

Note: Model structure of the CGE model for Jordan

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I owe the nested-CES/CET structure of the CGE model for Jordan employed by Hosoe (1998) to Devarajan *et al.* (1990)¹. But some modifications are made to equip their original model with the international trade model with three regions. Some parts of the model may be a little bit complicated due to the unique structure of the GTAP version 4 database, particularly in the treatment of international transportation services.

The Armington structure between domestic and imported Goods:

The CES aggregation function:

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¹ Hosoe, N. (1998) "A General Equilibrium Analysis of Jordan's Trade Liberalization," mimeo.

$$Q_{j,r} = \lambda_{1,j,r} \left(\lambda_{2,j,r} QD_{j,r}^{\frac{\sigma_j-1}{\sigma_j}} + (1 - \lambda_{2,j,r}) QD_{j,r}^{\frac{\sigma_j-1}{\sigma_j}} \right)^{\frac{\sigma_j}{\sigma_j-1}}, \quad \forall j,r$$

Demand functions derived from the CES function:

$$QD_{j,r} = \left(\frac{\lambda_{1,j,r}^{\frac{\sigma_j-1}{\sigma_j}} \lambda_{2,j,r} p q_{j,r}}{p q d_{j,r}} \right)^{\sigma_j} Q_{j,r}, \quad \forall j,r$$

$$QM_{j,r} = \left(\frac{\lambda_{1,j,r}^{\frac{\sigma_j-1}{\sigma_j}} (1 - \lambda_{2,j,r}) p q_{j,r}}{p q m_{j,r}} \right)^{\sigma_j} Q_{j,r}, \quad \forall j,r$$

The Armington structure between import sources:

CES aggregation function:

$$QM_{j,r} = \omega_{1,j,r} \left(\sum_s \omega_{2,j,s,r} Q T_{j,s,r}^{\frac{\sigma_m-1}{\sigma_m}} \right)^{\frac{\sigma_m}{\sigma_m-1}}, \quad \forall j,r$$

$$Q T_{j,s,r} = \left(\frac{\omega_{1,j,r}^{\frac{\sigma_m-1}{\sigma_m}} \omega_{2,j,s,r} p q m_{j,r}}{\left((1 + \tau_{e,j,s,r}) p q t_{j,r} \cdot Exch_{s,r} + \tau_{s,j,s,r} p q q t \cdot Exch_{ROW,r} \right) (1 + \tau_{m,j,s,r})} \right)^{\sigma_m} Q M_{j,r},$$

$\forall j,s,r$

The CET transformation structure between domestic uses and exports:

The CET function:

Devarajan, S., J. D. Lewis, and S. Robinson (1990) "Policy Lessons from Trade-Focused Two-Sector Models," *Journal of Policy Modeling* 12 (4): 625-657.

$$\begin{aligned}
 Z_{j,r} &= \delta 1_{j,r} \left(\delta 2_{j,r} QD_{j,r}^{\frac{1+\alpha_j}{\alpha_j}} + (1-\delta 2_{j,r}) QE_{j,r}^{\frac{1+\alpha_j}{\alpha_j}} \right)^{\frac{\alpha_j}{1+\alpha_j}} + QTS_r, \quad i = SRV, \forall r \\
 &= \delta 1_{j,r} \left(\delta 2_{j,r} QD_{j,r}^{\frac{1+\alpha_j}{\alpha_j}} + (1-\delta 2_{j,r}) QE_{j,r}^{\frac{1+\alpha_j}{\alpha_j}} \right)^{\frac{\alpha_j}{1+\alpha_j}}, \quad i \neq SRV, \forall r
 \end{aligned}$$

Supply functions derived from the CET function:

$$\begin{aligned}
 QD_{j,r} &= \left(\frac{\delta 1_{j,r}^{\frac{1+\alpha_j}{\alpha_j}} \delta 2_{j,r} (1+\tau_{j,r}) pz_{j,r}}{pqd_{j,r}} \right)^{-\alpha_j} (Z_{j,r} - QTS_r), \quad i = SRV, \forall r \\
 &= \left(\frac{\delta 1_{j,r}^{\frac{1+\alpha_j}{\alpha_j}} \delta 2_{j,r} (1+\tau_{j,r}) pz_{j,r}}{pqd_{j,r}} \right)^{-\alpha_j} Z_{j,r}, \quad i \neq SRV, \forall r
 \end{aligned}$$

$$\begin{aligned}
 QE_{j,r} &= \left(\frac{\delta 1_{j,r}^{\frac{1+\alpha_j}{\alpha_j}} (1-\delta 2_{j,r}) (1+\tau_{j,r}) pz_{j,r}}{pqe_{j,r}} \right)^{-\alpha_j} (Z_{j,r} - QTS_r), \quad i = SRV, \forall r \\
 &= \left(\frac{\delta 1_{j,r}^{\frac{1+\alpha_j}{\alpha_j}} (1-\delta 2_{j,r}) (1+\tau_{j,r}) pz_{j,r}}{pqe_{j,r}} \right)^{-\alpha_j} Z_{j,r}, \quad i \neq SRV, \forall r
 \end{aligned}$$

The CGE transformation structure between export destinations:

$$\begin{aligned}
 QE_{j,r} &= \gamma 1_{j,r} \left(\sum_s \gamma 2_{j,s,r} QT_{j,s,r}^{\frac{1+\sigma_j}{\sigma_j}} \right)^{\frac{\sigma_j}{1+\sigma_j}}, \quad \forall j, r \\
 QT_{j,s,r} &= \left(\frac{\gamma 1_{j,r}^{\frac{1+\sigma_j}{\sigma_j}} \gamma 2_{j,s,r} pqe_{j,r}}{pqt_{j,r}} \right)^{-\sigma_j} QE_{j,r}, \quad \forall j, s, r
 \end{aligned}$$

The CES value-added aggregation function and the derived factor demand functions:

$$Y_{j,r} = \beta 1_{j,r} \left(\sum_h \beta 2_{h,j,r} F_{h,j,r}^{\frac{\sigma_j-1}{\sigma_j}} \right)^{\frac{\sigma_j}{\sigma_j-1}}, \quad \forall j, r$$

$$F_{h,j,r} = \left(\frac{\beta 1_{j,r}^{\frac{\sigma_j-1}{\sigma_j}} \beta 2_{h,j,r} p y_{j,r}}{p f_{h,r}} \right)^{\sigma_j} Y_{j,r}, \quad \forall h, j, r$$

The intermediate goods demand functions and the zero-profit conditions derived from the

Leontief function:

$$X_{i,j,r} = a x_{i,j,r} Z_{j,r}, \quad \forall i, j, r$$

$$Y_{j,r} = a y_{j,r} Z_{j,r}, \quad \forall j, r$$

$$p z_{j,r} = \sum_i a x_{i,j,r} (1 + \tau_{i,j,r}) p q_{i,r} + a y_{j,r} p y_{j,r}, \quad \forall j, r$$

The final demand functions:

Household:

$$\begin{aligned} (1 + \tau_{j,HOH,r}) p q_{j,r} Q C_{j,HOH,r} &= \alpha_{j,r} \left(\sum_h p f_{h,r} F F_{h,r} + \sum_{i,s} T m_{i,s,r} + \sum_{i,s} T e_{i,r,s} \right. \\ &\quad \left. + \sum_i T z_{i,r} + \sum_{i,j} T x_{i,j,r} + \sum_{i,l} T c_{i,l,r} + Exch_{ROW,r} CAB_r \right. \\ &\quad \left. - \sum_{i,l2} (1 + \tau_{i,l2,r}) p q_{i,r} Q C_{i,l2,r} \right), \quad \forall j, r \end{aligned}$$

Government and investment:

$$Q C_{i,l2,r} = Q C_{i,l2,r}^0, \quad \forall i, l2, r$$

Taxes and freight:

Import tariffs:

$$T m_{i,r,s} = \tau m_{i,r,s} \left((1 + \tau_{i,r,s}) p q t_{i,r,s} Exch_{r,s} + \tau_{i,r,s} p q q t \cdot Exch_{ROM,s} Q T_{i,r,s} \right), \quad \forall i, r, s$$

Export taxes:

$$T e_{j,r,s} = \tau e_{j,r,s} p q t_{j,r,s} Q T_{j,r,s}, \quad \forall j, r, s$$

Indirect taxes on intermediate uses:

$$Tx_{i,j,r} = \tau_{i,j,r} pq_{i,r} X_{i,j,r}, \quad \forall i, j, r$$

Indirect taxes on final demand:

$$Tc_{i,l,r} = \tau_{i,l,r} pq_{i,r} QC_{i,l,r}, \quad \forall i, l, r$$

The BOP constraint:

$$\begin{aligned} & \sum_{i,r} (1 + \tau_{i,s,r}) Exch_{s,ROW} pq_{i,s,r} QT_{i,s,r} + CAB_s + (1 + \tau_{z,SRV,s}) Exch_{s,ROW} pz_{SRV,s} QTS_s \\ & = \sum_{i,r} (\tau_{i,r,s} pq_{i,r} \cdot Exch_{ROW,ROW} + (1 + \tau_{i,r,s}) Exch_{r,ROW} pq_{i,r,s}) QT_{i,r,s}, \quad \forall s \end{aligned}$$

Market-clearing conditions:

For commodities:

$$Q_{i,r} = \sum_j X_{i,j,r} + \sum_l QC_{i,l,r}, \quad \forall i, r$$

For factors:

$$FF_{h,r} = \sum_j F_{h,j,r}, \quad \forall h, r$$

The International transportation sector:

Generation of the total international trade service with inputs supplied by each region:

$$QQT = \rho \prod_r QTS_r^{\phi_r},$$

International trade service demand for each region:

$$QTS_s = \frac{\phi_s pq_{i,r}}{(1 + \tau_{z,SRV,s}) Exch_{s,ROW} pz_{SRV,s}} QQT, \quad \forall s$$

The Market-clearing condition of the international transportation services:

$$QQT = \sum_{i,r,s} \tau_{i,r,s} QT_{i,r,s},$$

The arbitrage condition on foreign exchange:

$$Exch_{r,s} = Exch_{r,rr} Exch_{rr,s}.$$

Notations are:

[Indices]

i, j, jj : goods (=AGR, ENG, MIN, TXA, LMN, CHM, NMM, MAN, SRV),

s, r, rr : regions (=JOR, E_U, ROW),

h : factors (=LND, LAB, CAP),

l : agents (=HOH, GOV, INV),

$l2$: the subset of l (=GOV, INV).

[Endogenous variables]

$Tm_{i,r,s}$: the amount of import tariffs on the i -th good imports from the r -th region to the s -th region,

$Te_{i,r,s}$: the amount of export taxes on the i -th good exports from the r -th region to the s -th region,

$Tz_{j,r}$: the amount of indirect taxes on the j -th good domestic production in the r -th

region,

$Tx_{i,j,r}$: the amount of indirect taxes on intermediate uses of the i -th good by the j -th sector in the r -th region,

$Tc_{i,l,r}$: the amount of indirect taxes on final uses of the i -th good by the l -th final users in the r -th region,

$QT_{i,r,s}$: transportation of the i -th good from the r -th region to the s -th region (including that from the r -th region to itself),

$QM_{j,r}$: composite imports of the j -th good in the r -th region,

$QE_{j,r}$: composite exports of the j -th good in the r -th region,

$QD_{j,r}$: the j -th domestic good in the r -th region,

$Q_{i,r}$: the i -th Armington's composite good in the r -th region,

$Z_{j,r}$: domestic output of the j -th good in the r -th region,

$F_{h,j,r}$: uses of the h -th factor by the j -th sector in the r -th region,

$Y_{j,r}$: uses of composite factor (i.e., value added) by the j -th sector in the r -th region,

$X_{i,j,r}$: uses of the i -th intermediate inputs by the j -th sector in the r -th region,

$QC_{i,l,r}$: final demand of the i -th good by the l -th agent in the r -th region,

QTS_r : exports of international transportation services by the r -th region,

QQT : aggregate international transportation services,

$pqt_{i,r,s}$: price of $QT_{i,r,s}$,

$pqm_{j,r}$: price of $QM_{j,r}$,

$pqe_{j,r}$: price of $QE_{j,r}$,

$pqd_{j,r}$: price of $QD_{j,r}$,

$pq_{i,r}$: price of $Q_{i,r}$ (and $QC_{i,l,r}$, $X_{i,j,r}$),

$pz_{j,r}$: price of $Z_{j,r}$

$pf_{h,r}$: price of $F_{h,j,r}$,

Note 1: which is common among sectors due to mobility of factors across sectors,

Note 2: $pf_{LAB,r}$ are set at unity as a numéraire,

$py_{j,r}$: price of $Y_{j,r}$,

$pqqt$: price of QQT ,

$Exch_{r,s}$: exchange rate which convert the r-th region's currency to that of the s-th region.

[Exogenous variables and key parameters]

$\tau m_{i,r,s}$: the import tariff rate for the i-th good imports from the r-th region to the s-th region,

$\tau e_{i,r,s}$: the export tax rate for the i-th good exports from the r-th region to the s-th region,

$\tau z_{j,r}$: the indirect tax rate for the j-th good domestic production in the r-th region,

- $\tau_{i,j,r}$: the indirect tax rate for uses of the i -th good by the j -th sector in the r -th region,
- $\tau_{i,l,r}$: the indirect tax rate for uses of the i -th good by the l -th final users in the r -th region,
- $\tau_{i,r,s}$: coefficients of international transportation service requirement of the i -th good shipped from the r -th region to the s -th region,
- CAB_r : the current account balance in the r -th region,
- $QC_{i,l,r}^0$: the initial value of $QC_{i,l,r}$
- $FF_{h,r}$: the h -th factor endowment in the r -th region,
- σ_j : elasticity of substitution among factors,
- σd_j : elasticity of substitution/transformation between composite imports/exports and domestic goods,
- σm_j : elasticity of substitution/transformation among import sources/export destinations,

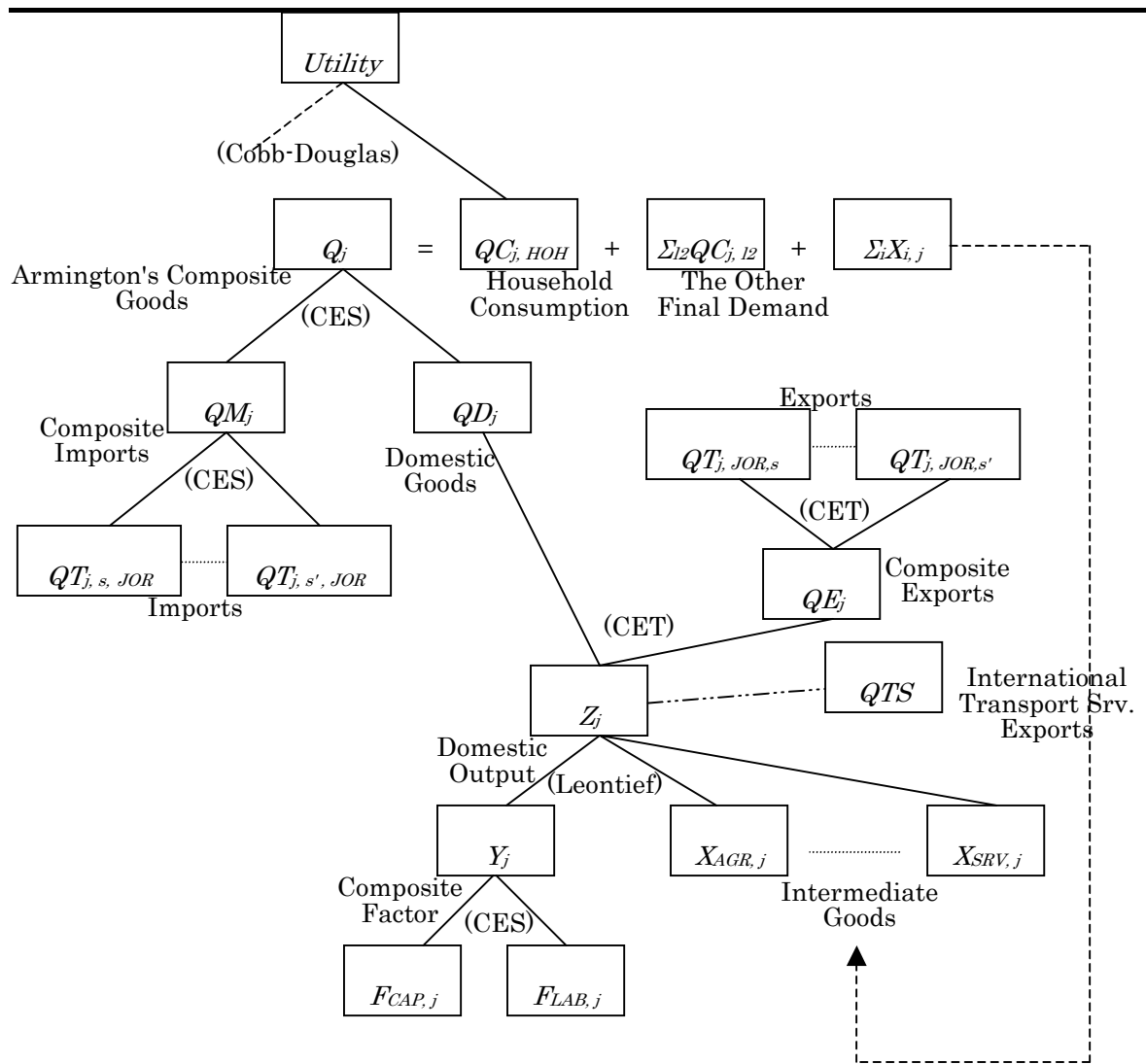
and the other Greek letters are coefficients.

Table: Elasticity Values

	sigma-d	sigma-m	sigma-v
AGR	2.2	4.4	0.56
ENG	2.8	5.6	1.12
MIN	2.8	5.6	1.12
TXA	3.3	6.6	1.26
LMN	2.2	4.4	1.12
CHM	1.9	3.8	1.26
NMM	2.8	5.6	1.26
MAN	2.8	5.6	1.26
SRV	1.9	3.8	1.26

Source: compiled from GTAP version 3.

Figure: The flowchart of commodities
(for the case of Jordan)



note: "Utility", at the top of the figure, represents utility of the household in each region.