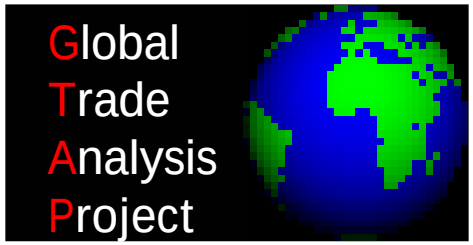
CGE approaches to modeling energy-economy-environment interactions



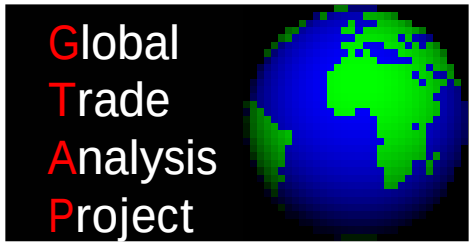
Energy-economy-environment interactions

GTAP

GTAP-E

GTAP-EL

GTAP-ELT

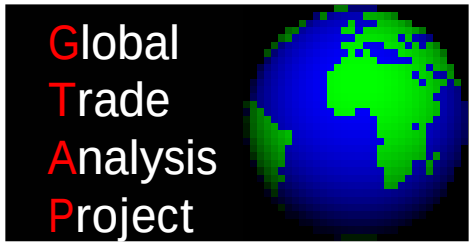


GTAP

http://www.gtap.agecon.purdue.edu/

Global Trade Analysis Project

Purdue University West Lafayette Indiana



GTAP databases

Input-output data bases from over 80 regions

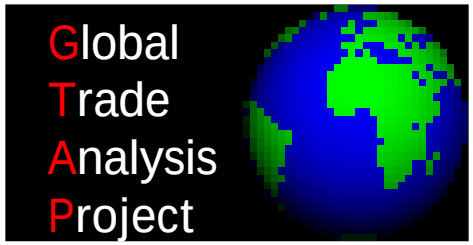
and over 50 sectors

Balanced bilateral trade flow data

Tariff data

Energy flow data

Emission data

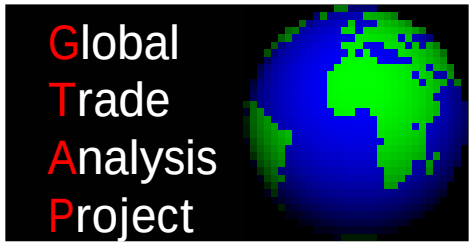


GTAP Model

Multi-sectoral Multi-regional
Computable General Equilibrium (CGE) Model

Used mainly for international Trade Analysis

Issues such as Tariff negotiations



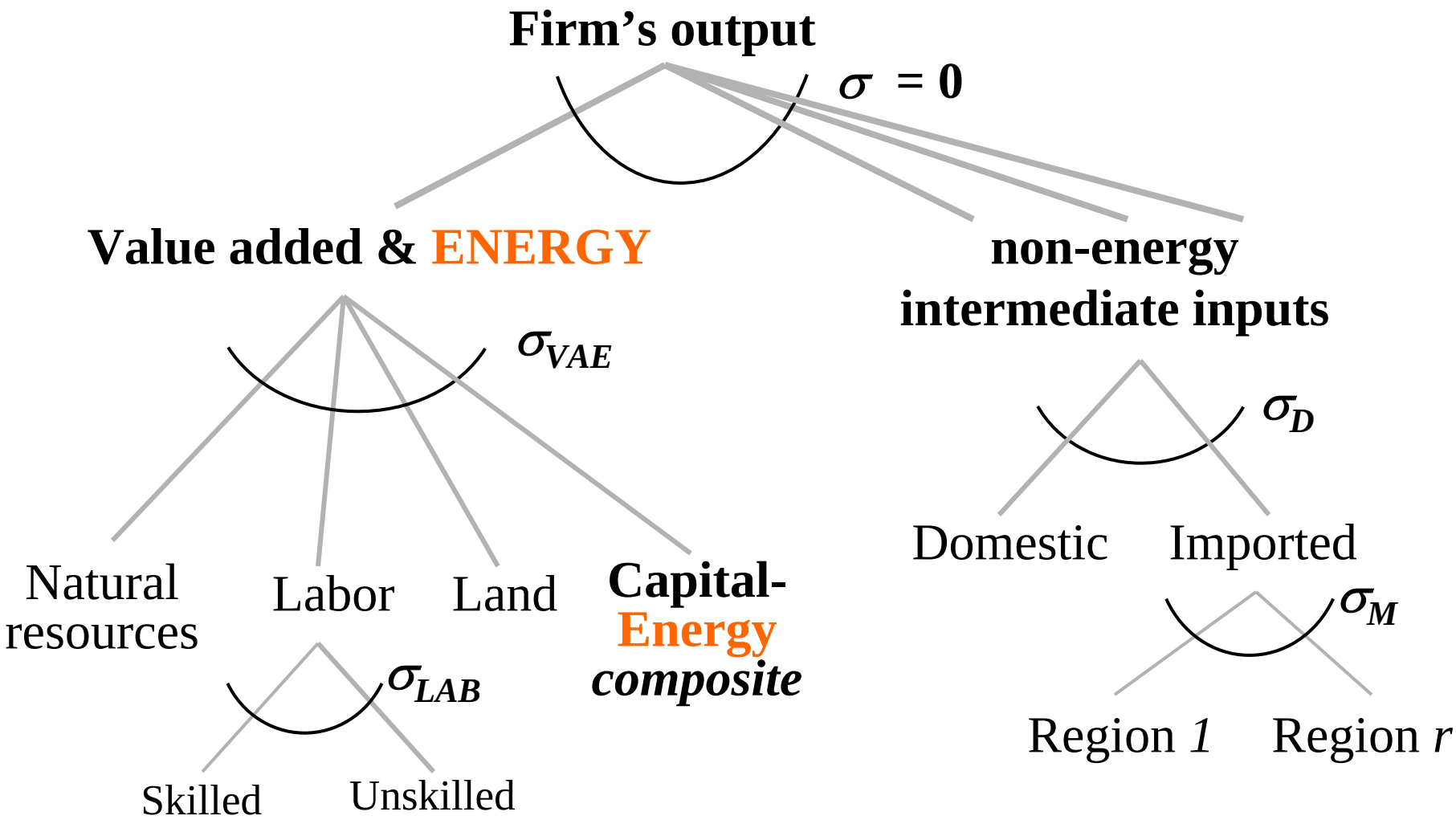
GTAP

GTAP has a ‘top-down’ structure for energy production / consumption

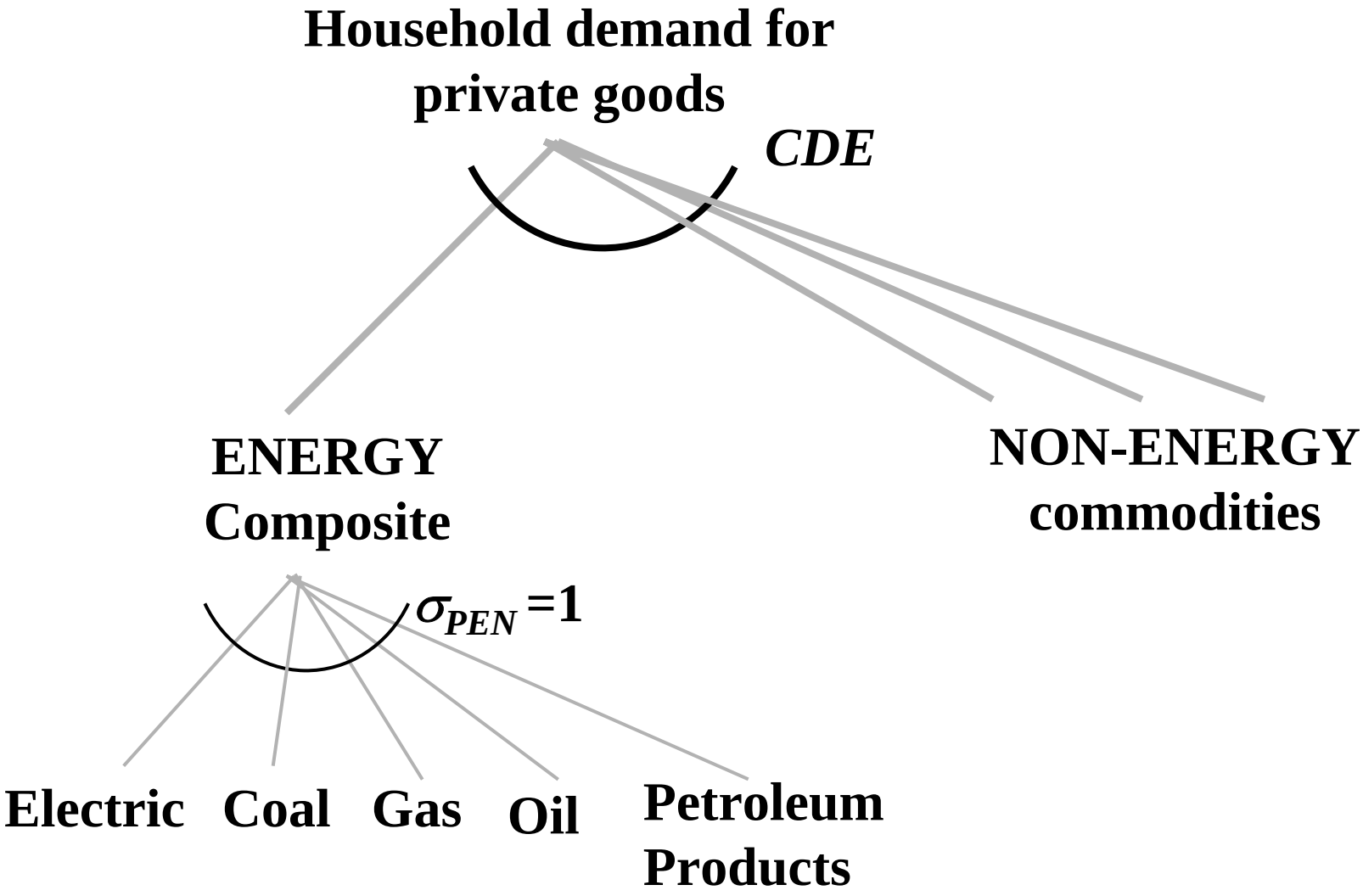
- no energy substitution in production
- some limited scope for energy substitution in consumption

GTAP-E Model

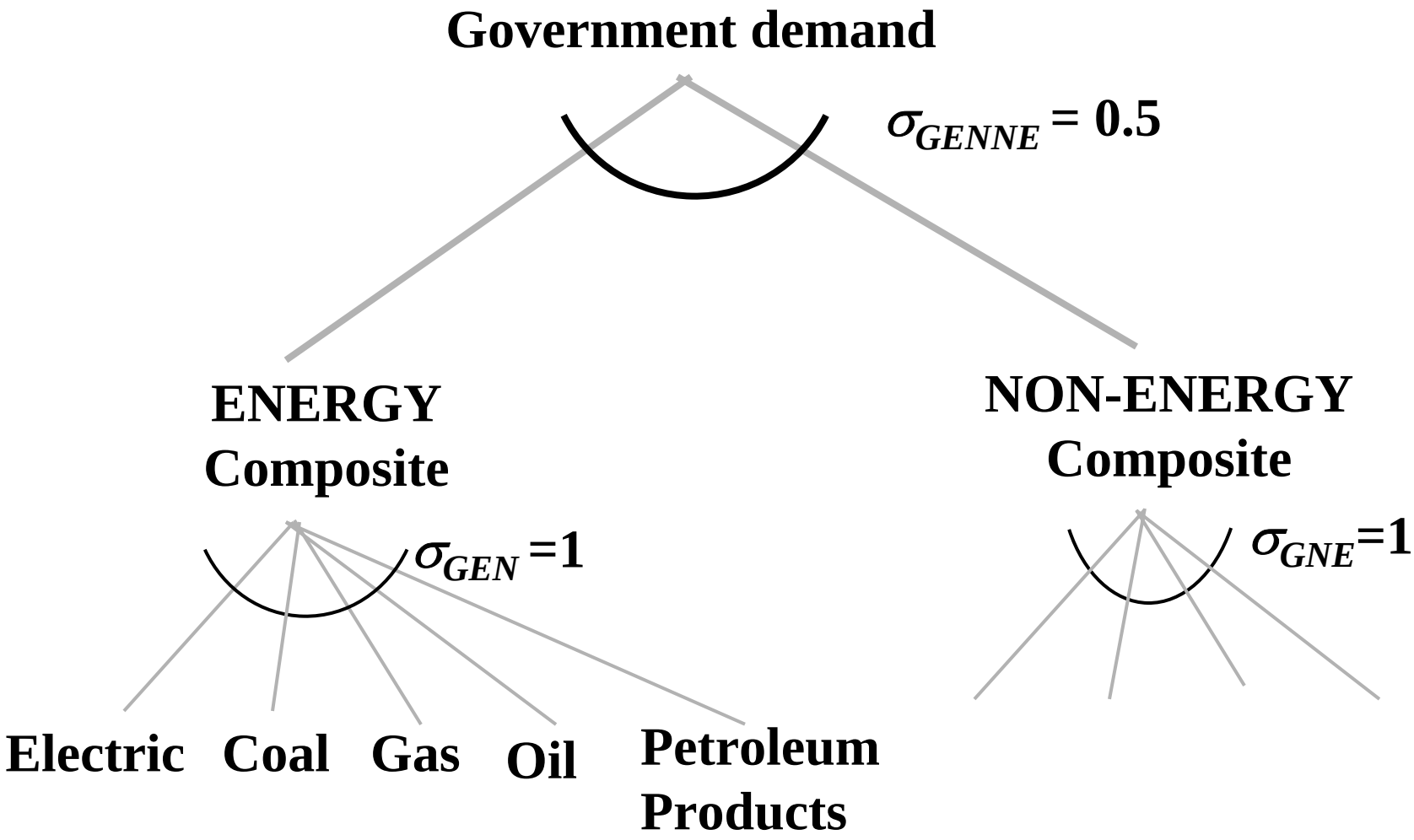
GTAP-E production structure



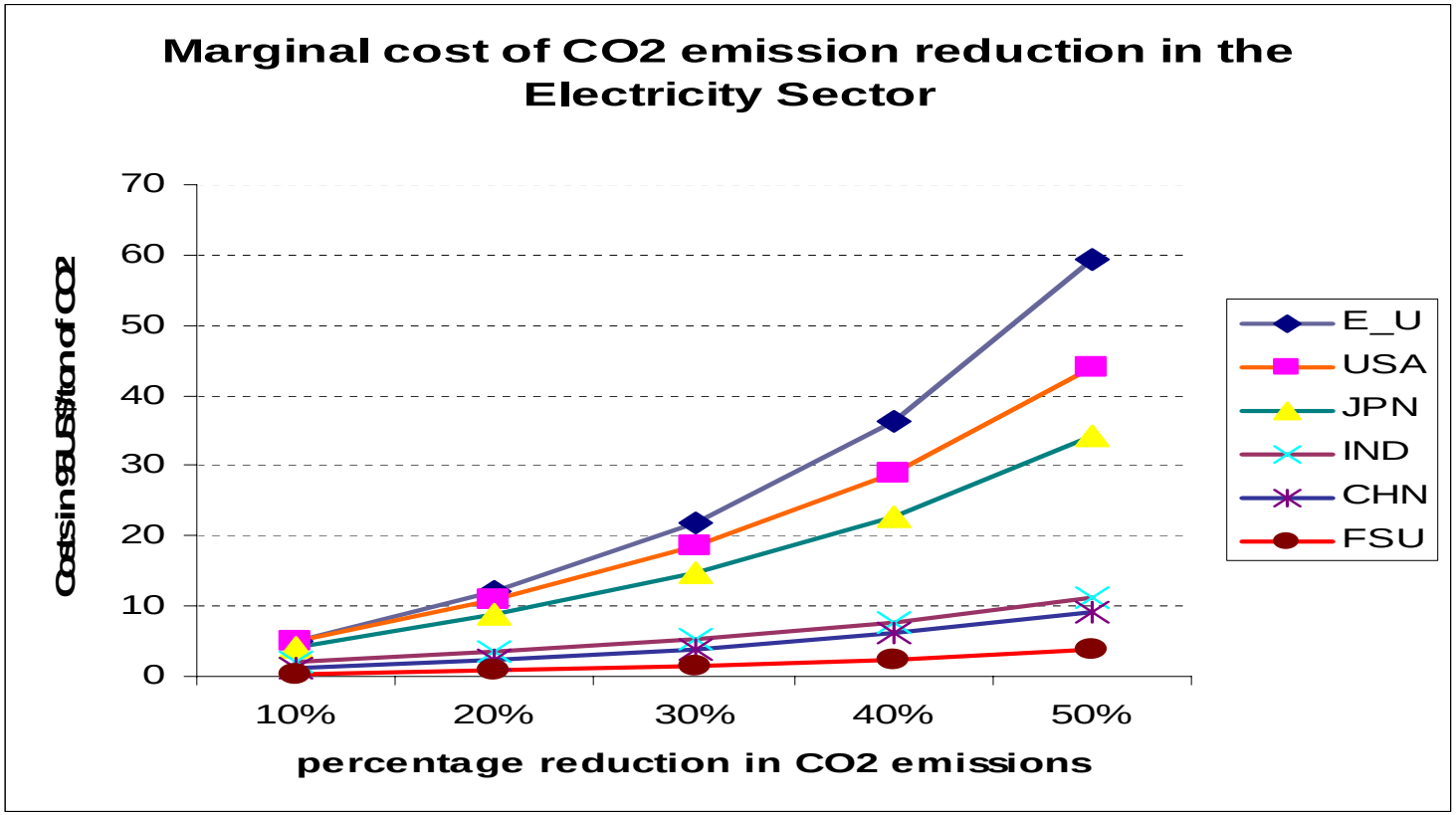
GTAP-E: private consumption



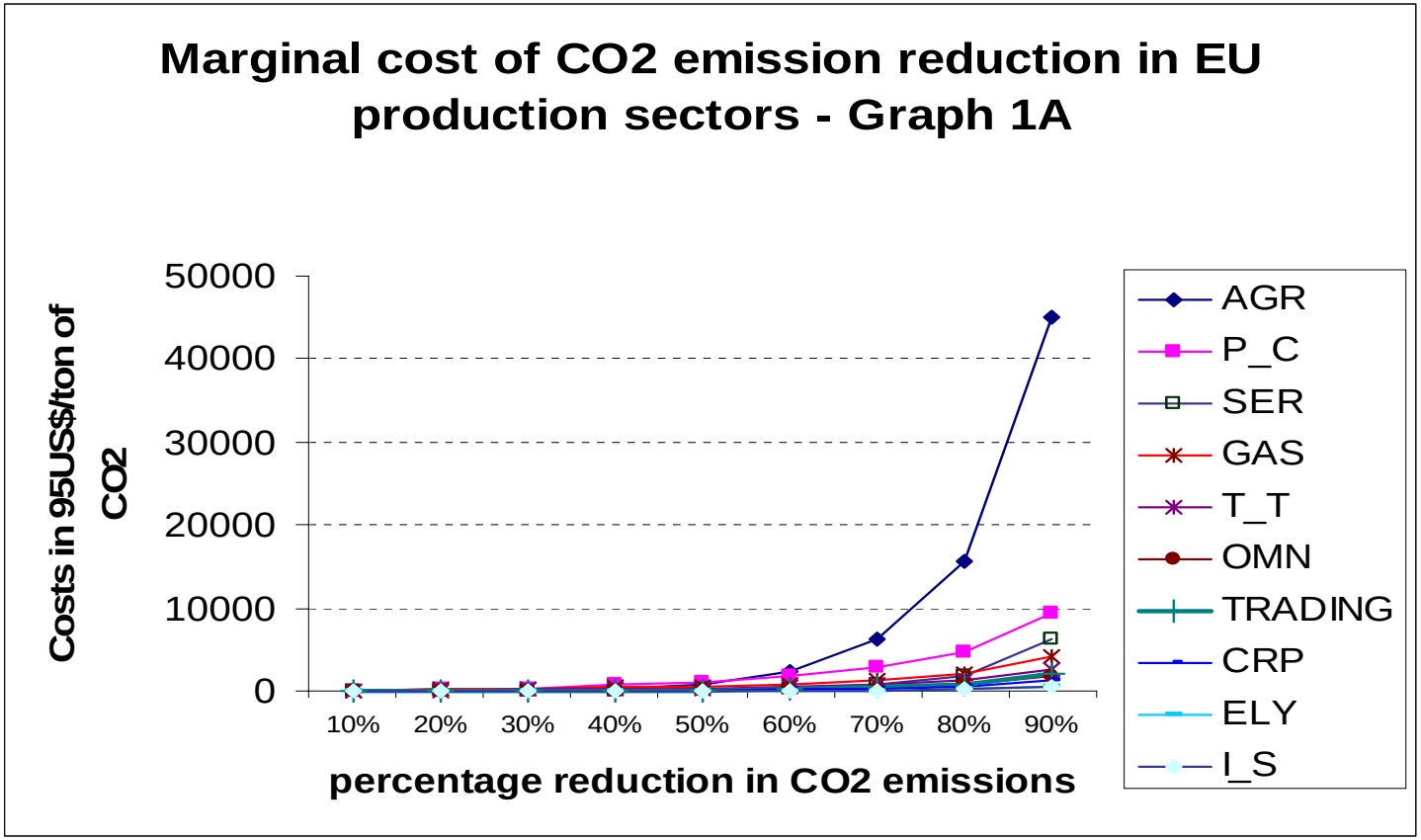
GTAP-E: public consumption



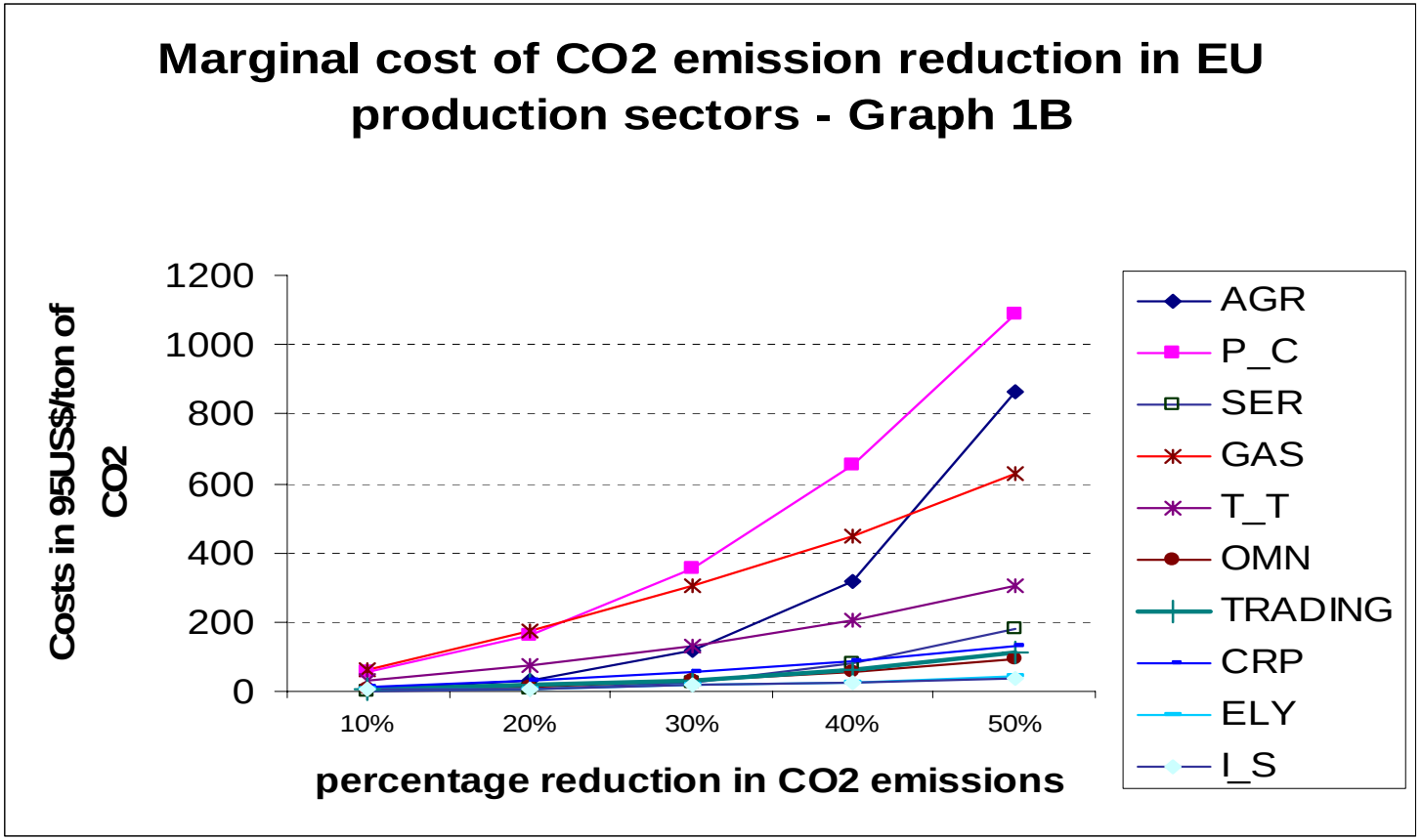
CO_2 Tax in Different Regions



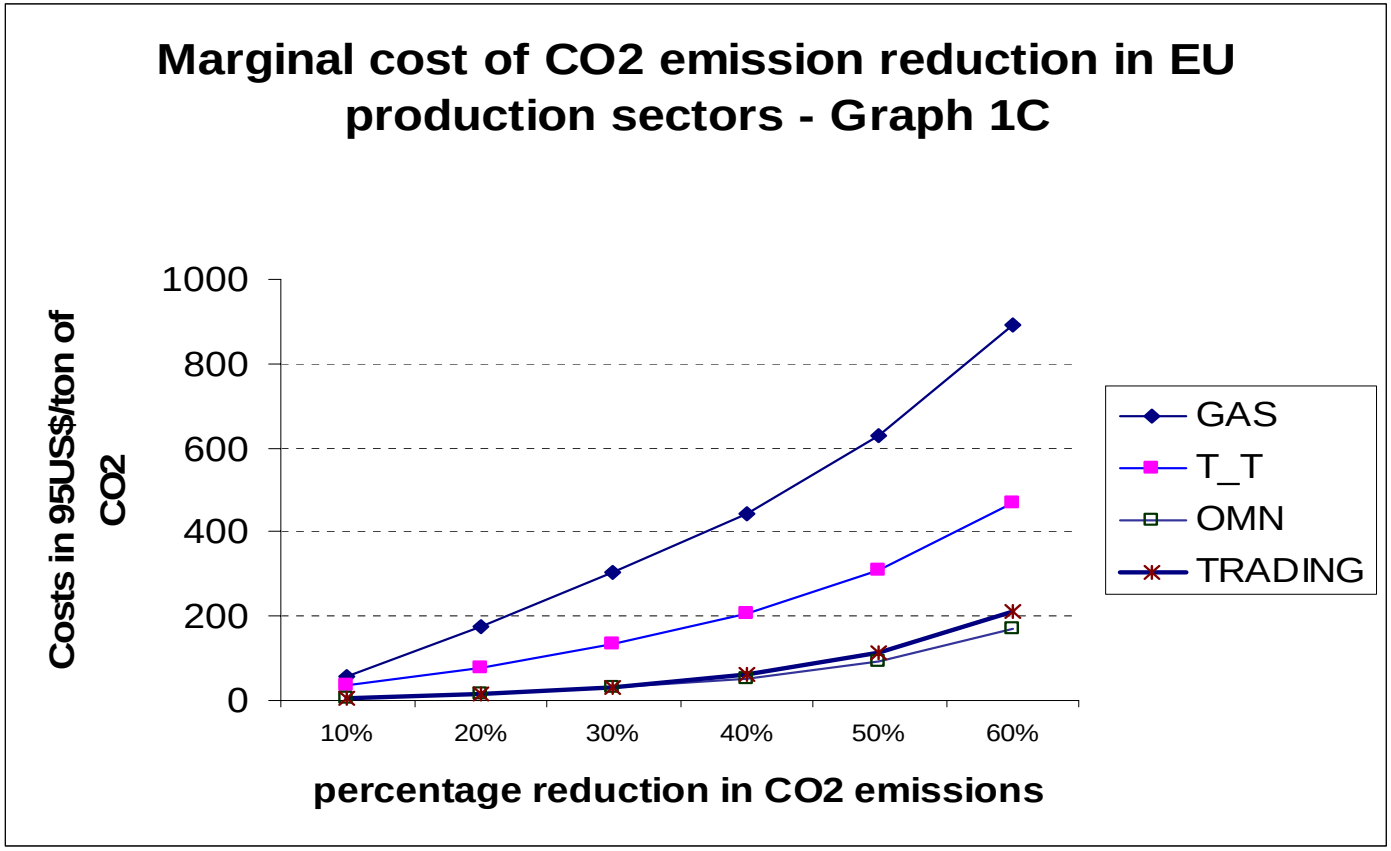
CO_2 Tax in Different Sectors



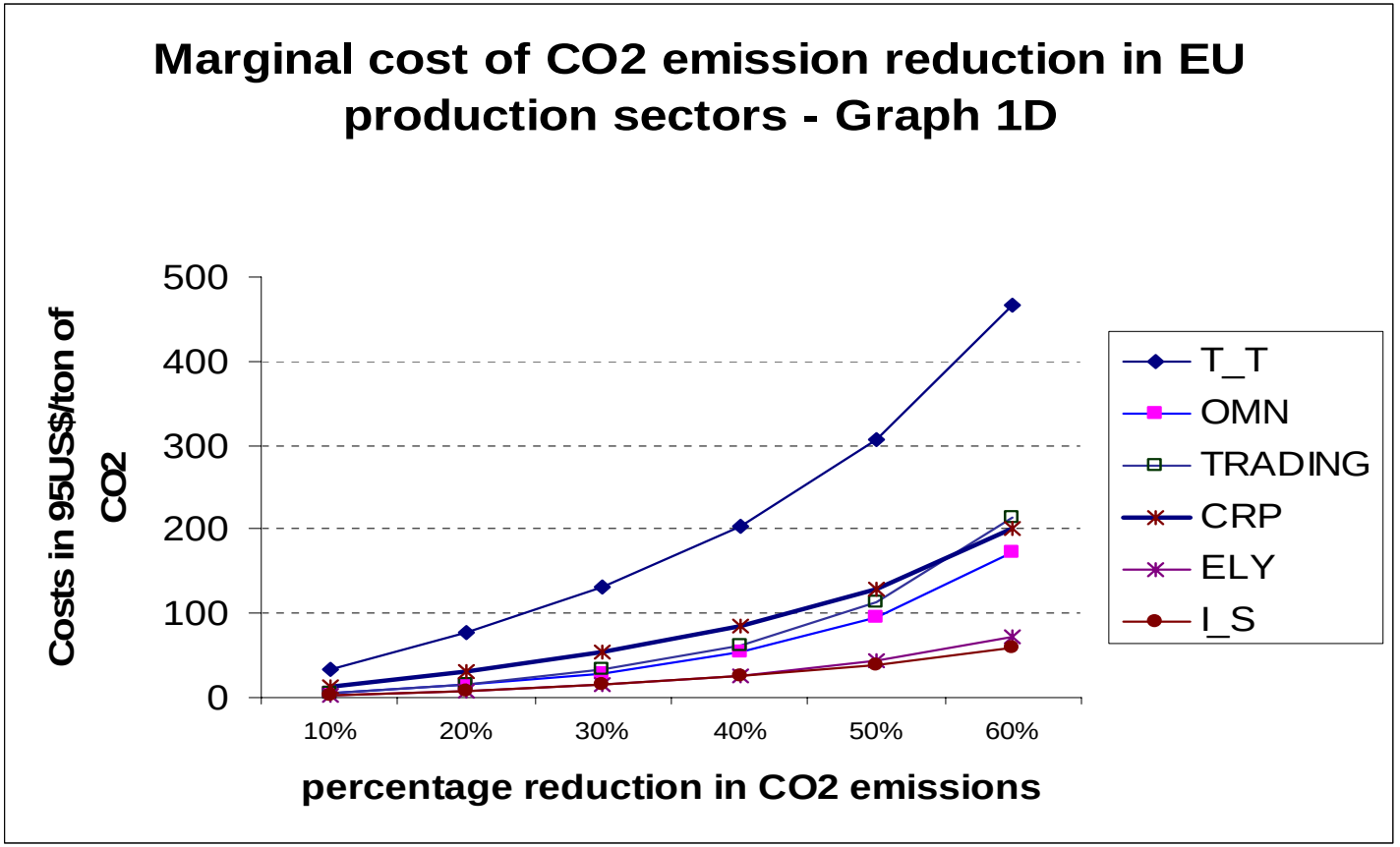
CO_2 Tax in Different Sectors (ctd.)



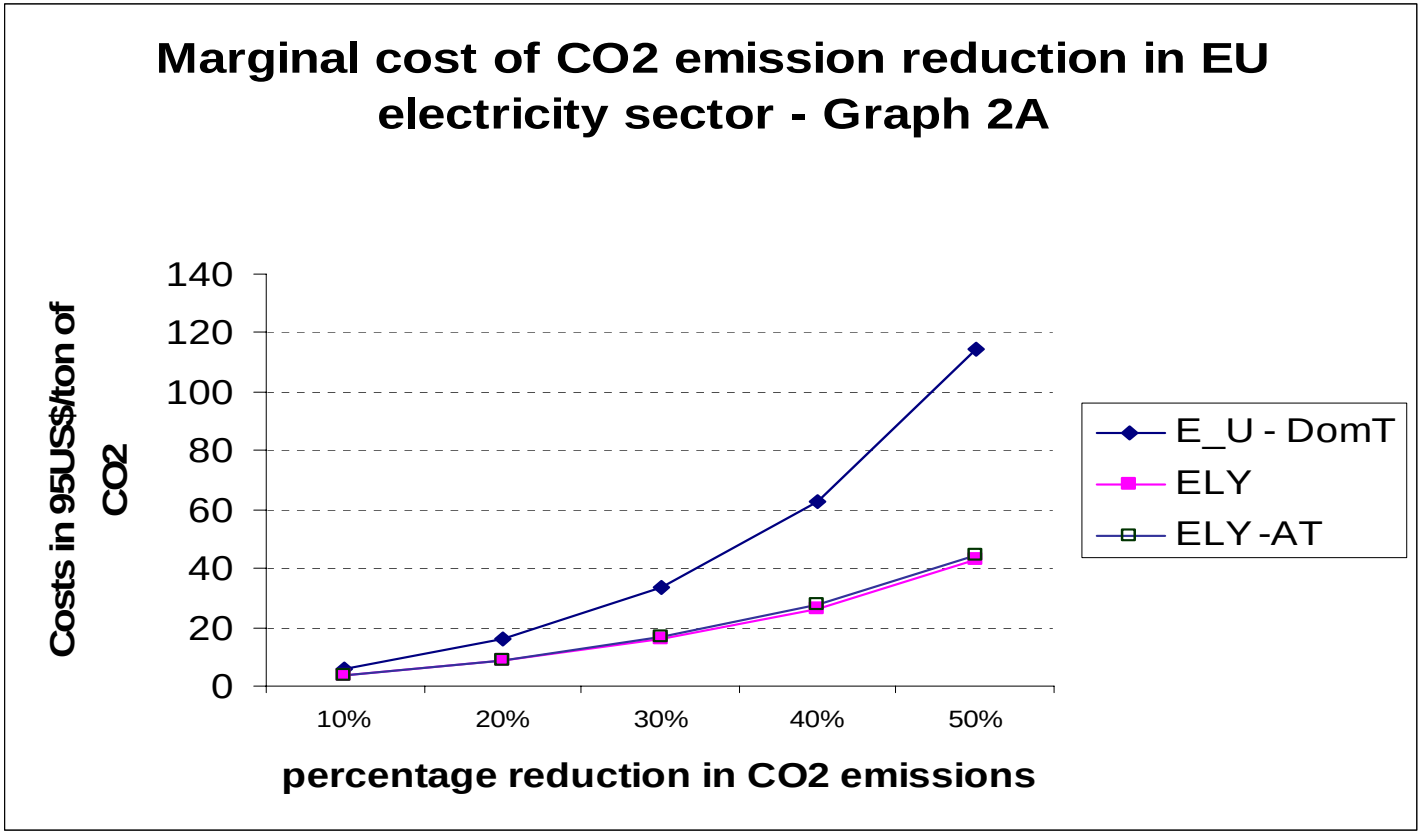
CO_2 Tax in Different Sectors - with and without trading



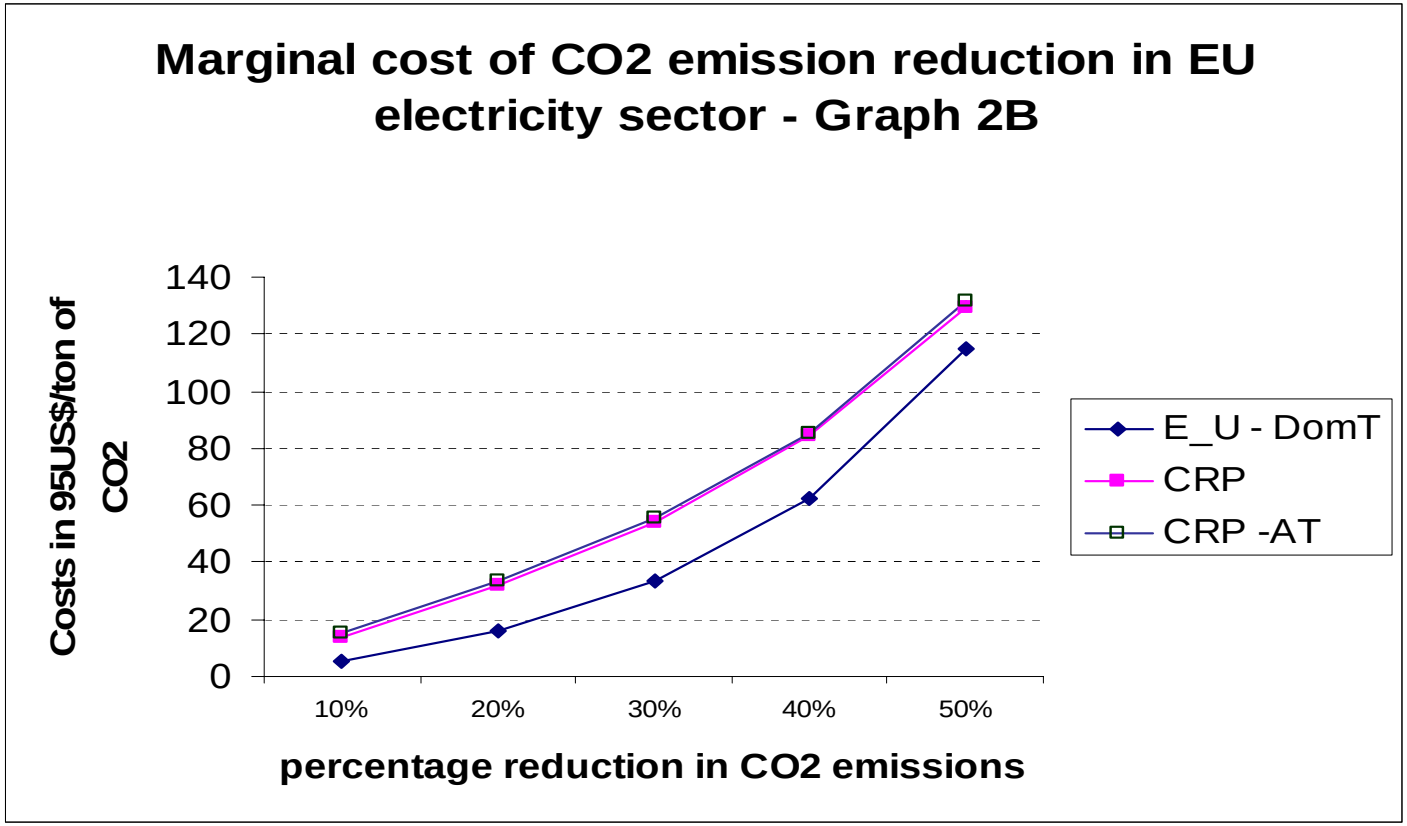
CO_2 Tax in Different Sectors - with and without trading (ctd.)



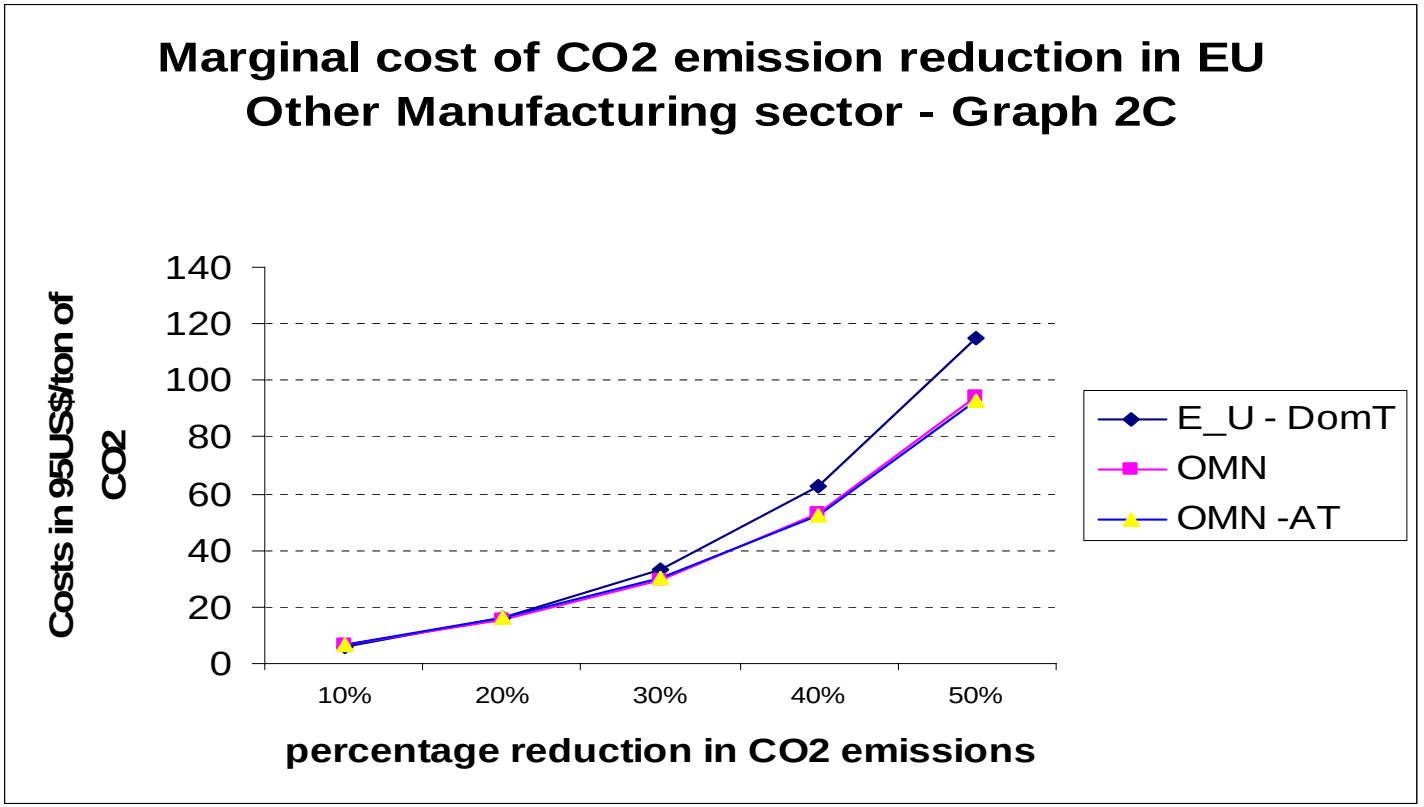
CO_2 Tax in Different Sectors - GE effects across regions



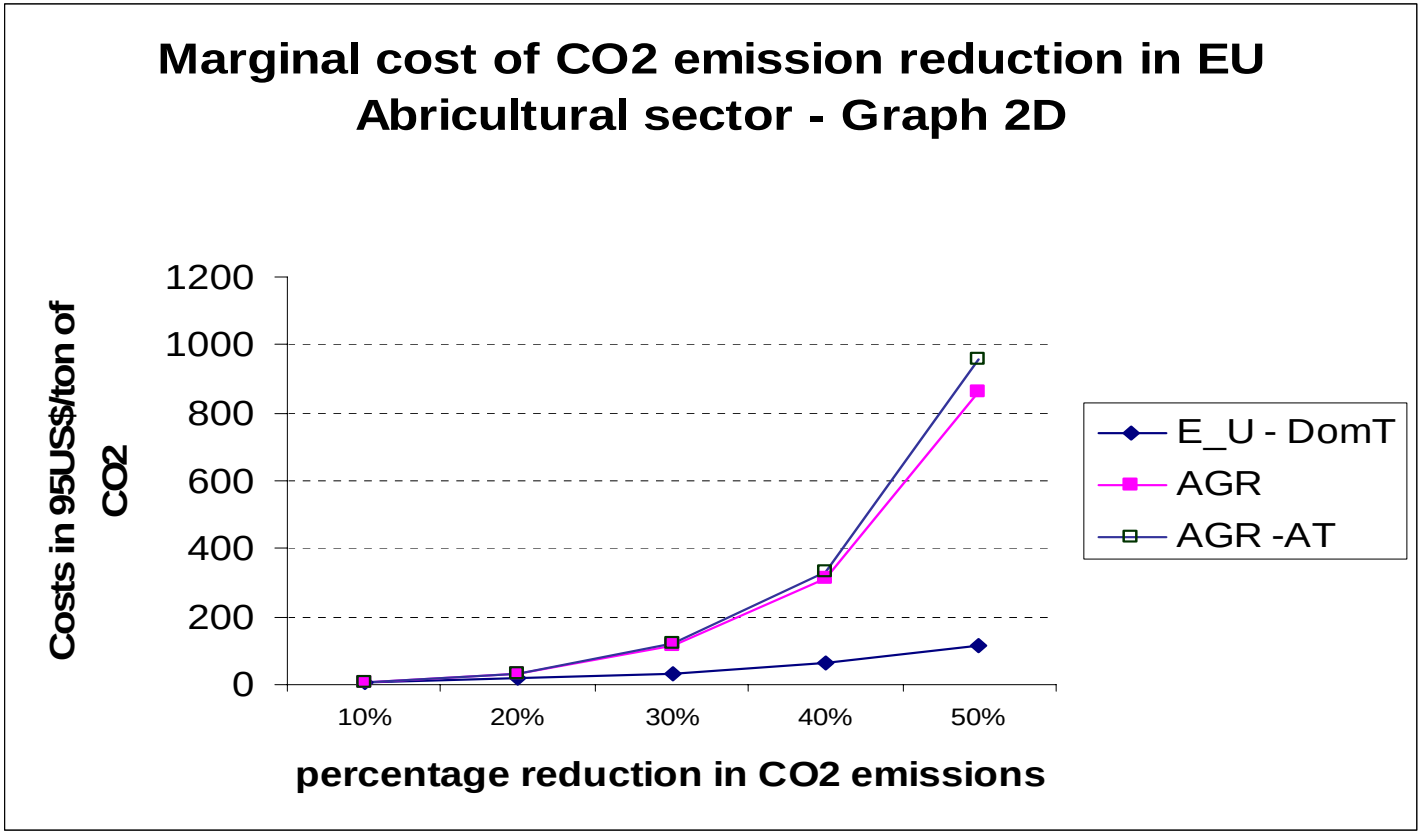
CO_2 Tax in Different Sectors - GE effects across regions (ctd.)



CO_2 Tax in Different Sectors - GE effects across regions (ctd.)



CO_2 Tax in Different Sectors - GE effects across regions (ctd.)



Energy modeling (ctd.)

Top-down approach is:

- *rich* in macroeconomic, sectoral, and international trade details
- *but* highly *aggregate* in energy demand / supply function specifications

Energy modeling (ctd.)

Bottom-up approach is:

- *lacking* in macroeconomic, sectoral, and international trade details,
- but *rich* in energy technology description

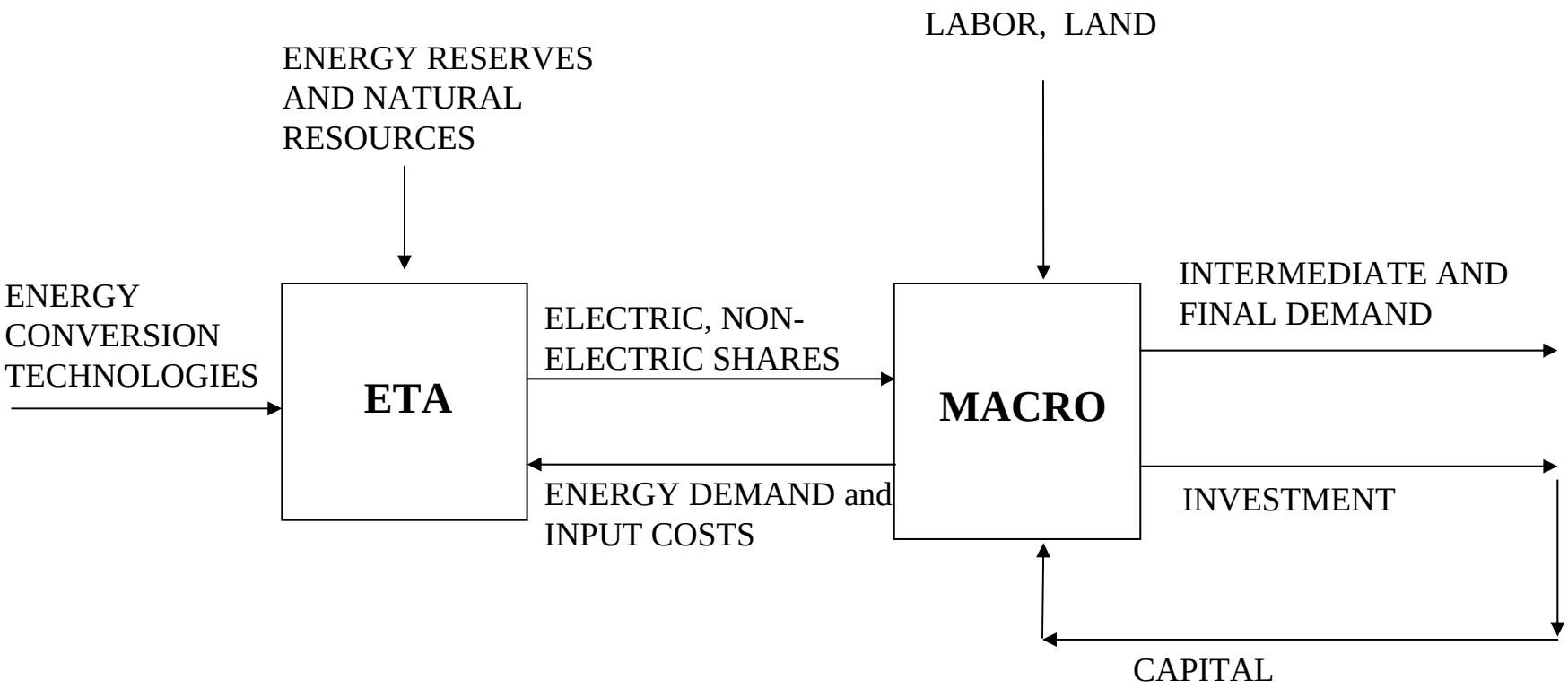
Energy modeling (ctd.)

we look at 2 models:

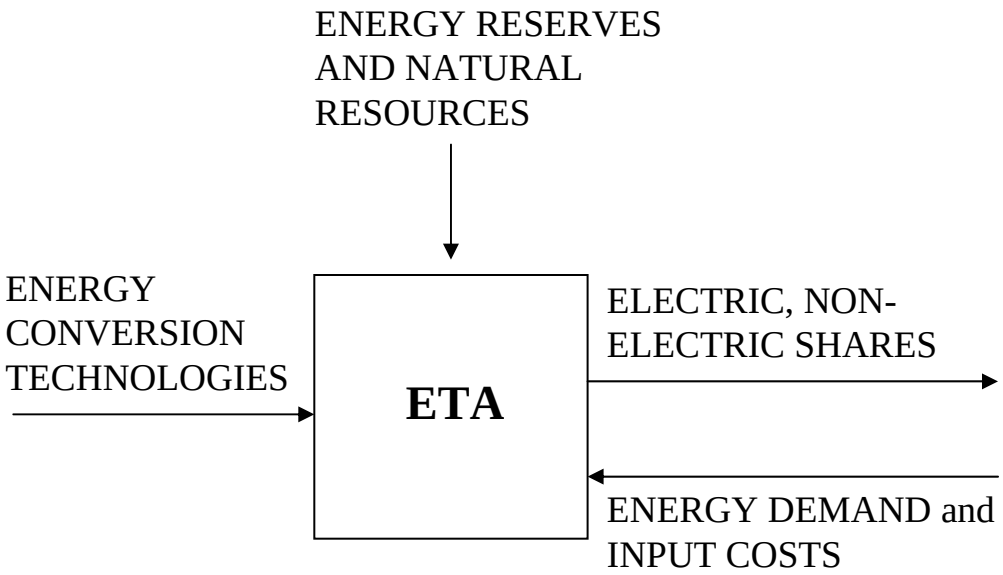
- CETM (USA, Rutherford et al.)
- GREEN (OECD, Burniaux et al.)

CETM model

hybrid: a bottom-up model (ETA) linked to a top-down model (MACRO)



CETM model (ctd.)



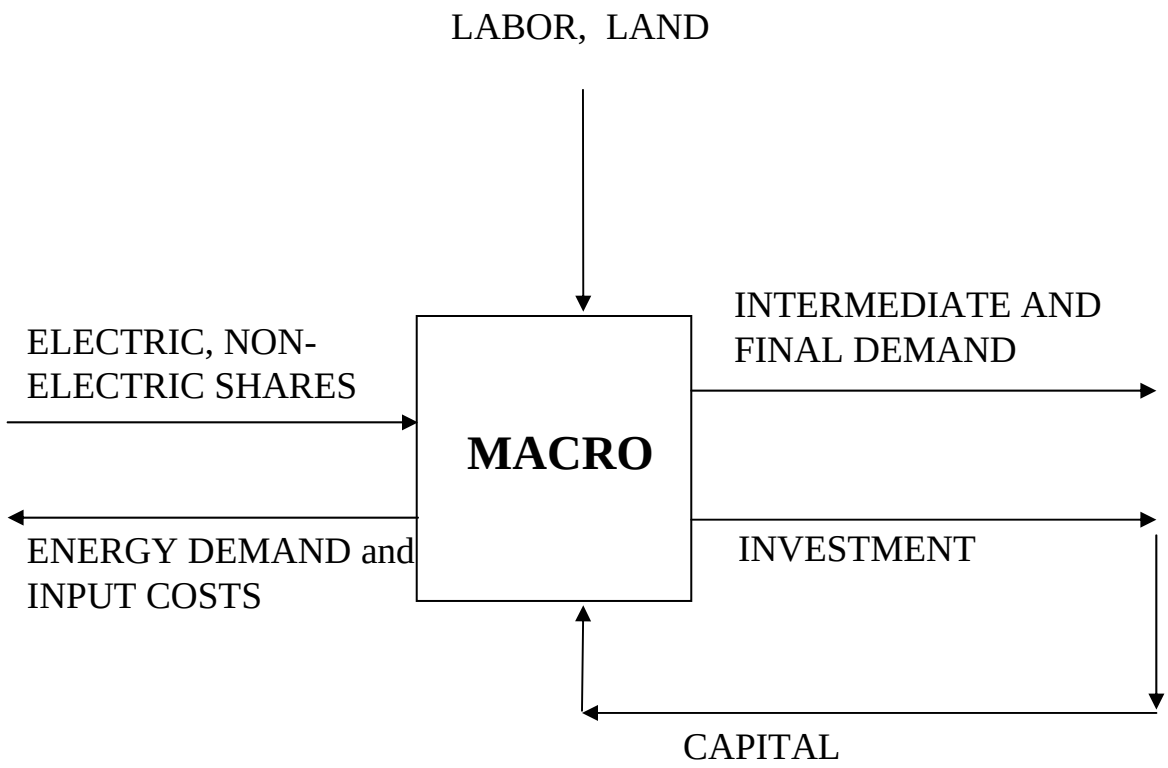
(ETA) is a 'process' model,

partial equilibrium,

but rich in technology description

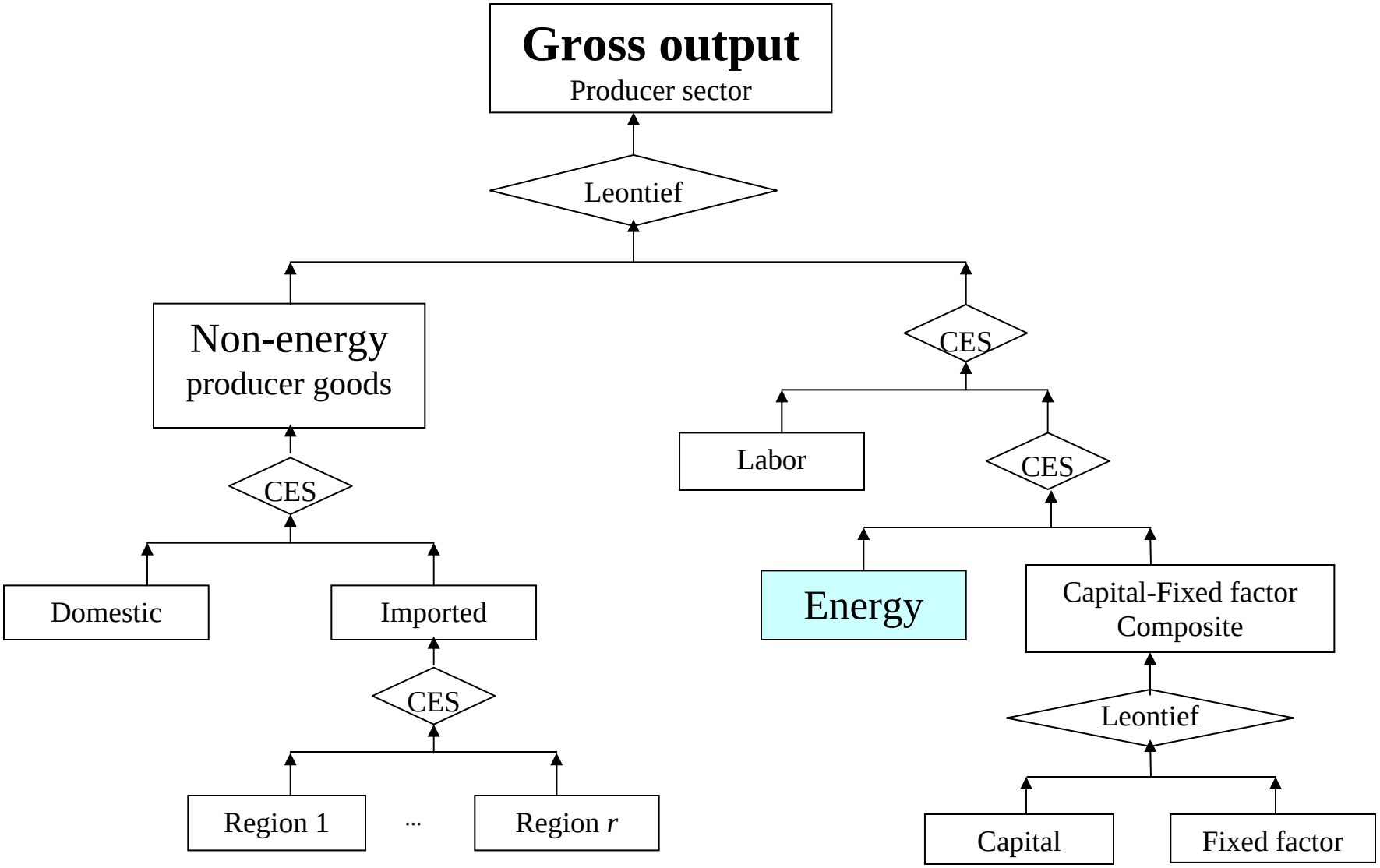
CETM model (ctd.)

MACRO is a CGE model with details about sectoral distribution and international trade

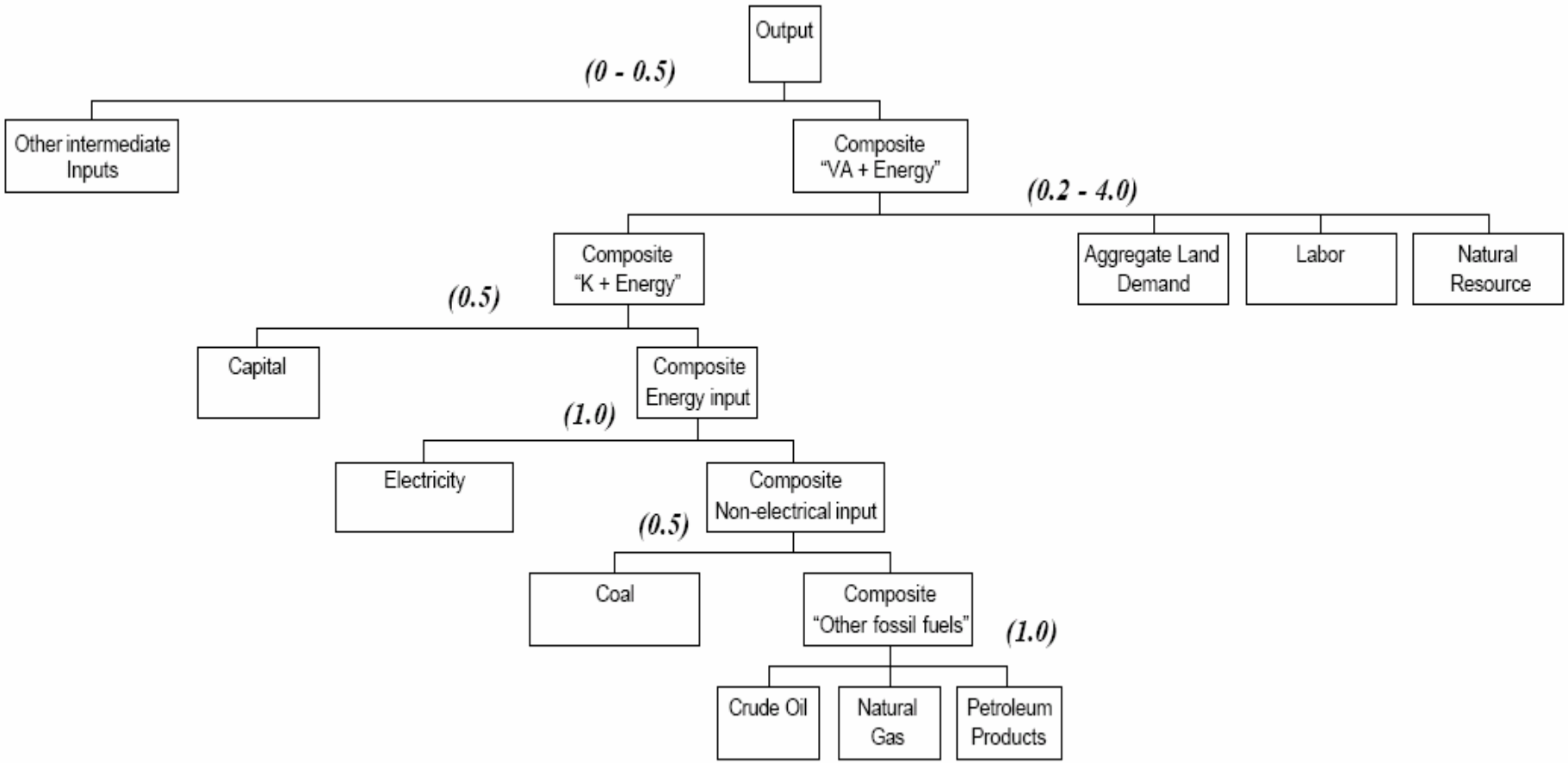


GREEN model

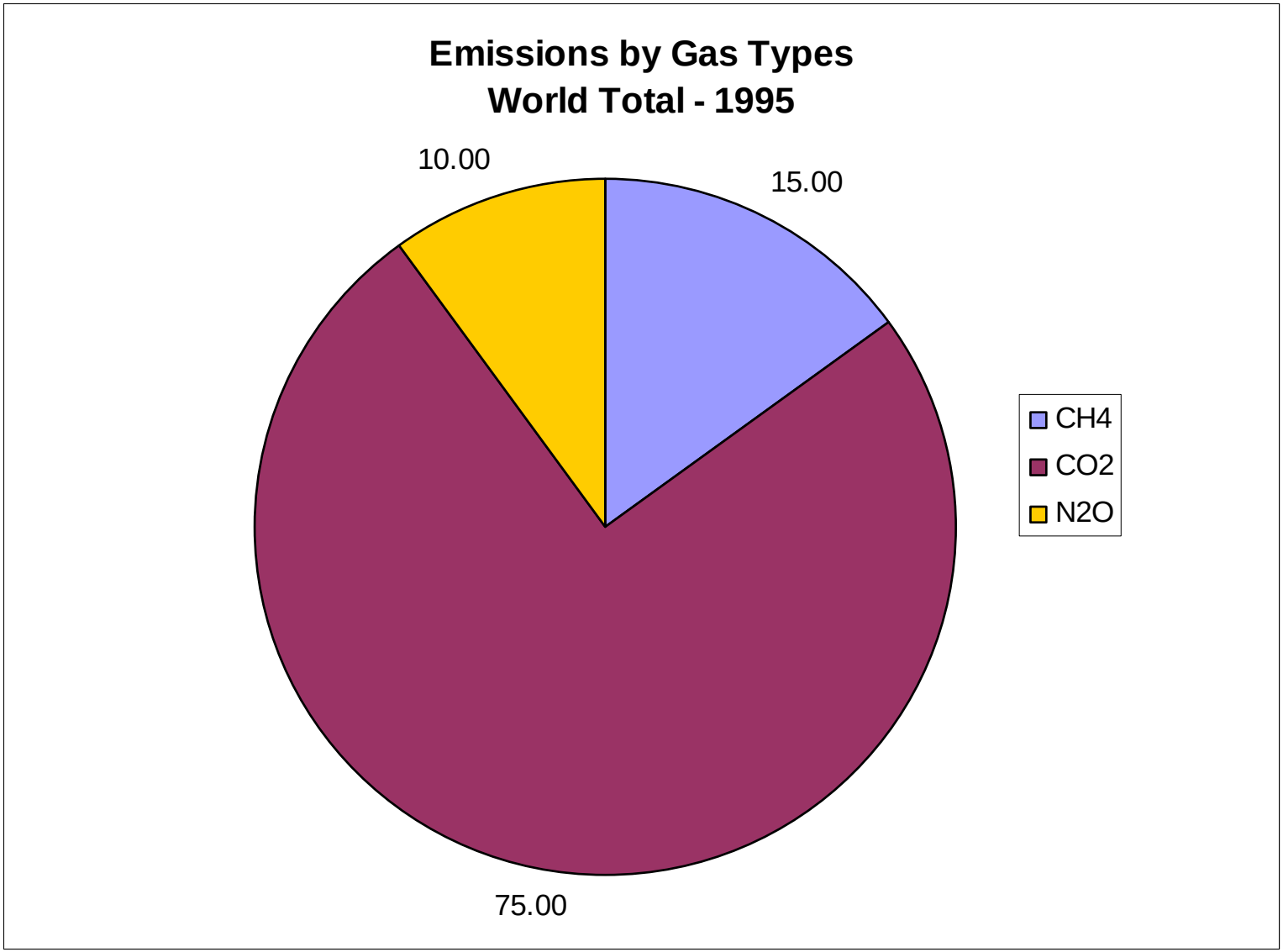
Production structure

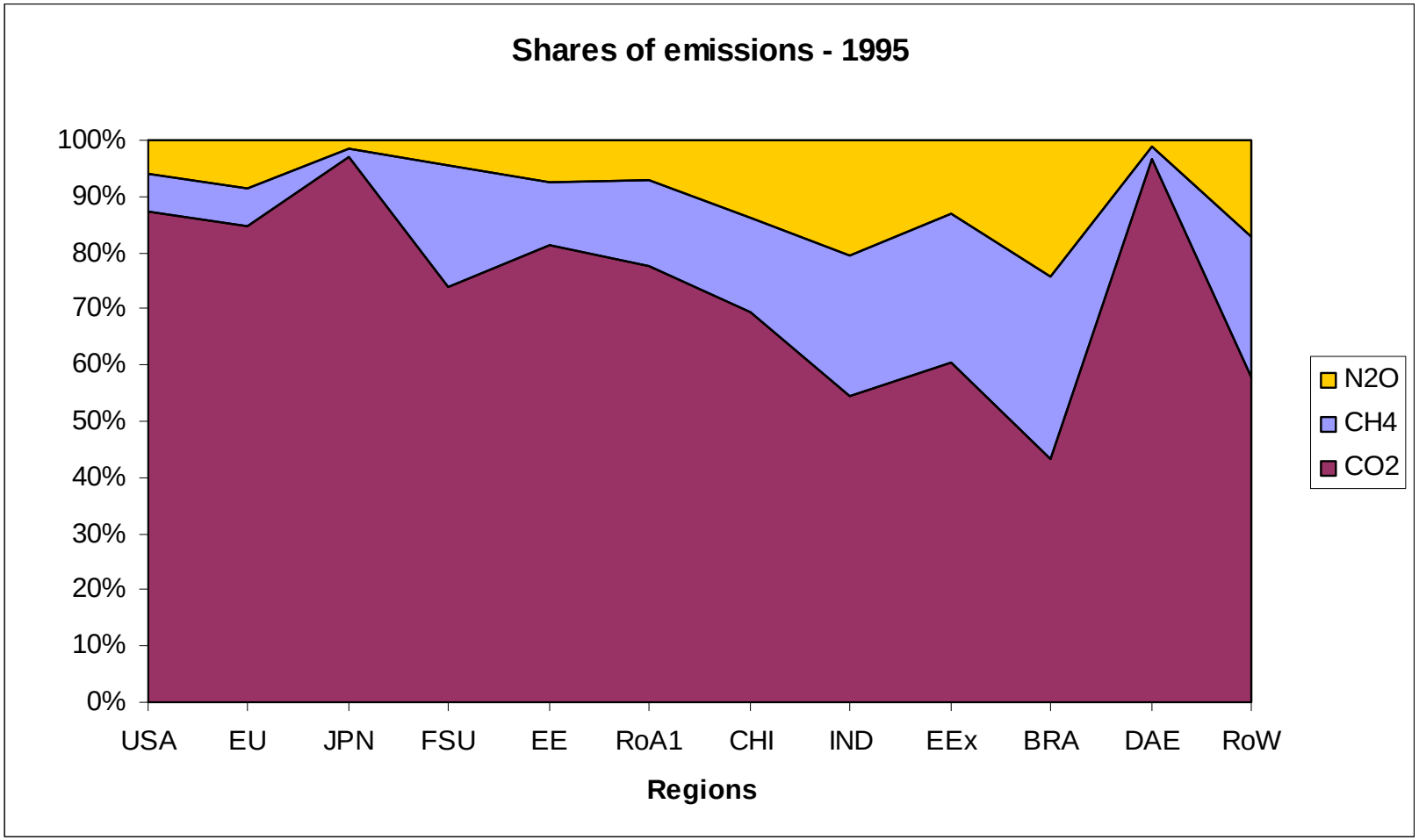


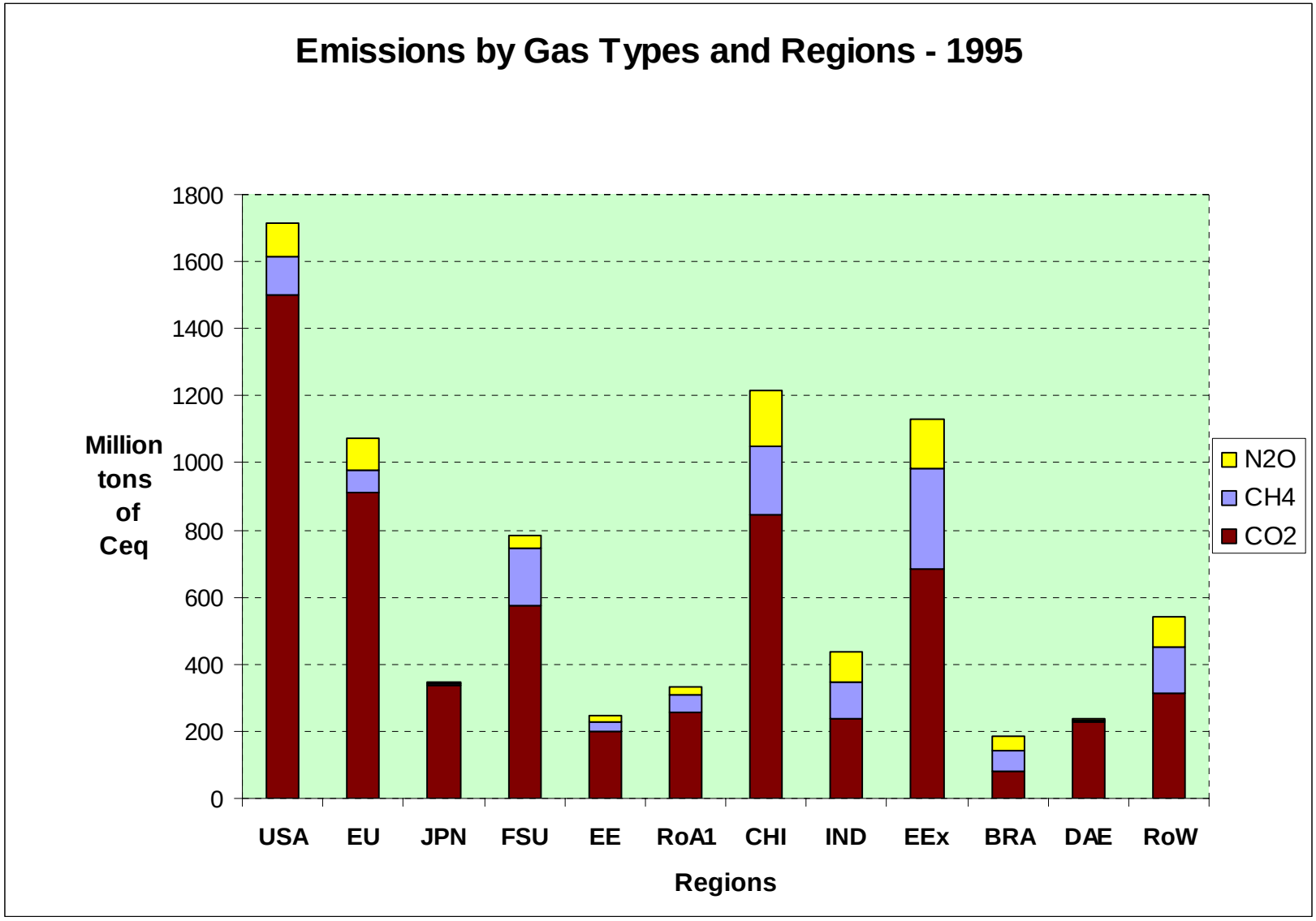
GTAP-EL:
Modelling Non-CO2 Gas Abatement and Land Use Changes in a CGE Model

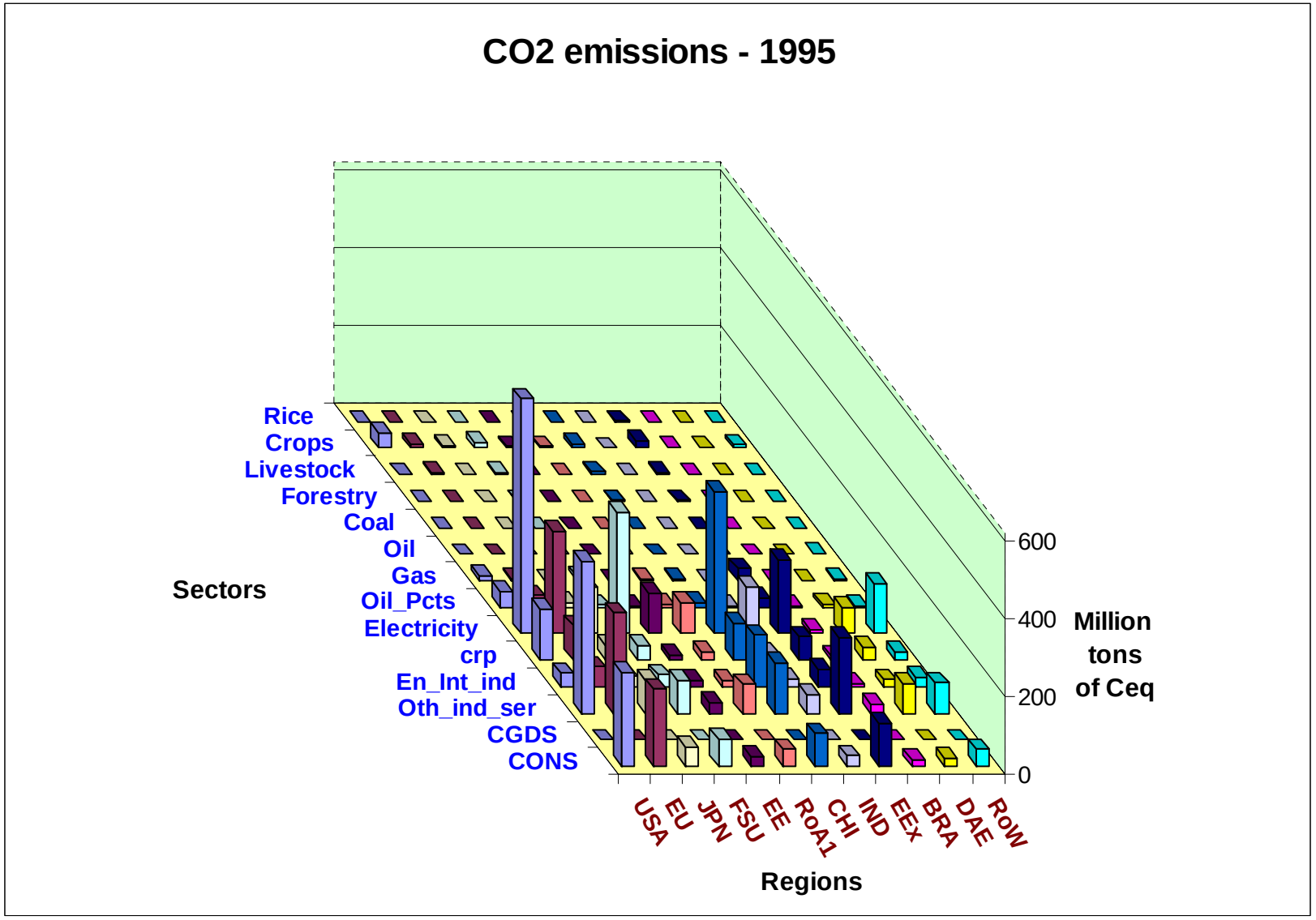

Output
(0 - 0.5)
Other intermediate Inputs
Composite "VA + Energy"
(0.2 - 4.0)
Composite "K + Energy"
Aggregate Land Demand
Labor
Natural Resource
(0.5)
Capital
Composite Energy input
(1.0)
Electricity
Composite Non-electrical input
(0.5)
Coal
Composite "Other fossil fuels"
(1.0)
Crude Oil
Natural Gas
Petroleum Products

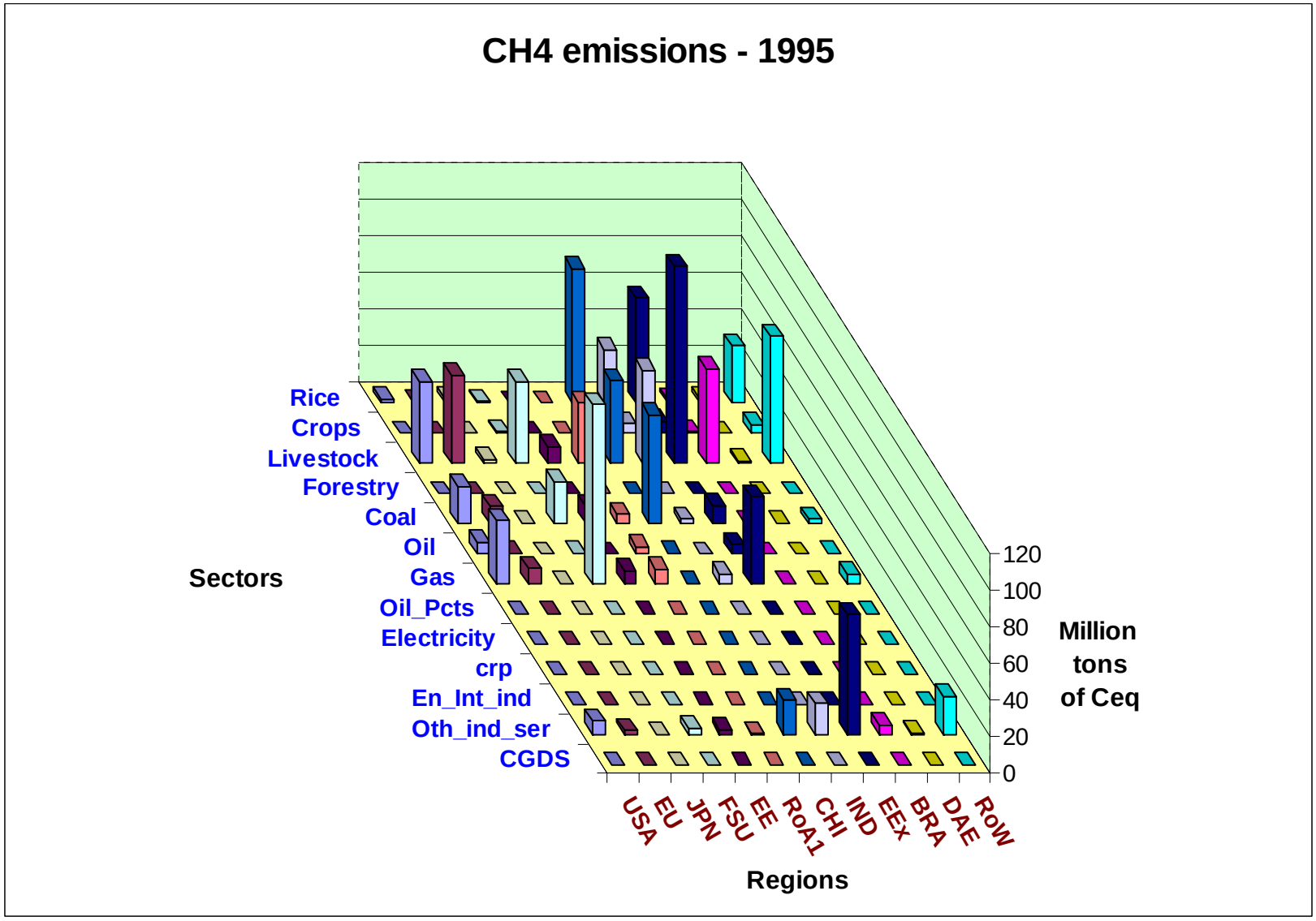
Gases	Lifetime	GWP	Carbon Equivalent (Ceq) [2]
Carbon dioxide (CO_2)	50-200	1	(12/44) = 0.27
Methane (CH_4)	5	21	21×(12/44) = 5.73
Nitrous Oxide (N_2O)	120	310	310×(12/44) = 84.55

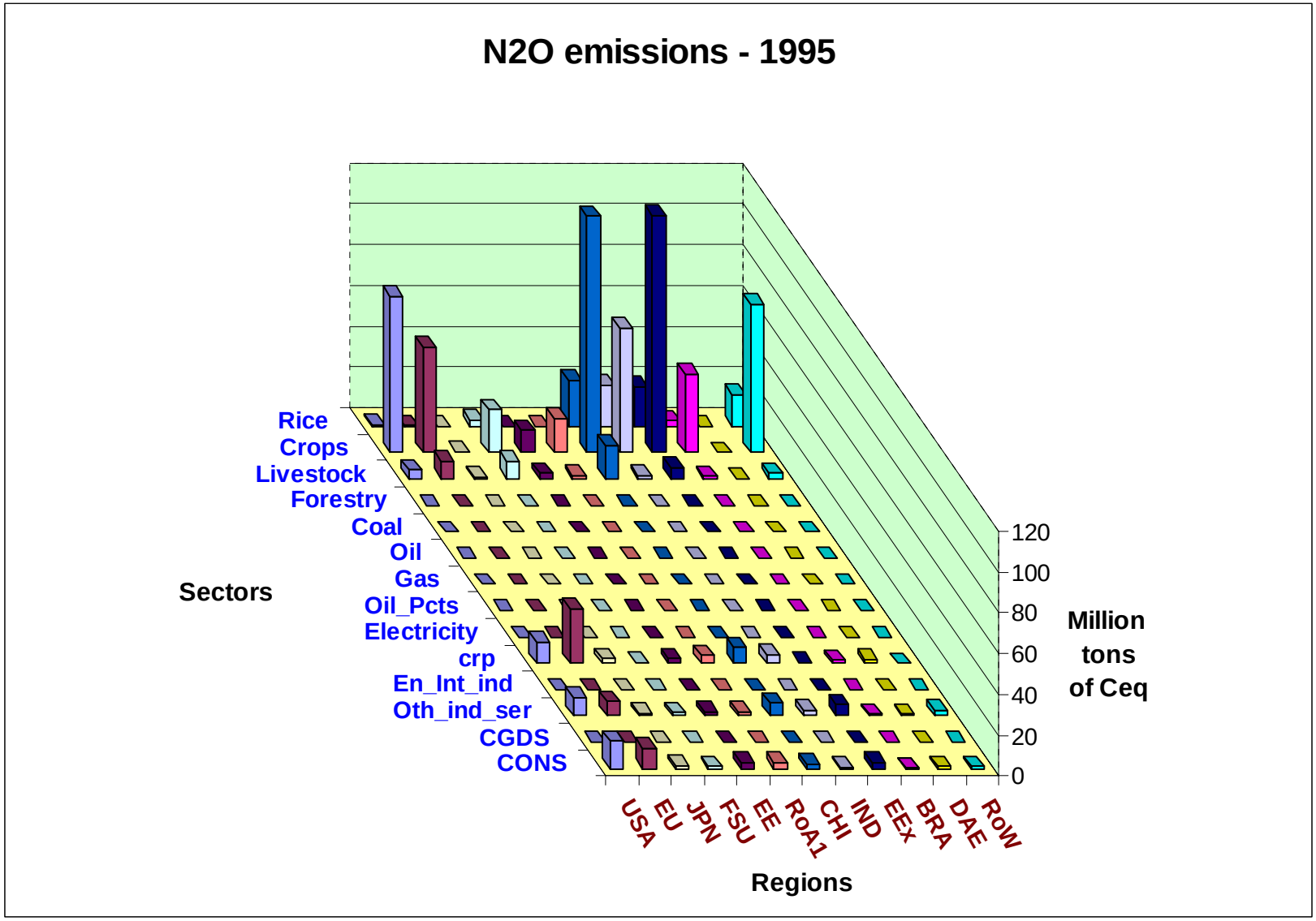

Emissions by Gas Types
World Total - 1995
10.00
15.00
75.00
CH4
CO2
N2O

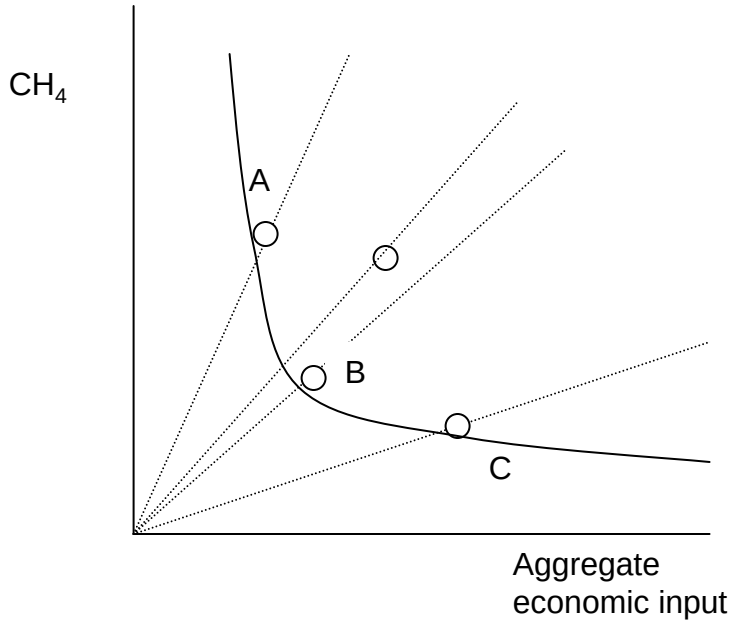

Shares of emissions - 1995
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
USA
EU
JPN
FSU
EE
RoA1
CHI
IND
EEx
BRA
DAE
RoW
Regions
N2O
CH4
CO2

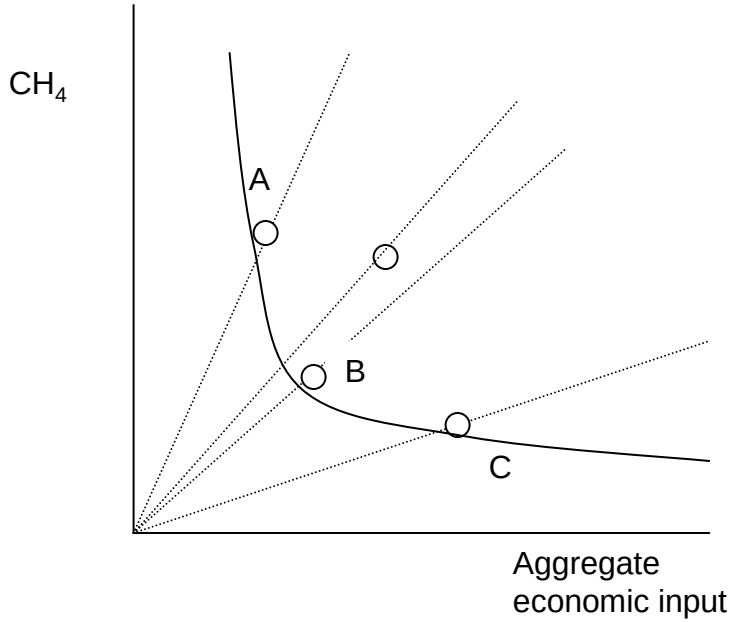

Emissions by Gas Types and Regions - 1995
Million tons of Ceq
1800
1600
1400
1200
1000
800
600
400
200
0
USA
EU
JPN
FSU
EE
RoA1
CHI
IND
EEx
BRA
DAE
RoW
Regions
N2O
CH4
CO2

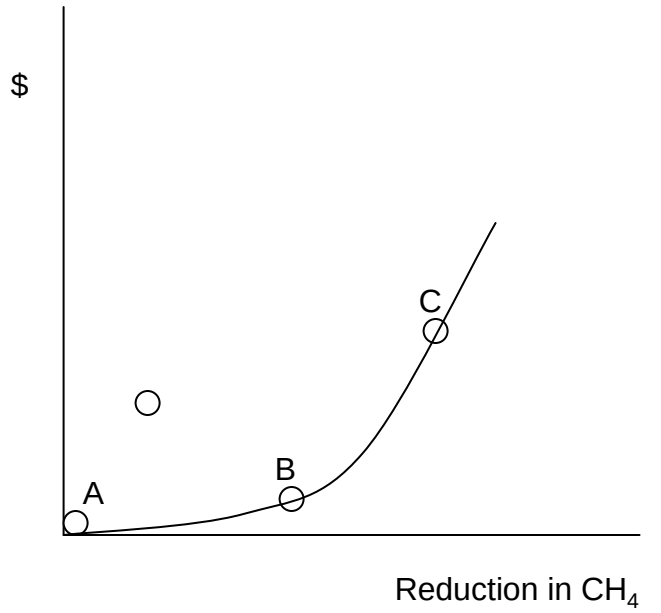

CO2 emissions - 1995
Rice
Crops
Livestock
Forestry
Coal
Oil
Gas
Oil_Pcts
Electricity
crp
En_Int_ind
Oth_ind_ser
CGDS
CONS
Sectors
600
400
200
0
Million tons of Ceq
USA
EU
JPN
FSU
EE
RoA1
CHI
IND
EEx
BRA
DAE
RoW
Regions


CH4 emissions - 1995
Sectors
Rice
Crops
Livestock
Forestry
Coal
Oil
Gas
Oil_Pcts
Electricity
crp
En_Int_ind
Oth_ind_ser
CGDS
120
100
80
60
40
20
0
Million tons of Ceq
USA
EU
JPN
FSU
EE
RoA1
CHI
IND
EEx
BRA
DAE
RoW
Regions

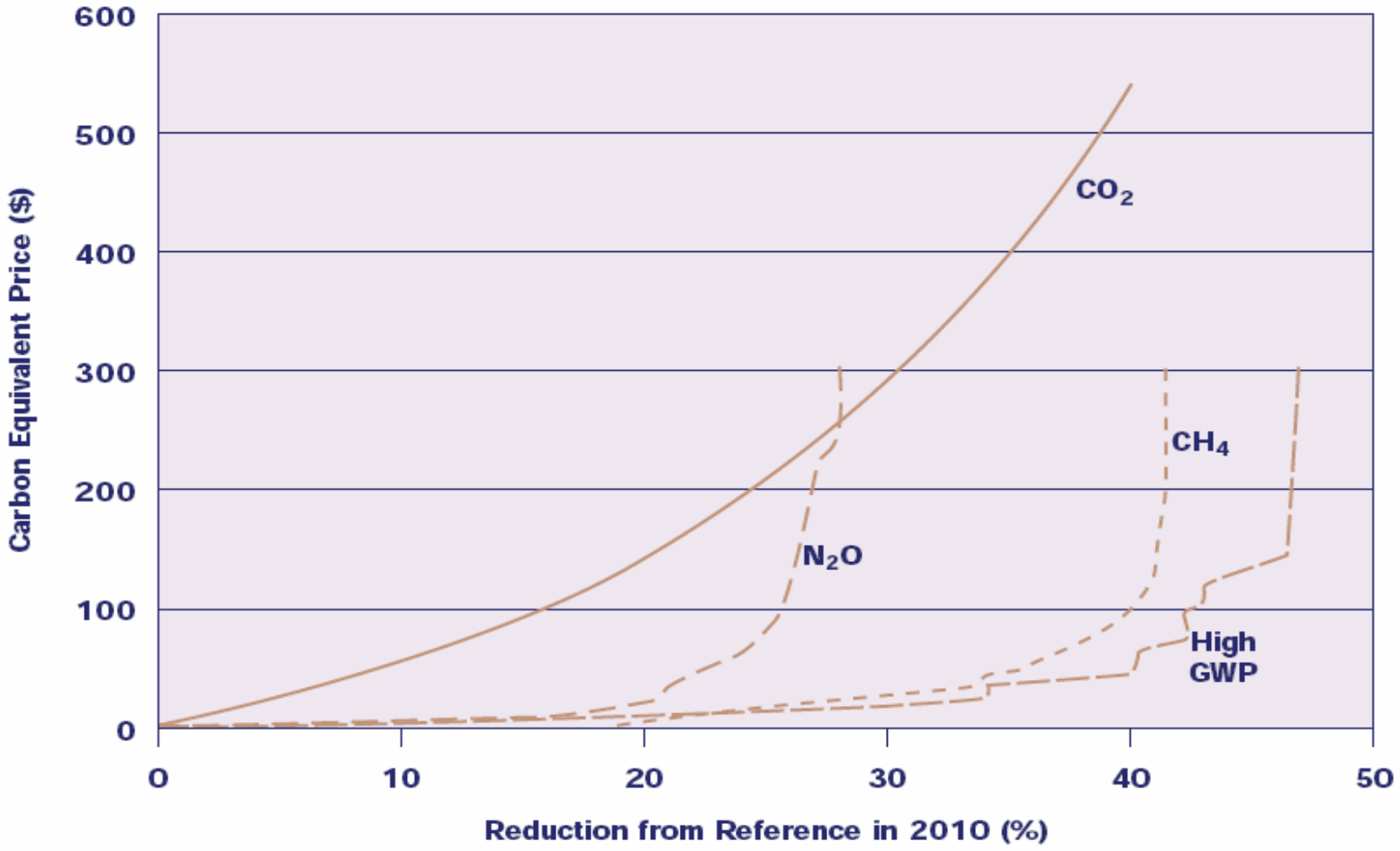

N2O emissions - 1995
Rice
Crops
Livestock
Forestry
Coal
Oil
Gas
Oil_Pcts
Electricity
crp
En_Int_ind
Oth_ind_ser
CGDS
CONS
Sectors
120
100
80
60
40
20
0
Million tons of Ceq
USA
EU
JPN
FSU
EE
RoA1
CHI
IND
EEx
BRA
DAE
RoW
Regions


CH_4
A
B
C
Aggregate
economic input


CH_4
A
B
C
Aggregate
economic input


$
C
B
A
Reduction in CH_4

Marginal Abatement Curves for CO_2, CH_4, N_2O, and the High-GWP Industrial Gases (HFCs, PFCs, SF_6)



Sources: Methane: U.S. EPA, 1999; High-GWP Industrial gases: U.S. EPA, 2001b; Nitrous oxide: Jochen Harnisch, 2001, private communication and authors' own calculations; CO_2: Authors' own calculations based on EPPA model simulations.

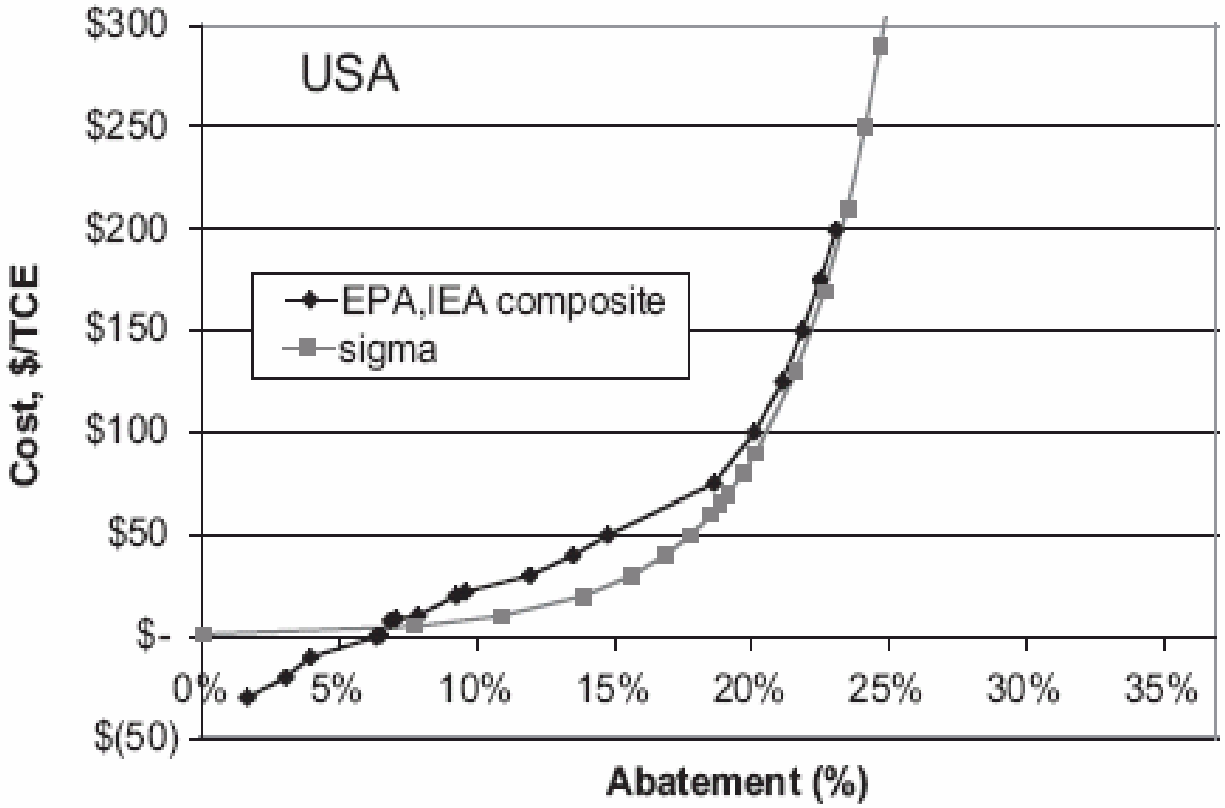
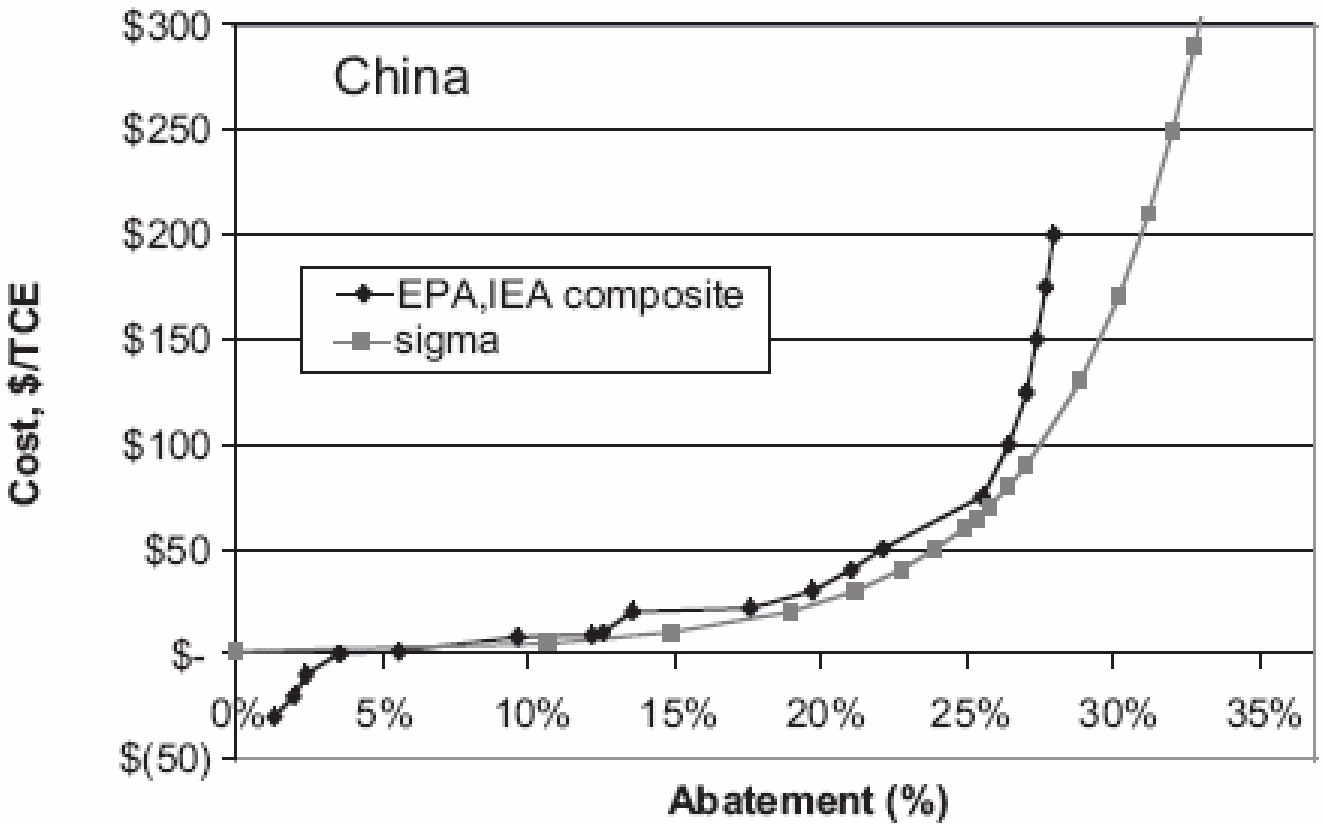
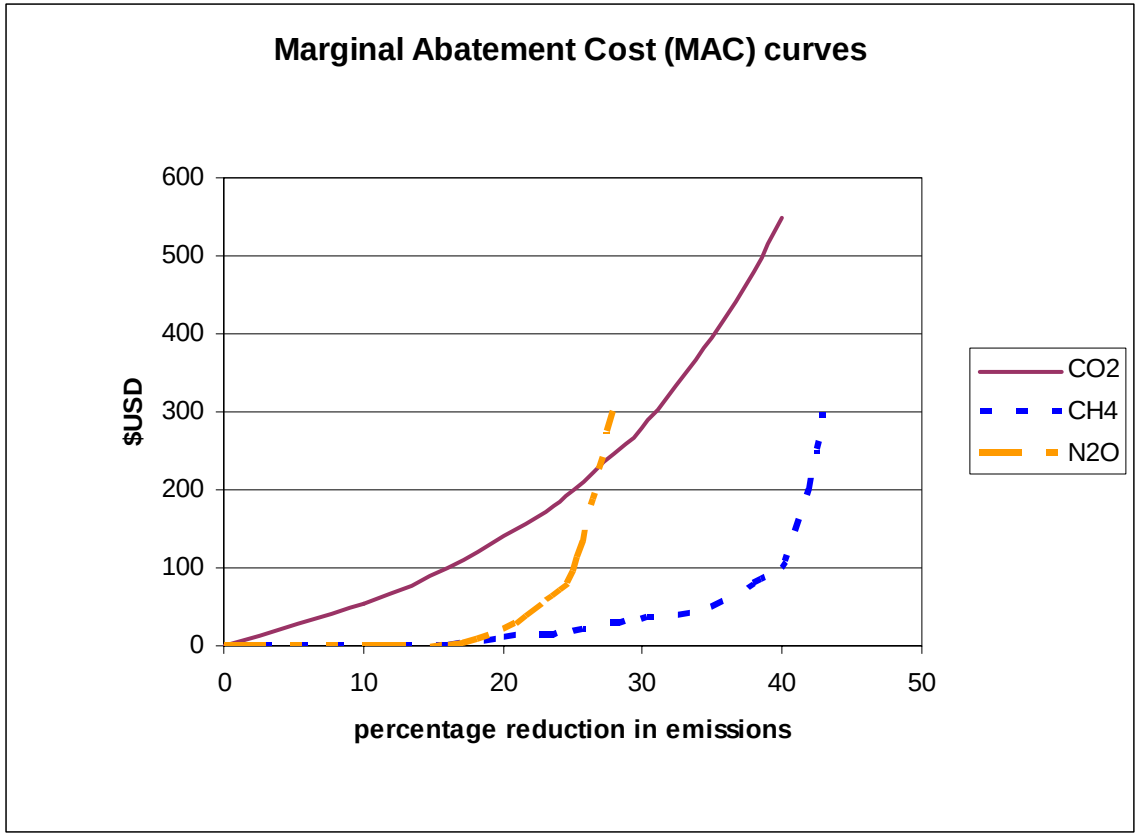


Figure 2. Comparison of EPPA parameterization (squares) with methane marginal abatement curves (diamonds) for China (top panel), and the USA (bottom panel) *Source*: Bottom-up abatement curves were derived by combining data from IEA (1998, 1999) and U.S. EPA (1999); for details, see Hyman (2001).

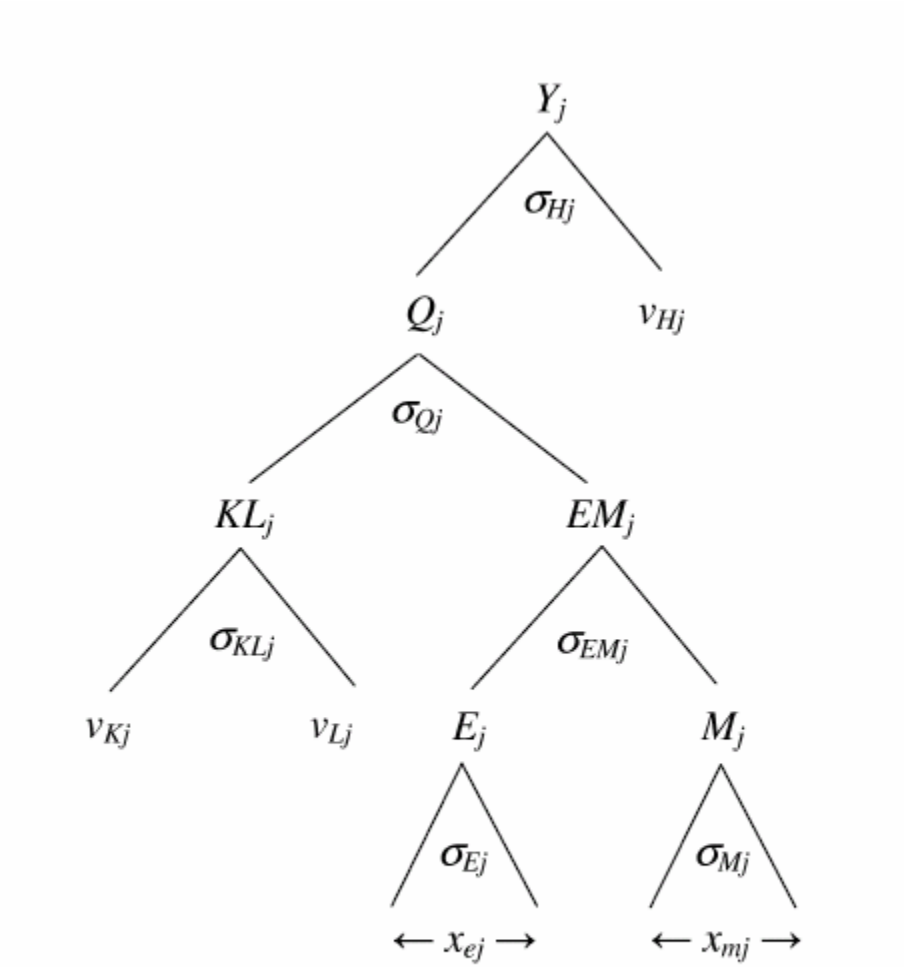

China
$300
$250
$200
$150
$100
$50
$-
$(50)
0%
5%
10%
15%
20%
25%
30%
35%
EPA,IEA composite
sigma
Cost, $/TCE
Abatement (%)


Marginal Abatement Cost (MAC) curves
600
500
400
300
200
100
0
$USD
0
10
20
30
40
50
percentage reduction in emissions
CO2
CH4
N2O

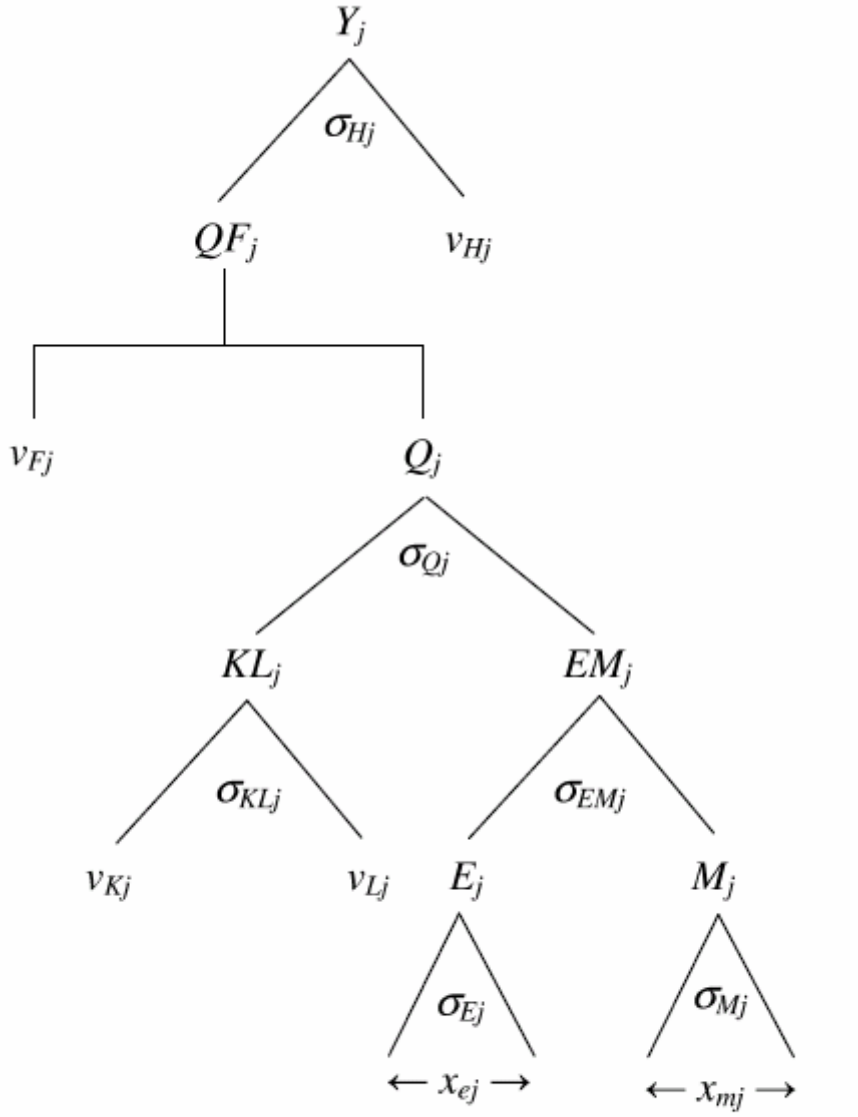
ESUBCH4	1 USA	2 EU	3 JPN	4 FSU	5 EE	6 RoA1	7 CHI	8 IND	9 EEx	10 BRA	11 DAE	12 RoW
1 Rice	0.05	0.08	0.07	0.05	0.08	0.04	0.07	0.04	0.02	0.02	0.07	0.03
2 Crops	0	0	0	0	0	0	0	0	0	0	0	0
3 Livestock	0.05	0.08	0.07	0.05	0.08	0.04	0.07	0.04	0.02	0.02	0.07	0.03
4 Forestry	0	0	0	0	0	0	0	0	0	0	0	0
5 Coal	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
6 Oil	0	0	0	0	0	0	0	0	0	0	0	0
7 Gas	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
8 Oil_Pcts	0	0	0	0	0	0	0	0	0	0	0	0
9 Electricity	0	0	0	0	0	0	0	0	0	0	0	0
10 crp	0	0	0	0	0	0	0	0	0	0	0	0
11 En_Int_ind	0	0	0	0	0	0	0	0	0	0	0	0
12 Oth_ind_ser	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
13 CGDS	0	0	0	0	0	0	0	0	0	0	0	0

ESUBN2O	1 USA	2 EU	3 JPN	4 FSU	5 EE	6 RoA1	7 CHI	8 IND	9 EEx	10 BRA	11 DAE	12 RoW
1 Rice	0	0	0	0	0	0	0	0	0	0	0	0
2 Crops	0.04	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.02	0.02
3 Livestock	0	0	0	0	0	0	0	0	0	0	0	0
4 Forestry	0	0	0	0	0	0	0	0	0	0	0	0
5 Coal	0	0	0	0	0	0	0	0	0	0	0	0
6 Oil	0	0	0	0	0	0	0	0	0	0	0	0
7 Gas	0	0	0	0	0	0	0	0	0	0	0	0
8 Oil_Pcts	0	0	0	0	0	0	0	0	0	0	0	0
9 Electricity	0	0	0	0	0	0	0	0	0	0	0	0
10 crp	0	0	0	0	0	0	0	0	0	0	0	0
11 En_Int_ind	0	0	0	0	0	0	0	0	0	0	0	0
12 Oth_ind_ser	0	0	0	0	0	0	0	0	0	0	0	0
13 CGDS	0	0	0	0	0	0	0	0	0	0	0	0

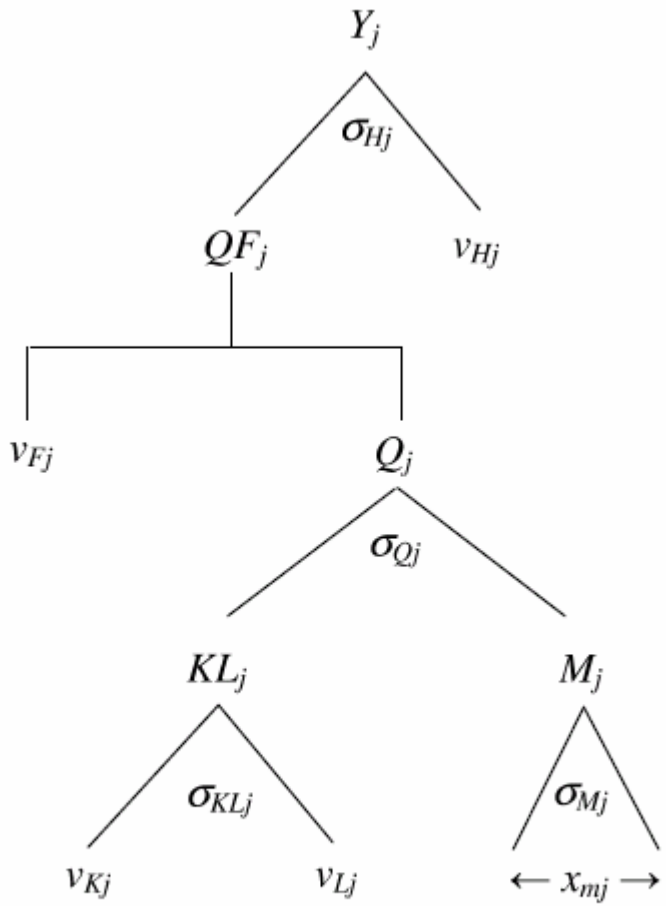
GTAP-ETC Model



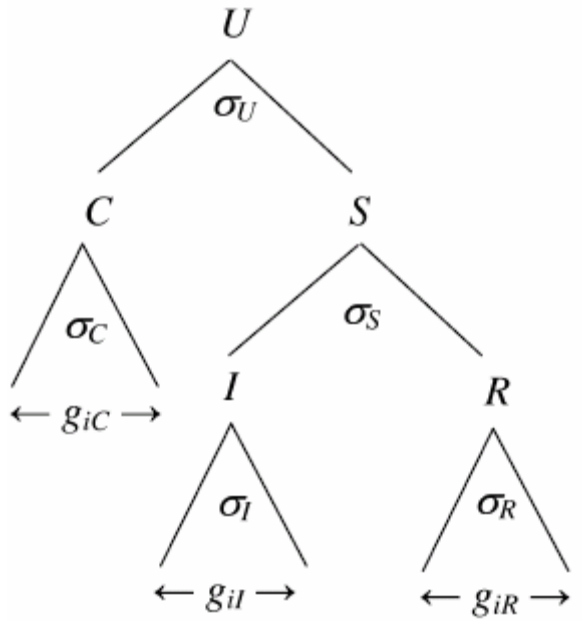
(a) Manufacturing, Services and Carbon-Based Electricity



(b) Natural Resource, Mining and Agriculture Sectors



(c) Carbon-Free Electricity


U
σ_U
C
S
σ_C
σ_S
$\leftarrow g_{iC} \rightarrow$
I
R
σ_I
σ_R
$\leftarrow g_{iI} \rightarrow$
$\leftarrow g_{iR} \rightarrow$

(d) Demand