cgemod

Computable General Equilibrium Modelling in Stata

User Manual

Version 2.0.0

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1 Introduction

CGEMOD is a Stata package for applied general equilibrium analysis. It takes a social accounting matrix (SAM) as input and covers the whole chain of a CGE study: preparing and balancing the SAM, calibrating a standard open-economy model, simulating policies under alternative closures, measuring welfare and poverty effects, projecting recursive-dynamic growth paths, testing the robustness of results, and documenting and sharing scenario comparisons. Elasticities that feed the model can be estimated within the same package, with residual diagnostics and remedies.

The model belongs to the family of the IFPRI standard model (Lofgren et al., 2002) and the PEP models (Decaluwé et al., 2013). Its dynamic module follows the recursive-dynamic tradition of the IFPRI dynamic model (Diao and Thurlow, 2012) and the World Bank's MAMS framework (Lofgren et al., 2013). Everything runs inside Stata: no GAMS licence or external solver is needed, all computations are done in Mata, and the results are returned as Stata matrices and datasets that can be passed to any other Stata command.

The package was written with three groups of users in mind:

- analysts in ministries, central banks and international organisations who need a transparent, documented and reproducible model for policy briefs;
- researchers who want CGE results and household-survey evidence in the same do-file;
- teachers and students, for whom a model that can be read, modified and checked line by line is the best introduction to general equilibrium analysis.

1.1 What is new in version 2.0.0

Version 2.0.0 completes a four-stage development programme:

1. **Credibility**: SAM import from Excel, CSV and IFPRI tab files with automatic role detection, extended SAM structures (make matrix, home consumption, trade margins, enterprises, stock changes, transfers between institutions and with the rest of the world), and replication tools (`cgemod compare`).
2. **Policy modules**: poverty and inequality microsimulation, wage-curve unemployment, carbon taxes with revenue recycling, fiscal closures, import and export quotas and price caps.
3. **Dynamics**: recursive growth paths with a calibrated GDP baseline, population growth, public capital and human capital accumulation, government debt and SDG-type indicators.
4. **Usability**: a scenario manager with Excel, CSV and HTML dashboard export, a validation suite, a quasi-Newton solver for large models, a synthetic SAM generator, this manual and a training course.

1.2 Files in the package

File	Content
`cgemod.ado`, `cgemod.sthlp`	the command and its help file
`cgemod_manual.pdf`	this manual
`cgemod_example.do`	a tour of all subcommands
`cgemod_training.do`	a six-module training course with exercises
`cgemod_cert.do`	certification script: compares results with an independent implementation
`cgemod_unittest.do`	unit tests of input checking and of every subcommand
`cgemod_nigeria.do`	import of the IFPRI 2018 Nigeria SAM
`cgemod_sam3.dta`	a three-sector illustrative SAM
`cgemod_sam_ext.csv`, `.dta`	an extended SAM: make matrix, margins, enterprises, oil imports
`cgemod_survey.dta`	a simulated household survey linked to the example SAMs
`cgemod_tsdata.dta`, `cgemod_paneldata.dta`	data for elasticity estimation
`*_reference.csv`	reference results used by `cgemod compare` and the certification

1.3 Installation

From the Statistical Software Components (SSC) archive:

```
. ssc install cgemod
```

From a folder that holds the package files:

```
. net install cgemod, from("`c(pwd)'") replace
. net get cgemod, from("`c(pwd)'") replace
```

The second line copies the example data, do-files and this manual to the working directory. The package requires Stata 15 or later. After installation, run `do cgemod_cert.do` once: it checks that every module reproduces the reference results to within 10^{-6}.

1.4 A first session

```
. cgemod samimport using cgemod_sam_ext.csv, name(EXT)
. cgemod samcheck, sam(EXT)
. cgemod calibrate, sam(EXT)
. cgemod check
. cgemod sim, tm(*0) title(Removal of all import tariffs)
```

The first command reads the SAM and shows how each account has been classified. The second audits its accounting identities. The third calibrates the model, the fourth checks it, and the last removes all tariffs and reports macroeconomic, sectoral, factor-market and household results.

2 The social accounting matrix

2.1 Layout

Rows receive and columns pay. Activities (producers) and commodities (markets) are separate accounts and need not be equal in number. Table 1 lists the flows the model reads; any other nonzero cell stops calibration with a list of the offending cells, so that no flow is silently ignored.

Table 1: Flows read by the model (payer → receiver)

Payer	Receivers
Activity	commodities (intermediate inputs), factors (value added), tax accounts (activity taxes)
Commodity	activities (make matrix), rest of world (imports), tax accounts (sales taxes, tariffs, export taxes), margin account
Margin account	commodities that supply trade and transport services
Factor	institutions, tax accounts (factor taxes), rest of world
Household	commodities, activities (home consumption), tax accounts (direct taxes), savings, other institutions, rest of world
Enterprise	tax accounts, savings, other institutions, rest of world
Government	commodities, institutions (transfers), savings, rest of world
Rest of world	commodities (exports), factors, institutions, government, savings (foreign savings)
Savings-investment	commodities (investment), stock-change account
Tax account	government

2.2 Import and role detection

`cgemod samimport` reads Excel, CSV and tab-delimited files laid out as a spreadsheet, with account names in the first row and in a label column. Blank cells are read as zero, thousands separators are removed, rows and columns labelled TOTAL are ignored, and columns are matched to rows by name. Roles are detected from common naming conventions, both prefixed names (`A_AGR`, `C_AGR`, `HH_RUR`, `TAX_TAR`) and the IFPRI convention of paired names (`amaiz`/`cmaiz`, `flab`, `hhd`, `gov`, `row`, `s-i`, `mtax`). The detected roles are displayed and used by `cgemod calibrate`; any role given explicitly overrides them. The IFPRI 2018 Nigeria SAM, for example, is read with

```
. cgemod samimport using "002_IFPRI_SAM_NGA_2018_SAM.tab", labelcol(2) name(NGA)
```

2.3 Audit

`cgemod samcheck` lists the accounts with the largest gaps between receipts and payments, negative cells and empty accounts. With roles, it checks each accounting identity by group and computes GDP at market prices from the income side (value added plus net indirect taxes) and from the expenditure side; the two must agree.

2.4 Balancing

`cgemod sambalance` finds the balanced SAM X closest to a prior SAM A in the weighted cross-entropy sense:

$$\min_{X} \sum_{ij} w_{ij} \left|a_{ij}\right| \left(z_{ij} \ln z_{ij} - z_{ij} + 1\right), \qquad z_{ij} = x_{ij}/a_{ij}, \tag{1}$$

subject to equal row and column totals for every account and to any control totals. Because $z_{ij} > 0$, every cell keeps its sign: negative savings, net taxes or stock changes remain negative, as in the GRAS method (Junius and Oosterhaven, 2003; Lenzen et al., 2007), and zero cells remain zero. Reliability weights w_{ij} make trusted cells move less, and cells can be locked individually or by account. The problem is solved through its dual by Newton's method; with control totals for all accounts and no negative cells the solution coincides with RAS. After balancing the command reports the Kullback–Leibler divergence between prior and balanced structures, the mean and largest percentage changes, sign changes, the largest movements, and any change in locked cells.

2.5 Monitoring, audit trail and export

`cgemod sammonitor` compares a new SAM with a benchmark and raises alerts for cells or account totals that drift by more than a threshold, new or vanished cells, sign changes, added or missing accounts and imbalance; it returns `r(status)` = OK or ALERT so that a scheduled do-file can stop on an alert. Every SAM command accepts `log()`, which appends one record per run (date, user, command, diagnostics) to a Stata dataset, giving an audit trail. `cgemod samexport` writes the SAM to Excel (with the prior, the changes and an information sheet), to CSV, or to a GAMS include file.

2.6 Synthetic SAMs

`cgemod samgen` generates a balanced SAM of any size with a deterministic rule, so that the same call gives the same SAM on every computer. It is used for teaching, for testing closures and for benchmarking the solvers:

```
. cgemod samgen, sectors(150) households(8) name(BIG)
. cgemod calibrate, sam(BIG) solver(broyden)
```

3 The model

Benchmark prices are normalised to one (composite prices to $1 + tq_c$), so that benchmark quantities equal SAM values. All CES and CET functions are written in calibrated share form, so the benchmark is reproduced exactly for any elasticity. Indices: a activities, c commodities, f factors, h households, i institutions.

3.1 Production

Output is a Leontief function of value added and intermediate inputs; value added is a CES function of factors:

$$VA_a = \kappa_a^{va} X_a, \qquad QINT_{ca} = \kappa_{ca}^{int} X_a, \tag{2}$$

$$\frac{VA_a}{VA_a^0} = TFP_a \left[\sum_f \delta_{fa} \left(\frac{FD_{fa}}{FD_{fa}^0} \right)^{\rho_a} \right]^{1/\rho_a}, \qquad \rho_a = \frac{\sigma_a^{va} - 1}{\sigma_a^{va}}, \tag{3}$$

with the dual price $PVA_a = TFP_a^{-1} \left[\sum_f \delta_{fa} W_{fa}^{1-\sigma_a^{va}} \right]^{1/(1-\sigma_a^{va})}$ and zero profit $PA_a(1 - ta_a) = \kappa_a^{va} PVA_a + \sum_c \kappa_{ca}^{int} PQ_c$.

3.2 Make matrix and output aggregation

Each activity supplies commodities in fixed proportions; the output of a commodity is a CES aggregate of the supplies of its producers with elasticity σ_c^x (option `sigmax()`), so activity prices may differ from the producer prices of commodities. Home consumption is valued at activity prices and is part of household demand.

3.3 Trade

Output is allocated between exports and domestic sales by a CET function with elasticity Ω_c; export prices are $PE_c = pwe_c \, EXR \, (1 - te_c)$. Absorption is an Armington CES aggregate of imports and domestic goods with elasticity σ_c^q, and $PM_c = pwm_c \, EXR \, (1 + tm_c)$. Trade margins are fixed quantities of margin services per unit of domestic sales and imports, so the Armington choice is between margin-inclusive prices $PD_c + m_c^d PMG$ and $PM_c + m_c^m PMG$, where PMG is the price of the margin bundle. Composite prices include the sales tax: $PQ_c = PQA_c(1 + tq_c)$.

3.4 Institutions

Factor income is distributed to institutions and the rest of the world in benchmark shares after factor taxes. Households and enterprises pay direct taxes at rates ty_i, save shares mps_i of disposable income, and transfer fixed shares of disposable income to other institutions and abroad. Households spend the remainder on a linear expenditure system,

$$P_c C_{ch} = P_c \gamma_{ch} + \beta_{ch}\Big(EH_h - \sum_{c'} P_{c'}\gamma_{c'h}\Big), \tag{4}$$

which reduces to Cobb–Douglas when the Frisch parameter is -1 (the default); otherwise subsistence quantities γ_{ch} are calibrated from the Frisch parameter and income elasticities. The government collects all taxes, buys commodities in fixed real quantities scaled by an adjuster, pays transfers indexed to the CPI, and saves the residual.

3.5 Factor markets

Each factor is mobile (one wage, fixed supply), sector-specific (fixed use by sector, rents adjust), unemployed (fixed real wage, employment adjusts) or on a wage curve (Blanchflower and Oswald, 1994):

$$u_f = u_f^0 \left(\frac{W_f/CPI}{W_f^0}\right)^{-1/e_f}, \qquad \text{employment}_f = LS_f(1-u_f). \tag{5}$$

3.6 Closures

- **External**: flexible exchange rate with fixed foreign savings (default), or fixed exchange rate with flexible foreign savings (`exchange(fixed)`).
- **Government**: flexible government savings (default), or fixed government savings with an adjusting instrument: direct-tax rates, transfers, a uniform sales-tax point change, or real spending (`gsav(fixed) fiscal()`).
- **Savings–investment**: savings-driven (fixed savings rates, investment adjusts) or investment-driven (fixed real investment, savings rates adjust).
- **Numeraire**: the consumer price index. A Walras slack variable confirms that the omitted market clears.

3.7 Policy modules

- **Carbon tax** (`ctax()`): a tax per unit of emissions, indexed to the CPI, levied on the absorption of emitting commodities (`emissions()`) and on process emissions of activities (`pemissions()`). Combined with `gsav(fixed) fiscal()` the revenue is recycled through lower direct taxes, transfers, sales taxes or spending.
- **Quotas and price caps** (`mquota()`, `xquota()`, `pcap()`): written as complementarity conditions, solved with the Fischer–Burmeister function (Fischer, 1992). When a quota binds, a rent appears and is paid to the government; when a cap binds, the government pays the subsidy that holds the price.

3.8 Welfare

The equivalent variation of each household is computed exactly from the LES expenditure function at benchmark prices and reported in levels and as a percentage of benchmark spending.

4 Solving the model

The model is a square system $F(z) = 0$ in prices, activity levels and closure variables. `cgemod` solves it with a damped Newton method: the Jacobian is computed by forward differences, the Newton step is found by LU decomposition (QR if the Jacobian is near-singular), and a backtracking line search ensures that the sum of squared residuals falls at every step (Dennis and Schnabel, 1983). The benchmark is the starting point, and a solution is accepted when the largest scaled residual is below 10^{-10}.

For large models, `solver(broyden)` replaces the finite-difference Jacobian after the first iteration with Broyden's rank-one update (Broyden, 1965),

$$J_{k+1} = J_k + \frac{(\Delta F_k - J_k \Delta z_k)\, \Delta z_k'}{\Delta z_k' \Delta z_k}, \tag{6}$$

recomputing the full Jacobian only when a step fails. An iteration then needs one model evaluation instead of one per unknown. Both solvers reach the same solution; `cgemod validate, performance` reports their speed on synthetic SAMs of increasing size.

5 Simulations and results

5.1 Shocks

Shocks are written as an operator and a value, either for all elements or by name:

Syntax	Meaning
`tm(*0)`	remove all tariffs
`tm(C_IND=0.05 C_AGR*0.5)`	set one rate, halve another
`ty(+0.01)`	raise all direct-tax rates by one point
`pwm(C_OIL*1.3)`	world oil price up 30%
`tfp(A_AGR*1.1)`	productivity in agriculture up 10%
`qg(C_EDUC*1.2)`	real government spending on education up 20%

Other shock options are `tq()` sales taxes, `te()` export taxes, `ta()` activity taxes, `pwe()` world export prices, `fs()` factor supplies, `wf()` fixed wages, `gadj()` government spending, `fsav()` foreign savings, `ctax()`, `mquota()`, `xquota()`, `pcap()`, `tmsched()` (a tariff schedule) and `gsavshare()`.

5.2 Results

`cgemod sim` displays and returns macroeconomic results (real GDP, absorption, consumption, investment, exports and imports at constant prices, exchange rate, price indices, savings, closure adjusters, emissions and rents), sector results (output, value added, prices), commodity results (supply, domestic sales, exports, imports, absorption and their prices), factor results (employment, returns, income, unemployment) and household results (income, consumption, equivalent variation). `cgemod compare` checks results against those of another implementation, for example the IFPRI model in GAMS.

6 Recursive dynamics

`cgemod dynamic` solves a sequence of within-period equilibria for a baseline and a policy path. Between periods:

- labour supplies grow at `lgrowth()`, productivity at `tfpgrowth()`;

- capital stocks are updated by $K_{t+1} = (1-d)K_t + I_t$, with new capital allocated across sectors in proportion to capital income, tilted towards sectors with above-average rents with responsiveness `mobility()`;
- household populations grow at `popgrowth()`; subsistence consumption and per-person transfers grow with them;
- real government consumption grows at `ggrowth()` and foreign savings at `fsavgrowth()`;
- government debt rises by the deficit: $DEBT_{t+1} = DEBT_t - GSAV_t$.

With `gdpgrowth(g)` the baseline is calibrated: in each period an economy-wide productivity factor θ_t is found by the secant method so that real GDP grows at exactly g. The policy path uses the same θ_t, so the difference between paths is due to the policy alone.

Public capital. A share `pubshare()` of investment is public and accumulates as $KG_{t+1} = (1-\delta_g)KG_t + \text{pubshare} \cdot I_t + I_t^x$, where I^x is additional public investment (`pubinv()`, a share of benchmark GDP, financed according to the fiscal closure). Productivity in each activity rises as $(KG_t/KG_0)^{\eta_a}$, with η_a given by `pubelas()`.

Human capital. Government consumption of the education commodity (`educom()`) accumulates into a stock KE with depreciation `edudep()`; the efficiency of the `edulabor()` factors rises as $(KE_t/KE_0)^{\epsilon}$ with ϵ = `eduelas()`.

Indicators. Each period reports real GDP and its components, prices, factor supplies, output by activity, government savings, debt and debt/GDP, population, GDP per capita, emissions, the public and education capital stocks and the productivity factor. `cgemod poverty, dynamic` follows poverty and inequality along both paths.

7 Poverty and distribution

`cgemod poverty` links the last simulation to a household survey in the top-down tradition of Bourguignon et al. (2008). Each survey household belongs to a SAM household group; its welfare changes by the group's equivalent variation (`method(ev)`), by the change in real consumption (`method(real)`), or by the change in its own income sources weighted by the change in factor returns and transfers, deflated by the group's price index (`method(income)`). The command reports the Foster–Greer–Thorbecke indices P_0, P_1, P_2 (Foster et al., 1984) and the Gini coefficient before and after the shock, overall and by any grouping variable, with survey weights and household size. With `dynamic`, welfare grows along the baseline and policy paths of the last `cgemod dynamic` run.

8 Sensitivity analysis

`cgemod ssa` measures how results depend on the elasticities. Each chosen elasticity is perturbed within a range around its value (uniform or triangular distribution); results are computed either at the nodes of a degree-3 Stroud quadrature, which requires only $2n$ solutions for n uncertain parameters (DeVuyst and Preckel, 1997; Arndt, 1996), or by Monte Carlo. The output gives the mean, standard deviation, approximate 95% bounds (mean ± 1.96 standard deviations under quadrature, 5th and 95th percentiles under Monte Carlo) of every result and the share of solutions with the same sign as the central result.

9 Estimating elasticities

A calibrated model has no residuals; econometric diagnostics apply to the estimation of its elasticities. `cgemod elast` estimates Armington, CET and value-added elasticities from time-series or panel data and reports tests for normality (Jarque and Bera, 1980), heteroskedasticity (Koenker, 1981), serial correlation (Breusch, 1978; Godfrey, 1978), functional form (Ramsey, 1969), parameter stability (Brown et al., 1975; Andrews, 1993; Hansen, 2000), cross-sectional dependence (Pesaran, 2015), multicollinearity and endogeneity. When a problem is found it applies a remedy: robust or Newey–West standard errors (Newey and West, 1987), dynamic specifications, Driscoll–Kraay errors (Driscoll and Kraay, 1998), common correlated effects (Pesaran, 2006), or instrumental variables. The estimate can be stored and passed to `cgemod calibrate`.

10 The scenario manager

Policy work compares many scenarios. The scenario manager stores them by name, runs them in one call and keeps the results together:

```
. cgemod scenario define free, tm(*0) description("All tariffs removed")
. cgemod scenario define free_fix, tm(*0) closure(exchange(fixed))
. cgemod scenario define oil, pwm(C_OIL*1.3)
. cgemod scenario define vat, tq(+0.02) closure(gsav(fixed) fiscal(dirtax))
. use cgemod_survey, clear
. cgemod scenario run, poverty(group(group) welfare(pcexp) weight(weight) ///
>       hhsize(hhsize) line(167.8))
. cgemod scenario graph, households
. cgemod scenario export using dashboard.html, replace
. cgemod scenario export using results.xlsx, replace
```

A scenario may carry its own closure; it is then solved on a model recalibrated with the last calibration options and that closure, and the original model is restored afterwards. A scenario that fails to solve is reported and the others are still run. The HTML dashboard is a single self-contained file, with charts of the main indicators and tables of macroeconomic, sectoral, factor-market, welfare and poverty results, that can be e-mailed or posted without Stata.

11 Model checks and validation

11.1 Diagnostics

`cgemod check` verifies SAM balance, exact replication of the benchmark, admissible parameters, the rank and conditioning of the Jacobian, convergence under a test shock, Walras' law, price homogeneity, and uniqueness of the solution from perturbed starting points.

11.2 Validation suite

`cgemod validate` adds the tests that the CGE literature uses to detect coding and closure errors (Dixon and Rimmer, 2013):

1. a battery of standard shocks, each of which must solve, satisfy Walras' law and keep the numeraire;
2. path independence: a shock applied in steps reaches the same equilibrium as in one step;
3. symmetry: $\pm 1\%$ shocks give mirror-image first-order effects;
4. agreement of the Newton and Broyden solvers;

5. homogeneity of degree zero in prices under a non-trivial shock;
6. units invariance: the SAM multiplied by 1,000 gives the same percentage results.

With `performance`, synthetic models of increasing size are solved with both solvers and timed.

11.3 Certification and unit tests

`cgemod_cert.do` compares, to 10^{-6}, about 200 results of every module with an independent implementation of the same equations: SAM balancing, comparative statics under all closures, the extended SAM, the policy modules, dynamic paths, sensitivity analysis, poverty, synthetic SAMs, the two solvers and the scenario manager. `cgemod_unittest.do` checks that invalid input is rejected with the right error code and that every subcommand runs end to end. Both should be run after installation and after any modification of the code.

`cgemod_runall.do` runs the unit tests, the certification, the Nigeria application and the worked example in one session and writes `cgemod_runall.log`. Table 2 summarises the run of version 2.0.0 in Stata 17.

Table 2: Certification of version 2.0.0 (Stata 17)

Component	Content	Result
`cgemod_unittest.do`	input validation, error codes, every subcommand	48 of 48 passed
`cgemod_cert.do`	about 200 results against the reference implementation	all within 10^{-6}
`cgemod compare`	extended SAM and Nigeria SAM, several closures	0 differences above tole
`cgemod check` (Nigeria)	8 diagnostics, 135 unknowns	8 of 8 passed
`cgemod validate` (extended SAM)	shock battery and five structural tests	12 of 12 passed

Table 3 reports `cgemod validate, performance sizes(10 25 50 100)` on synthetic SAMs. Newton needs three iterations and Broyden six at every size; Broyden is about 2.5 times faster on the largest model, and both solvers reach the same solution. A synthetic model with 150 sectors (316 accounts) is solved by Broyden in six iterations.

Table 3: Solver performance on synthetic SAMs (seconds, Stata 17)

Sectors	Unknowns	Calibration	Newton	Iterations	Broyden	Iterations
10	35	0.003	0.061	3	0.031	6
25	80	0.007	0.189	3	0.070	6
50	155	0.010	0.653	3	0.292	6
100	305	0.039	2.067	3	0.812	6

12 Case studies

The case studies use the extended example SAM (`cgemod_sam_ext.csv`): three activities, four commodities (one imported but not produced), labour and capital, rural and urban households, enterprises, government with five tax accounts, trade margins, and the rest of the world. The results below are those of the certified model.

12.1 Tariff reform under alternative closures

All tariffs are removed under four closures (Table 4). Real GDP at factor cost hardly moves: factor supplies are fixed and the efficiency gain is small. The closures decide where the adjustment falls. With a flexible exchange rate and fixed foreign savings, the currency depreciates by about 7% to restore the external balance, exports rise, and the loss of tariff revenue lowers government

savings; with savings-driven investment, real investment falls by 11%, so households gain about 4% of their spending partly at the expense of future capacity. With a fixed exchange rate, foreign savings absorb the shock: imports rise by almost 29%, exports fall and the extra foreign savings raise investment. With investment fixed in real terms, or with the lost tariff revenue replaced by higher sales taxes, the welfare gains shrink to at most 1.2% of spending and urban households can lose. The lesson is general: the welfare effect of a tariff reform cannot be read without its closure.

Table 4: Removal of all tariffs: percentage changes from the benchmark (EV in % of benchmark spending)

	Flexible exchange rate	Fixed exchange rate	Investment-driven	Sales tax replaces tariffs
Real GDP	0.00	0.00	0.00	0.00
Household consumption	4.25	4.42	0.66	0.16
Real investment	−10.72	34.85	0.00	1.12
Exports	9.17	−5.67	9.84	9.68
Imports	7.92	28.74	8.70	8.44
Exchange rate	6.97	0.00	7.07	4.56
EV, rural households (%)	4.24	3.90	1.17	0.55
EV, urban households (%)	4.19	4.79	0.17	−0.22

12.2 A public investment programme

A calibrated baseline grows at 5% a year with labour growing at 2.5%, rural and urban populations at 3% and 4%, government consumption at 4% and foreign savings at 3%; 30% of investment is public, public capital raises productivity with elasticities of 0.10–0.15, and education spending raises the efficiency of labour with elasticity 0.2. The policy adds public investment worth 1% of benchmark GDP from period 1, financed by borrowing:

```
. cgemod dynamic, periods(6) labor(LAB) capital(CAP) lgrowth(LAB=0.025)    ///
>     tfpgrowth(A_AGR=0.01) gdpgrowth(0.05) popgrowth(HH_RUR=0.03 HH_URB=0.04) ///
>     ggrowth(0.04) fsavgrowth(0.03) pubshare(0.3) pubdep(0.05)             ///
>     pubelas(A_AGR=0.1 A_IND=0.15 A_SER=0.1) educom(C_SER) edulabor(LAB)   ///
>     eduelas(0.2) edudep(0.1) debt0(100) pubinv(0.01)
```

Table 5 shows that the programme raises GDP slightly in the first year, through demand and the first additions to public capital, but lowers it afterwards: with savings-driven investment, each unit of borrowing crowds out a unit of private investment, and the productivity effect of public capital is too small to offset the slower growth of private capital. Debt rises by about 19 units after six years. The same programme financed by direct taxes (`gsav(fixed) fiscal(dirtax)`) or with a larger productivity elasticity can be compared with the scenario manager.

Table 5: Public investment programme: deviations from the baseline

Period	0	1	2	3	4	5	6
Real GDP (% deviation)	0.00	0.07	−0.02	−0.10	−0.17	−0.23	−0.29
Government debt (level)	0.00	3.01	6.10	9.28	12.53	15.86	19.27
Poverty headcount, baseline (%)	39.98	39.14	38.05	37.48	36.87	36.40	35.36
Poverty headcount, policy (%)	39.98	39.12	38.11	37.48	36.90	36.58	35.68

12.3 Poverty along the growth path

The last two rows of Table 5 come from

```
. use cgemod_survey, clear
. cgemod poverty, group(group) welfare(pcexp) weight(weight) ///
>     hhsize(hhsize) line(167.81527955306038) dynamic
```

Growth of real consumption per person reduces the headcount by more than four points over six years on the baseline. The deficit-financed programme improves on it in the first year but leaves the headcount 0.3 points higher at the end of the horizon. Distributional effects through relative prices and factor returns can be studied with `method(income)` in the static model.

12.4 An application to the IFPRI 2018 Nigeria SAM

`cgemod_nigeria.do` applies the package to the 2018 SAM for Nigeria built by IFPRI (Randriamamonjy and Thurlow, 2021): 109 accounts with 42 activities and commodities, five factors (labour by education level, land and capital), ten households by rural or urban location and expenditure quintile, enterprises, government with four tax accounts, trade margins, stock changes and the rest of the world. `cgemod samimport` detects all roles from the account codes. `cgemod samcheck` finds every accounting identity satisfied and the same GDP at market prices, 129,061 billion naira, from the income and expenditure sides; the two negative cells (government and foreign savings) are kept negative by GRAS. The calibrated model has 135 unknowns, replicates the benchmark to 1.3×10^{-8} and passes all eight diagnostics.

Table 6 shows the removal of all import tariffs (average rate 2.6% of imports) under the default closures, with the quadrature sensitivity analysis of the four trade and production elasticities ($\pm 50\%$). Real GDP is unchanged, the exchange rate depreciates by 0.4%, and lower import prices raise real household consumption by 0.4% while the loss of tariff revenue reduces public saving and hence real investment by 1.6%. Every macro result keeps its sign over the whole elasticity range. Import-competing manufacturing (chemicals, metals, machinery, wood) contracts by 1.4 to 2.9%, while crude oil and hotels expand. The results agree with the reference implementation to 10^{-4}, also under a fixed exchange rate and with unemployed low-skill labour.

Table 6: Nigeria: removal of all import tariffs (% change)

Indicator	Point	Mean (SSA)	Lower 95%	Upper 95%
Real GDP at factor cost	−0.000	−0.000	−0.000	0.000
Real absorption	0.014	0.014	0.007	0.021
Real household consumption	0.413	0.412	0.405	0.420
Real investment	−1.584	−1.582	−1.602	−1.561
Real exports	1.597	1.579	0.715	2.444
Real imports	1.499	1.482	0.670	2.293
Exchange rate	0.381	0.387	0.266	0.508

Stroud degree-3 quadrature, 8 solutions; bounds are the mean ± 1.96 standard deviations.

13 Good practice

1. Keep every step in a do-file: SAM import, balancing (with `log()`), calibration, scenarios and exports. The scenario definitions themselves document the analysis.
2. Always inspect the detected account roles and run `cgemod check` and `cgemod validate` before simulating.

3. Report the closure with every result, and show how the main results change under the alternative closures.
4. Report the sensitivity of key results to the trade elasticities (`cgemod ssa`); estimate the elasticities when data allow, and report the diagnostics.
5. State the base year and sources of the SAM, the balancing method and the size of the adjustments.

14 Citation

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