MAST 2026 · WORKSHOP ON CGE MODELING AND GTAP



Session 4 · 15:15–16:45

Beyond the Basics: Data, Closures, Parameters, and Extensions

Roshen Fernando and Patrick Jaime Simba
Economic Research and Development Impact Department
Asian Development Bank

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SESSION 4 ROADMAP

From Running a Model to Doing a Study

15:15	1 · What the exercises showed
15:25	2 · Inside the GTAP Data Base
15:32	3 · How the model is solved
15:38	4 · Closures
15:50	5 · Parameters and sensitivity
16:00	6 · Welfare and interpretation
16:12	7 · From real policy to GTAP
16:20	8 · Beyond the standard model
16:25	Wrap-up, questions, evaluation

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Part I:
What the Exercises Showed

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EXERCISE 1 · REMOVING US FARM SUBSIDIES

Landowners Bear Most of the Adjustment



The wedge closes

Owners' land price falls more than the price farms pay

Consumers barely notice

Food is ~1% of US household spending

Partners had a point

Subsidies had raised US exports and held down their price

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EXERCISE 2 · IMMIGRATION AND WAGES

Same Shock, Opposite Wage Stories: The Elasticity Decides

% change from base	BORJAS (substitutes)	OTTA1 (complements)	OTTA2 (+ capital 6%)
Unskilled wage in AGR · pfe	−1.23	−9.38	−8.42
Skilled wage in MFG · pfe	−0.44	+10.30	+10.76
Capital rent in SER · pfe	−0.44	+9.72	−1.34
Real GDP · qgdp	+4.01	+3.85	+5.54

Substitutes

Easy substitution spreads the shock thinly: every factor price dips slightly

Complements

Unskilled wages fall sharply, but skilled wages and rents rise about 10%

Investment responds

More capital lowers its own price and lifts GDP the most

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EXERCISE 3 · TRDWAR1, UNILATERAL US TARIFF

Alone, the US Gains, Because Foreigners Pay Part of the Tariff

US MFG IMPORTS FROM ROW

Price incl. tariff · pmds	+4.65%
Border price · pcif	−0.28%
Import volume · qxs	−7.47%

All three signs match the theory

US WELFARE (EV), US$ BILLION



The terms-of-trade gain outweighs the efficiency loss, but the world as a whole loses (about −$10.9 billion).

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EXERCISE 3 · TRDWAR2, WITH RETALIATION

Retaliation Reverses the US Gain

US$ million	Allocative efficiency	Terms of trade	I–S terms of trade	Total EV
USA	−13,119	−15,195	−5,120	−33,434
ROW	−7,774	+15,096	+5,087	+12,409
World	−20,892	−99	−33	−21,025

US: +32.2 → −33.4 bn

US exporters now face ROW's tariff; the terms-of-trade gain turns into a loss

ROW: +12.4 bn

In this two-region model, retaliation wins back terms of trade for ROW

World: −21.0 bn

Terms-of-trade effects cancel out; efficiency losses do not

Question 4: the existing 1.23% tariff already cuts imports below the efficient level; cutting them further adds to the loss.

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DEBRIEF

Four Lessons from the Three Exercises

1 Wedges decide who pays

Ex 1: removing a subsidy hits the owner's price harder than the user's

2 Elasticities can flip signs

Ex 2: the skilled wage moves −0.44% or +10.30% depending on ESUBVA

3 Shifts vs losses

Ex 3: terms of trade move income between countries; efficiency losses add up for the world

4 Check before you interpret

Updated rates, element order, check values: most surprises are set-up errors

The rest of this session: the choices behind these results (data, closure, parameters) and how to report them.

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Part II:
Inside the GTAP Data Base

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THE GTAP DATA BASE

From Raw Data to Your Model Version

- National input–output tables
- Bilateral trade flows
- Tariffs and protection
- Macro, tax and energy data

→

Harmonize

Common sectors, regions, year, units

→

Reconcile and balance

Trade matches across partners; every SAM balances

→

Aggregate

GTAPAgg / FlexAgg → your version (e.g. NUS333)

Input–output tables are contributed by the GTAP network, country by country

Source year and quality differ by country: check your region's documentation

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Aggregation: Let the Question Choose Regions and Sectors

Rules of thumb

- Keep the regions and sectors the policy targets separate
- Keep main trading partners and competitors separate
- Group the rest; very small sectors cause trouble
- Too much aggregation hides effects (aggregation bias)
- Smaller models solve faster and are easier to explain

Illustration: a rice tariff study

Regions: Philippines · Viet Nam · Thailand · other ASEAN · China · rest of world

Sectors: paddy and processed rice · other crops · food · manufacturing · services

Factors: land · skilled and unskilled labor · capital · natural resources

NUS333 (2 × 3 × 3) is deliberately extreme: fine for learning, too coarse for policy work

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Version 7: Activities and Commodities Can Differ

MAKE MATRIX: WHO PRODUCES WHAT

Activity ↓	Milk	Meat	Power
Dairy farm	Main	Joint	
Coal plant			Yes
Solar plant			Yes

A dairy farm makes milk and, jointly, meat. NUS333 is one-to-one (a diagonal make matrix).

ETRAQ

One activity, several products

How easily an activity shifts its output mix (CET)

ESUBQ

One product, several activities

How buyers substitute between producers of the same good

Base data: MAKB (make matrix at basic prices), MAKS (before net taxes)

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The Files Behind Every Model Version

File	What it holds	In RunGTAP
sets.har	Lists: REG, COMM, ACT, ENDW, MARG and mappings from the full database	View › Sets
basedata.har	Value flows in US$ million, e.g. VMSB (imports), EVFB (factor payments), MAKB, SAVE, POP	View › Base Data
default.prm	Elasticities and other parameters	View › Parameters
Tax rates	Rates computed from the base data: RTO, RTFE, RTFD, RTFM, RTMS…	View › Base Data › Tax Rates
TAB file	The model's equations, written in GEMPACK	View › Tab files
Experiment	Your shocks, closure, parameter file and solution method	Solve › Save / Load Experiment

.har = GEMPACK header array file; open any of them with ViewHAR

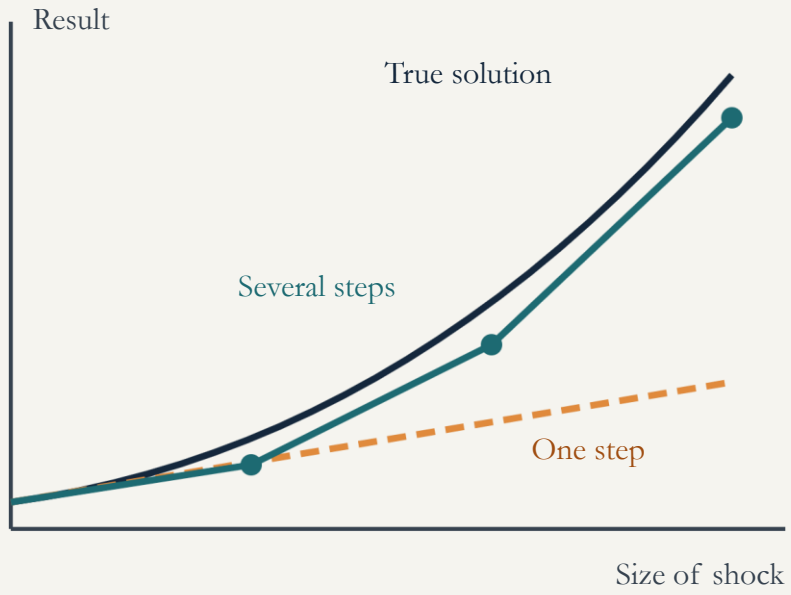
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Part III:
How the Model Is Solved

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HOW THE MODEL IS SOLVED

Small Linear Steps Add Up to an Exact Answer



Linearized equations

GEMPACK writes every equation in % changes

Johansen: one step

Fast, but inaccurate for large shocks

Euler and Gragg: many steps

Split the shock, update the data after each step

Gragg 2-4-6

Solves with 2, 4, and 6 steps and extrapolates to the exact result

RunGTAP shows an accuracy summary after each solve

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HOW THE MODEL IS SOLVED

Model Code, Modules, and Condensation

TAB file

The full model: sets, coefficients, variables and equations, in GEMPACK code. Readable in RunGTAP or TABmate.

Modules

RunGTAP ships classic and version 7 modules. Pick one under Version › Modules; it must match the database.

Condensation

Substitutes variables out to shrink the system. Faster, but those variables can no longer be shocked or read.

The workshop's NUS333 uses the **uncondensed version 7** module, so every tax variable is available. New models (imperfect competition, quotas) mean new TAB files.

After changing modules, run Tools › Run Test Simulation

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HOW THE MODEL IS SOLVED

Seven Checks Before You Believe a Result

1. The accuracy summary shows no warnings
2. Updated tax rates equal your targets
3. **walraslack** is (close to) zero
4. The updated SAM still balances
5. Signs match your predictions, or you can explain why not
6. Welfare components add up to total EV
7. Sizes are plausible given the shock and the sector's share

⚠ A surprising result is a set-up error until proven otherwise

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Part IV: Closures

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CLOSURES

A Closure Is a Set of Economic Assumptions

The mechanics

Endogenous variables = number of equations

A **swap** makes one exogenous variable endogenous and one endogenous variable exogenous, so the count stays right

Then the newly fixed variable can be shocked

EACH QUESTION IS A CLOSURE CHOICE

- Is labor fully employed, or is the wage sticky?
- Can capital move between sectors in the time frame?
- Is the trade balance free to change?
- Must the government replace lost revenue?

Choose the closure that matches your policy question and time horizon, and report it.

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CLOSURES

The Standard Closure: A Medium-run, Full-employment World

Factors
Fixed endowments, fully employed; labor and capital mobile, land sluggish

Savings
A fixed share of regional income

Investment
Allocated by the global bank, following expected returns

Trade balance
Free to adjust with savings and investment

Government
A fixed share of income; no budget target

Prices
Relative to the numeraire, pfactwld

Think of it as: "after firms and workers have had time to move, but before capital stocks grow."

All three group exercises used this closure

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Labor, Macro, and Fiscal Closures

Closure	What it assumes	Add below “Rest Endogenous”
Unemployment	The real wage is fixed; employment of the factor adjusts	swap qe(e,r) = pebfactreal(e,r);
Fixed trade balance	Savings adjust so the trade balance stays a fixed share of income	swap dpsave(r) = del_tbalry(r);
Tax replacement	A consumption tax adjusts to keep indirect taxes a fixed share of income	swap tpreg(r) = del_ttaxr(r);
Government spending	Fix (and shock) government consumption; private and saving shares adjust	swap dpgov(r) = ug(r);

</> Use specific elements, e.g. **swap qe("LABOR","USA") = pebfactreal("LABOR","USA");**

Source: exercise workbook appendix A3, Table ME 3.3 (Burfisher)

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Quantity Controls and Baselines

Closure	What it assumes	Add below “Rest Endogenous”
Export quota	A bilateral export volume is fixed; the export tax measures the quota rent	swap qxs(c,s,d) = txs(c,s,d);
Import quota	An import volume is fixed; a uniform tariff adjusts to hold it	swap qmw(c,d) = tm(c,d);
Baseline	Real GDP growth is set; productivity (TFP) is solved to match it	swap qgdp(r) = afereg(r);

Quotas

Turn a quantity limit into its price-equivalent, so the rent shows up

Baselines

Project the economy forward with GDP, population and labor-force targets, then run policies on top

Source: exercise workbook appendix A3, Table ME 3.3 (Burfisher)

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CLOSURES

Short Run or Long Run? The Closure Sets the Clock

	Short run	Long run
Capital	Stuck in its sector; rents absorb the shock	Moves between sectors; the stock adjusts to restore returns
Labor	Wages may be sticky, so employment changes	Fully employed; wages adjust
Results	Bigger price and return changes, smaller output shifts	Larger reallocation of output between sectors
Typical use	First-year effects of a shock or reform	Structural reforms, trade agreements

Present both when timing matters: decision-makers want to know the pain now and the gain later.

Implemented through factor mobility settings and closure swaps

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Same Shock, Two Closures: A 10% US Manufacturing Subsidy

Expected effect on…	Full employment (standard)	US labor unemployment closure
US employment	Fixed	Rises
US real wage	Rises	Fixed
US MFG output	Rises	Rises by more
US AGR and SER output	Fall: they lose workers	Fall less, or rise
Welfare (EV)	Efficiency and terms of trade	Plus an endowment (extra jobs) gain

Try it: reload **10toMFG**, add **swap qe("LABOR","USA") = pebfactreal("LABOR","USA");**, save as 10toUN, solve, compare.

Expected directions, not results · Workbook appendix A3, steps 8–9

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Changing the Closure in Four Steps

1. Solve tab › **Load Experiment** you want to change
2. **Closure** tab: type the swap below "Rest Endogenous"
3. **Save Experiment** under a new name: the closure is saved with it
4. **Solve**, verify, then delete the swap before the next experiment

CLOSURE TAB, END OF FILE

```
…
Rest Endogenous ;

swap qe("LABOR","USA")
= pebfactreal("LABOR","USA");
```

One-for-one swaps keep the model square. A "singular matrix" error usually means the closure no longer pins down every variable.

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Part V:
Parameters, Elasticities, and Sensitivity

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PARAMETERS

The Key Parameters in default.prm

Parameter	Governs substitution or transformation between…	Stage
ESUBT	value added and intermediate inputs (top of the nest)	Production
ESUBC	different intermediate inputs	Production
ESUBVA	primary factors: land, labor, capital	Production
ESUBD	domestic and imported goods	Trade (Armington)
ESUBM	imports from different sources	Trade (Armington)
ETRAQ · ESUBQ	an activity's products · producers of one commodity	Make matrix
ETRAE	uses of a sluggish factor across sectors	Factor supply
INCPAR · SUBPAR	income and price responses in private demand (CDE)	Households
RORFLEX · RORDELTA	how investment responds to rates of return	Investment

View › Parameters · Values differ by sector and, for some, by region

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PARAMETERS

Where Elasticities Come From, and How to Handle Them

Econometric Estimates

e.g., Armington elasticities estimated from trade data (Hertel et al., 2007)

Calibration Targets

CDE parameters are set to match estimated income and price elasticities

Rules of Thumb

ESUBM ≈ 2 × ESUBD; many values are shared across regions

GOOD PRACTICE

- Know which parameters drive your result
- Use local estimates when you have them
- Test the ones that matter and report ranges

Exercise 2 showed one parameter can change the sign of a result

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SENSITIVITY ANALYSIS

Systematic Sensitivity Analysis (SSA) in RunGTAP

1
Solve the experiment
With the default parameters

2
Choose what varies
Tools › Sensitivity › w.r.t. parameters or shocks

3
Set the range
e.g., ESUBVA ±100%, triangular distribution

4
Read mean and SD
For every result, in ViewSOL

Gaussian quadrature: a handful of well-chosen runs instead of thousands of random ones

Works for uncertain shocks too, e.g. a climate yield loss of 5–15%

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SENSITIVITY ANALYSIS

From Mean and SD to a Confidence Statement

CHEBYSHEV: NO DISTRIBUTION ASSUMED

Confidence	Mean ± k × SD
75%	k = 2
88.9%	k = 3
95%	k = 4.47
99%	k = 10

Robust: output +19%, SD 1

95% interval: **14.5 to 23.5**. Positive under all tested elasticities.

Not robust: imports +5%, SD 3

95% interval: **−8.4 to 18.4**. Even the sign is uncertain.

Report it

"Output rises 19% (95% interval 15–23%)" beats a single number.

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Part VI:
Welfare and Interpreting Results

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WELFARE

Equivalent Variation: Welfare in Money Terms

EV = the change in income, at **base prices**, that gives the regional household the same utility as the policy does

Covers all three uses

Private consumption, government consumption, and saving

In US$ million

Positive = better off; comparable across regions

Adds up

Regional EVs sum to a world total

Results: EV(r) · also reported per capita and as % of income in some summaries

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WELFARE

The Welfare Decomposition Explains EV

Component	Gain or loss from…	Typical driver
Allocative efficiency	volumes of taxed or subsidized activities changing	Tariffs, subsidies (Ex 1, 3)
Endowment	more or fewer factors in use	Migration, unemployment closure
Technical change	productivity	Shocks to "a" variables
Population	population growth	pop
Terms of trade	export prices vs import prices	Large-country tariffs (Ex 3)
Investment–savings ToT	price of capital goods vs savings	Shifts in trade balances
Preferences	a change in how income is split	Closure changes

RunGTAP: View › Updated Data › Welfare Decomposition. Detailed headers break each part down by tax, commodity and region.

Method: Huff and Hertel (2000), GTAP Technical Paper 5

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WELFARE

GDP and Welfare Answer Different Questions

`qgdp(r)`

Real GDP: how much is produced

Moves with factors, productivity and efficiency. Ignores changes in what exports can buy.

Ex 2: GDP rises 3.9–5.5% in every run, yet the unskilled wage falls by up to 9.4%

`EV(r)`

Welfare: how well-off people are

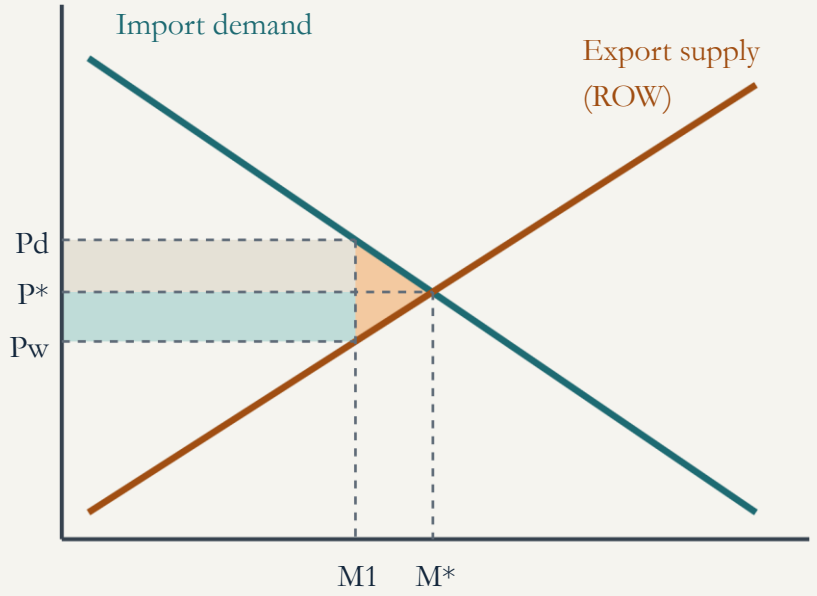
Includes terms-of-trade and investment–savings effects as well as efficiency.

Ex 3: US welfare rises $32 bn under TRDWAR1 while its efficiency falls

Report both, plus who gains and who loses. Averages hide distribution.

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A Large Country's Tariff: A Gain and a Loss



Terms-of-trade gain: foreign suppliers accept a lower price (Pw)

Efficiency loss: trade squeezed below the efficient level

Paid by home buyers: a transfer to government, not a net loss

Net gain if the rectangle beats the triangles, and if partners do not retaliate

Exercise 3: pmds +4.65% (Pd up), pcif −0.28% (Pw down), qxs −7.47% (M1 below M)*

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INTERPRETING RESULTS

Explaining a Result: Six Habits

1

Size × share

Food is ~1% of US spending, so the consumer effect is small (Ex 1)

2

Predict first

Write the signs down before reading any result

3

Follow the chain

Prices → quantities → factor markets → incomes

4

Biggest numbers first

Then the surprising ones: are they real, or set-up errors?

5

Decompose

Use the welfare decomposition to say why EV moved

6

One change at a time

Compare runs that differ in only one assumption (Ex 2)

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INTERPRETING RESULTS

Briefing a Policymaker in One Minute

Headline → **Mechanism** → **Winners and losers** → **How sure** → **Caveats**

Do

- Round: “about 1.4%”, not “1.4217%”
- Say “compared with no policy”
- State the closure and time horizon
- Give ranges from sensitivity analysis

Avoid

- “The model predicts GDP will be…”
- Results with no mechanism behind them
- Hiding who loses inside an average
- Claiming more precision than the data has

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Part VII:
From Real-world Policy to GTAP

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POLICY TO MODEL

One Real Policy Usually Means Several Shocks

Policy	Economic Mechanisms	Possible GTAP Shocks
Import tariff	Higher domestic price of imports	Bilateral tariffs (tms)
Free trade agreement	Lower tariffs and non-tariff barriers; easier customs	Tariffs (tms), trade costs (ams), export taxes (txs)
Carbon tax	Dearer fossil energy; changes in energy use	Taxes on energy inputs (tfd, tfm); energy model GTAP-E
Infrastructure investment	Lower transport costs; higher productivity	Margins and trade costs; productivity (a variables)
Farm support reform	Lower input and factor subsidies	tfe, tfd, tfm (Exercise 1)



Model the economic mechanism, not the wording of the policy.

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POLICY TO MODEL

A Four-Step Framework for Translating Policies

1

Real-world Policy

What exactly changes, for whom, by how much, from when?

2

Economic Mechanism

Which prices, costs or quantities move? Who responds first?

3

Model Representation

Which variables, which shock sizes, which closure and parameters?

4

Simulation Design

Which scenarios, which outputs, which sensitivity tests?

Try it: how would you model a ban on rice exports? (Hint: an export quota, a txs swap, or a large export tax)

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POLICY TO MODEL

Non-tariff Measures: Two Ways to Model Them

Standards, licensing, customs delays: first estimate an **ad valorem equivalent** (AVE) from the literature, then choose how it enters the model.

`tms (or txs)`

As a tax-like wedge

The barrier creates a rent that someone collects, e.g. quota or licence holders

`ams(c,s,d)`

As a real trade cost

Resources are wasted ("iceberg" cost); cutting it works like a productivity gain in trade

⚠ The choice matters for welfare: removing a cost frees resources; removing a rent only moves income.

ams = import-augmenting technical change on the route s → d

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POLICY TO MODEL

From One Experiment to a Full Study

1 · Question
Focused, with the outcomes that matter named

2 · Aggregation
Regions and sectors that the question needs

3 · Baseline
Base year, or a projected future economy

4 · Scenarios
A central case plus alternatives

5 · Closure
Matched to the time horizon, then tested

6 · Parameters
Documented, with SSA on the key ones

7 · Checks
Accuracy, Walras, plausibility, decomposition

8 · Report
Headline, mechanism, distribution, ranges, caveats

Good studies are iterative: results send you back to the question, the shocks and the assumptions.

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Part VIII:
Beyond the Standard Model

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BEYOND THE STANDARD MODEL

The GTAP Model Family

GTAP-E, E-Power

Energy substitution, CO2 emissions, power technologies

GTAP-AEZ

Land use by agro-ecological zone: farming, forestry, biofuels

GDyn

Recursive dynamics: capital accumulation and international capital mobility

GTAP-MRIO, GTAP-VA

Global value chains: import sourcing by user; value added in trade

GTAP-HET

Heterogeneous firms and imperfect competition

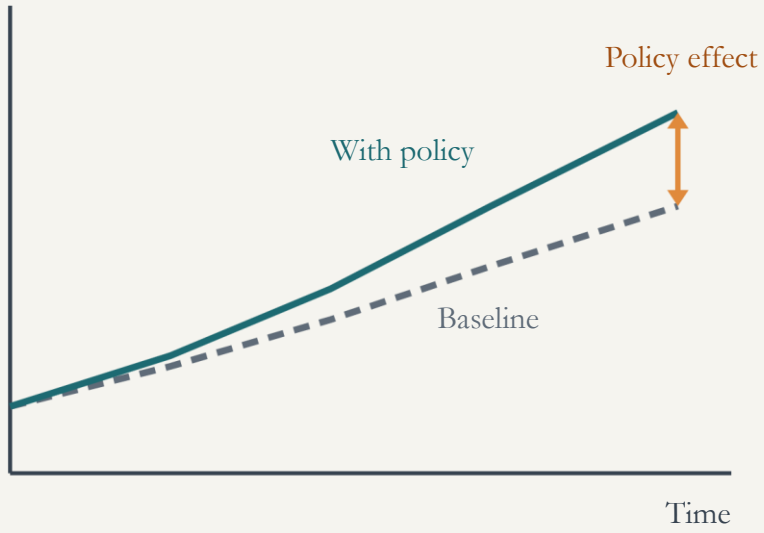
GTAP-POV

Poverty and household-level effects

Same data and core logic; each adds the mechanism a particular question needs.

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Static vs Dynamic: Two Ways to Ask “What If?”



Static (today)

One base year vs. one counterfactual; the closure and elasticities imply the time frame. Clear and quick.

Dynamic

A projected baseline (GDP, population, labor force, capital) and a policy path. The effect is the year-by-year gap.

When you need dynamics

Phased reforms, climate, demographics, investment-led growth

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WRAP-UP

What CGE Models Can and Cannot Do

Well suited to

- Economy-wide effects of a policy
- Comparing policy alternatives
- Links across sectors and regions
- Trade-offs and spillovers, in numbers
- "What if?" questions

Less suited to

- Predicting exact future values
- Short-term forecasting
- Individual firms or households (without links)
- Mechanisms the model leaves out
- Producing one "correct" answer

A CGE model is a decision-support tool. Use it alongside other evidence.

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WRAP-UP

Where CGE Models Support Real Decisions

Trade Policy

Tariffs, trade agreements, supply-chain disruptions

Climate and Energy

Carbon pricing, energy transition, renewables

Growth and Productivity

Infrastructure, technology adoption

Fiscal Policy

Tax reform, spending, subsidy reform

Agriculture and Food

Food price shocks, farm productivity, export restrictions

Global Shocks

Pandemics, commodity prices, geopolitical conflict

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KEY TAKEAWAYS

Five Things to Remember from Today

1. **Start with the question**, not the model
2. **Understand the mechanism**: prices, incentives and resource reallocation
3. **Design the experiment with care**: shocks, closure, parameters, outputs
4. **Interpret, don't just report**: explain why, and who gains or loses
5. **Know the limits**: test assumptions, report ranges, combine with other evidence

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WRAP-UP

Where to Go from Here

Learn

- GTAP 101 Course (Online)
- GTAP Short Course (Hybrid)
- Burfisher, *Introduction to CGE Models*, 3rd ed. (2021)
- GTAP Annual Conference

Read

- Corong et al. (2017), "The Standard GTAP Model, Version 7", JGEA
- Hertel (ed.) (1997), *Global Trade Analysis*
- RunGTAP and GEMPACK manuals

Practice

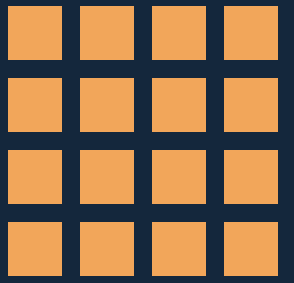
- Replicate a published study
- Vary closures and elasticities
- Build your own aggregation

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Questions and Discussion

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MAST 2026 · WORKSHOP ON CGE MODELING AND GTAP



Happy CGE Modeling!

Roshen Fernando, Economist | Patrick Jaime Simba, Economic Analyst
rsfernando@adb.org | psimba@adb.org

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