

MAMS: Core CGE and MDG Modules

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1. Introduction

- Starting point for MAMS: IFPRI static standard model
- MAMS extends this model in two respects:
 - (recursive) dynamics
 - endogenous MDG and education outcomes

1. Introduction

- Characteristics of “standard” models:
 - Separation between model code and database (facilitates application to new databases)
 - Flexible (dis)aggregation
 - Pre-programmed alternative treatments of “closures” and other features.

1. Introduction

Presentation outline:

2. IFPRI static standard model:

- a. Data
- b. Structure

3. MAMS

- a. Core CGE component
 - b. MDGs and Education
- The “within-period” part of 3a is very similar to the IFPRI standard model.

2a. Database of Static Model

- The database consists of
 - Social Accounting Matrix (SAM) — available for a large number of developing countries
 - Elasticities
 - Optional factor quantity data
- A SAM is
 - A comprehensive, economywide data framework
 - A square matrix in which
 - each account is represented by a row and a column
 - each cell shows the payment from its column account to its row account

Figure. SAM Structure

	Expenditures					
Receipts	Activities	Commodities	Factors	Domestic Institutions	Rest of World	Totals
Activities		Market sales		Home consumption		Activity income
Commodities	Intermediate inputs	Transactions costs		Final market demands	Exports	Commodity demand
Factors	Value added				Transfers	Factor income
Domestic Institutions	Taxes	Tariffs, Taxes	Income, Taxes	Transfers, Taxes, Savings	Transfers, Savings	Institution income
Rest of World		Imports				Foreign exchange outflow
Totals	Activity spending	Commodity supply	Factor spending	Institution spending	Foreign exchange inflow	

2a. Database of Static Model

- The program checks that the SAM is
 - properly structured
 - balanced (activating a balancing program if needed)
- The standard model works with a wide variety of SAM structures

2b. Structure of Static Model

- Computable → solvable numerically
- General → economy-wide (like the SAM)
- Equilibrium →
 - optimizing agents have found their best solutions subject to their budget constraints
 - quantities demanded = quantities supplied in factor and commodity markets
 - macroeconomic balance
- Model written as a set of simultaneous equations; no objective function.

2b. Structure of Static Model

- Distinguishing model characteristics:
 - transactions costs in domestic and foreign trade
 - household home consumption
- How is the model related to the SAM?
 - The model “explains” all the payments and quantity flows in the SAM.
 - The model follows the SAM disaggregation.
 - The model is “calibrated” to the SAM.

Stylized Model Structure

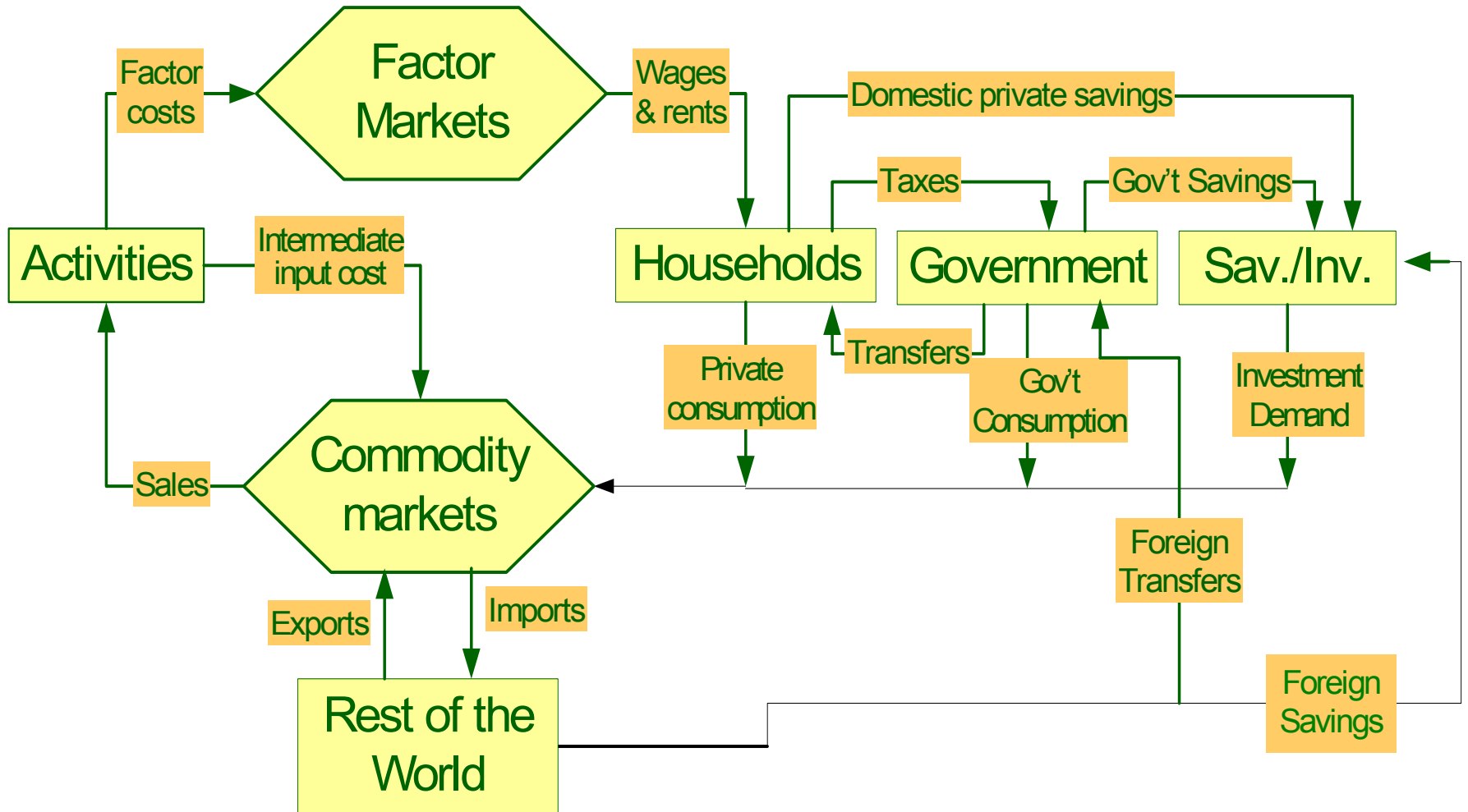


Figure. Production technology

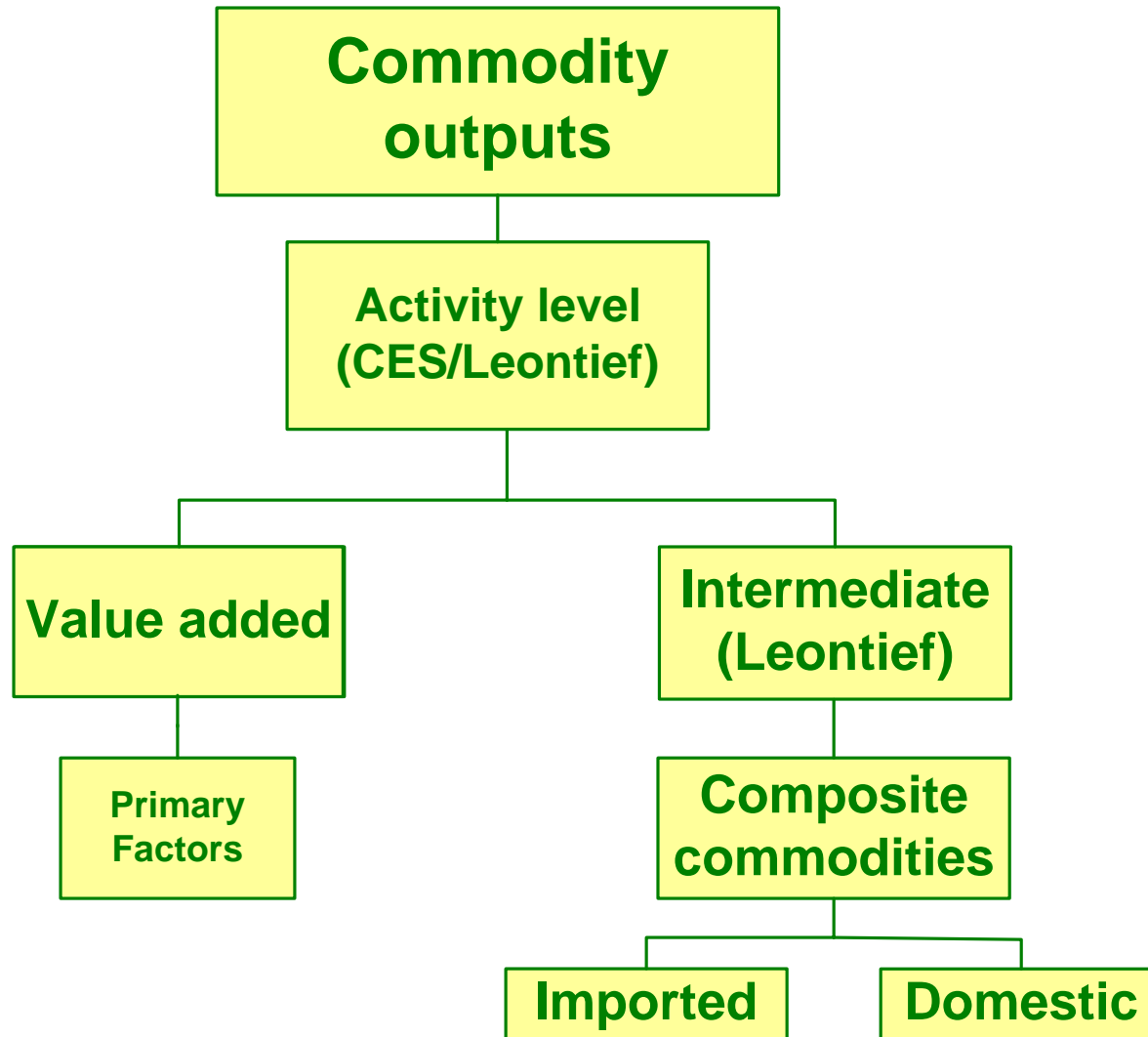
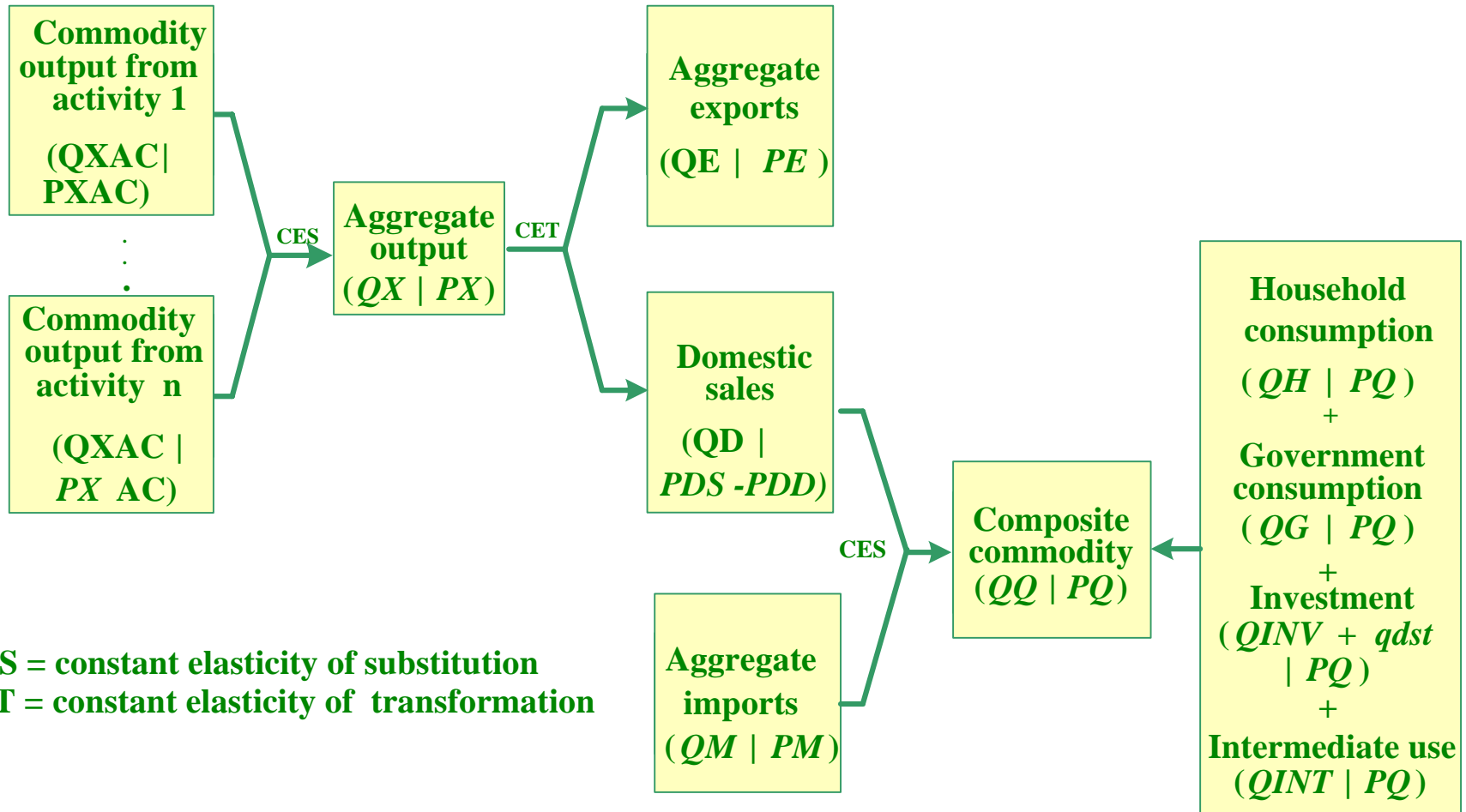


Figure. Commodity flows



2b. Structure of Static Model

- Alternative closures for factor markets:
 - Market clearing by wage or (un)employment?
 - Integrated or segmented markets?
- Alternative closures for macro balances:
 - Government: direct taxes or savings
 - Rest-of world: exchange rate or savings
 - Savings-investment: MPS or investment demand

3. MAMS

- MAMS is dynamic-recursive, i.e. the solution in any time period depend on current and past periods, not the future.
- MAMS can be solved in two alternative modes:
 - Single-pass (all periods at the same time)
 - Multi-pass (period by period)
- For any simulation, you can solve in either (or both) modes.

3. MAMS

- Pros of solving in single-pass mode:
 - Faster
 - Potentially, decisions may depend on correct insights about future outcomes.
- Cons of solving in single-pass mode:
 - Less robust
 - More difficult to debug
- Suggestion: start in multi-pass; switch to single-pass for simulations for which this works.

3. MAMS

- The rest of this section covers selected relationships in MAMS:
 - a. Core CGE model
 - b. MDGs and education
- Simplified to focus on main points.
- In the equations:
 - parameters have Greek or lower-case Latin letters; variables have upper-case Latin letters; variables with a bar on top are fixed in the current example but may be flexible under different assumption.
 - variables for period $t-1$ are fixed.

3a. Government Consumption

$$QG_{c,t} = QG_{c,t-1} \cdot \left(1 + \overline{RQGCT}_{c,t}\right)$$

$$\begin{bmatrix} \text{real government} \\ \text{consumption} \\ \text{of } c \text{ in } t \end{bmatrix} = \begin{bmatrix} \text{real government} \\ \text{consumption} \\ \text{of } c \text{ in } t - 1 \end{bmatrix} \cdot \left[1 + \begin{bmatrix} \text{growth} \\ \text{rate} \end{bmatrix}\right]$$

3a. Government investment

$$DKGOV_{f,t} \geq \sum_{\substack{a \in A \\ |(f,a) \in MFA}} \left(ifa_{f,a} \cdot QA_{a,t} \cdot \frac{QA_{a,t}}{QA_{a,t-1}} \right) - QFACINS_{gov,f,t} \cdot (1 - depr_f)$$

$$\left[\begin{array}{l} \text{gross government} \\ \text{investment demand} \\ \text{for capital} \end{array} \right] = \left[\begin{array}{l} \text{anticipated demand for capital} \\ \text{next year (based on current} \\ \text{production and its growth)} \end{array} \right] - \left[\begin{array}{l} \text{remaining capital stock} \\ \text{(after depreciation) next} \\ \text{year if no investment} \end{array} \right]$$

3a. Government investment financing

$$INVVAL_{gov,t} = GSAV_t - \sum_{c \in C} PQ_{c,t} \cdot qdst_{c,gov,t} + \overline{DGBONDTOT}_t$$

$$\left[\begin{array}{l} \text{government fixed} \\ \text{investment value} \end{array} \right] = \left[\begin{array}{l} \text{government} \\ \text{savings} \end{array} \right] - \left[\begin{array}{l} \text{spending on} \\ \text{stock changes} \end{array} \right] + \left[\begin{array}{l} \text{total change in holdings} \\ \text{of government bonds} \end{array} \right]$$

$$+ \overline{CBBORTOT}_t + \left(\overline{FBOR}_{gov,t} + \overline{FGRANT}_{gov,t} \right) \cdot EXR_t$$

$$+ \left[\begin{array}{l} \text{Government Central Bank} \\ \text{borrowing (deficit monetization)} \end{array} \right] + \left[\begin{array}{l} \text{foreign borrowing and} \\ \text{foreign grants (in LCU)} \end{array} \right]$$

3a. Private investment financing

$$INVVAL_{i,t} = INSSAV_{i,t} - \sum_{c \in C} PQ_{c,t} \cdot qdst_{c,i,t} - DGBOND_{i,t}$$

$$\left[\begin{array}{c} \text{non-government fixed} \\ \text{investment value} \end{array} \right] = \left[\text{savings} \right] - \left[\begin{array}{c} \text{stock} \\ \text{changes} \end{array} \right] - \left[\begin{array}{c} \text{change in holdings of} \\ \text{government bonds} \end{array} \right]$$

$$-CBBOR_{i,t} + \left(\overline{FBOR}_{i,t} + \overline{FGRANT}_{i,t} + fdi_{i,t} \right) \cdot EXR_t$$

$$- \left[\begin{array}{c} \text{Government Central} \\ \text{Bank borrowing} \end{array} \right] + \left[\begin{array}{c} \text{foreign borrowing, grants,} \\ \text{and direct investment (in LCU)} \end{array} \right]$$

3a. Private investment

$$PK_{f,t} \cdot DKINS_{i,f,t} = gfcfshr_{f,i,t} \cdot INVVAL_{i,t}$$

$$\left[\begin{array}{l} \textit{non-government spending} \\ \textit{on capital stock f} \end{array} \right] = \left[\begin{array}{l} \textit{total fixed investment value} \\ \textit{times share for capital stock f} \end{array} \right]$$

3a. BoP – uses of foreign exchange

$$\begin{aligned}
 & \sum_{c \in CM} pwm_{c,t} \cdot QM_{c,t} + \frac{\sum_{f \in F} YIF_{row,f,t}}{EXR_t} + \frac{\sum_{i \in INSDNG} TRII_{row,i,t}}{EXR_t} \\
 & \left[\begin{array}{c} \text{import} \\ \text{spending} \end{array} \right] + \left[\begin{array}{c} \text{factor income} \\ \text{to Rest of World} \end{array} \right] + \left[\begin{array}{c} \text{transfers from domestic} \\ \text{non-gov institutions to RoW} \end{array} \right] \\
 & + trnsfr_{row,gov,t} + \sum_{i \in INSD} fintrat_{i,t} \cdot FDEBT_{i,t} = \\
 & + \left[\begin{array}{c} \text{transfers from} \\ \text{government to RoW} \end{array} \right] + \left[\begin{array}{c} \text{interest payment} \\ \text{on foreign debt} \end{array} \right] =
 \end{aligned}$$

3a. BoP – sources of foreign exchange

$$\begin{aligned}
 &= \sum_{c \in CE} pwe_{c,t} \cdot QE_{c,t} + \sum_{i \in INSDNH} trnsfr_{i,row,t} + \sum_{h \in H} trnsfrpc_{h,row,t} \cdot POP_{h,t} \\
 &= \left[\begin{array}{c} \text{export} \\ \text{revenue} \end{array} \right] + \left[\begin{array}{c} \text{transfers from RoW to domestic} \\ \text{non-household institutions} \end{array} \right] + \left[\begin{array}{c} \text{transfers from RoW to} \\ \text{domestic households} \end{array} \right] \\
 &+ \sum_{f \in F} trnsfr_{f,row,t} + \sum_{i \in INSD} \left(\overline{FBOR}_{i,t} + \overline{FGRANT}_{i,t} \right) + fdi_{row,t} \\
 &+ \left[\begin{array}{c} \text{factor income} \\ \text{from RoW} \end{array} \right] + \left[\begin{array}{c} \text{borrowing} \\ \text{from RoW} \end{array} \right] + \left[\begin{array}{c} \text{grants} \\ \text{from RoW} \end{array} \right] + \left[\begin{array}{c} \text{foreign direct} \\ \text{investment} \end{array} \right]
 \end{aligned}$$

3a. Labor market

- Labor segmented by education; educational system defines maximum disaggregation
- In each segment, minimum un-/under-employment rate is imposed (5%?); base-year replicates observed rates.
- Two labor-market regimes are possible:
 - unemployment rate $>$ minimum \rightarrow minimum wage
 - unemployment rate = minimum \rightarrow wage flexible
- Endogenous minimum wage (determined by by unemployment rate and other variables)

3a. Employment

$$QFS_{f,t} = (1 - UERAT_{f,t}) \cdot \sum_{i \in INS} QFACINS_{i,f,t}$$

$$\left[\begin{array}{c} \text{total quantity employed} \\ \text{of factor } f \end{array} \right] = \left[\begin{array}{c} 1 - \text{unemployment rate} \\ \text{(i.e., employment rate)} \end{array} \right] \cdot \left[\begin{array}{c} \text{sum of all} \\ \text{institutional endowments} \end{array} \right]$$

3a. Minimum (reservation) wage

$$WFMIN_{f,t} = WF_f^{00} \cdot \left(\frac{(1 - UERAT_{f,t})}{(1 - UERAT_f^{00})} \right)^{\phi_{wferat}_f}$$

$$\left[\begin{array}{l} \text{minimum wage for factor } f \text{ in year } t \\ \text{(if factor } f \text{ has endogenous unemployment)} \end{array} \right] = \left[\begin{array}{l} \text{economy-wide wage} \\ \text{for factor } f \text{ in the base year} \end{array} \right]$$

· [influence of : employment rate (relative to its base year value)]

3a. Labor market mixed-complementarity conditions

$$WF_{ft} \geq WFMIN_{ft}$$

$$UERAT_{ft} \geq ueratmin_{ft}$$

$$(WF_{ft} - WFMIN_{ft})(UERAT_{ft} - ueratmin_{ft}) = 0$$

- Implications of the last relationship:
 1. unemployment rate > minimum rate → wage = minimum wage
 2. wage > minimum wage → unemployment rate > minimum rate

3a. Stock updating

- Updating equations for
 - Stocks (population, factor endowments, foreign debt, government bonds)
 - Total factor productivity (efficiency) by activity.

3a. Households

- (Potential) multiple-household structure complicates stock-updating.
- Why multiple representative households (RHs)?
 - More accurate simulation results (prices, wages, production).
 - Poverty and distributional analysis based on representative households is facilitated.

3a. Households

- Each RH has various characteristics (consumption and savings pattern, factor endowments, other assets and liabilities)
- For each RH, population growth is more (less) rapid than overall rate if the labor types with which the RH is highly endowed grow more rapidly than the labor force as a whole.

3a. Households

- This does not reflect higher natural population growth for the population of any RH; it reflects “migration” from one RH to another as a larger or smaller share of the population take on various characteristics.

3a. Household population

- Defining RH population in t:

$$POP_{h,t} = POPSCAL_t \cdot POP_{h,t-1} \cdot \frac{\sum_{f \in FLAB} QFACINS_{h,f,t}}{\sum_{f \in FLAB} QFACINS_{h,f,t-1}}$$

$$\begin{bmatrix} \text{population of} \\ \text{household } h \\ \text{in year } t \end{bmatrix} = \begin{bmatrix} \text{population} \\ \text{scaling} \\ \text{factor for } t \end{bmatrix} \cdot \begin{bmatrix} \text{population of} \\ \text{household } h \\ \text{in year } t-1 \end{bmatrix} \cdot \begin{bmatrix} \text{factor for labor} \\ \text{force growth} \\ \text{for household } h \end{bmatrix}$$

3a. Household assets

- The population growth of any RH relative to the average influences the distribution of factors and other assets or liabilities.
- For factors with exogenous total stocks (similar treatment for capital)...

3a. Households and exogenous factors

$$QFACINS_{h,f,t} = QFSCAL_{f,t} \cdot POP_{h,t} \cdot qfpc_{h,f,t}$$

$$\left[\begin{array}{l} \text{stock of non-labor} \\ \text{factor } f \text{ by household} \end{array} \right] = \left[\begin{array}{l} \text{scaling} \\ \text{factor} \end{array} \right] \cdot \left[\begin{array}{l} \text{population for} \\ \text{household } h \end{array} \right] \cdot \left[\begin{array}{l} \text{per-capita stock} \\ \text{for household } h \end{array} \right]$$

$$qfachhtot_{f,t} = \sum_{h \in H} QFACINS_{h,f,t}$$

$$\left[\begin{array}{l} \text{total household stock of} \\ \text{exogenous, non-labor factors} \end{array} \right] = \left[\begin{array}{l} \text{sum of disaggregated} \\ \text{household stocks} \end{array} \right]$$

3a. TFP

- TFP by activity is updated on the basis of:
 - changes in public infrastructure capital stocks
 - changes in openness (trade share in GDP)
 - trend term (exogenous except for calibration simulations where GDP growth is imposed)

3a. TFP

$$\alpha_{va}{}_{a,t} = \alpha_{va2}{}_{a,t} \cdot \prod_{f \in FCAP} \left[\frac{\sum_{i \in INS} QFACINS_{i,f,t}}{\sum_{i \in INS} QFACINS_{i,f}^0} \right]^{tjfpelasqg_{a,f,t}}$$

$$\cdot \left(\frac{\sum_{t' \in T} tfptrdwt_{t,t'} \cdot TRDGDP_{t'}}{TRDGDP^0} \right)^{tjfpelastrd_a}$$

$$\left[\begin{array}{l} \text{efficiency} \\ \text{term for} \\ \text{activity } a \end{array} \right] = \left[\begin{array}{l} \text{endogenous} \\ \text{trend} \\ \text{term for} \\ \text{activity } a \end{array} \right] \cdot \left[\begin{array}{l} \text{product of: ratio of all} \\ \text{current real capital} \\ \text{endowment } f \text{ to initial} \\ \text{value, raised} \\ \text{to the relevant elasticity} \end{array} \right] \cdot \left[\begin{array}{l} \text{weighted avg. (over time)} \\ \text{of ratios of openness} \\ \text{to initial value, raised} \\ \text{to the relevant elasticity} \end{array} \right]$$

3a. Macro closure rules

Table 5. Alternative closure rules for macro balances

Government	GOV-1	GOV-2	GOV-3	GOV-4	GOV-5
Direct tax rates	fixed	flexible*	fixed	flexible*	fixed
Government savings	flexible	flexible	flexible	fixed	flexible
Government bond borrowing	flexible	fixed	fixed	fixed	fixed
Foreign borrowing	fixed	fixed	fixed	fixed	flexible
Foreign grants	fixed	fixed	flexible	flexible	fixed
Rest of World	ROW-1	ROW-2	ROW-3		
Exchange rate	flexible	flexible	flexible		
Foreign grants	fixed	flexible	fixed		
Foreign borrowing	fixed	fixed	flexible		
Savings-investment	SI-1	SI-2			
Private investment absorption share	fixed	flexible			
Private savings rate	flexible	fixed**			

Notes: * uniform point change for selected domestic non-government institutions;
 **The private savings rate is not fixed but determined endogenously according to Equation 37 (with fixed levels for DMPS and MPSADJ); it is not free to vary to finance an investment value that is exogenous or determined through some other mechanism.

3b. MDG and education module

- Indicators for MDGs and educational outcomes are defined by a nested structure with a logistic function at the top and a constant-elasticity (CE) function at the bottom.
- The equations for the MDGs will be shown.

3b. MDG and education module

- Logistic function for MDGs 4, 5, 7a, 7b:

$$MDGVAL_{mdg,t} = extmdg_{mdg} + \frac{\alpha_{mdg_{mdg}}}{1 + EXP(\gamma_{mdg_{mdg}} + \beta_{mdg_{mdg}} \cdot ZMDG_{mdg,t})}$$

$$\begin{bmatrix} MDG \\ value \end{bmatrix} = \begin{bmatrix} logistic\ function\ of\ intermediate \\ MDG\ value\ (ZMDG_{mdg,t}) \end{bmatrix}$$

3b. MDG Intermediate variable

$$\begin{aligned}
 ZMDG_{mdg,t} = & \alpha_{mce_{mdg}} \cdot \left(\prod_{cmdg \in CMDG} \left(\sum_{\substack{c \in C \\ |(cmdg,c) \in MCM}} \frac{QQ_{c,t}}{poptot_t} \right)^{\varphi_{m_{mdg,cmdg}}} \right) \\
 & \cdot \left(\sum_{i \in INS} QFACINS_{i,"fcapgovinf",t} \right)^{\varphi_{m_{mdg},"fcapgovinf"}} \cdot \\
 & \cdot \left(\prod_{mdg' \in MDGSTD} MDGVAL_{mdg',t}^{\varphi_{m_{mdg},mdg'}} \right) \cdot QHPC_t^{\varphi_{m_{mdg},"hhdconspc"}}
 \end{aligned}$$

$$\left[\begin{array}{l} \text{intermediate variable} \\ \text{for MDGs 4 and 5} \end{array} \right] = \left[\begin{array}{l} \text{exogenous} \\ \text{parameter} \end{array} \right] \cdot \left[\begin{array}{l} \text{influence of: real value for services per capita;} \\ \text{level of infrastructure; water and sanitation MDGs;} \\ \text{household consumption per capita} \end{array} \right]$$

3b. Parameters of MDG functions

A simultaneous equation model solves for parameter values. For the MDG case:

- As $ZMDG \rightarrow +inf$, 2nd term $\rightarrow 0$ and $MDGVAL \rightarrow ext$
- α_{mdg} is defined so that, when $ZMDG$ is at base value, $MDGVAL$ is also at base value (if slope > 0 , α_{mdg} and 2nd term are negative).
- β_{mdg} is defined so that, for a pre-specified scenario, $MDGVAL$ hits its 2015 target.
- The φ_m 's (elasticities of the CE function) are defined so that base-year elasticities of $MDGVAL$ w.r.t. the arguments of the CE function are replicated.
- γ_{mdg} determines whether base-year point is above/below/at the inflection point, where decreasing MR sets in. (MR are decreasing if $\beta_{mdg} \cdot ZMDG - \gamma_{mdg} > 0$).

3b. Full elasticity of MDG indicators

$$e^{full} = e^{top} e^{bottom} = \frac{dM}{dZ} \frac{Z}{M} \phi = \frac{-\alpha e^{\gamma+\beta Z} \beta}{\left(1 + e^{\gamma+\beta Z}\right)^2} \frac{Z}{ext + \frac{\alpha}{\left(1 + e^{\gamma+\beta Z}\right)}} \phi$$

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