red numbers** contain formulas that will update automatically

Exercises folder

Exercise 1 - Macro SAM.xlsx



Day 1 Exercise - Building a Macro SAM

	Activity	Commodit	Labor	Capital	Enterprise	Household	Governme	Taxes	Savings-In	Stock char	Rest of wo	Total			
Activity		0										0	0		
Commodity												0	0		
Labor												0	0		
Capital												0	0		
Enterprises				0								0	0		
Households			0		0							0	0		
Government								0				0	0		
Taxes												0	0		
Savings-Investment					0	0	0					0	0		
Stock changes									0			0	0		
Rest of world												0	0		
Total	0	0	0	0	0	0	0	0	0	0	0				

Exogenous savings rate 0.00% 0.00%

National accounts

Receipts		*Payments*	
GDPfc	16,254	Private co	11,354
Labor	6,077	Governme	1,028
Capital	10,176	Gross fixe	5,218
Indirect ta	861	Changes i	0
		Exports	3,263
		Imports	-3,749
Total	17,114	Total	17,114
		Difference	0

Government account

Revenues		*Expenditures*		
Activity ta	0	Consumpt	1,028	*i.e., salari*
Personal t	148	Household	164	*e.g., Socia*
Corporate	354	Enterprise	460	*e.g., Dom*
Labor tax	0	Rest of wo	16	*e.g., Forei*
Capital ta:	0			
Import tax	369			
Export tax	0			
Sales tax	491			
Household	3			
Enterprise	247			
Rest of wo	22	Savings	-34	*i.e., Recurrent surplus*
Total	1,634	Total	1,634	
		Difference	0	

Current account

Receipts		*Payments*	
Export goo	3,012	Import goo	3,163
Export ser	252	Import ser	586
Labor	2	Labor	0
Capital	5	Capital	218
Household	740	Household	3
Enterprise	49	Enterprise	6
Governme	22	Governme	16
Balance	-88		
Total	3,993	Total	3,993
		Difference	0

Supply-Use Table | Details

Incomes across rows

Expenditures down columns

	Act	Com	Fact	Ent	Hhd	Gov	Tax	S-I	Stk	Wld	Tot
Activities											
Commodities											
Factors											
Enterprises											
Households											
Government											
Taxes											
Savings											
Stock change											
Rest of world											
Total											

86 activities + 86 commodities

IFPRI Standard NEXUS SAM structure
Individual countries may vary

Supply-Use Table | Accounts

Agricultural activities/commodities	
35	Maize | Sorghum + millet | Rice | Wheat + barley | Other cereals | Pulses | Groundnuts | Other oilseeds | Cassava | Irish potatoes | Sweet potatoes | Other roots | Leafy vegetables | Other vegetables | Sugarcane | Tobacco | Cotton + fibers | Nuts | Bananas + plantains | Other fruits | Tea | Coffee | Cocoa | Cut flowers | Rubber | Other crops | Cattle | Raw milk | Poultry | Eggs | Sheep + goats | Other livestock | Forestry | Aquaculture | Capture fisheries
Industrial activities/commodities	
39	Coal | Crude oil | Natural gas | Other mining | Meat | Fish + seafood | Dairy | Fruits + vegetables | Fats + oils | Maize milling | Sorghum + millet milling | Rice milling | Wheat + barley milling | Other grain milling | Sugar refining | Coffee processing | Tea processing | Other foods | Animal feed | Beverages | Tobacco | Cotton yarn | Textiles | Clothing | Leather + footwear | Wood | Paper | Petroleum | Chemicals | Non-metal minerals | Metals + metal products | Machinery | Equipment | Vehicles | Other manufacturing | Electricity + gas | Water supply + sewage | Construction
Service activities/commodities	
12	Wholesale + retail trade | Transportation + storage | Accommodation | Food services | Information + communication | Finance + insurance | Real estate activities | Business services | Public administration | Education | Health + social work | Other services

IFPRI Standard NEXUS SAM structure
Individual countries may vary

Supply-Use Table | Data Sources

- **Main data sources:**
  - National accounts (GDP by sector, trade margins)
  - Agricultural and industrial production data and surveys
  - Input-output table
  - Trade and tax data (esp. VAT and customs duties)
  - Household expenditure survey (consumption demand vector)

- **Standardized concordance between SAM and classification systems**
  - ISIC3.1, ISIC4, HS2012, COICOP → Disaggregated SAM accounts

- **Inconsistent values across sources requires reconciliation:**
  - Balanced using cross-entropy techniques in GAMS®

Social Transfers | Details

Incomes across rows

Expenditures down columns

	Act	Com	Fact	Ent	Hhd	Gov	Tax	S-I	Stk	Wld	Tot
Activities											
Commodities											
Factors											
Enterprises											
Households											
Government											
Taxes											
Savings											
Stock change											
Rest of world											
Total											

13 factors

15 households

IFPRI Standard NEXUS SAM structure
Individual countries may vary

Social Transfers | Accounts

Factors of production	
13	Crop land | Crop, livestock, mining and nonagricultural capital | Rural and urban labor by education category

Household groups	
15	Rural farm and nonfarm households and urban households by national per capita expenditure quintiles

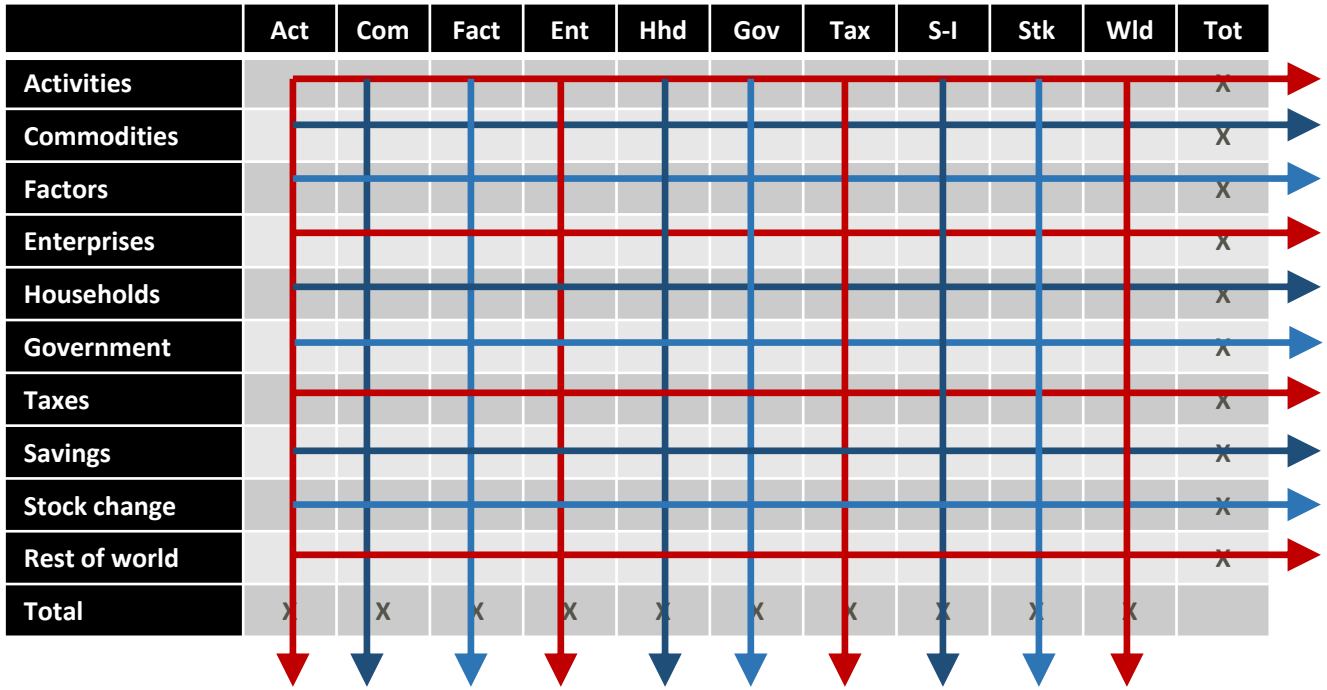
IFPRI Standard NEXUS SAM structure
Individual countries may vary

Social Transfers | Data Sources

- **Main data sources:**
  - Household & labor force surveys
- **Map sector of employment to Nexus activities**
  - ISIC3.1, ISIC4 → Disaggregated SAM accounts
- **Map consumption items to Nexus commodities**
  - COICOP, etc. → Disaggregated SAM accounts
- **Maintain macro SAM and non-factor/household accounts**
  - Only imbalances are for detailed household accounts
  - Balanced using cross-entropy in GAMS

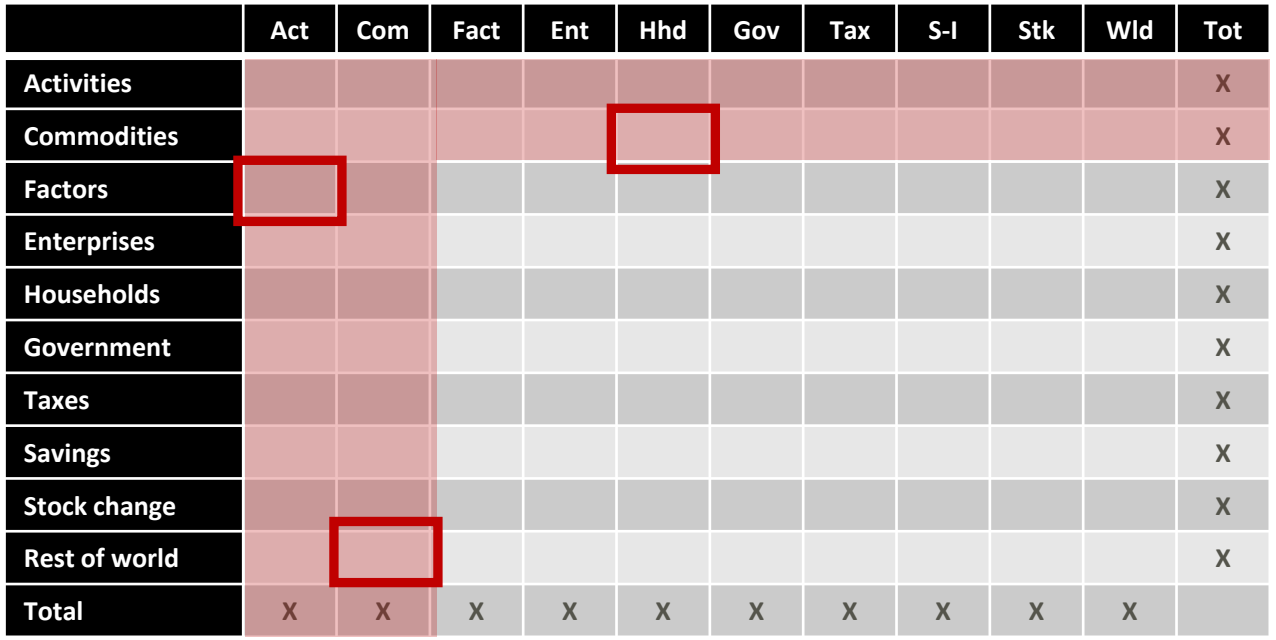
Balancing SAMs | RAS Method

- **One approach is to use the RAS method**
  - Rows and columns are uniformly scaled in iteration until totals converge
  - **Advantages**: Simple to implement (even in Excel)
  - **Shortcoming**: Can do significant "damage" to the original data (will adjust cells, even if they are not causing the imbalance)



Balancing SAMs | Cross-Entropy Method

- **Better approach is to use the cross-entropy method**
  - Each cell is adjusted individually (rather than entire rows & columns)
  - Minimize deviation from original data (using error distributions)
  - **Advantages**: Focus more on cells that are causing imbalances
  - **Shortcoming**: More complex (need GAMS rather than just Excel)



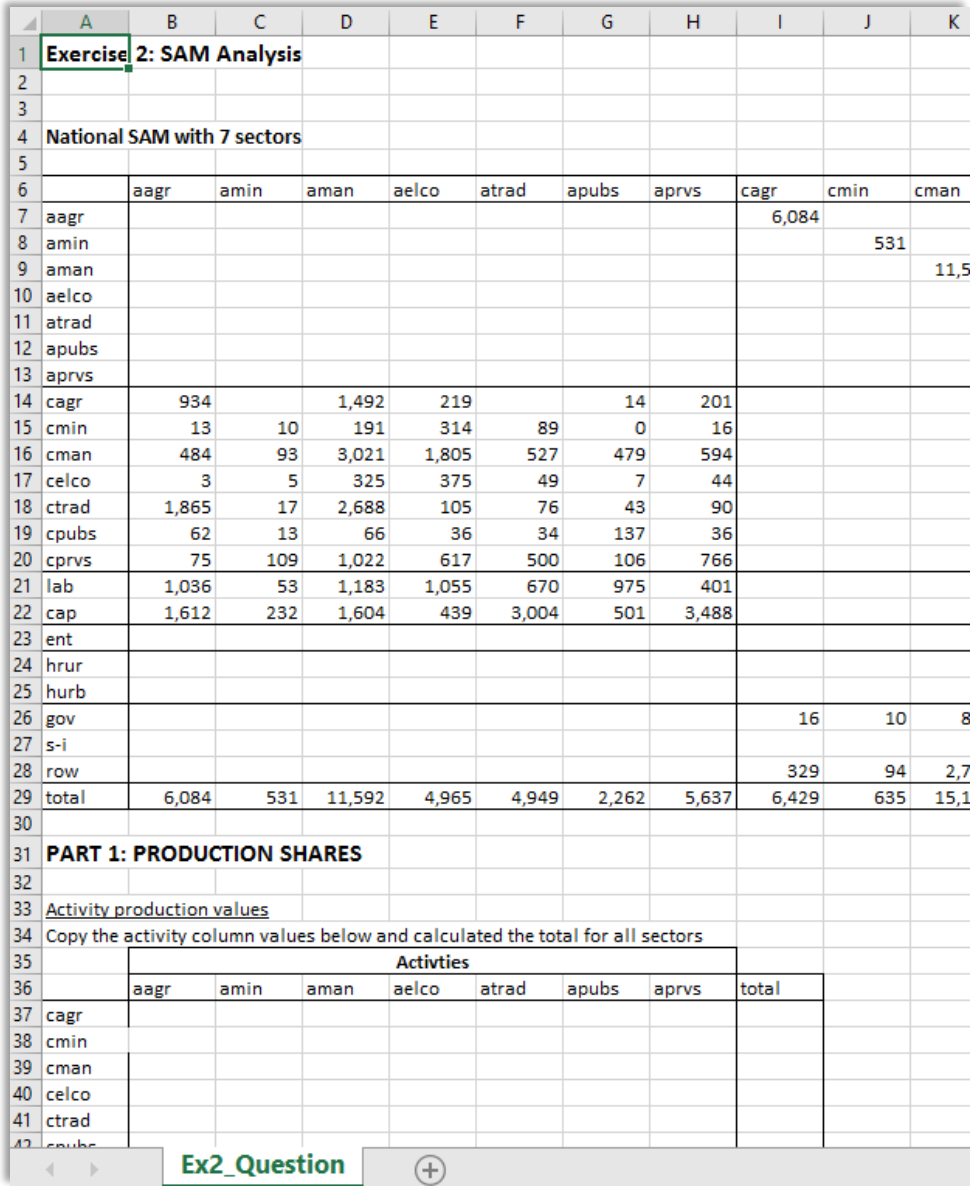
Exercise 2 | SAM Analysis

- **Aggregated SAM**
  - 7 activities, 7 commodities
  - 2 households (rural & urban)

- **Answer questions about the structure of the economy**
  - Link to data in the SAM
  - Check your answers as you go (correct values shown in blue)

Exercises folder

Exercise 2 – SAM Analysis.xlsx



	A	B	C	D	E	F	G	H	I	J	K
1	**Exercise 2: SAM Analysis**										
2											
3											
4	**National SAM with 7 sectors**										
5											
6		aagr	amin	aman	aelco	atrad	apubs	aprvs	cagr	cmin	cman
7	aagr								6,084		
8	amin									531	
9	aman										11,5
10	aelco										
11	atrad										
12	apubs										
13	aprvs										
14	cagr	934		1,492	219		14	201			
15	cmin	13	10	191	314	89	0	16			
16	cman	484	93	3,021	1,805	527	479	594			
17	celco	3	5	325	375	49	7	44			
18	ctrad	1,865	17	2,688	105	76	43	90			
19	cpubs	62	13	66	36	34	137	36			
20	cprvs	75	109	1,022	617	500	106	766			
21	lab	1,036	53	1,183	1,055	670	975	401			
22	cap	1,612	232	1,604	439	3,004	501	3,488			
23	ent										
24	hrur										
25	hurb										
26	gov								16	10	8
27	s-i										
28	row								329	94	2,7
29	total	6,084	531	11,592	4,965	4,949	2,262	5,637	6,429	635	15,1
30											
31	**PART 1: PRODUCTION SHARES**										
32											
33	Activity production values										
34	Copy the activity column values below and calculated the total for all sectors										
35		**Activties**									
36		aagr	amin	aman	aelco	atrad	apubs	aprvs	total		
37	cagr										
38	cmin										
39	cman										
40	celco										
41	ctrad										

Ex2_Question

Exercise 2x | Detailed SAM Analysis

- **Answer the questions using data from the data**
  - Use the workings sheet for calculations

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**Structure of the Micro SAM**																	
2																		
3		Activities	Commodit	Transactio	Labor	Land	Capital	Enterprise	Household	Governme	Direct taxe	Factor tax	Import tar	Sales taxes	Investmen	Stock char	Rest of wo	Total
4	Activities		30 x 30						30 x 5									
5	Commodities	30 x 30		30 x 1					30 x 5	30 x 1					30 x 1	30 x 1	30 x 1	
6	Transaction costs		1 x 30															
7	Labor	4 x 30																
8	Land	1 x 30																
9	Capital	1 x 30																
10	Enterprises						1 x 1			1 x 1								
11	Households				5 x 4	5 x 1	5 x 1	5 x 1		5 x 1							5 x 1	
12	Government							1 x 1	1 x 5		1 x 1	1 x 1	1 x 1	1 x 1				
13	Direct taxes							1 x 1	1 x 5									
14	Factor taxes						1 x 1											
15	Import tariffs		1 x 30															
16	Sales taxes		1 x 30															
17	Savings							1 x 1	1 x 5	1 x 1							1 x 1	
18	Stock changes																	
19	Rest of world		1 x 30															
20	Total																	
21																		

	A	B	C	D
1	**Questions**		**Answers**	**Hints and suggestions**
2	Use the information contained in the SAM to answer the following questions.			
3				
4	**GDP**			
5	1	What is the value of total GDP measured at factor cost?		GDP at factor is the sum of all f
6	2	What are the shares of agriculture, industry and services in total GDP?		Agriculture = cereals to fisherie
7	3	Which is the largest agricultural subsector in terms of GDP?		First calculate GDP for each (by
8	4	What is the share of food and agriculture-related processing within manufacturing GDP?		
9	5	What is the share of the government (incl. health and education) in total GDP?		
10	6	What is the value of GDP measured at market prices?		GDP mp = C + I + G + X - M

Exercises folder

Exercise 2x – Detailed SAM Analysis.xlsx

IFPRI Modeling Systems

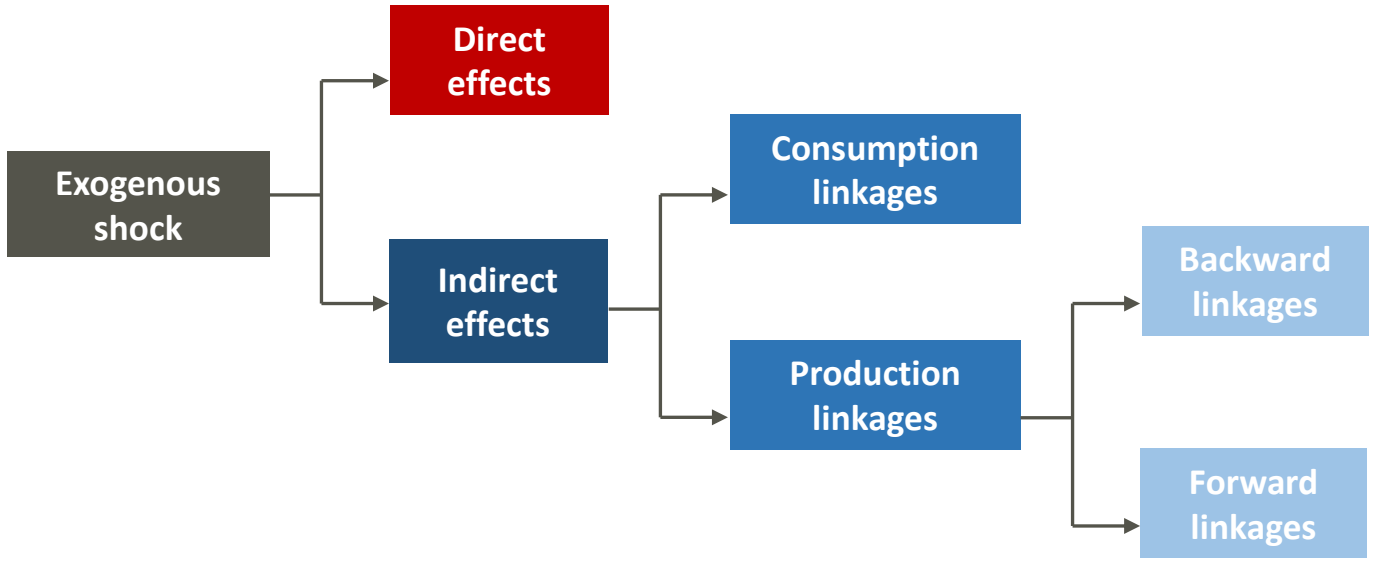
Informing future pathways and priorities

Part 3

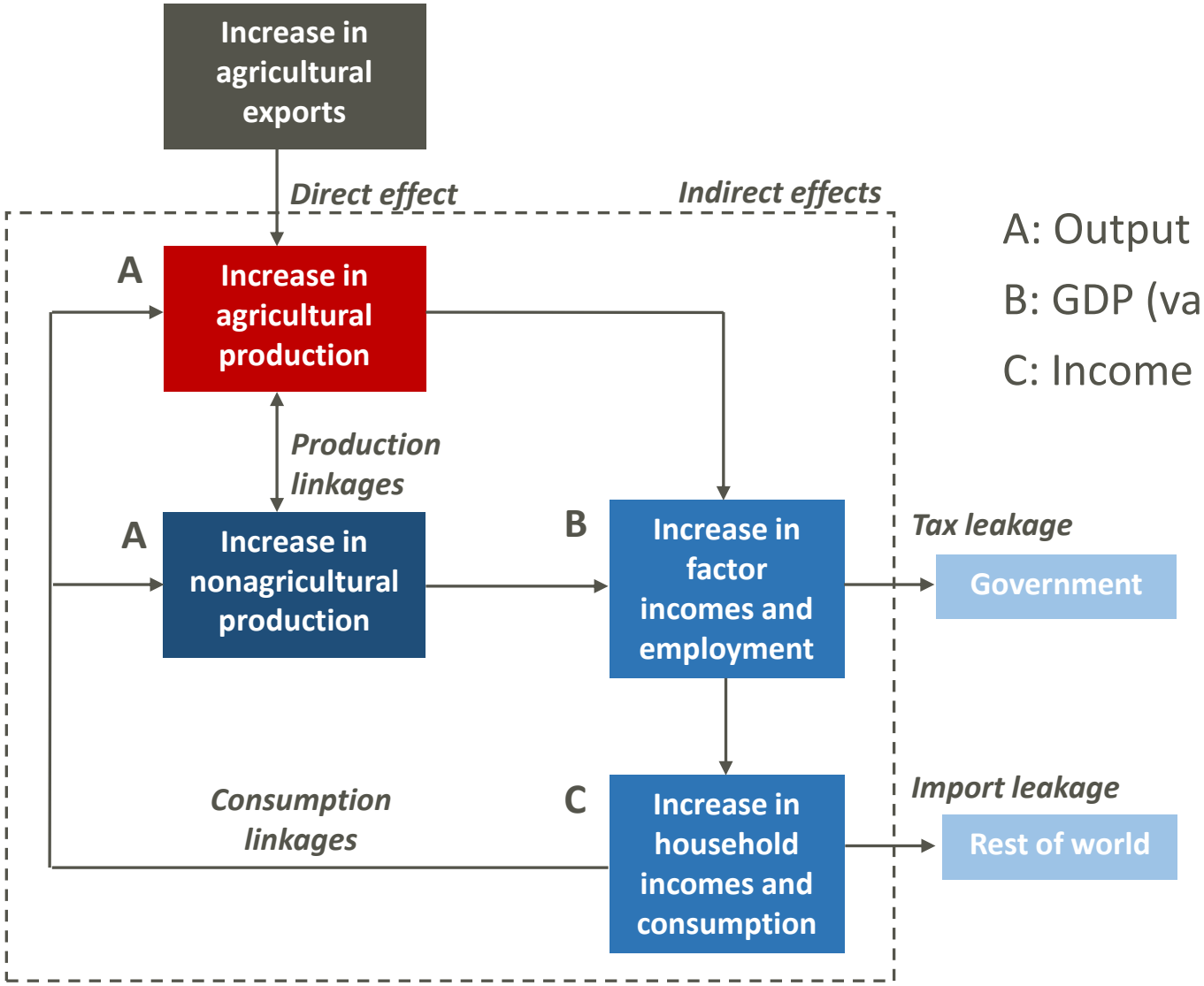
SAM Multiplier Analysis

Direct and Indirect Linkages

- **Total impact of demand shock = Direct effects + Indirect effects**
- **Indirect effects = Production linkages + Consumption linkages**
  - Consumption linkages: incomes → demand for other sectors' products
- **Production linkages = Backward linkages + forward linkages**
  - Backward linkages: producers purchase of inputs from other sectors
  - Forward linkages: supply of upstream producers with intermediate inputs



Circular Income Flow in Multiplier Process



A: Output multipliers

B: GDP (value-added) multiplier

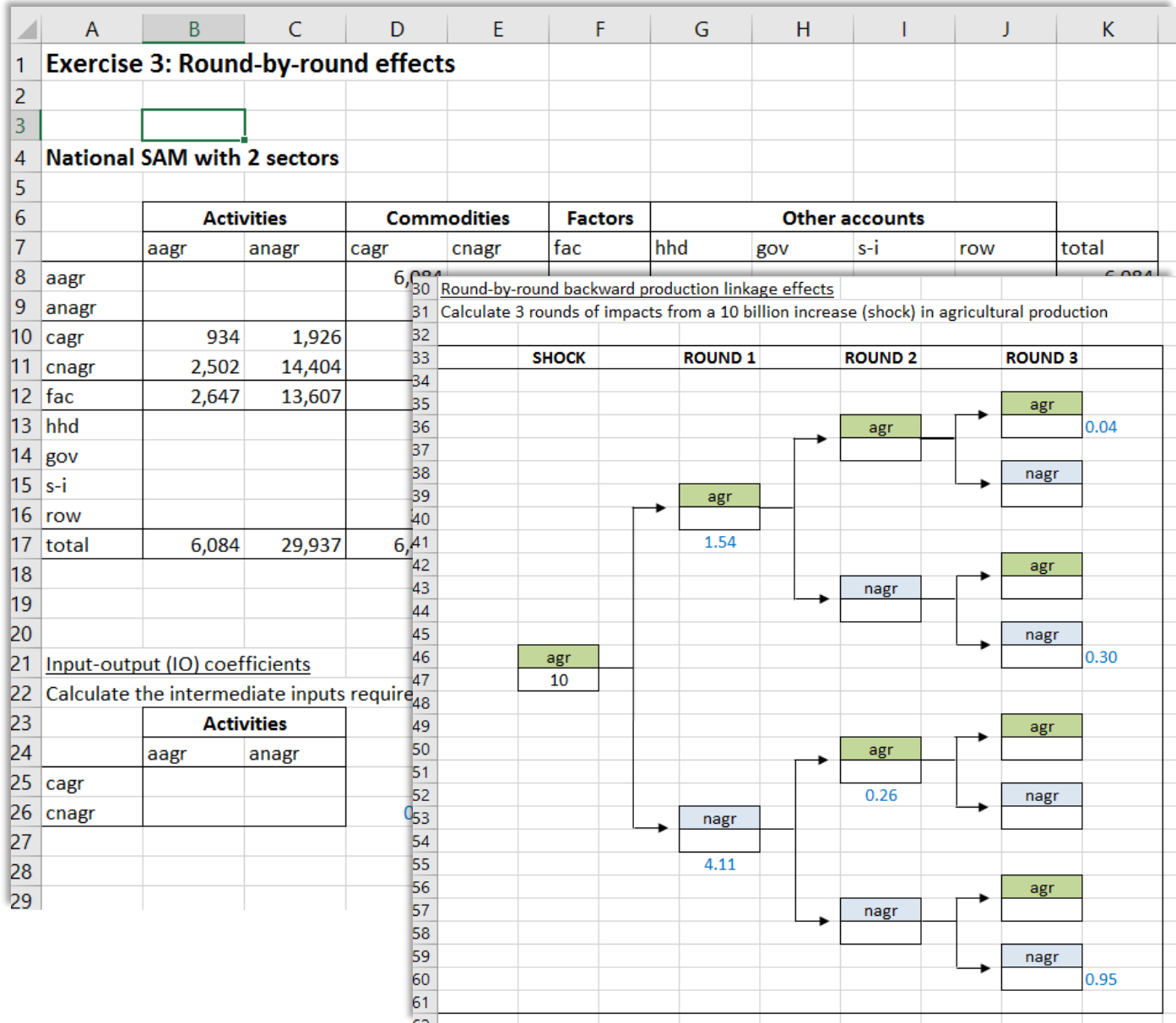
C: Income multiplier

Exercise 3 | Round-By-Round Effects

- **Manually calculate indirect effects**
  - Backward production linkages only
  - 3 rounds of effects
- **Check calculations as you go (blue)**

Exercises folder

Exercise 3 – Round-By-Round Effects.xlsx



Exercise 3: Round-by-round effects

National SAM with 2 sectors

	Activities		Commodities		Factors	Other accounts				
	aagr	anagr	cagr	cnagr	fac	hhd	gov	s-i	row	total
aagr			6,084							
anagr										
cagr	934	1,926								
cnagr	2,502	14,404								
fac	2,647	13,607								
hhd										
gov										
s-i										
row										
total	6,084	29,937	6,084							

Input-output (IO) coefficients

Calculate the intermediate inputs required

	Activities	
	aagr	anagr
cagr		
cnagr		

Round-by-round backward production linkage effects

Calculate 3 rounds of impacts from a 10 billion increase (shock) in agricultural production

Key Assumptions for Multipliers

- **Three assumptions behind multipliers…**

  - **Fixed prices**: Any changes in demand lead to changes in physical output rather than prices.

  - **Unlimited resources**: Factor supplies are unconstrained, so that any increase in demand is matched by increased supply.

  - **Fixed input coefficients**: Production technologies and households' consumption patterns are unaffected by exogenous changes in demand (i.e., linkage effects are linear and there is no behavioral change).

SAM Entries Using Letters or Symbols

We can replace the values appearing in the SAM with letters so that we can use them in deriving the multiplier formula…

	Activities		Commodities		Factors	House-holds	Exogenous demand	Total
	A1	A2	C1	C2	F	H	E	
A1			X_1					X_1
A2				X_2				X_2
C1	Z_{11}	Z_{12}				C_1	E_1	Z_1
C2	Z_{21}	Z_{22}				C_2	E_2	Z_2
F	V_1	V_2						V
H					$V_1 + V_2$			Y
E			L_1	L_2		S		E
Total	X_1	X_2	Z_1	Z_2	V	Y	E	

X = gross output of each activity (i.e., X_1 and X_2)
Z = total demand for each commodity (i.e., Z_1 and Z_2)
V = total factor income (equal to household income)
Y = total household income (equal to total factor income)
E = exogenous components of demand (i.e., government, investment & exports)

Coefficient Matrix (M)

We then divide each column through by its column total to derive a coefficients matrix (called “M-matrix”)…

	Activities		Commodities		Factors	House-holds	Exogenous demand	Total
	A1	A2	C1	C2	F	H	E	
A1			$b_1 = X_1/Z_1$					X_1
A2				$b_2 = X_2/Z_2$				X_2
C1	$a_{11}=Z_{11}/X_1$	$a_{12}=Z_{12}/X_2$				$c_1 = C_1/Y$	E_1	Z_1
C2	$a_{21}=Z_{21}/X_1$	$a_{22}=Z_{22}/X_2$				$c_2 = C_2/Y$	E_2	Z_2
F	$v_1=V_1/X_1$	$v_2=V_2/X_2$						V
H					1			Y
E			$l_1 = L_1/Z_1$	$l_2 = L_2/Z_2$		s = S/Y		E
Total	1	1	1	1	1	1	E	

a = technical coefficients (i.e., input or intermediate shares in production)
b = share of domestic output in total demand
v = the share of value-added or factor income in gross output
l = share of the value of total demand from imports or commodity taxes
c = household consumption expenditure shares
s = household savings rate (i.e., savings as a share of total household income)

Multiplier Formula (1)

Total demand Z in each sector is the sum of intermediate input demand, household consumption demand, and other **exogenous sources of demand E**…

$$Z_1 = a_{11} X_1 + a_{12} X_2 + c_1 Y + E_1$$

$$Z_2 = a_{21} X_1 + a_{22} X_2 + c_2 Y + E_2$$

From the SAM we know that **gross output X** is only part of total demand Z…

$$X_1 = b_1 Z_1 \qquad X_2 = b_2 Z_2$$

We also know **household income Y** depends on factor earnings in each sector…

$$Y = v_1 X_1 + v_2 X_2 = v_1 b_1 Z_1 + v_2 b_2 Z_2$$

We can now replace X and Y in the demand equations…

$$Z_1 = a_{11} b_1 Z_1 + a_{12} b_2 Z_2 + c_1 (v_1 b_1 Z_1 + v_2 b_2 Z_2) + E_1$$

$$Z_2 = a_{21} b_1 Z_1 + a_{22} b_2 Z_2 + c_2 (v_1 b_1 Z_1 + v_2 b_2 Z_2) + E_2$$

Multiplier Formula (2)

From the previous slide…

$$Z_1 = a_{11}b_1\,Z_1 + a_{12}b_2\,Z_2 + c_1(v_1b_1Z_1 + v_2b_2Z_2) + E_1$$

$$Z_2 = a_{21}b_1\,Z_1 + a_{22}b_2\,Z_2 + c_2(v_1b_1Z_1 + v_2b_2Z_2) + E_2$$

Move all terms, except for exogenous demand E, onto the left-hand side…

$$Z_1 - a_{11}b_1\,Z_1 - c_1v_1b_1Z_1 - a_{12}b_2\,Z_2 - c_1v_2b_2Z_2 = E_1$$

$$-a_{21}b_1\,Z_1 - c_2v_1b_1Z_1 + Z_2 - a_{22}b_2\,Z_2 - c_2v_2b_2Z_2 = E_2$$

Finally, we group Z terms together…

$$(1 - a_{11}b_1 - c_1v_1b_1)\,Z_1 + (-a_{12}b_2 - c_1v_2b_2)\,Z_2 = E_1$$

$$(-a_{21}b_1 - c_2v_1b_1)\,Z_1 + (1 - a_{22}b_2 - c_2v_2b_2)\,Z_2 = E_2$$

Multiplier Formula (3)

From the previous slide…

$$(1-a_{11}b_1-c_1v_1b_1)\,Z_1+(-a_{12}b_2-c_1v_2b_2)\,Z_2=E_1$$

$$(-a_{21}b_1-c_2v_1b_1)\,Z_1+(1-a_{22}b_2-c_2v_2b_2)\,Z_2=E_2$$

We can now use matrix algebra to convert the equations into matrix format…

$$\begin{pmatrix} 1-a_{11}b_1-c_1v_1b_1 & -a_{12}b_2-c_1v_2b_2 \\ -a_{21}b_1-c_2v_1b_1 & 1-a_{22}b_2-c_2v_2b_2 \end{pmatrix}\begin{pmatrix} Z_1 \\ Z_2 \end{pmatrix}=\begin{pmatrix} E_1 \\ E_2 \end{pmatrix}$$

The first term is the identity matrix (I) minus the coefficient matrix (M). We can also rename the other two vectors Z and E…

$$(I-M)\,Z=E$$

Finally, by rearranging terms, we arrive at the unconstrained multiplier formula….

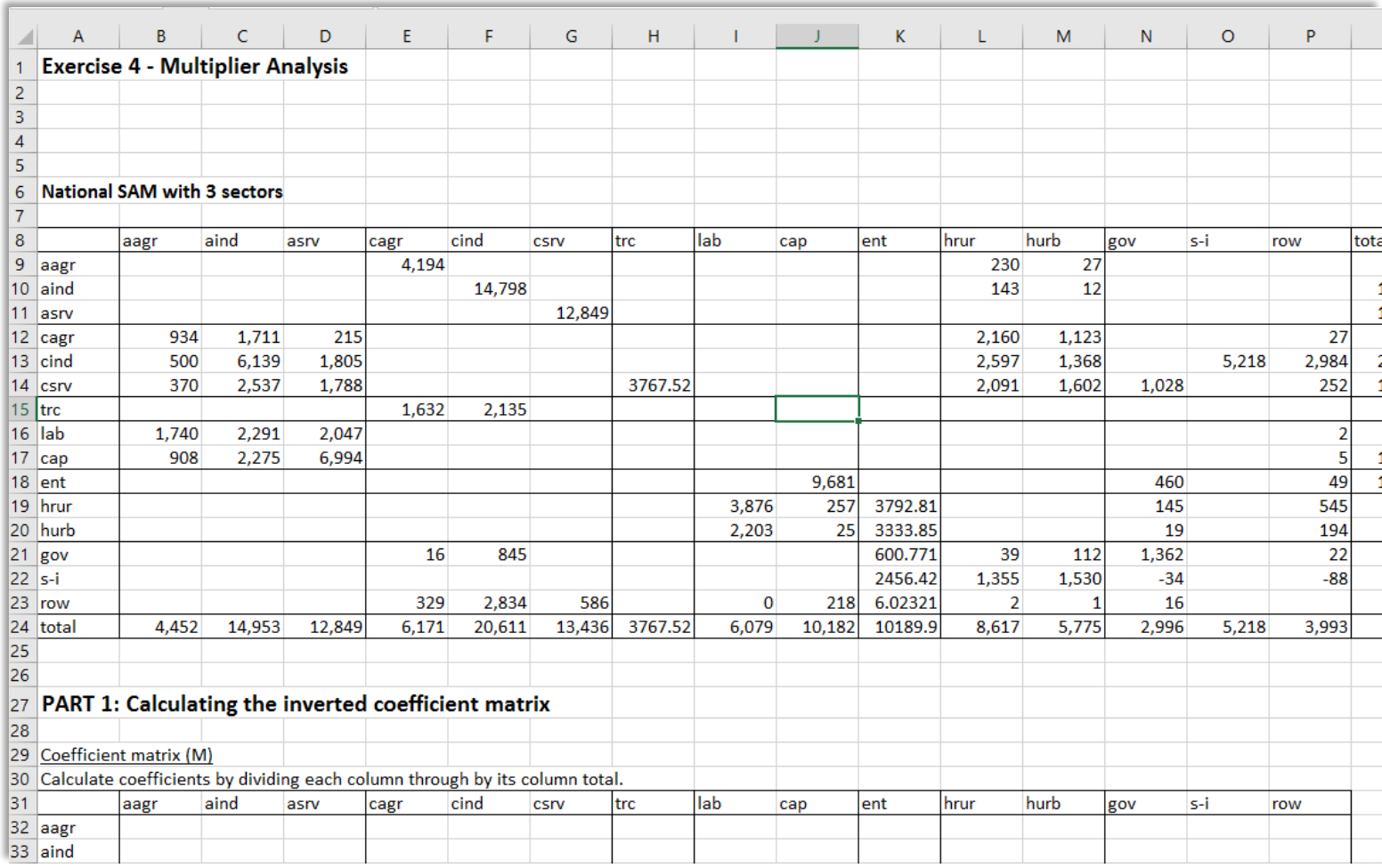
$$Z=(I-M)^{-1}\,E$$

Exercise 4 | Multiplier Analysis

- **Estimate multiplier effects from an exogenous increase in demand**
  - Will need multiplier functions **MINVERSE** and **MMULT** (CTRL+SHIFT+ENTER)

Exercises folder

Exercise 4 – Multiplier Analysis.xlsx



Exercise 4 - Multiplier Analysis

National SAM with 3 sectors

	aagr	aind	asrv	cagr	cind	csrv	trc	lab	cap	ent	hrur	hurb	gov	s-i	row	tota
aagr				4,194							230	27				
aind					14,798						143	12				1
asrv						12,849										1
cagr	934	1,711	215								2,160	1,123			27	
cind	500	6,139	1,805								2,597	1,368		5,218	2,984	2
csrv	370	2,537	1,788				3767.52				2,091	1,602	1,028		252	1
trc				1,632	2,135											
lab	1,740	2,291	2,047												2	
cap	908	2,275	6,994												5	1
ent									9,681				460		49	1
hrur								3,876	257	3792.81			145		545	
hurb								2,203	25	3333.85			19		194	
gov				16	845					600.771	39	112	1,362		22	
s-i										2456.42	1,355	1,530	-34		-88	
row				329	2,834	586		0	218	6.02321	2	1	16			
total	4,452	14,953	12,849	6,171	20,611	13,436	3767.52	6,079	10,182	10189.9	8,617	5,775	2,996	5,218	3,993	

PART 1: Calculating the inverted coefficient matrix

Coefficient matrix (M)

Calculate coefficients by dividing each column through by its column total.

	aagr	aind	asrv	cagr	cind	csrv	trc	lab	cap	ent	hrur	hurb	gov	s-i	row
aagr															
aind															

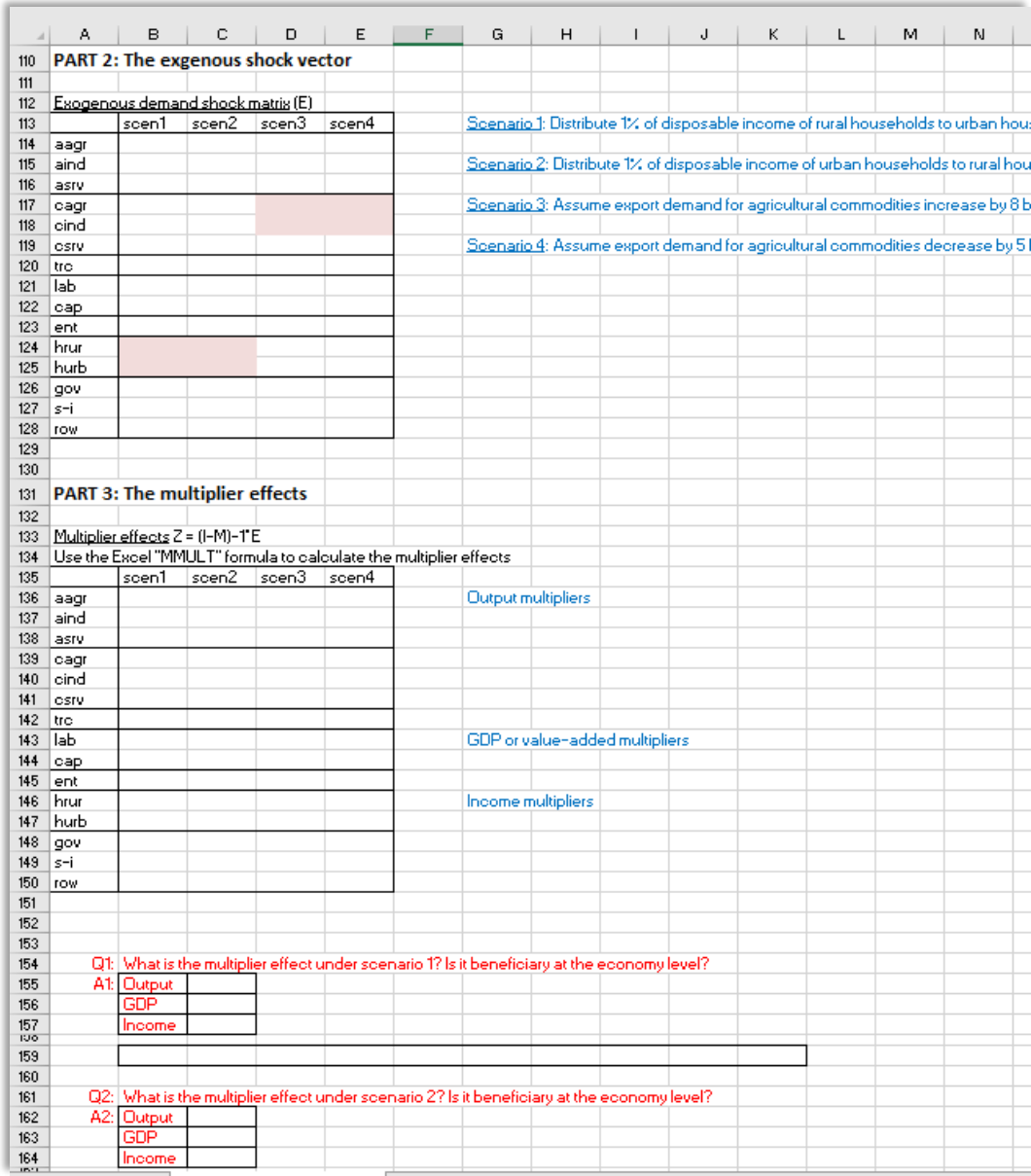
Exercise 4x | Multiplier Scenarios

- **Same SAM and multiplier model from Exercise 4**

- **Run four simulations**
  - **1 & 2**: Redistribute rural and urban incomes
  - **3 & 4**: Changes in agricultural export demand

Exercises folder

Exercise 4x – Multiplier Scenarios.xlsx



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
110	**PART 2: The exgenous shock vector**													
111														
112	Exogenous demand shock matrix (E)													
113		scen1	scen2	scen3	scen4		Scenario 1: Distribute 1% of disposable income of rural households to urban hou							
114	aagr													
115	aind						Scenario 2: Distribute 1% of disposable income of urban households to rural hou							
116	asrv													
117	cagr						Scenario 3: Assume export demand for agricultural commodities increase by 8 b							
118	cind													
119	csrv						Scenario 4: Assume export demand for agricultural commodities decrease by 5							
120	trc													
121	lab													
122	cap													
123	ent													
124	hrur													
125	hurb													
126	gov													
127	s-i													
128	row													
129														
130														
131	**PART 3: The multiplier effects**													
132														
133	Multiplier effects Z = (I-M)-1*E													
134	Use the Excel "MMULT" formula to calculate the multiplier effects													
135		scen1	scen2	scen3	scen4									
136	aagr						Output multipliers							
137	aind													
138	asrv													
139	cagr													
140	cind													
141	csrv													
142	trc													
143	lab						GDP or value-added multipliers							
144	cap													
145	ent													
146	hrur						Income multipliers							
147	hurb													
148	gov													
149	s-i													
150	row													
151														
152														
153														
154	Q1: What is the multiplier effect under scenario 1? Is it beneficiary at the economy level?													
155	A1: Output													
156	GDP													
157	Income													
159														
160														
161	Q2: What is the multiplier effect under scenario 2? Is it beneficiary at the economy level?													
162	A2: Output													
163	GDP													
164	Income													

IFPRI Modeling Systems

Informing future pathways and priorities

Part 4

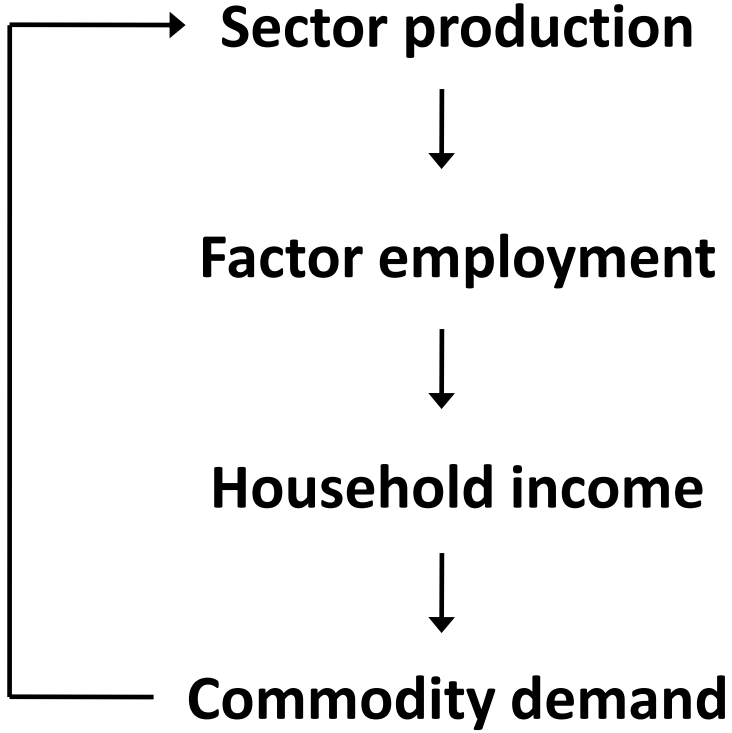
Simple CGE Model

Tracing an Economic Shock

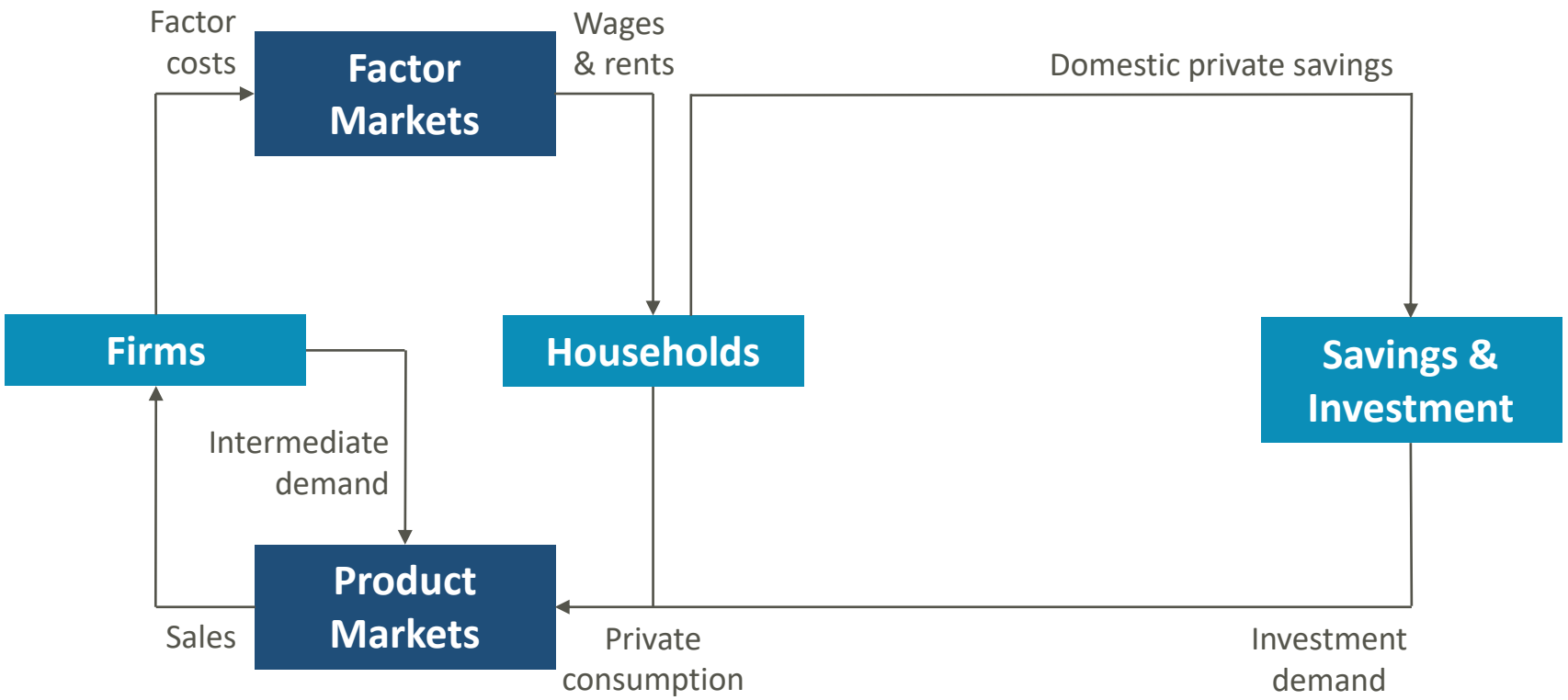
- Using the SAM, we can trace economywide effects of production and demand changes

Example

Investment demand doubles



Closed-Economy, No Government



Simple SAM

Incomes across rows

Expenditures down columns

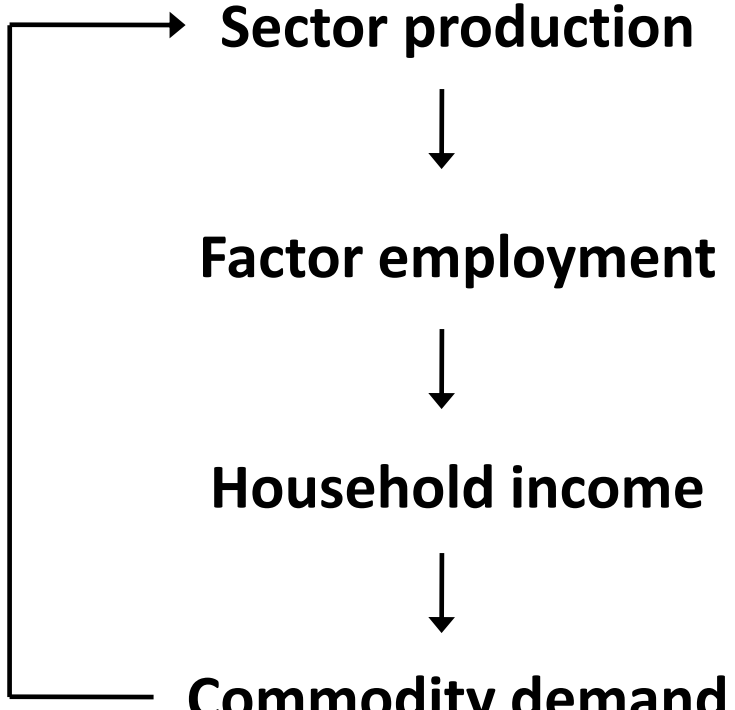
		ACT		COM		FAC		HHD		INV	TOT
		AG	NAG	AG	NAG	LAB	CAP	RUR	URB		
ACT	AG			60		0.66	0.40				60
	NAG				50	0.33	0.40				50
COM	AG						0.20	40	20		60
	NAG					1.00	1.00	20	20	10	50
FAC	LAB	40	20								60
	CAP	20	30								50
HHD	RUR					40	20				60
	URB					20	30				50
SAV									10		10
TOT		60	50	60	50	60	50	60	50	10	

0.66	0.40
0.33	0.60
1.00	1.00

0.66	0.40
0.33	0.60
1.00	1.00

Tracing an Economic Shock

- Using the SAM, we can trace economywide effects of production and demand changes



Example

Investment demand doubles

Non-agricultural production rises

Non-agric. is capital-intensive - so capital incomes rise more than labor incomes

Most capital income goes to urban households

Urban households spend income on both agric. and non-agric. goods – so both sectors' production must increase

Tracing Direct and Indirect Effects

Incomes across rows

Expenditures down columns

		ACT		COM		FAC		HHD		INV	TOT
		AG	NAG	AG	NAG	LAB	CAP	RUR	URB		
ACT	AG			60		0.66	0.40				60
	NAG				60	0.33	0.40				60
COM	AG			0.66	0.40		0.20	42.6	22.25		60
	NAG			0.33	0.60	1.00	1.00	21.8	22.25	20	60
FAC	LAB	40	24	1.00	1.00			0.66	0.40		64
	CAP	20	36					0.33	0.60		56
HHD	RUR					42.4	22	1.00	1.00		64.4
	URB					21.6	34				55.6
SAV									11.1		10
TOT		60	60	60	60	64	56	64.4	55.6	10	

Why Do We Need a Model?

- **Even for a simple aggregate SAM, tracing the economywide impact of a shock quickly becomes complex**
  - In our example, we stopped before second-round effects got started
  - We assumed no resource competition (i.e., production is unconstrained)

- **CGE models follow the logic of our example, but use equations to capture all structural linkages in the SAM**
  - It is more precise and can use much larger and more complex SAMs
  - It captures resource constraints and market competition (i.e., role of prices in allocating labor/capital and agricultural/non-agricultural goods)

Simple CGE | Activity Production Functions

		ACT	
		AG	NAG
FAC	LAB	40	20
	CAP	20	30
TOT		60	50

Production technologies are from SAM

$$Q_a = \alpha \cdot LAB_a^{\beta_a} \cdot CAP_a^{1-\beta_a}$$

Resources are scarce and there is fixed supply

$$\overline{LABS} = \sum_a LAB_a \qquad \overline{CAPS} = \sum_a CAP_a$$

So producers maximize profits while competing for scarce resources
(they pay wages and rents equal to the value of labor and capital's marginal product)

$$w = \frac{\beta_a \cdot P_a \cdot Q_a}{LAB_a} \qquad r = \frac{(1-\beta_a) \cdot P_a \cdot Q_a}{CAP_a}$$

Simple CGE | Household Incomes and Spending

		FAC		TOT
		LAB	CAP	
HHD	RUR	40	20	**60**
	URB	20	30	**50**
TOT		**60**	**50**	

Factor incomes are paid to households based on fixed factor income shares (θ)

$$\sum_h \theta_h^{LAB} = 1 \qquad \sum_h \theta_h^{CAP} = 1$$

$$Y_h = \theta_h^{LAB} \cdot \sum_a w \cdot LAB_a + \theta_h^{CAP} \cdot \sum_a r \cdot CAP_a$$

Households save (S<1) and spend remainder on goods (fixed budget shares δ) to maximize utility

$$P_a \cdot D_{ah} = \delta_{ah} \cdot (1 - S_h) \cdot Y_h$$

$$\sum_a \delta_{ah} = 1$$

		HHD	
		RUR	URB
COM	AG	40	20
	NAG	20	20
SAV			10
TOT		**60**	**50**

Simple CGE | Savings and Investment

		INV
COM	AG	
	NAG	10
TOT		10

In equilibrium, investment demand equals total savings

$$P_a \cdot I_a = \lambda_a \cdot \sum_h S_h \cdot Y_h \qquad \sum_a \lambda_a = 1$$

BUT savings rates (S) and investment (I) cannot both be flexible

We must fix one of these variables… $\overline{S_h}$ or $\overline{I_a}$

This is a **macroeconomic closure** rule, which tells the model how to balance the savings-investment account (i.e., should savings drive investment, or should investment drive savings?)

Simple CGE | Equations & Variables in the Model

$$Q_a = \alpha \cdot LAB_a^{\beta_a} \cdot CAP_a^{1-\beta_a}$$

2eqs = 2vars Q_a

$$w = \frac{\beta_a \cdot P_a \cdot Q_a}{LAB_a} \qquad r = \frac{(1-\beta_a) \cdot P_a \cdot Q_a}{CAP_a}$$

4eqs = 4vars LAB_a, CAP_a

$$\overline{LABS} = \sum_a LAB_a \qquad \overline{CAPS} = \sum_a CAP_a$$

2eqs = 2vars w, r

$$Y_h = \theta_h^{LAB} \cdot \sum_a w \cdot LAB_a + \theta_h^{CAP} \cdot \sum_a r \cdot CAP_a$$

2eqs = 2vars Y_h

$$P_a \cdot I_a = \lambda_a \cdot \sum_h S_h \cdot Y_h$$

2eqs = 2vars S_h or I_a

$$P_a \cdot D_{ah} = \delta_{ah} \cdot (1 - S_h) \cdot Y_h$$

4eqs = 4vars D_{ah}

One More Equation

We have equations ensuring that total factor demand equals supply

Total commodity supply (Q_a) must equal the sum of household and investment demands

$$Q_a = \sum_h D_{ah} + I_a$$

There are two of these equations and two price variables (P_a) so we are now 'square' (i.e., no. equations = no. endogenous variables)

We need a 'numeraire' = a fixed price against which all other prices are compared to (i.e., acts as a value 'anchor' for the model)

If we fix a variable, we must drop an equation to stay 'square'

Model Calibration and Simulation

- **Attach SAM values to the model's parameters and variables**
  - SAM is balanced, so model is initially balanced (i.e., in equilibrium)

- **When we shock the model, it falls out of equilibrium**
  - Solve the model to find a new equilibrium
  - Difference in the values of the variables between the old and the new equilibriums is the impact of the shock (i.e., comparative statics)

- **We use the General Algebraic Modeling System (GAMS)**
  - GEMPACK is another specialized modeling language/environment

Extensions in IFPRI Standard CGE Model

- **We use more complicated (flexible) functional forms:**
  - Constant Elasticity of Substitution (CES) production functions so technologies change with relative factor prices
  - Linear Expenditure System (LES) of demand systems to allow for non-unity income elasticities

- **Include government and the rest of the world**
  - CES and CET trade functions allow producers and consumers to shift between domestic and foreign markets
  - We also have two extra macro-closures
  - Government: Flexible tax rates or spending?
  - Current account: Flexible exchange rate or deficit?

IFPRI Modeling Systems

Informing future pathways and priorities

Part 5

IFPRI Standard CGE Model

Why Have a Standard Model?

- **Common core model**
  - Avoid reinventing the wheel
  - Quick to get up and running for new countries/SAMs
  - Can focus on new analysis rather than lots of programming

- **Versatile**
  - Captures most unique country characteristics (e.g., taxes)
  - Can add complexity or special country characteristics

- **Easier to debug or to explain to others what you're doing**

Too Many Equations, Variables and Parameters!

51 variables & 46 parameters

48 equations

APPENDIX A: MATHEMATICAL SUMMARY STATEMENT FOR THE STANDARD CGE MODEL

SETS

$\alpha \in A$
$\alpha \in ACES(\subset A)$
$\alpha \in ALEO(\subset A)$
$c \in C$
$c \in CD(\subset C)$
$c \in CDN(\subset C)$
$c \in CE(\subset C)$
$c \in CEN(\subset C)$
$c \in CM(\subset C)$
$c \in CMN(\subset C)$
$c \in CT(\subset C)$
$c \in CX(\subset C)$
$f \in F$
$i \in INS$
$i \in INSD(\subset INS)$
$i \in INSDNG (\subset INSD)$
$h \in H(\subset INSDNG)$

PARAMETERS
Latin Letters

$cwts_c$
$dwts_c$
$ica_{c\,a}$
$icd_{c\,c'}$
$ice_{c\,c'}$
$icm_{c\,c'}$
$inta_a$

EXOGENOUS VARIABLES

$\overline{CPI}$	consumer price index
$\overline{DTINS}$	change in domestic institution tax share (= 0 for base; exogenous variable)
$\overline{FSAV}$	foreign savings (FCU)
$\overline{GADJ}$	government consumption adjustment factor
$\overline{IADJ}$	investment adjustment factor
$\overline{MPSADJ}$	savings rate scaling factor (= 0 for base)
$\overline{QFS}_f$	quantity supplied of factor
$\overline{TINSADJ}$	direct tax scaling factor (= 0 for base; exogenous variable)
$\overline{WFDIST}_{f\,a}$	wage distortion factor for factor f in activity a

ENDOGENOUS VARIABLES

$DMPS$	change in domestic institution savings rates (= 0 for base; exogenous variable)
DPI	producer price index for domestically marketed output
EG	government expenditures
EH_h	consumption spending for household
EXR	exchange rate (LCU per unit of FCU)
$GOVSHR$	government consumption share in nominal absorption
$GSAV$	government savings
$INVSHR$	investment share in nominal absorption
MPS_i	marginal propensity to save for domestic non-government institution (exogenous variable)
PA_a	activity price (unit gross revenue)
PDD_c	demand price for commodity produced and sold domestically
PDS_c	supply price for commodity produced and sold domestically
PE_c	export price (domestic currency)
$PINTA_a$	aggregate intermediate input price for activity a
PM_c	import price (domestic currency)
PQ_c	composite commodity price
PVA_a	value-added price (factor income per unit of activity)
PX_c	aggregate producer price for commodity
$PXAC_{a\,c}$	producer price of commodity c for activity a
QA_a	quantity (level) of activity
QD_c	quantity sold domestically of domestic output

EQUATIONS

Price Block

Import price

$$PM_c = pwm_c \cdot (1+tm_c) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'\,c} \qquad c \in CM \qquad (1)$$

[import price (LCU)] = [import price (FCU)] · [tariff adjustment] · [exchange rate (LCU per FCU)] + [cost of trade inputs per import unit]

Export price

$$PE_c = pwe_c \cdot (1-te_c) \cdot EXR - \sum_{c' \in CT} PQ_{c'} \cdot ice_{c'\,c} \qquad c \in CE \qquad (2)$$

[export price (LCU)] = [export price (FCU)] · [tariff adjustment] · [exchange rate (LCU per FCU)] − [cost of trade inputs per export unit]

Demand price of domestic nontraded goods

$$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'\,c} \qquad c \in CD \qquad (3)$$

[domestic demand price] = [domestic supply price] + [cost of trade inputs per unit of domestic sales]

Absorption

$$PQ_c \cdot (1-tq_c) \cdot QQ_c = PDD_c \cdot QD_c + PM_c \cdot QM_c \qquad c \in (CD \cup CM) \qquad (4)$$

[absorption (at demand prices net of sales tax)] = [domestic demand price times domestic sales quantity] + [import price times import quantity]

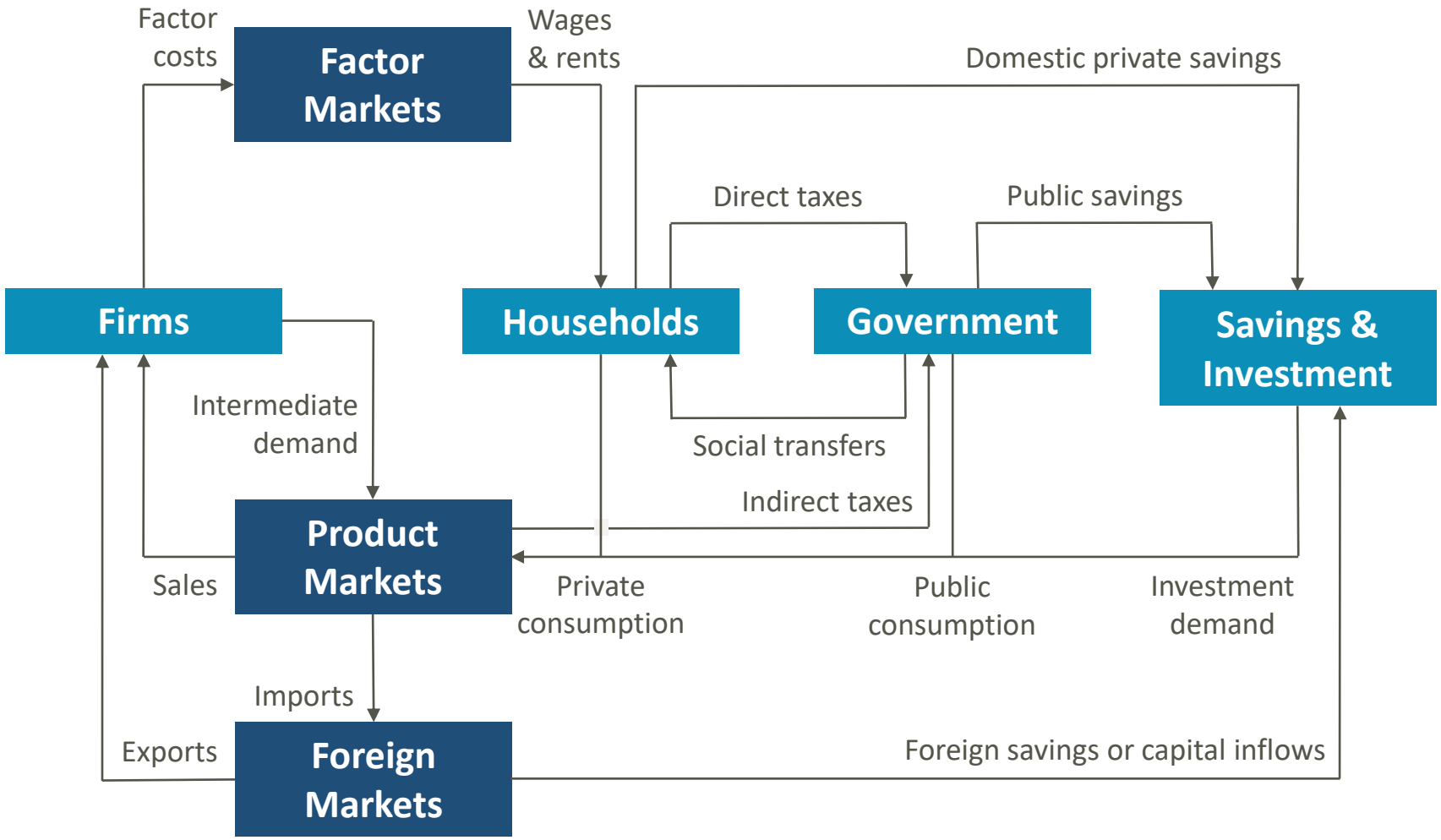
Factor demand

$$WF_f \cdot \overline{WFDIST}_{f\,a} = PVA_a \cdot (1-tva_a) \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{f\,a}^{va} \cdot QF_{f\,a}^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{f\,a}^{va} \cdot QF_{f\,a}^{-\rho_a^{va}-1} \qquad a \in A,\ f \in F \qquad (16)$$

[marginal cost of factor f in activity a] = [marginal revenue product of factor f in activity a]

Better to start with a conceptual understanding of the model →

Flows in the Standard Model

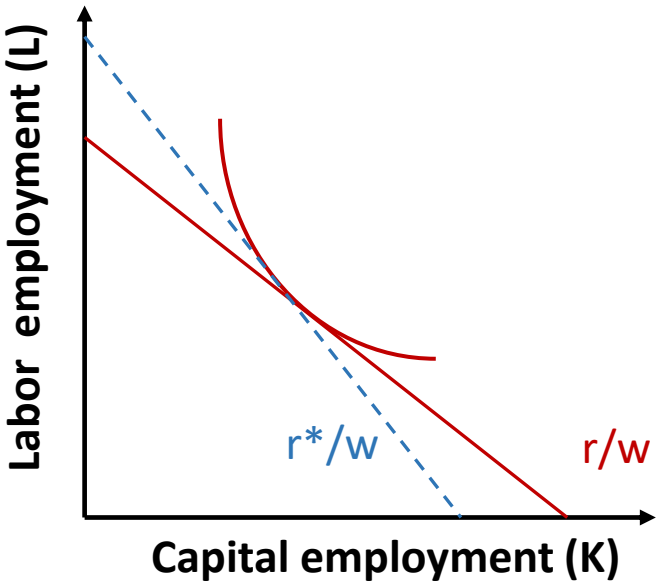


Functional Forms

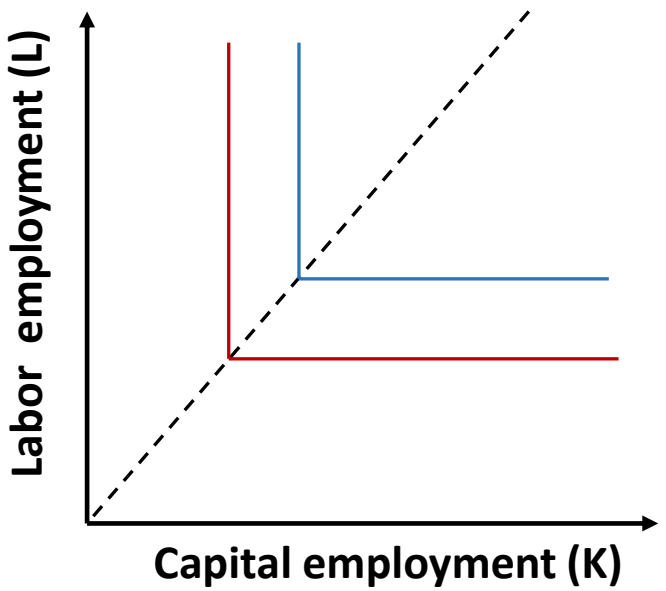
Cobb-Douglas (CD)
Constant expenditure shares

$$Q = \alpha \cdot L^{\beta} \cdot K^{1-\beta}$$
$$w \cdot L = \beta \cdot P \cdot Q$$
$$r \cdot K = (1-\beta) \cdot P \cdot Q$$

Constant Elasticity of Substitution (CES)
Shares relative to prices



Leontief
Fixed quantity ratios



Linkages vs. Trade-Offs

Basic SAM layout

	A	C	F	H	G	I	W	TOT
A								
C								
F								
H								
G								
I								
W								
TOT								

A = Activities
C = Commodities
F = Factors
H = Households
G = Government
I = Investment
W = Rest of world

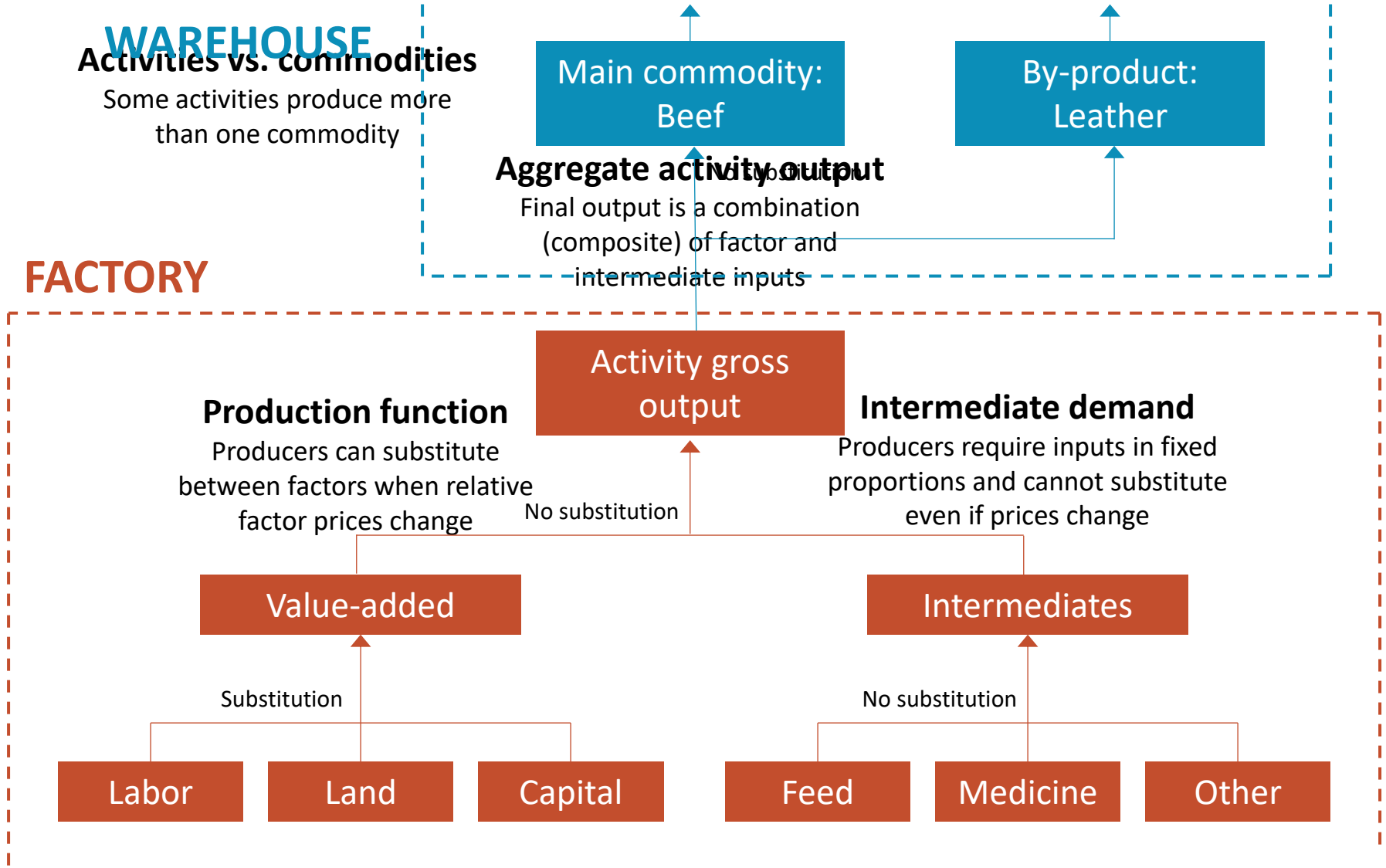
- **Linkages in the SAM**
  - Backward & forward production linkages
  - Income/demand linkages
  - Foreign trade
- **Multiplier models assume unlimited resources**
  - Implies that prices are fixed
  - No trade-offs
- **Resource constraints introduce trade-offs**
  - Factors are limited = wage rates are set in markets
  - Product supply is limited = product prices adjust
  - Foreign exchange is limited = exchange rate adjusts

Supply Chains | Activity Output

Basic SAM layout

	A	C	F	D	W	TOT
A						
C						
F						
D						
W						
TOT						

A = Activities
C = Commodities
F = Factors
D = Final demanders
W = Rest of world



Supply Chains | Commodity Supply & Demand

Product market closure
Demand & supply balance maintained via price changes

Basic SAM layout

	A	C	F	D	W	TOT
A						
C						
F						
D						
W						
TOT						

A = Activities
C = Commodities
F = Factors
D = Final demanders
W = Rest of world

SUPERMARKET

Households | Government | Investment | Intermediates

No substitution | No substitution | No substitution | No substitution

Total demand

Total supply — Composite commodity

Import demand function — Substitution — **Export supply function**

Imports | Domestic sales | Exports

Combines commodities from different activities & allows substitution to ensure lowest composite price

WAREHOUSE

Aggregate commodity output

Substitution

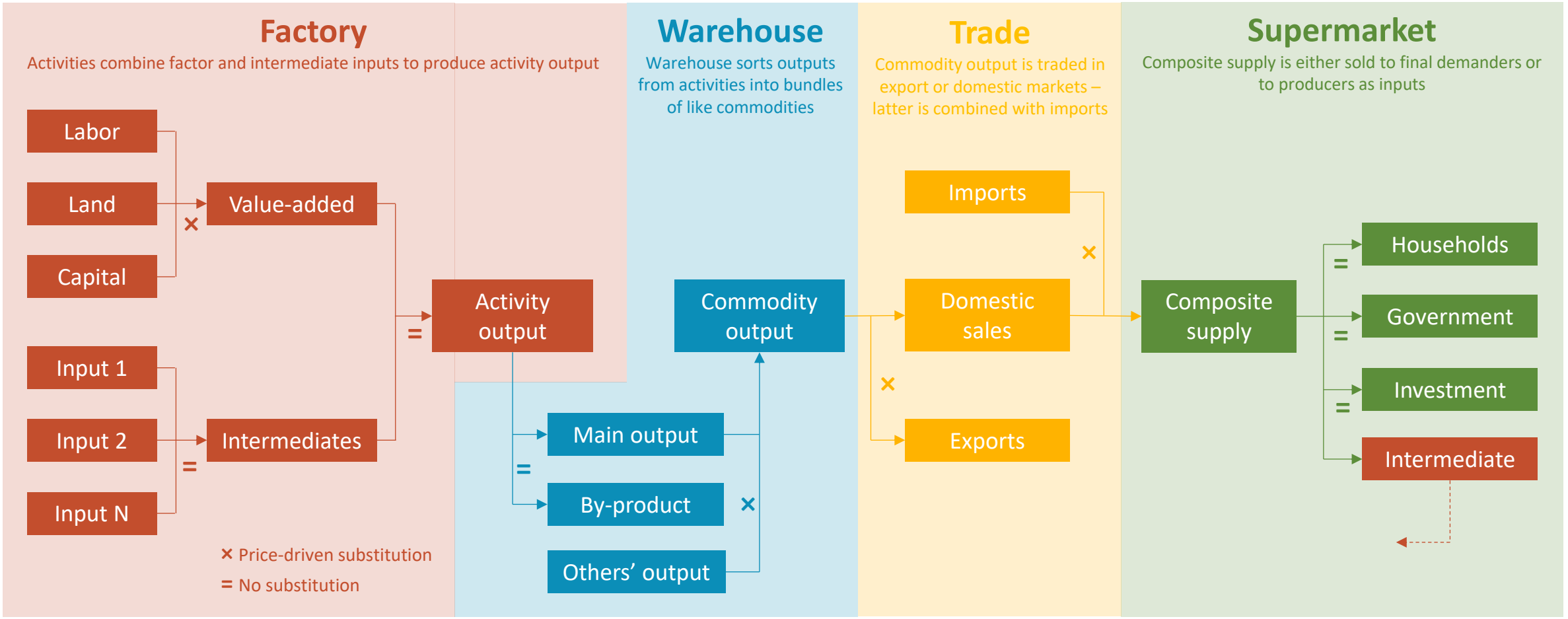
Main activity: Leather | Second activity: Livestock

Supply Chains | Summary

Equilibrium: Total commodity supply must equal total demand (mediated by prices changes)

A = Activities
C = Commodities
F = Factors
D = Final demand
W = Rest of world

	A	C	F	D	W	TOT
A						
C						
F						
D						
W						
TOT						

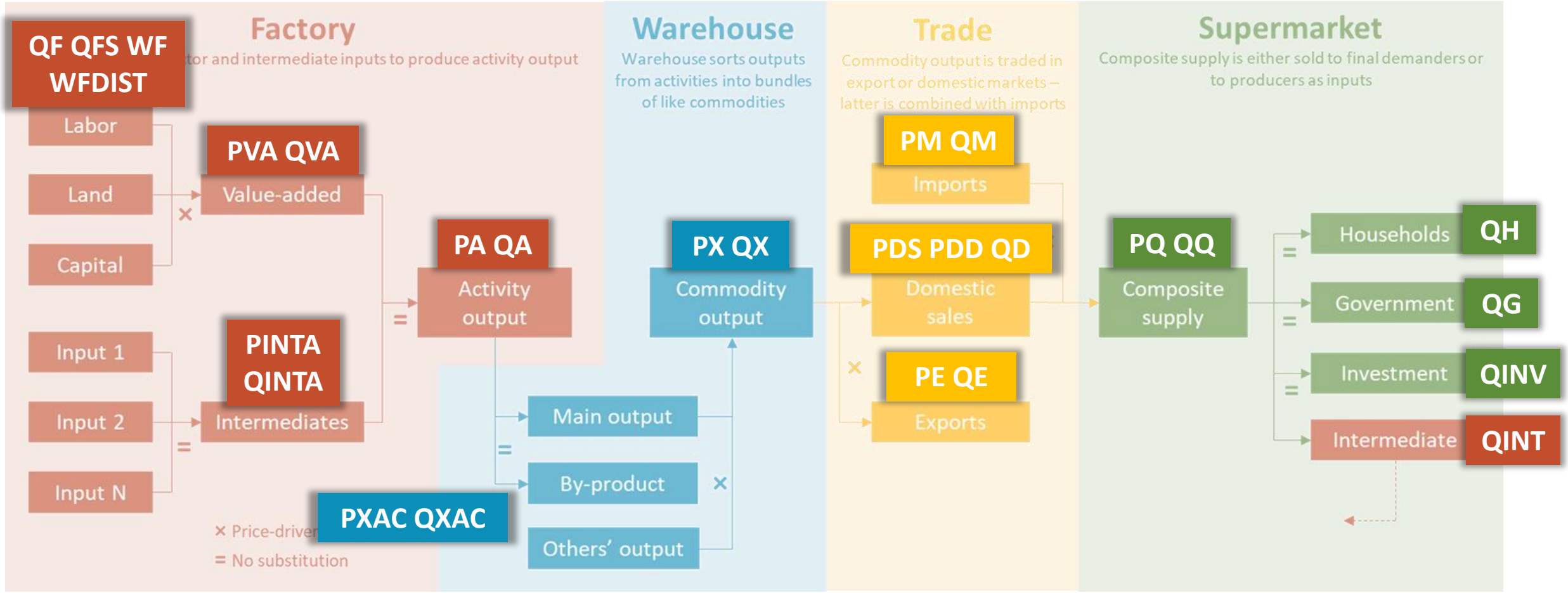


Supply Chains | Summary

Equilibrium: Total commodity supply must equal total demand (mediated by prices changes)

A = Activities
C = Commodities
F = Factors
D = Final demand
W = Rest of world

	A	C	F	D	W	TOT
A						
C						
F						
D						
W						
TOT						

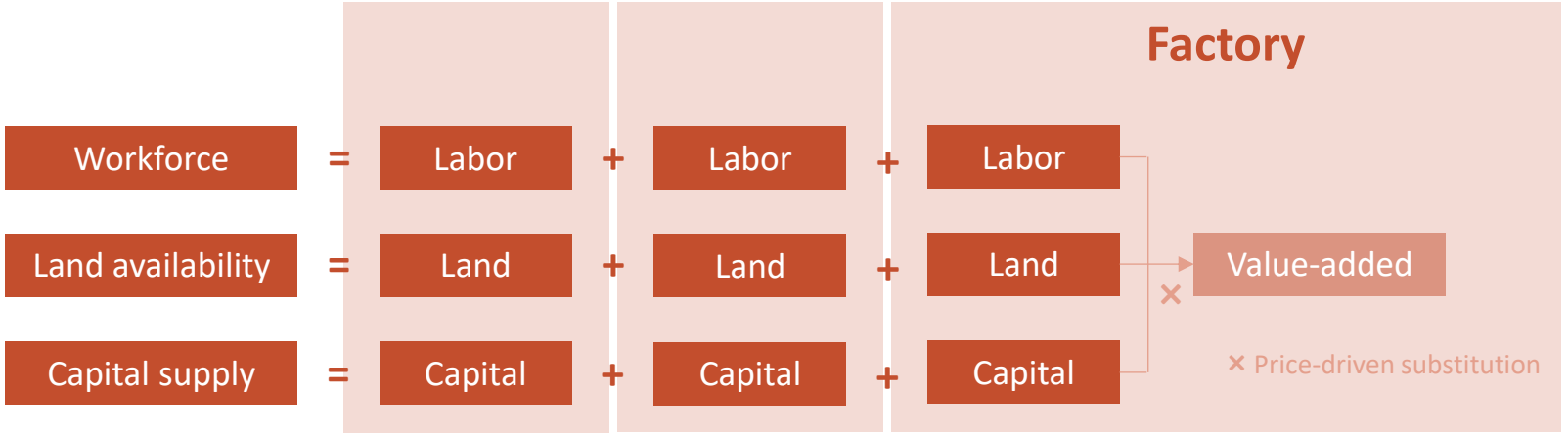


Factor Markets | Closure Rules

Equilibrium: Total factor supply must equal sum of sectoral factor demand
(determined by "closure rules")

A = Activities
C = Commodities
F = Factors
D = Final demand
W = Rest of world

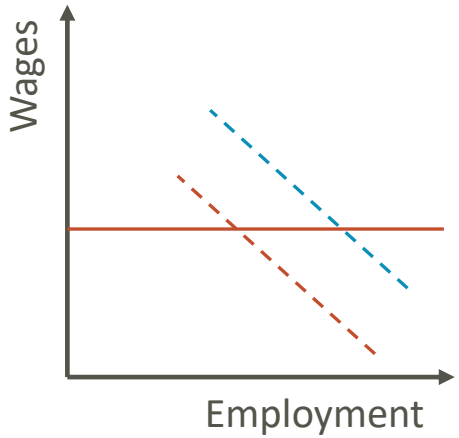
	A	C	F	D	W	TOT
A						
C						
F						
D						
W						
TOT						



Fix one
Economywide wage
Total factor supply

Factor market closure
- Adjust total factor supply?
- Adjust wages?

Option 1
Full employment



Option 2
Unemployment

Institutions | Incomes & Spending

Basic SAM layout

	A	C	F	H	G	I	W	TOT
A								
C								
F								
H								
G								
I								
W								
TOT								

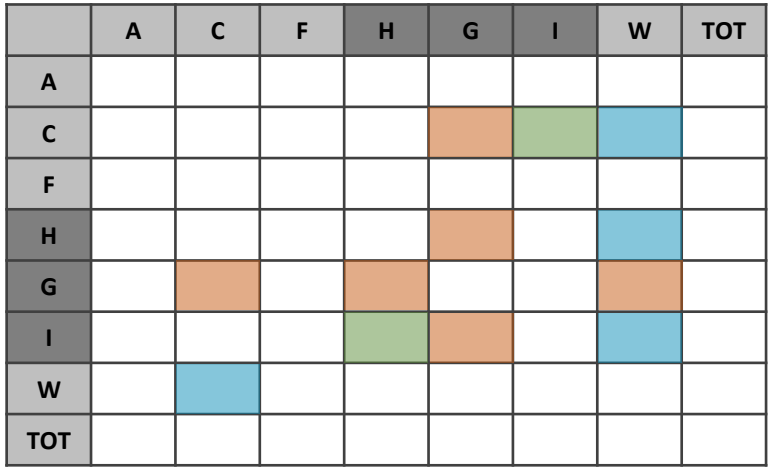
A = Activities
C = Commodities
F = Factors
H = Households
G = Government
I = Investment
W = Rest of world

	Households	Government	Investment	World
Total income	Factor earnings	Direct taxes	Private savings	Exports
	+	+	+	+
	Transfers	Indirect taxes	Public savings	Grants + Remit.
	+	+	+	+
	Remittances	Grants	Foreign savings	Foreign savings
	=	=	=	=
Total spending	Consumption	Consumption	Investment	Imports
	+	+		
	Direct taxes	Transfers		
	+	+		
	Savings	Savings		

Macroeconomy | Closure Rules

Equilibrium: Total receipts must equal total expenditures
(determined by "closure rules")

A = Activities
C = Commodities
F = Factors
H = Households
G = Government
I = Investment
W = Rest of world



Government

Recurrent fiscal deficit (savings) equals total revenues (taxes and grants) less total expenditures (consumption and transfers)

Direct taxes + Indirect taxes + Grants = Consumption + Transfers + Public saving

Fix two
Tax rates
Consumption
Public savings

Current account

Total inflow of foreign exchange (exports, grants and remittances) must equal total outflows (imports)

Exports + Grants + Remittances + Foreign saving = Imports

Fix one
Exchange rate
Foreign savings

Savings – Investment

Total supply of loanable funds (savings) must equal total investment demand

Private saving + Public saving + Foreign saving = Investment

Fix one
Private savings rates
Investment

Standard CGE Model | Key Features

- **Capture all economic linkages** (based on the SAMs)

- **Drop the assumption that resources are unconstrained** (i.e., fixed prices, as in multiplier models)
  - Product prices
  - Factor prices (labor wages, land rents, capital profits)
  - Exchange rate

- **Maintain macroeconomic & resource balances** (no “free lunch”)
  - Government fiscal accounts
  - Investment & savings
  - Current account / balance of payments
  - Factor markets

- **Provides a consistent framework for tracking economywide impacts**
  - Macro-accounting principles are respected (e.g., receipts must equal payments)
  - Macro and micro feedbacks are tracked (e.g., sectors, workers, households)

Standard CGE Model | Other Features

- **Enterprises**
  - Receive some factor incomes (usually capital)
  - Pay taxes (corporate), save, remit
  - Pay whatever is left to households (i.e., indirect capital payments)

- **Taxes**
  - Indirect: Producer taxes, sales taxes, factor taxes, and export taxes
  - Direct: Personal income taxes, corporate taxes
  - Tax changes can be proportional or point changes

- **Change in stocks or inventories**
  - Residual investment (drawing down or increasing inventories)
  - No behavior or effect on savings-investment closure

Standard CGE Model | Calibration

- **Attach values to the model's variables and parameters**

- **Most data comes directly from the SAM**
  - Usually assume that prices are equal to one – so quantities are equal to SAM values

- **But some data must come from external sources**
  - Employment numbers (QF and QFS) – non-unitary wages (WF and WFDIST)
  - Household income elasticities for each commodity (budget surveys?)
  - Factor and trade substitution elasticities (GTAP?)

IFPRI Modeling Systems

Informing future pathways and priorities

Part 6

Microsoft-Excel® Interface

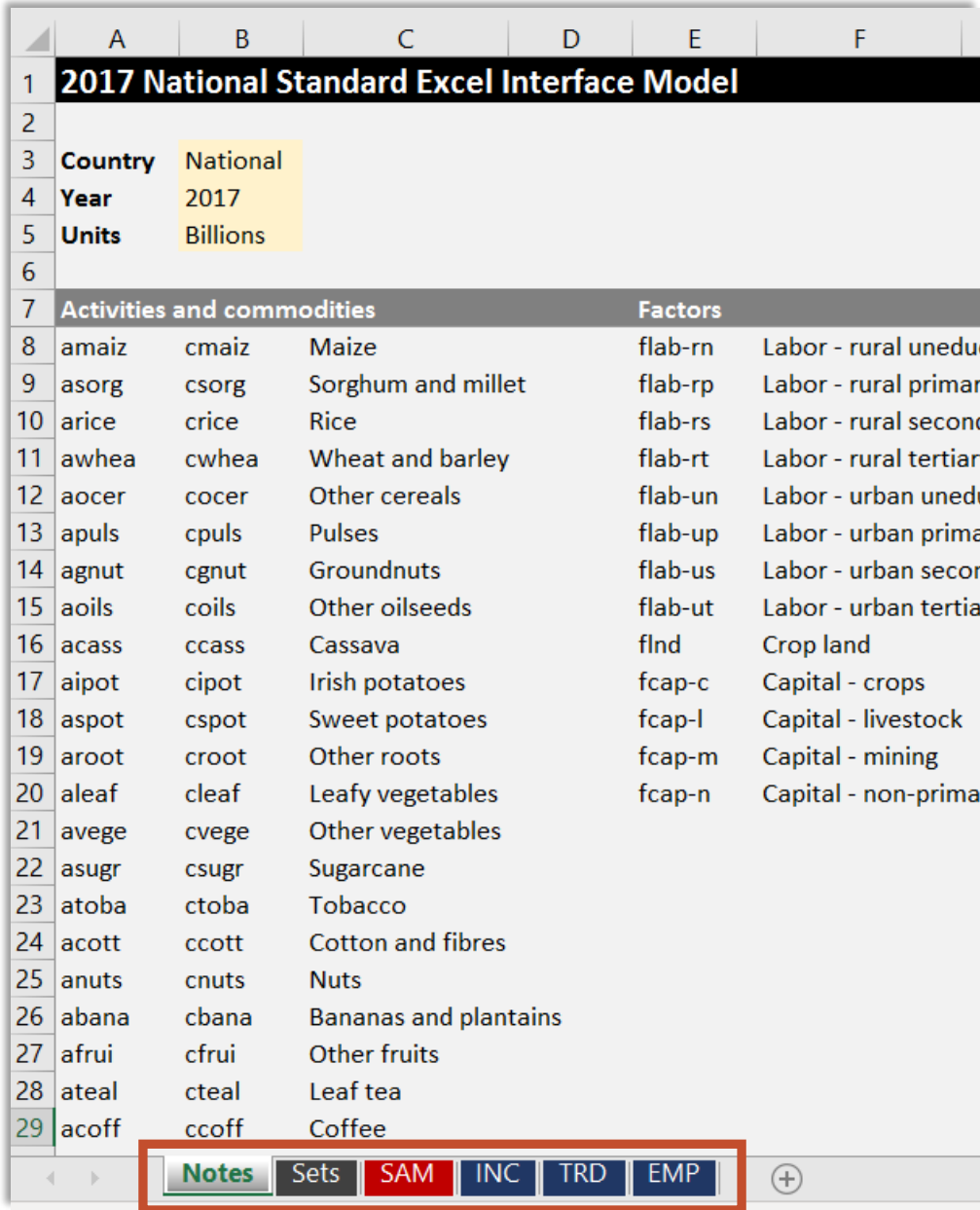
Standard Model

- **IFPRI's standard static model**

- **Nexus SAM**
  - 86 activities & 86 commodities
  - 13 factors of production
  - 15 household groups

- **National data file sheets**
  - SAM social accounting matrix
  - INC income elasticities
  - TRD trade/production elasticities
  - EMP wages & employment

1national.xlsx | Notes



	A	B	C	D	E	F
1	**2017 National Standard Excel Interface Model**					
2						
3	**Country**	National				
4	**Year**	2017				
5	**Units**	Billions				
6						
7	**Activities and commodities**				**Factors**	
8	amaiz	cmaiz	Maize		flab-rn	Labor - rural unedu
9	asorg	csorg	Sorghum and millet		flab-rp	Labor - rural primar
10	arice	crice	Rice		flab-rs	Labor - rural secon
11	awhea	cwhea	Wheat and barley		flab-rt	Labor - rural tertiar
12	aocer	cocer	Other cereals		flab-un	Labor - urban unedu
13	apuls	cpuls	Pulses		flab-up	Labor - urban prima
14	agnut	cgnut	Groundnuts		flab-us	Labor - urban secor
15	aoils	coils	Other oilseeds		flab-ut	Labor - urban tertia
16	acass	ccass	Cassava		flnd	Crop land
17	aipot	cipot	Irish potatoes		fcap-c	Capital - crops
18	aspot	cspot	Sweet potatoes		fcap-l	Capital - livestock
19	aroot	croot	Other roots		fcap-m	Capital - mining
20	aleaf	cleaf	Leafy vegetables		fcap-n	Capital - non-prima
21	avege	cvege	Other vegetables			
22	asugr	csugr	Sugarcane			
23	atoba	ctoba	Tobacco			
24	acott	ccott	Cotton and fibres			
25	anuts	cnuts	Nuts			
26	abana	cbana	Bananas and plantains			
27	afrui	cfrui	Other fruits			
28	ateal	cteal	Leaf tea			
29	acoff	ccoff	Coffee			

Notes | Sets | SAM | INC | TRD | EMP

Five Steps to Running Simulations

1 **Model interface**
1model.xlsx

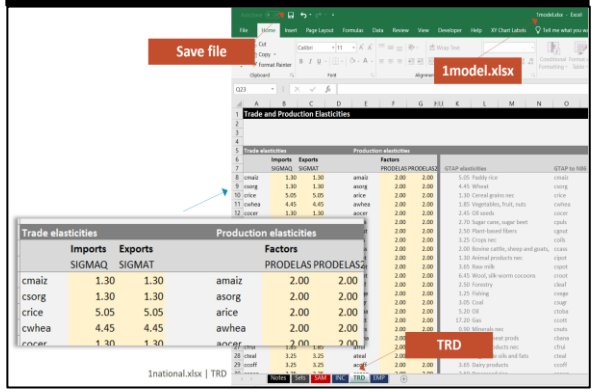
2 **Model code**
1model.gms

3 **Simulation interface**
2simulation.xlsx

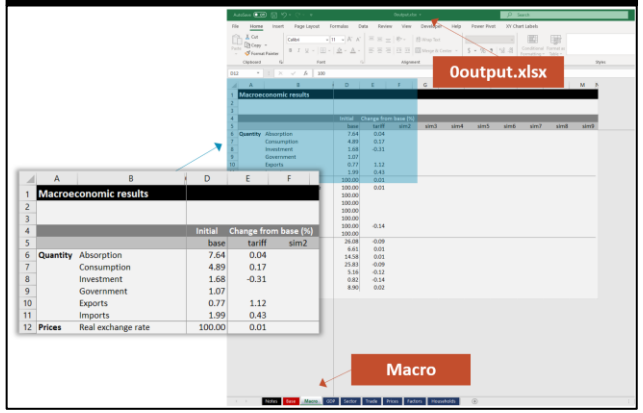
4 **Simulation code**
2simulation.gms

5 **Results interface**
0output.xlsx

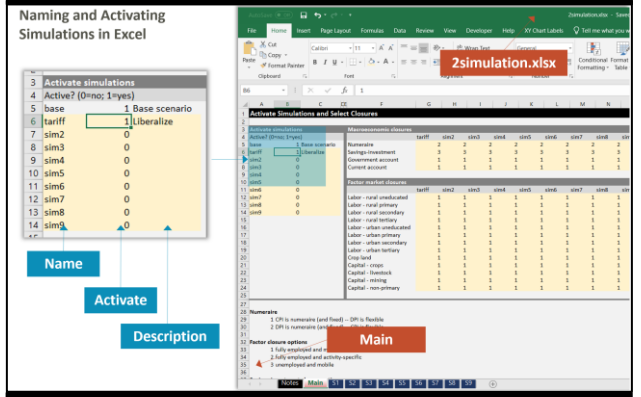
Data SAM, elasticities



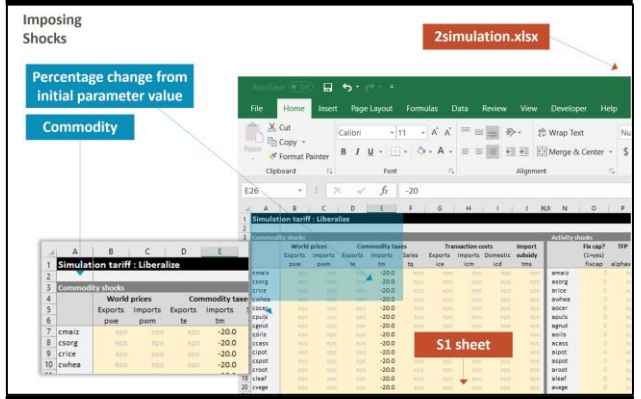
Results Macro, sector, household, etc.



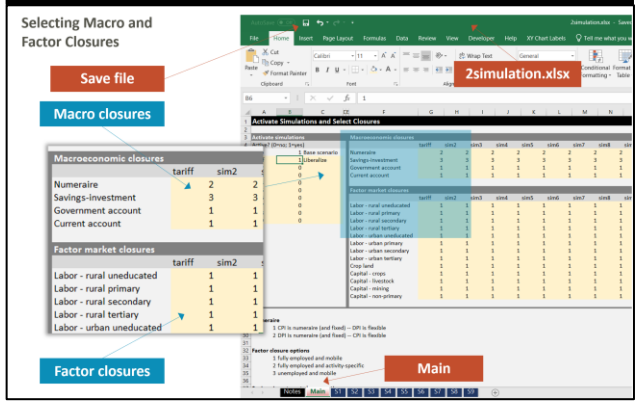
Step 1 Name & activate simulations



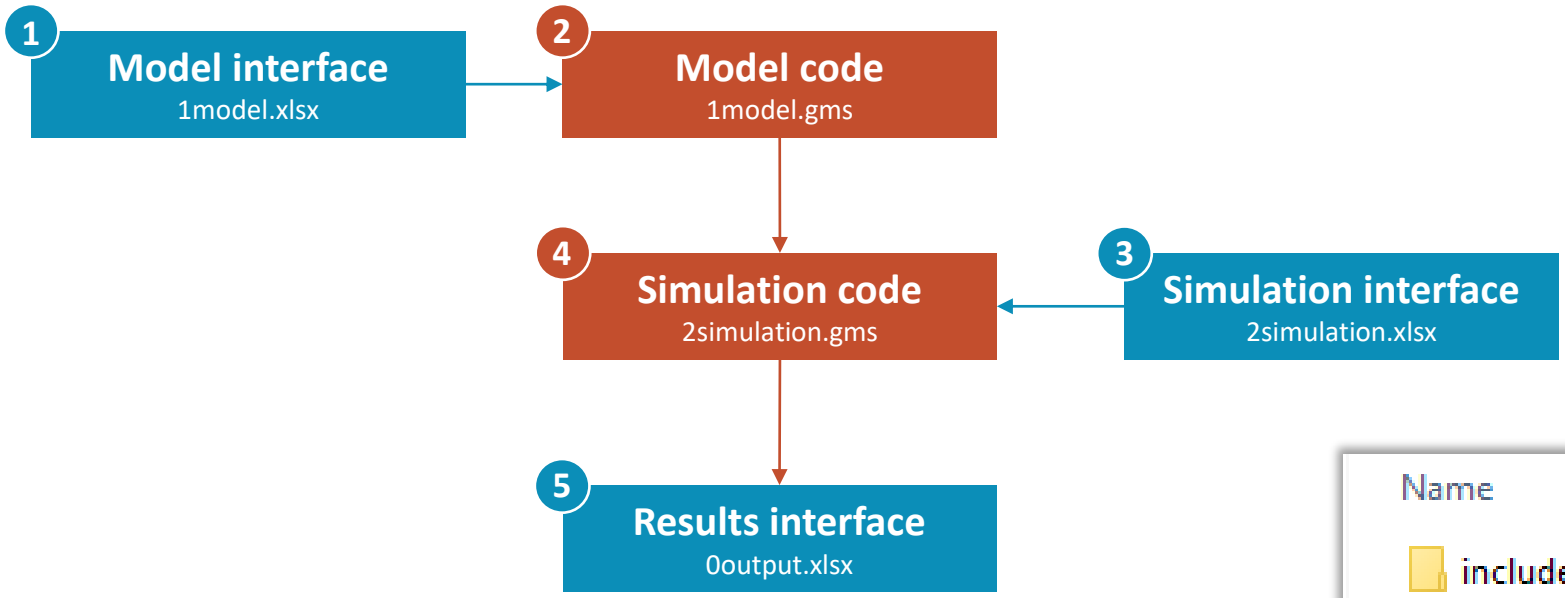
Step 2 Impose shocks

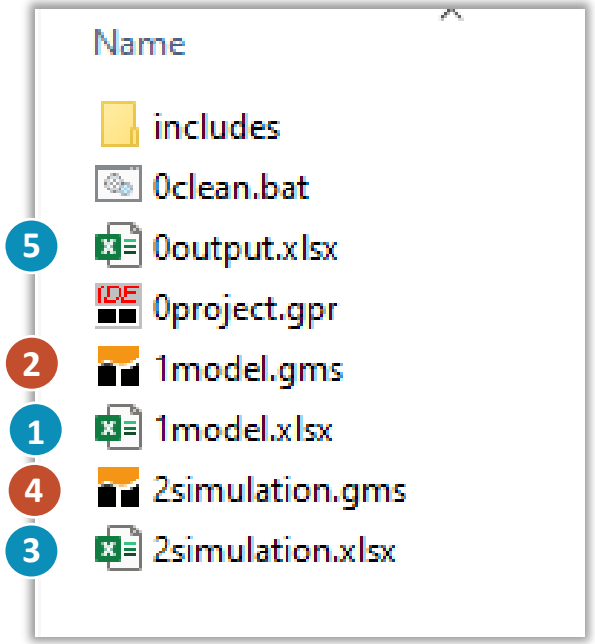


Step 3 Select closures



Files in the Folder





Step 1 | Changing Elasticities (Optional)

1model.xlsx

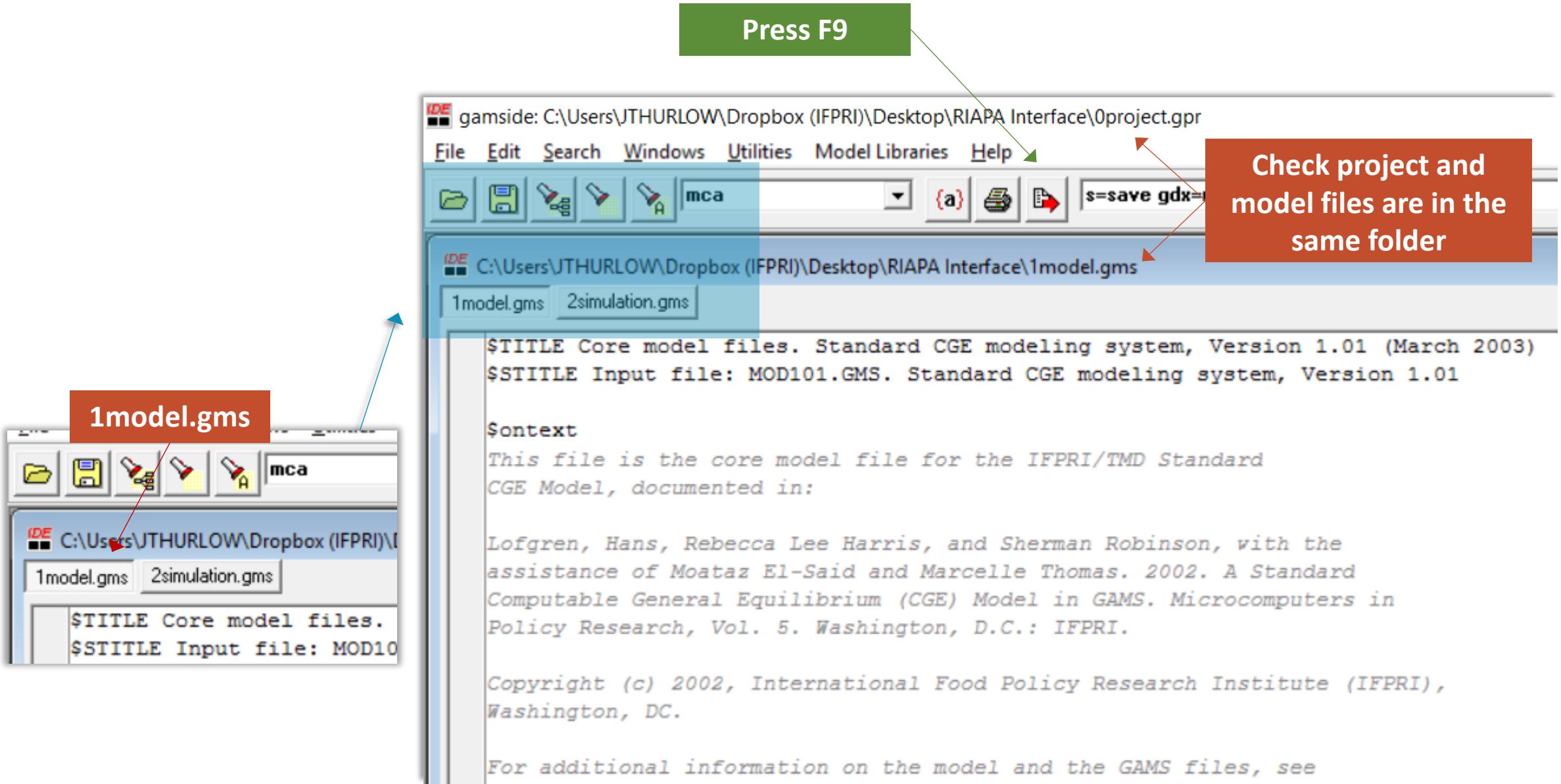
Save file

Trade elasticities			Production elasticities		
	Imports	Exports		Factors	
	SIGMAQ	SIGMAT		PRODELAS	PRODELAS2
cmaiz	1.30	1.30	amaiz	2.00	2.00
csorg	1.30	1.30	asorg	2.00	2.00
crice	5.05	5.05	arice	2.00	2.00
cwhea	4.45	4.45	awhea	2.00	2.00
cocer	1.30	1.30	aocer	2.00	2.00

1national.xlsx | TRD

TRD

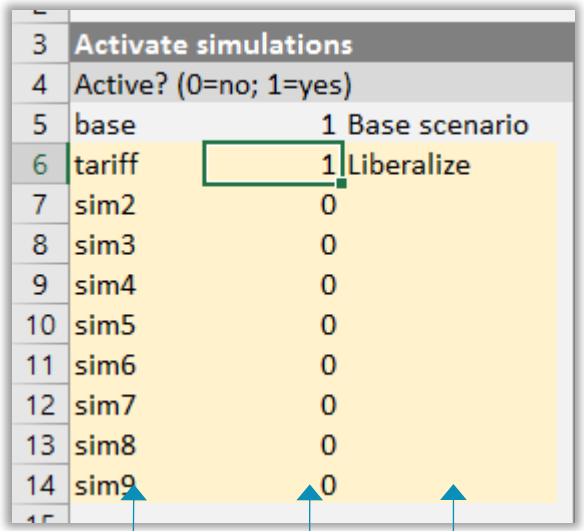
Step 2 | Initializing Model (Push F9)



Step 3.1 | Designing Simulations

2simulation.xlsx

Naming and Activating Simulations in Excel

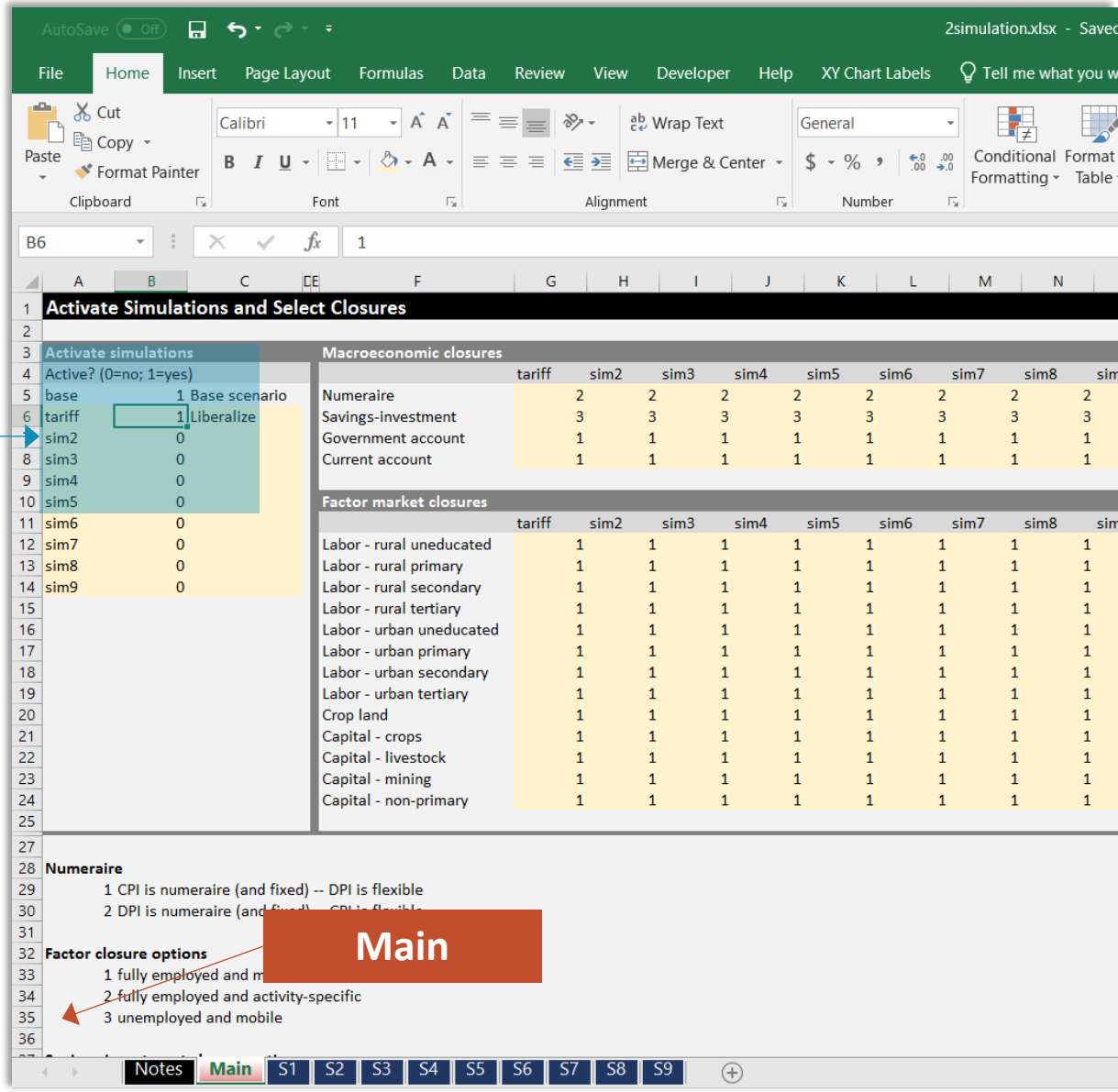


3	**Activate simulations**		
4	Active? (0=no; 1=yes)		
5	base	1	Base scenario
6	tariff	1	Liberalize
7	sim2	0	
8	sim3	0	
9	sim4	0	
10	sim5	0	
11	sim6	0	
12	sim7	0	
13	sim8	0	
14	sim9	0	

Name

Activate

Description



Activate Simulations and Select Closures

Activate simulations		
Active? (0=no; 1=yes)		
base	1	Base scenario
tariff	1	Liberalize
sim2	0	
sim3	0	
sim4	0	
sim5	0	
sim6	0	
sim7	0	
sim8	0	
sim9	0	

Macroeconomic closures

	tariff	sim2	sim3	sim4	sim5	sim6	sim7	sim8
Numeraire	2	2	2	2	2	2	2	2
Savings-investment	3	3	3	3	3	3	3	3
Government account	1	1	1	1	1	1	1	1
Current account	1	1	1	1	1	1	1	1

Factor market closures

	tariff	sim2	sim3	sim4	sim5	sim6	sim7	sim8
Labor - rural uneducated	1	1	1	1	1	1	1	1
Labor - rural primary	1	1	1	1	1	1	1	1
Labor - rural secondary	1	1	1	1	1	1	1	1
Labor - rural tertiary	1	1	1	1	1	1	1	1
Labor - urban uneducated	1	1	1	1	1	1	1	1
Labor - urban primary	1	1	1	1	1	1	1	1
Labor - urban secondary	1	1	1	1	1	1	1	1
Labor - urban tertiary	1	1	1	1	1	1	1	1
Crop land	1	1	1	1	1	1	1	1
Capital - crops	1	1	1	1	1	1	1	1
Capital - livestock	1	1	1	1	1	1	1	1
Capital - mining	1	1	1	1	1	1	1	1
Capital - non-primary	1	1	1	1	1	1	1	1

Numeraire

1 CPI is numeraire (and fixed) -- DPI is flexible

2 DPI is numeraire (and fixed) -- CPI is flexible

Factor closure options

1 fully employed and m

2 fully employed and activity-specific

3 unemployed and mobile

Main

Notes | Main | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9

Step 3.2 | Designing Simulations

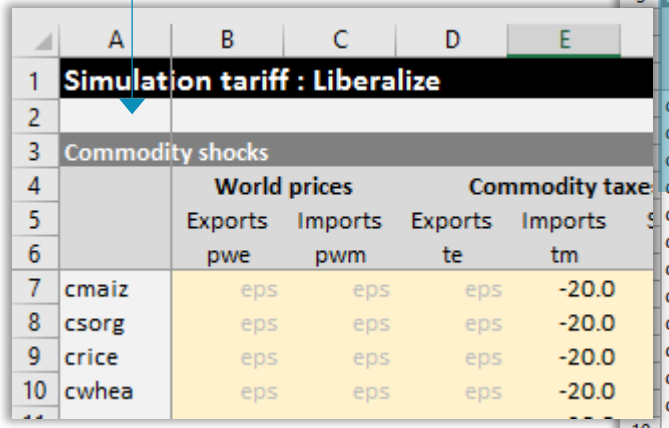
Imposing Shocks

2simulation.xlsx

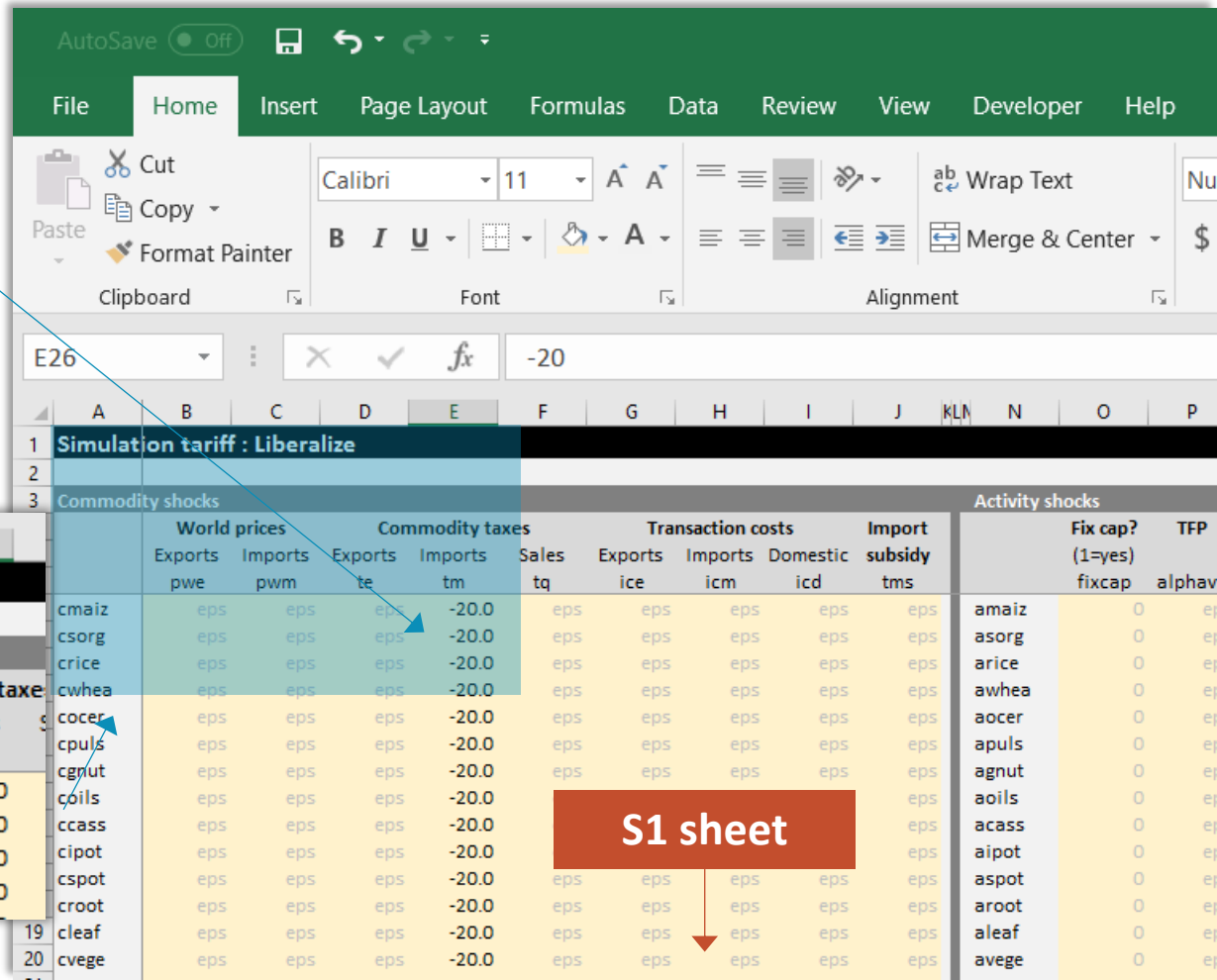
Percentage change from initial parameter value

Commodity

S1 sheet



	A	B	C	D	E
1	Simulation tariff : Liberalize				
2					
3	Commodity shocks				
4		World prices		Commodity taxe	
5		Exports	Imports	Exports	Imports
6		pwe	pwm	te	tm
7	cmaiz	eps	eps	eps	-20.0
8	csorg	eps	eps	eps	-20.0
9	crice	eps	eps	eps	-20.0
10	cwhea	eps	eps	eps	-20.0



AutoSave Off

File Home Insert Page Layout Formulas Data Review View Developer Help

Cut Copy Format Painter Paste Clipboard

Calibri 11 Font

Wrap Text Merge & Center Alignment

E26 -20

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Simulation tariff : Liberalize															
2																
3	Commodity shocks													Activity shocks		
		World prices		Commodity taxes			Transaction costs			Import					Fix cap?	TFP
		Exports	Imports	Exports	Imports	Sales	Exports	Imports	Domestic	subsidy					(1=yes)	
		pwe	pwm	te	tm	tq	ice	icm	icd	tms					fixcap	alphav
	cmaiz	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				amaiz	0	ep
	csorg	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				asorg	0	ep
	crice	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				arice	0	ep
	cwhea	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				awhea	0	ep
	cocer	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				aocer	0	ep
	cpuls	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				apuls	0	ep
	cgnut	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				agnut	0	ep
	coils	eps	eps	eps	-20.0					eps				aoils	0	ep
	ccass	eps	eps	eps	-20.0					eps				acass	0	ep
	cipot	eps	eps	eps	-20.0					eps				aipot	0	ep
	cspot	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				aspot	0	ep
	croot	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				aroot	0	ep
19	cleaf	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				aleaf	0	ep
20	cvege	eps	eps	eps	-20.0	eps	eps	eps	eps	eps				avege	0	ep

Step 3.3 | Designing Simulations

2simulation.xlsx

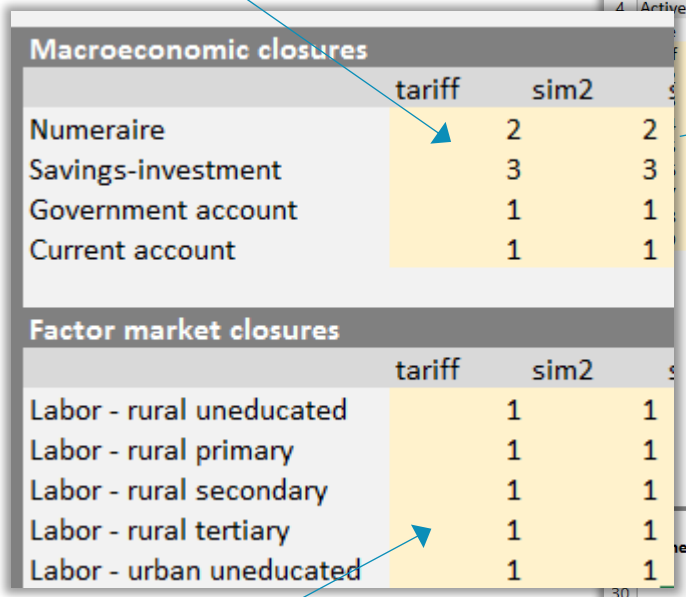
Selecting Macro and Factor Closures

Save file

Macro closures

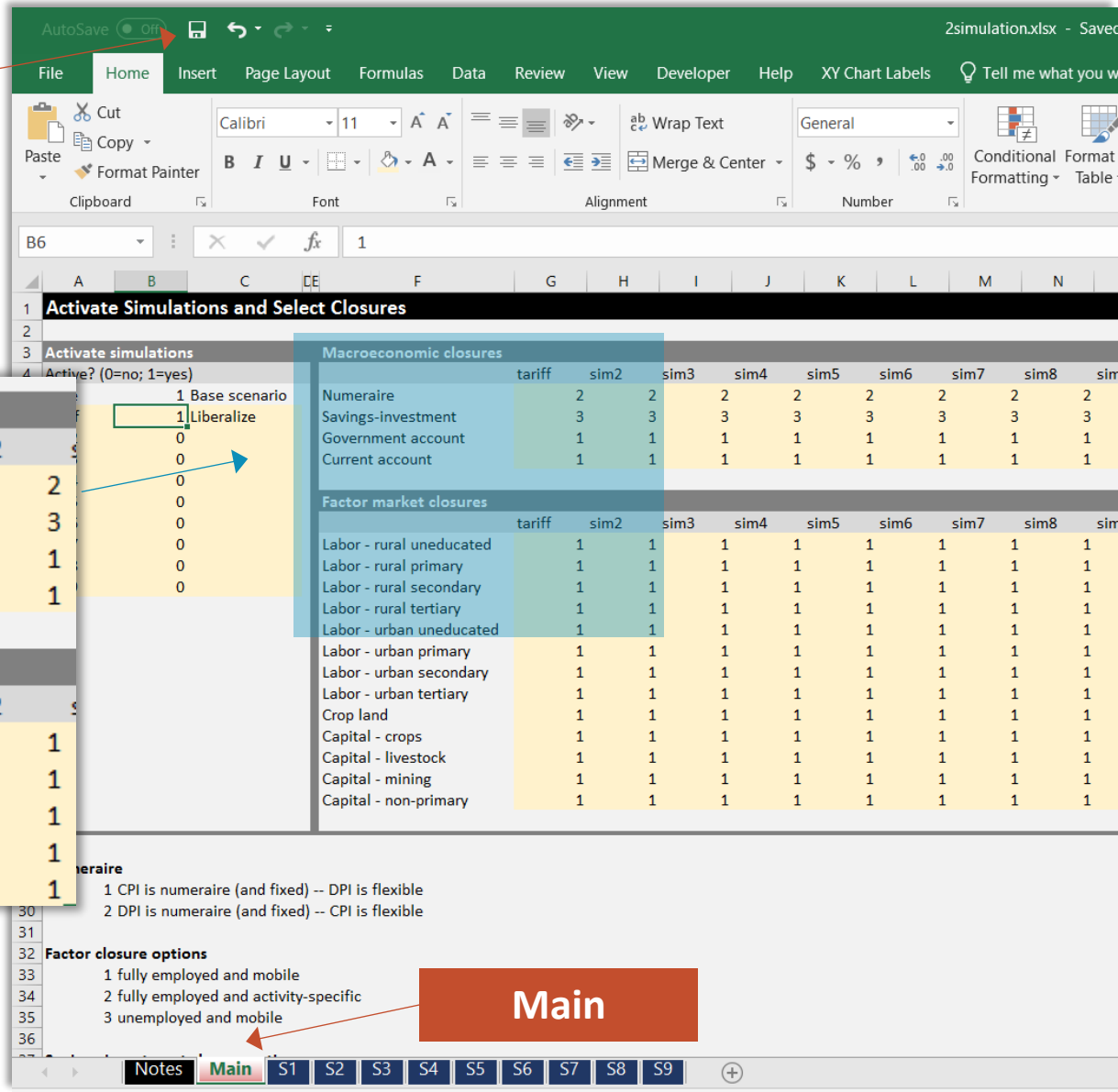
Factor closures

Main



Macroeconomic closures	tariff	sim2
Numeraire	2	2
Savings-investment	3	3
Government account	1	1
Current account	1	1

Factor market closures	tariff	sim2
Labor - rural uneducated	1	1
Labor - rural primary	1	1
Labor - rural secondary	1	1
Labor - rural tertiary	1	1
Labor - urban uneducated	1	1



Activate Simulations and Select Closures

Activate simulations

Active? (0=no; 1=yes)

1 Base scenario
1 Liberalize

Macroeconomic closures

	tariff	sim2	sim3	sim4	sim5	sim6	sim7	sim8
Numeraire	2	2	2	2	2	2	2	2
Savings-investment	3	3	3	3	3	3	3	3
Government account	1	1	1	1	1	1	1	1
Current account	1	1	1	1	1	1	1	1

Factor market closures

	tariff	sim2	sim3	sim4	sim5	sim6	sim7	sim8
Labor - rural uneducated	1	1	1	1	1	1	1	1
Labor - rural primary	1	1	1	1	1	1	1	1
Labor - rural secondary	1	1	1	1	1	1	1	1
Labor - rural tertiary	1	1	1	1	1	1	1	1
Labor - urban uneducated	1	1	1	1	1	1	1	1
Labor - urban primary	1	1	1	1	1	1	1	1
Labor - urban secondary	1	1	1	1	1	1	1	1
Labor - urban tertiary	1	1	1	1	1	1	1	1
Crop land	1	1	1	1	1	1	1	1
Capital - crops	1	1	1	1	1	1	1	1
Capital - livestock	1	1	1	1	1	1	1	1
Capital - mining	1	1	1	1	1	1	1	1
Capital - non-primary	1	1	1	1	1	1	1	1

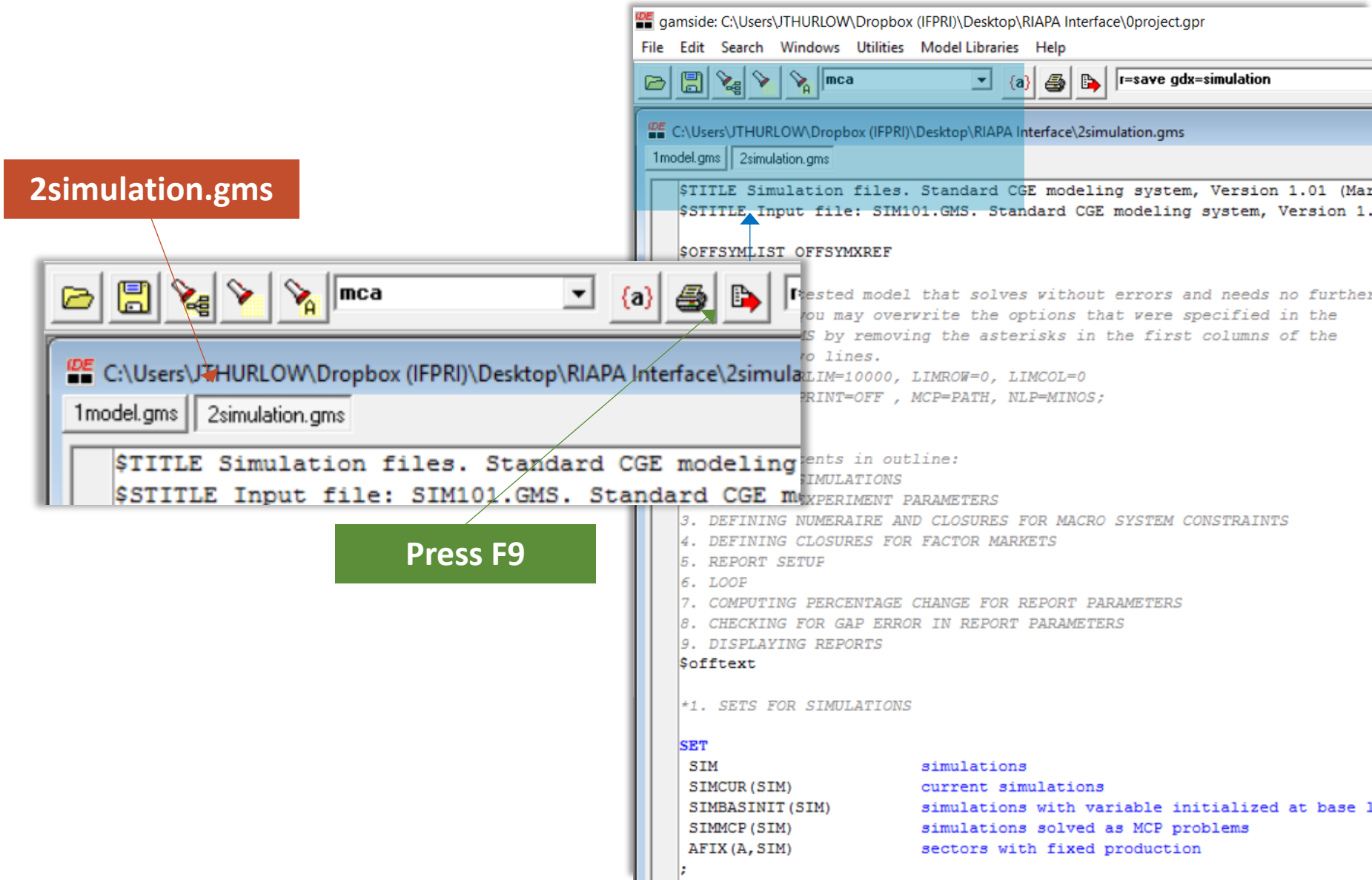
1 CPI is numeraire (and fixed) -- DPI is flexible
2 DPI is numeraire (and fixed) -- CPI is flexible

Factor closure options

1 fully employed and mobile
2 fully employed and activity-specific
3 unemployed and mobile

Notes | Main | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9

Step 4 | Running Simulations (Push F9)

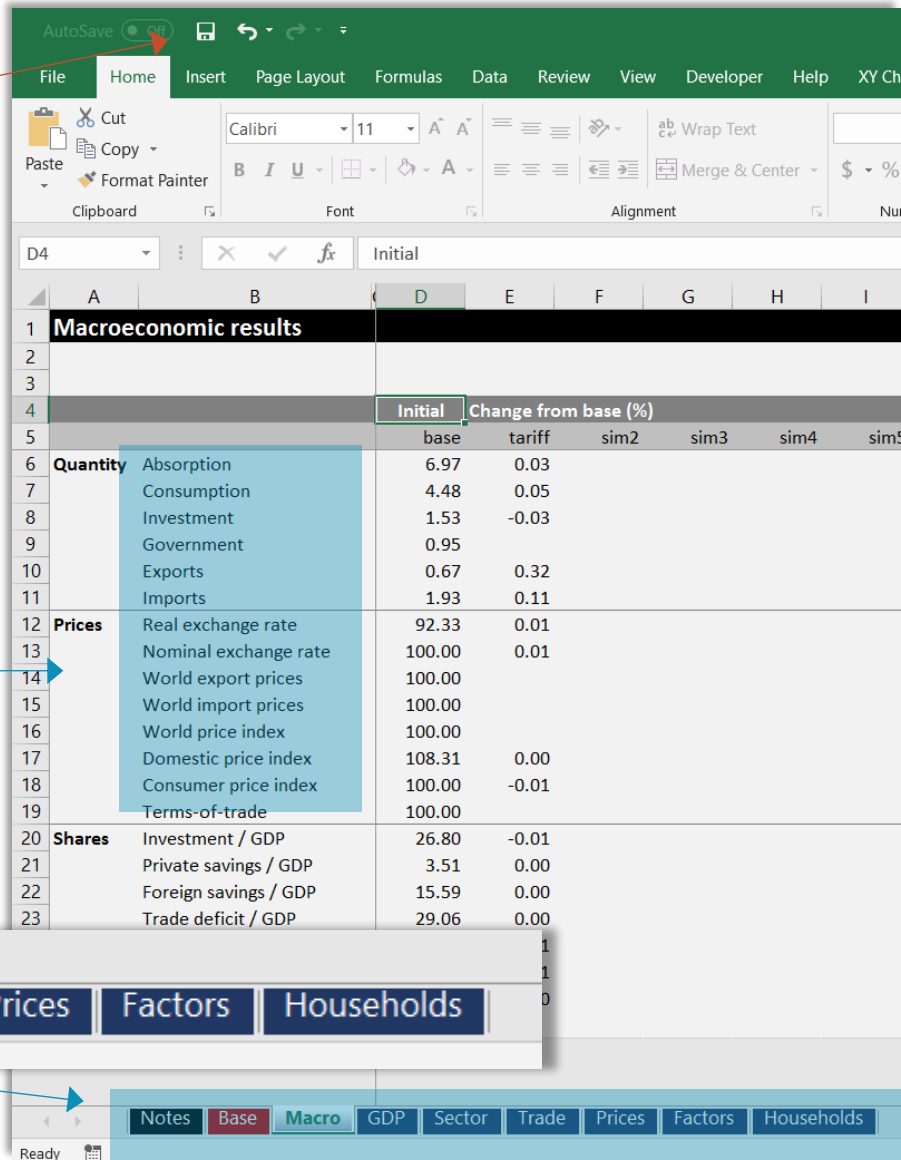


Step 5 | Reviewing Simulation Results

0output.xlsx

Automatically saves and closes before reporting results

5		
6	**Quantity**	Absorption
7		Consumption
8		Investment
9		Government
10		Exports
11		Imports
12	**Prices**	Real exchange rate
13		Nominal exchange rate
14		World export prices
15		World import prices
16		World price index
17		Domestic price index
18		Consumer price index
19		Terms-of-trade



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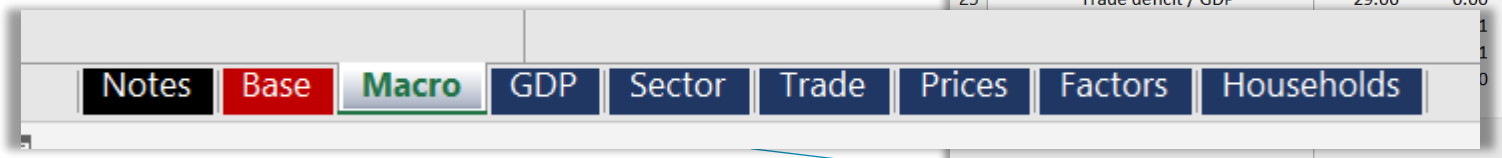
D4 Initial

Macroeconomic results

			Initial	Change from base (%)				
			base	tariff	sim2	sim3	sim4	sim5
6	**Quantity**	Absorption	6.97	0.03				
7		Consumption	4.48	0.05				
8		Investment	1.53	-0.03				
9		Government	0.95					
10		Exports	0.67	0.32				
11		Imports	1.93	0.11				
12	**Prices**	Real exchange rate	92.33	0.01				
13		Nominal exchange rate	100.00	0.01				
14		World export prices	100.00					
15		World import prices	100.00					
16		World price index	100.00					
17		Domestic price index	108.31	0.00				
18		Consumer price index	100.00	-0.01				
19		Terms-of-trade	100.00					
20	**Shares**	Investment / GDP	26.80	-0.01				
21		Private savings / GDP	3.51	0.00				
22		Foreign savings / GDP	15.59	0.00				
23		Trade deficit / GDP	29.06	0.00				



Notes | Base | Macro | GDP | Sector | Trade | Prices | Factors | Households

Notes Base Macro GDP Sector Trade Prices Factors Households

Ready

Step 5 | Reviewing Simulation Results

Worksheet	Tables
Base	Initial sectoral production, trade and tax structure
Macro	Macroeconomic results, including exchange rates and CPI
GDP	GDP by expenditure group (nominal and real)
Sector	Sectoral GDP at factor cost
Trade	Real value of imports and exports
Prices	Producer, market and world prices
Factors	Total factor supply, economy-wide returns, total factor incomes, and sectoral factor demand
Households	Institutional incomes, equivalent variation (welfare), real expenditure by commodity, and institutional tax rates and collections

Note | Some Constraints to Using Interface

- **To run the interface version of the standard model you need licensed versions of Excel and GAMS (Path)**

- **You cannot change SAM structure (for this you would need to adapt the interface)**
  - **BUT** you can update the model to a more recent year using the SAM Toolkit

- **You cannot add new parameters to the interface**
  - BUT all of the existing parameters in the standard model can be shocked using the interface

Note | Available Shock Parameters

Category	Parameter	Description
Commodity shocks	pwm pwe	World import and export prices
	tm te	Import and export taxes
	tq	Sales taxes
	ice icm icd	Export, import and domestic transaction costs
Activity shocks	alphava	TFP (production function shift parameter)
	ta tva	Activity and value-added taxes
Factor shocks	tf	Factor taxes
	wf	Economywide (average) factor returns
	qfs	Total factor supply
Macroeconomic shocks	exr	Exchange rate
	fsav	Foreign savings (capital inflows)
	gsav	Government savings/deficit
	gadj	Government recurrent expenditures

IFPRI Modeling Systems

Informing future pathways and priorities

Part 6 (continued)

Exercises Using the Interface Model

Exercise 5 | Foreign Capital Outflows

Shock

- Increase foreign capital outflows by 10% (i.e., +10% foreign savings)

Four sets of closures

- **Sim1**: Full employment, savings-driven investment (fixed savings rates, flexible investment)
- **Sim2**: Full employment, investment-driven savings (fixed investment, flexible savings rates, scaled MPS adjustment)
- **Sim3**: Unemployment, investment-driven savings (fixed wage rate, flexible labor supply , scaled MPS adjustment)
- **Sim4**: Unemployment, investment-driven savings (fixed wage rate, flexible labor supply , uniform MPS adjustment)

Current account

Total inflow of foreign exchange (exports, grants and remittances) must equal total outflows (imports)

Exports + Grants + Remittances + Foreign saving = Imports

Fix one
Exchange rate
Foreign savings

Savings – Investment

Total supply of loanable funds (savings) must equal total investment demand

Private saving + Public saving + Foreign saving = Investment

Fix one
Savings rates
Investment

Exercise 5 | Walkthrough

Macro

- ↓Foreign savings = Exchange shortage → Real exchange rate depreciation → ↑Exports & ↓Imports
- ↓Foreign savings = ↓Loanable funds → ↓Investment OR ↑Private savings

  ↑Private savings → ↓Private consumption

Trade (+ Base)

- Depreciation → ↑Export-oriented commodities (e.g., cocoa) & ↓Import-intensive commodities (e.g., cars)

Sector

- ↓Investment → ↓Construction
- ↓Private consumption → ↓Food (e.g., crops, livestock, etc.)

Factors

- ↓Wages OR ↑↓Employment (larger ↓wage with ↓construction, which is capital-intensive)

Households

- ↓Private consumption (larger with ↑private savings)
- Poor rural households are worst-affected

Exercise 6 | Tariff Liberalization

Shock

- Eliminate all tariffs (i.e., -100%)

Two sets of closures

- **Sim1**: Full employment, savings-driven investment, deficit financed (fixed savings rates, flexible investment, flexible government savings)
- **Sim2**: Full employment, savings-driven investment, tax financed (fixed savings rates, flexible investment, flexible direct tax rates)

Government

Recurrent fiscal deficit (savings) equals total revenues (taxes and grants) less total expenditures (consumption and transfers)

Direct taxes + Indirect taxes + Grants = Consumption + Transfers + Public saving

Fix two
Tax rates
Consumption
Public savings

Savings – Investment

Total supply of loanable funds (savings) must equal total investment demand

Private saving + Public saving + Foreign saving = Investment

Fix one
Savings rates
Investment

Exercise 6 | Walkthrough

Macro

- ↓Tariffs → ↑Imports → Real exchange rate depreciation → ↑Exports
- ↓Tariffs → ↓Consumer prices → ↑Private consumption
- ↓Tariffs = Revenue shortfall → ↓Public savings OR ↑Tax rates
  - ↓Public savings → ↓Investment
  - ↑Tax rates → Smaller ↑private consumption

Trade (+ Base)

- ↓Tariffs → ↑Import-intensive commodities

Sector

- ↓Tariffs → ↓GDP for import-competing sectors

Households

- ↑Private consumption (smaller with ↑private savings)
- ↑Tax rates → ↓Consumption for high-income urban households

Group Exercises (1)

1. **Flooding the fields**
   - Reduce crop productivity (TFP) by 20%
2. **Running on empty**
   - Increase world oil (petroleum and fertilizer) prices by 30%
3. **Lights out**
   - Productivity (TFP) in the electricity sector falls by 20%
4. **Buck stops here**
   - Halve foreign remittance inflows
5. **Emperor's clothes**
   - World prices for textiles and clothing drop 30%

Group Exercises (2)

6. **Saving the planet**
   - Impose a 50% tax (negative subsidy) on fossil fuel-related imports
7. **Robin Hood**
   - Double government transfers to poor households (find a way to pay for it)
8. **Building bridges**
   - Increase capital investment in trade and transport infrastructure
9. **Filling the coffers**
   - Increase government revenues using different instruments

IFPRI Modeling Systems

Informing future pathways and priorities

Part 7

Extending the Standard Model

Three Extensions

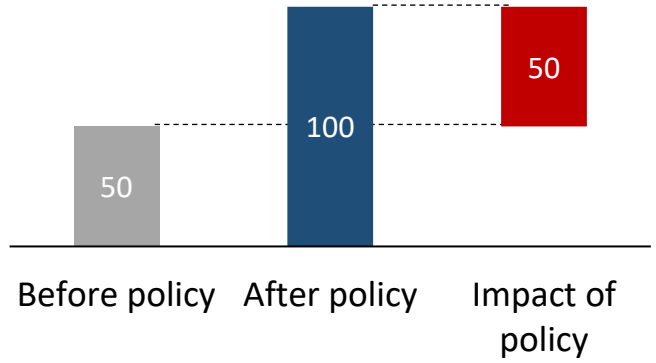
- **Recursive dynamics**
  - Simple dynamic specification
- **Microsimulation**
  - Linking to the household survey
- **Additional accounts**
  - Environmental accounts (e.g., natural resources, pollution, etc.)
  - Financial accounts (i.e., monetary sector variables)

Recursive Dynamics | Counterfactual Analysis

CGE model is a laboratory for experimenting with different policies and shocks

- Counterfactual analysis measures outcomes with (before) and without (after) shock or intervention

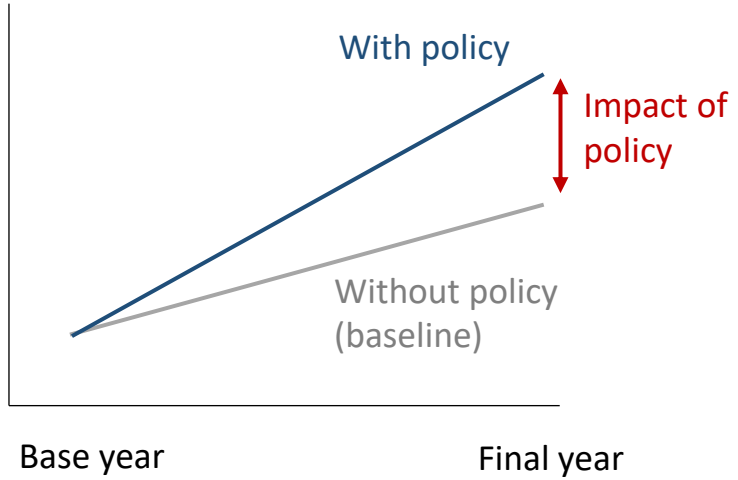
In a static model:



Can be used as either static or dynamic model

- Choice depends on the policy or shock being analyzed (e.g., impacts of a rapid onset shock vs. designing long-term investment strategies)

In a dynamic model:



Recursive Dynamics | Annual Updates

CGE model is solved annually with inter-annual updates to key parameters

- Endogenous updates depend on results from previous years
- Exogenous updates are fixed over time

Endogenous Updating

Capital accumulation rate

- Depends on previous year's investment levels, which are themselves endogenous (i.e., of national incomes and savings rates)

Capital allocation by sector

- Depends on past investment allocations and previous year's relative profits across sectors

Exogenous Updating

Population & labor supply

- Rural & urban projections from UNDESA or official data
- Labor adjusted using labor force survey trends

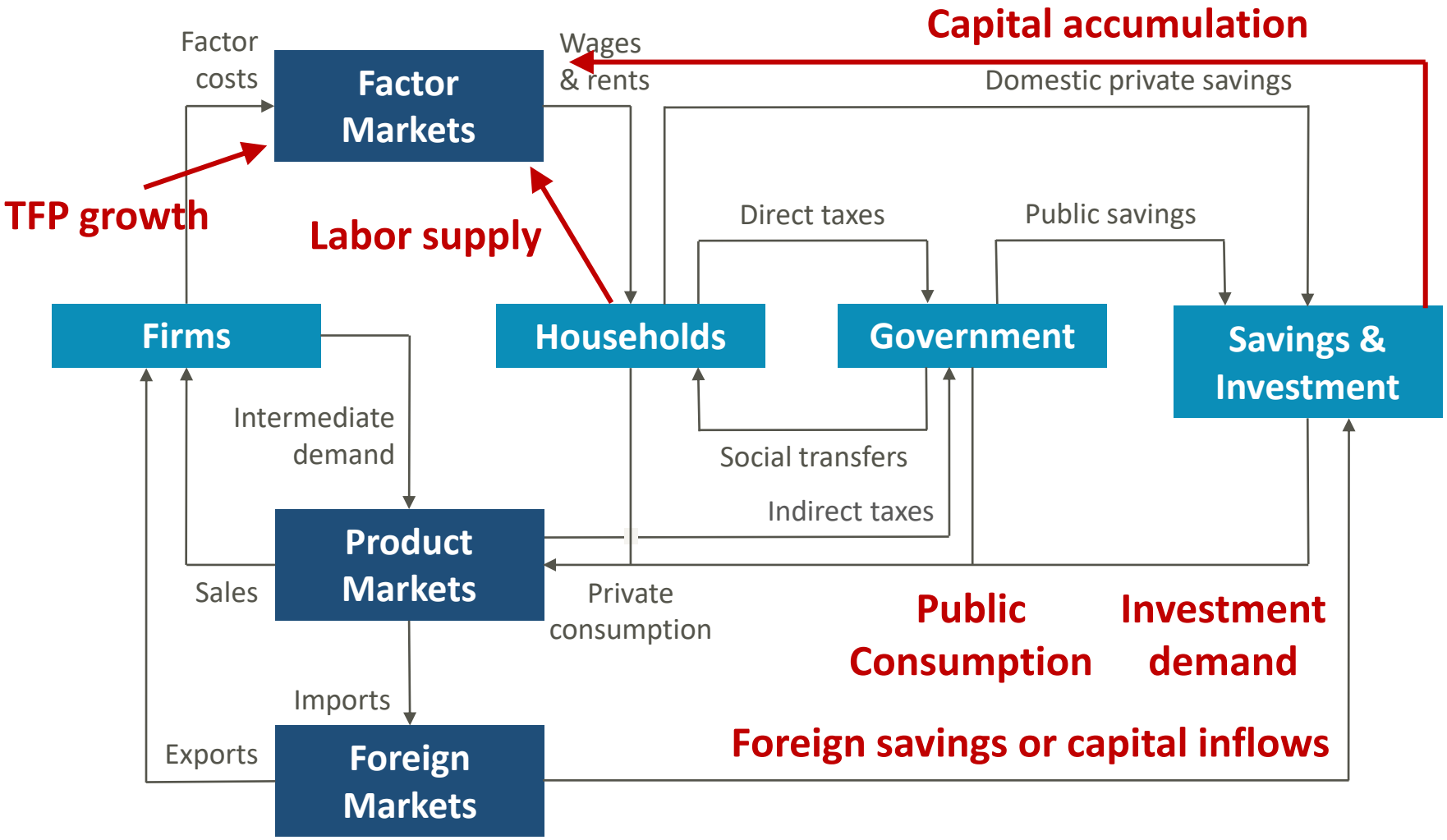
Land supply & agric. productivity

- Based on FAO or official trends (total cultivated area)

Macroeconomy

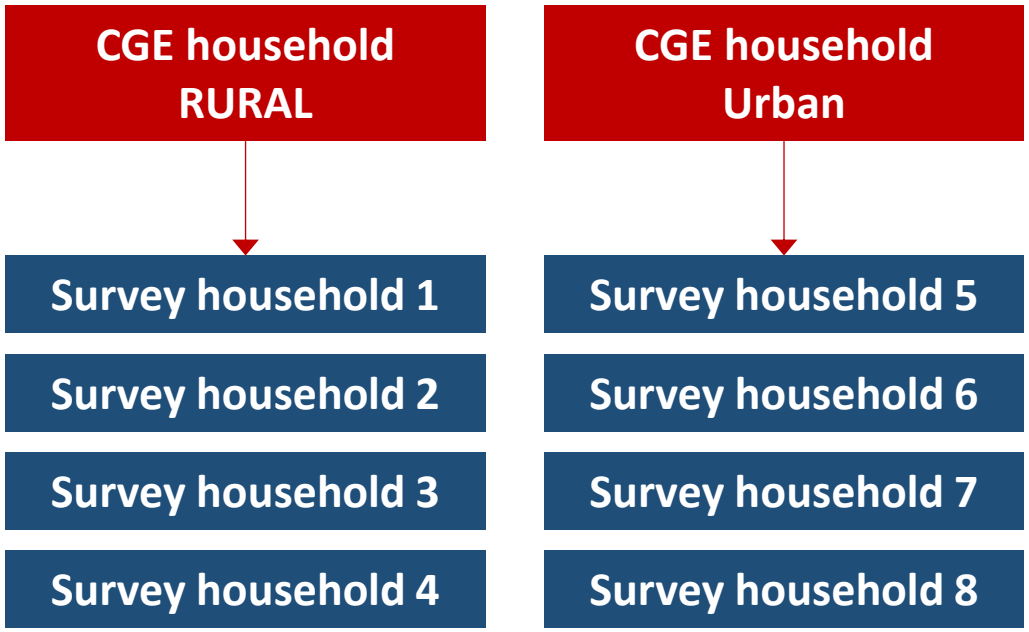
- Baseline assumes trends from previous decade continues (incl. GDP growth by sector, absorption structure, trade balance, remittances/FDI, etc.)

Recursive Dynamics | Endogenous Capital Accumulation



Microsimulation | Linking to Survey Households

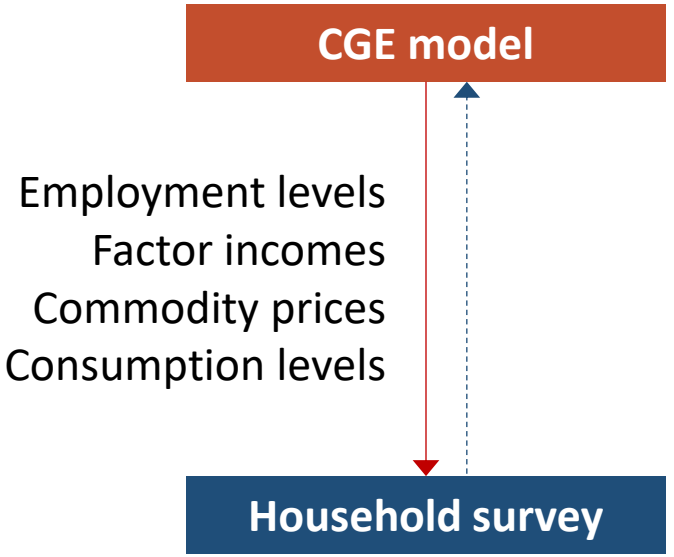
- Each household in the CGE model represents a group of individual households in the household survey (like survey weights)
- Each CGE household is linked to its corresponding survey households



Microsimulation | Tracking Household Level Outcomes

- **Pass down changes in key variables from CGE model to survey**
  - Recalculate per capita expenditures for survey households

- **Some microsimulation models estimate who loses or gains a job**
  - e.g., Occupational choice models
  - Some also pass information back up to the CGE model



Additional Accounts

- **Natural resource accounts**
  - Water use by industry and household (for water use rights or user fees)

- **Environmental accounts**
  - Pollution levels for each industry (for pollution taxes or health feedbacks)
  - Carbon emissions for each industry and product (for carbon taxes or cap-and-trade schemes)

- **Financial accounts**
  - New institutions (banking sector)
  - Assets and liabilities (investments, money holdings, bonds, loans, etc.)
  - Allows for CGE models with monetary variables (e.g., money supply, interest rates, inflation, etc.)

RIAPA | Data & Modeling System

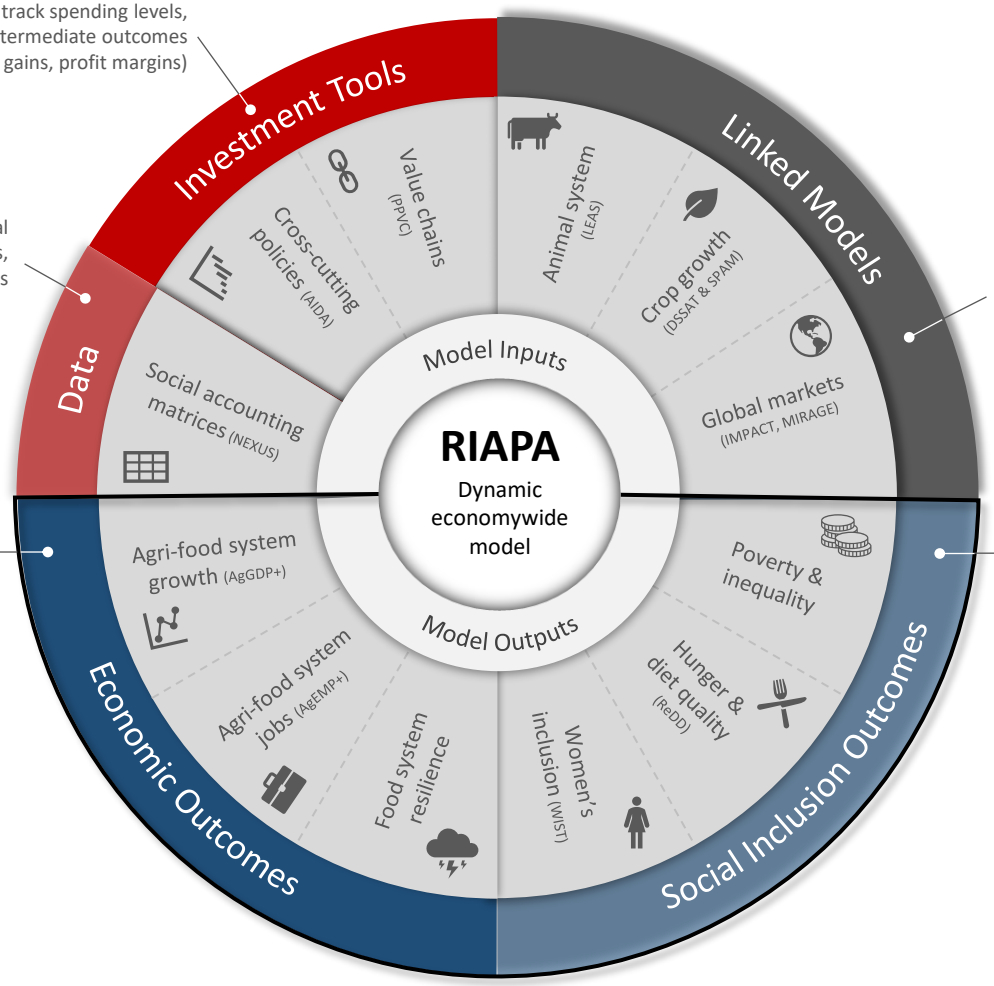
Rural Investment and Policy Analysis (RIAPA)

Forward-looking economywide framework that captures entire national economies, unpacks agrifood systems and subnational regions, and tracks how policies, investments, and climate risks affect different sectors, workers and population groups

Investment tools track spending levels, unit costs, and intermediate outcomes (e.g., productivity gains, profit margins)

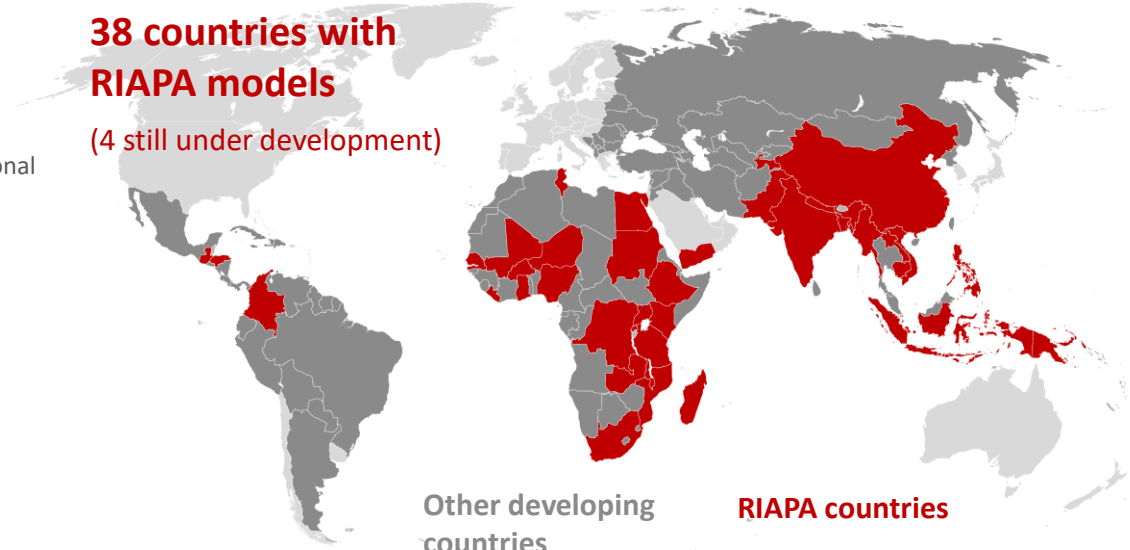
SAMs reconcile data from national accounts, government finances, and firm/household surveys

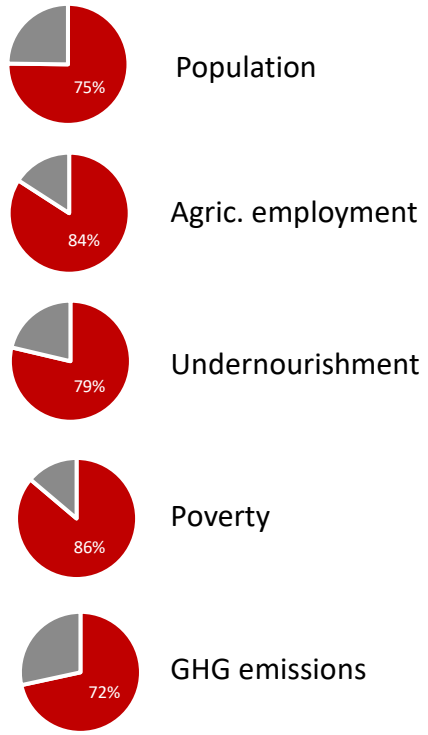
Outcomes are tracked across the **agri-food system** (e.g., farming, processing, trade, transport, hotels, food services)



Linked models track global and biophysical drivers (e.g., animal herds, crop yields, world prices)

Survey-based **microsimulation** modules estimate outcomes at individual and household levels





Source: WB country classification (2019) & poverty (2014); ILO employment (2019); FAO undernourishment (2019); WRI emissions (2019)

Further Reading

- **Recursive dynamics**
  - Diao and Thurlow. 2012. A Recursive Dynamic Computable General Equilibrium Model. In Diao et al. (eds.). Strategies and Priorities for African Agriculture: Economywide Perspectives from Country Studies. Washington DC, USA: IFPRI.

- **Microsimulation**
  - Arndt et al. 2013. Explaining the Evolution of Poverty: The Case of Mozambique. American Journal of Agricultural Economics 95(1): 206-206.
  - Pauw and Thurlow. 2011. Agricultural Growth, Poverty, and Nutrition in Tanzania. Food Policy 36(6): 795-804.

- **Environment and natural resources**
  - Alton et al. 2014. Introducing Carbon Taxes in South Africa. Applied Energy 116(1): 344-354.
  - Hassan and Thurlow. 2011. Macro-Micro Feedback Links of Water Management in South Africa: CGE Analyses of Selected Policy Regimes. Agricultural Economics 42(2) : 235-247.

- **Shocks and extreme events**
  - Arndt et al. 2008. Higher fuel and food prices: impacts and responses for Mozambique. Agricultural Economics 39: 497-511.
  - Pauw et al. 2011. The Economic Costs of Extreme Weather Events: A Hydro-Meteorological CGE Analysis for Malawi. Environment and Development Economics 16(2) : 177-198.
  - Thurlow et al. 2011. The Impact of the Global Commodity and Financial Crises on Poverty in Vietnam. Journal of Globalization and Development 2(1): 1-29.