The ENVISAGE Model: Version 10.0

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Key dimensions

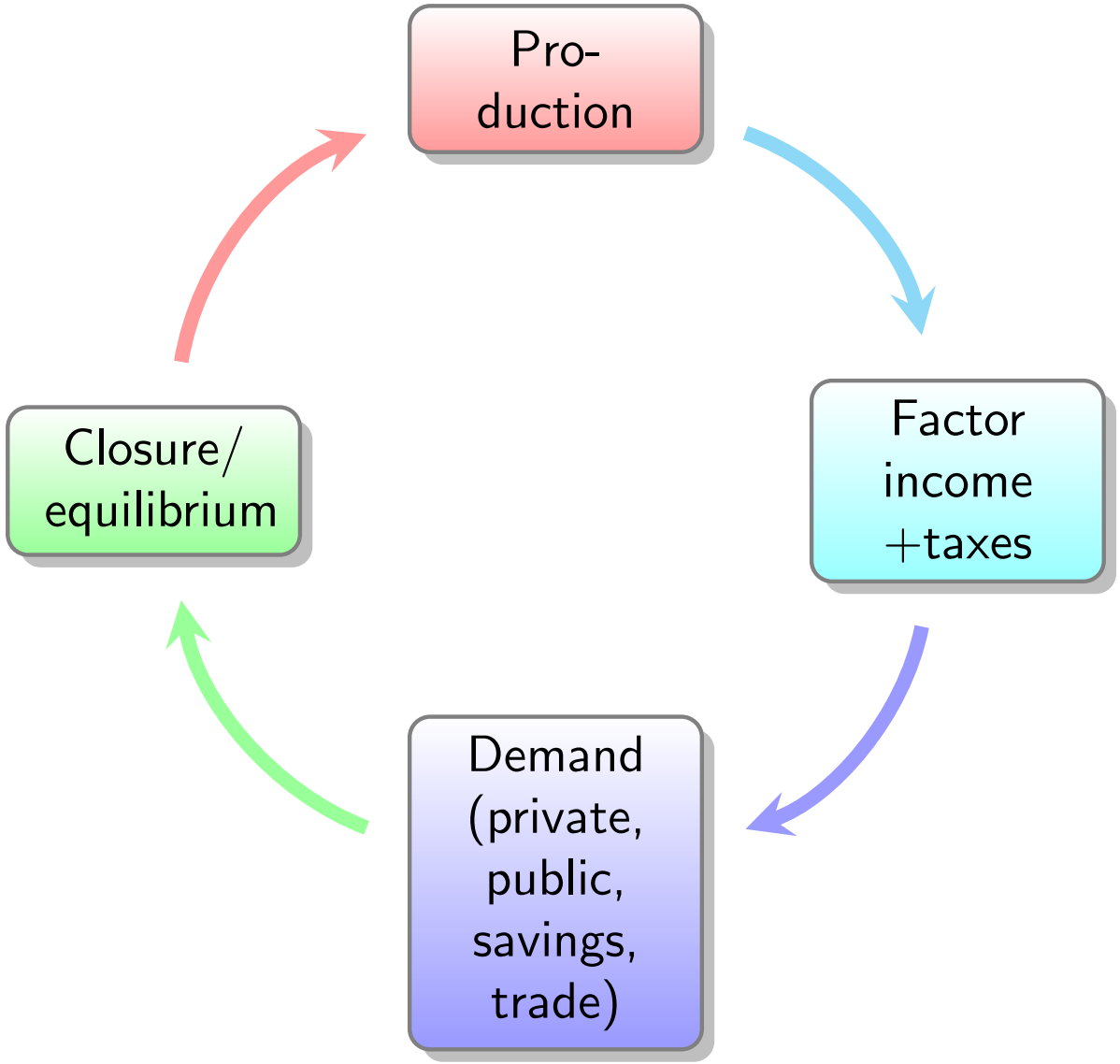
Armington agents (*aa*)					
Activities (*a*)			Domestic final demand (*fd*)		
Crops (*acr*)	Livest. (*alv*)	Other (*ax*)	Hhlds (*h*)	Other (*fdc*)	
				Gov (*gov*)	Inv (*inv*)

Commodities (*i*)	
Non-energy commodities (*ixn*)	Energy commodities (*e*)

Factors of production (*fp*)				
Labor (*l*)		Capital (*cap*)	Land (*lnd*)	Nat. Res. (*nrs*)
Unskilled (*ul*)	Skilled (*sl*)			

Regions (r)—aliases: source (s), destination (d)

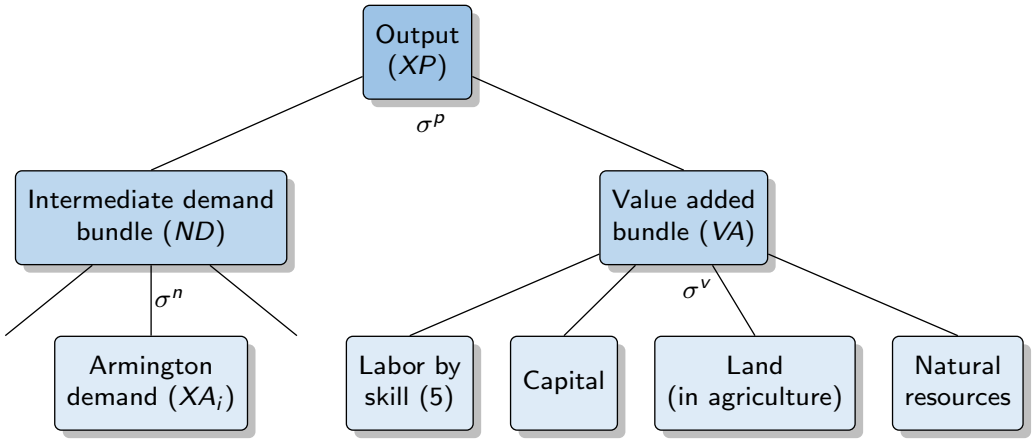
Economic circular flow



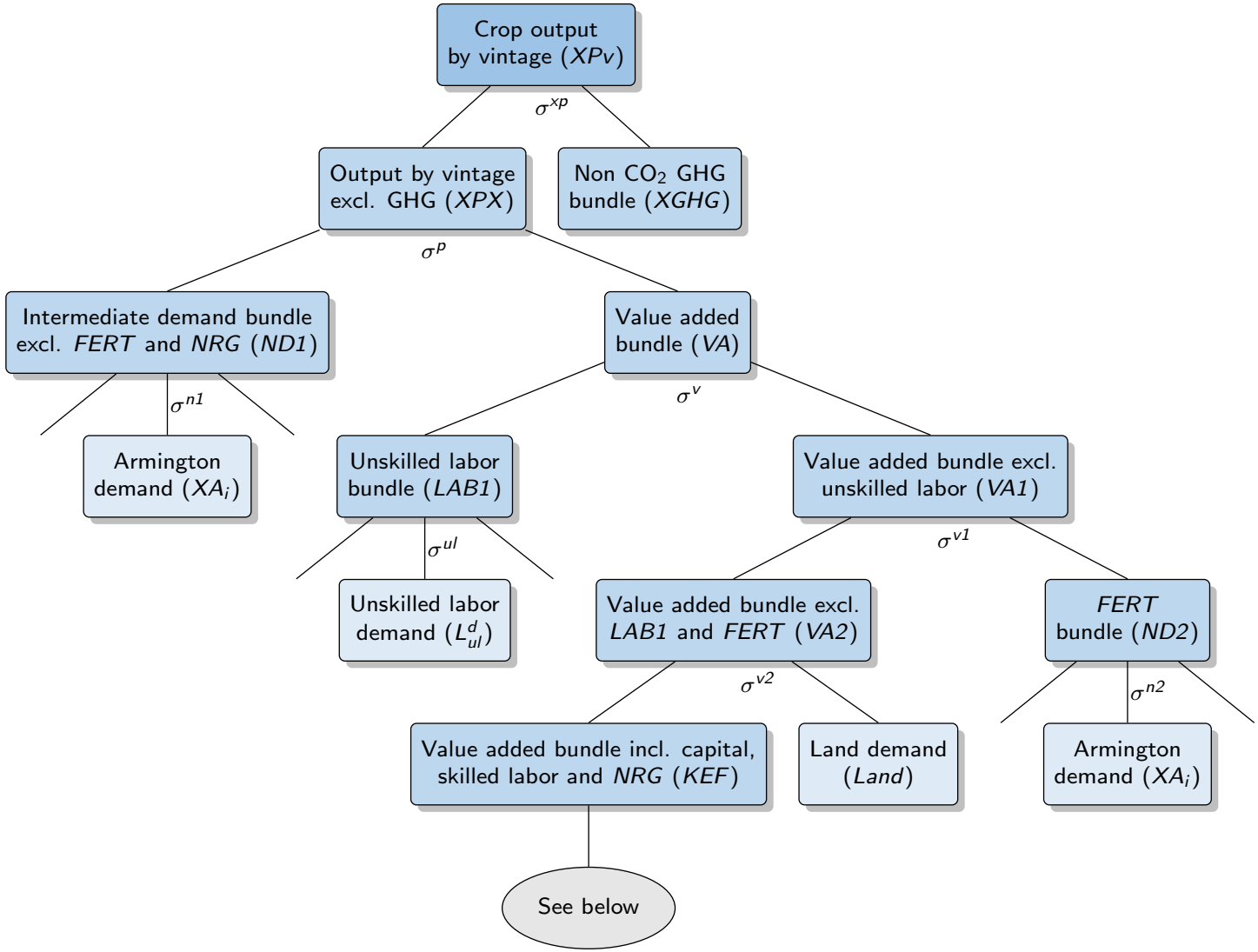
Production in ENVISAGE

- Minimize cost subject to a production function of inputs—intermediate goods and services and factors
- Plausibility, parsimony and regularity
- Flexible functional forms vs. nested CES
- GTAP has two aggregate bundles and two nests: aggregate intermediate demand and aggregate value added.
- ENVISAGE has three archetypes nests:
  1. Crops (role for land and agricultural chemicals, fertilizers)
  2. Livestock (role for land and feed)
  3. Standard (capital vs. labor, skill vs. unskilled)
- Energy has a strong role in all three archetypes
- Production is based on vintage capital—less flexibility (i.e. lower substitution elasticities) for *Old* capital than with *New* capital
- No matter the nesting, what emerges from the production module is (Armington) demand for goods and services and factors of production

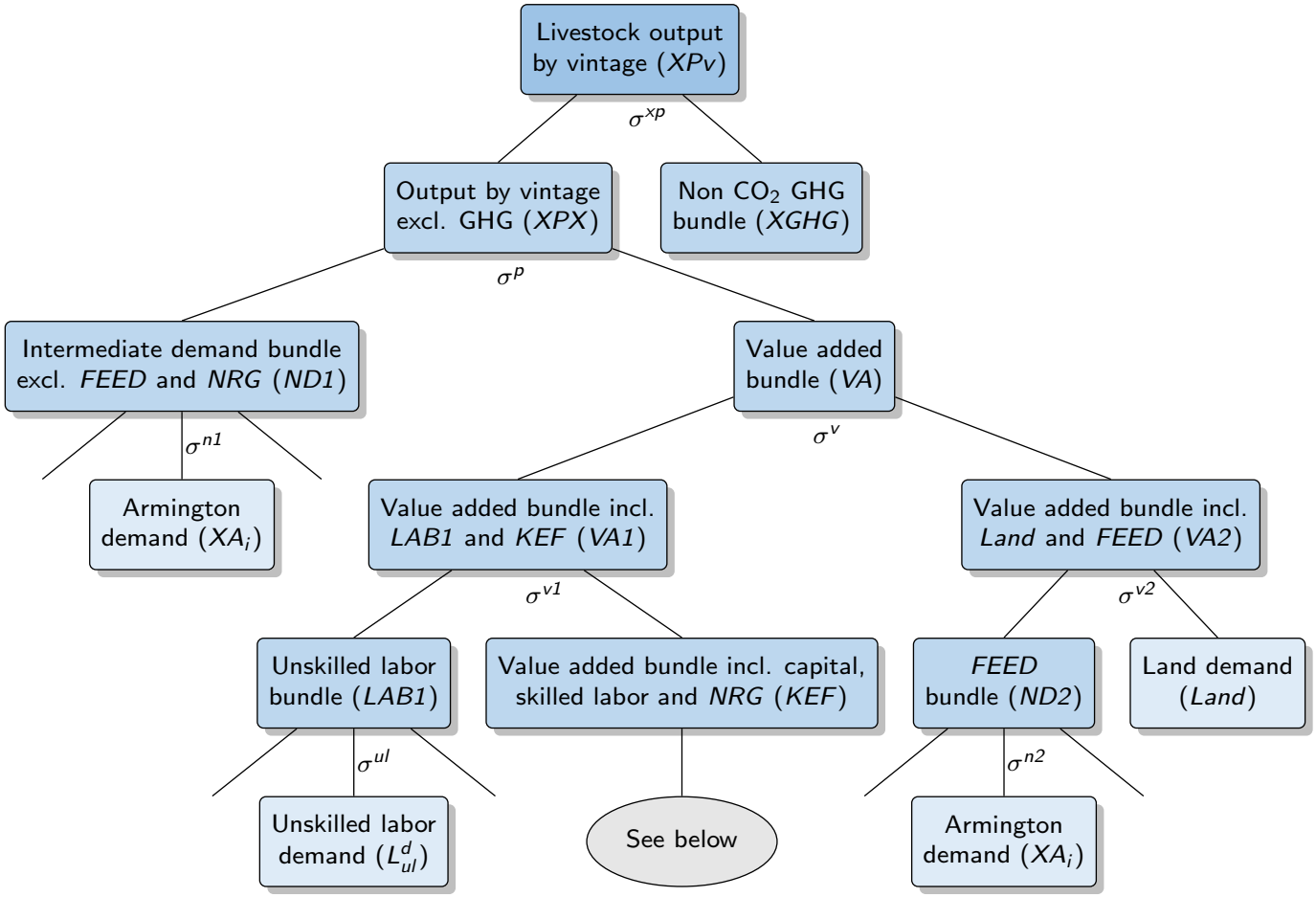
GTAP Nesting



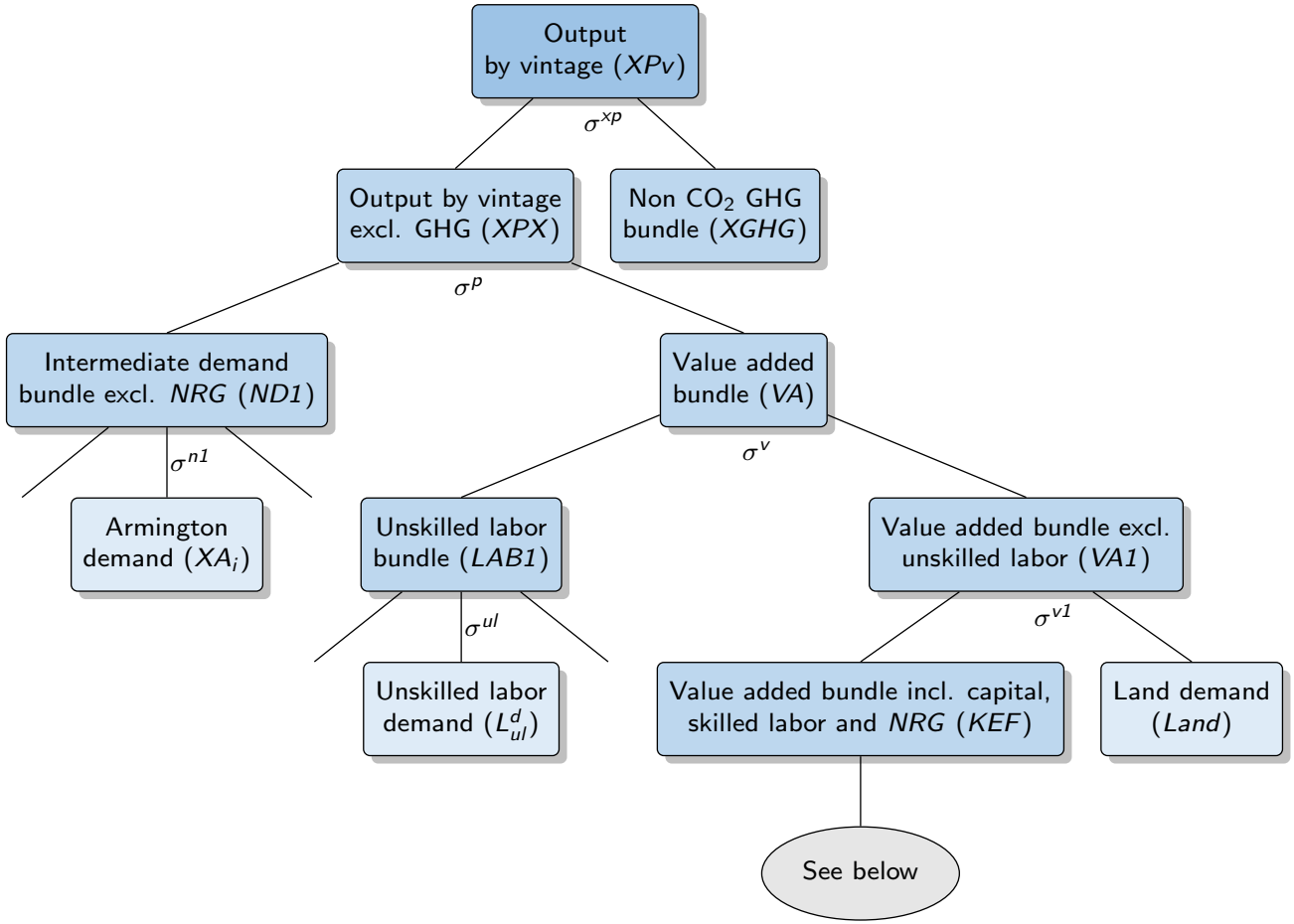
Production module—Crop Nesting



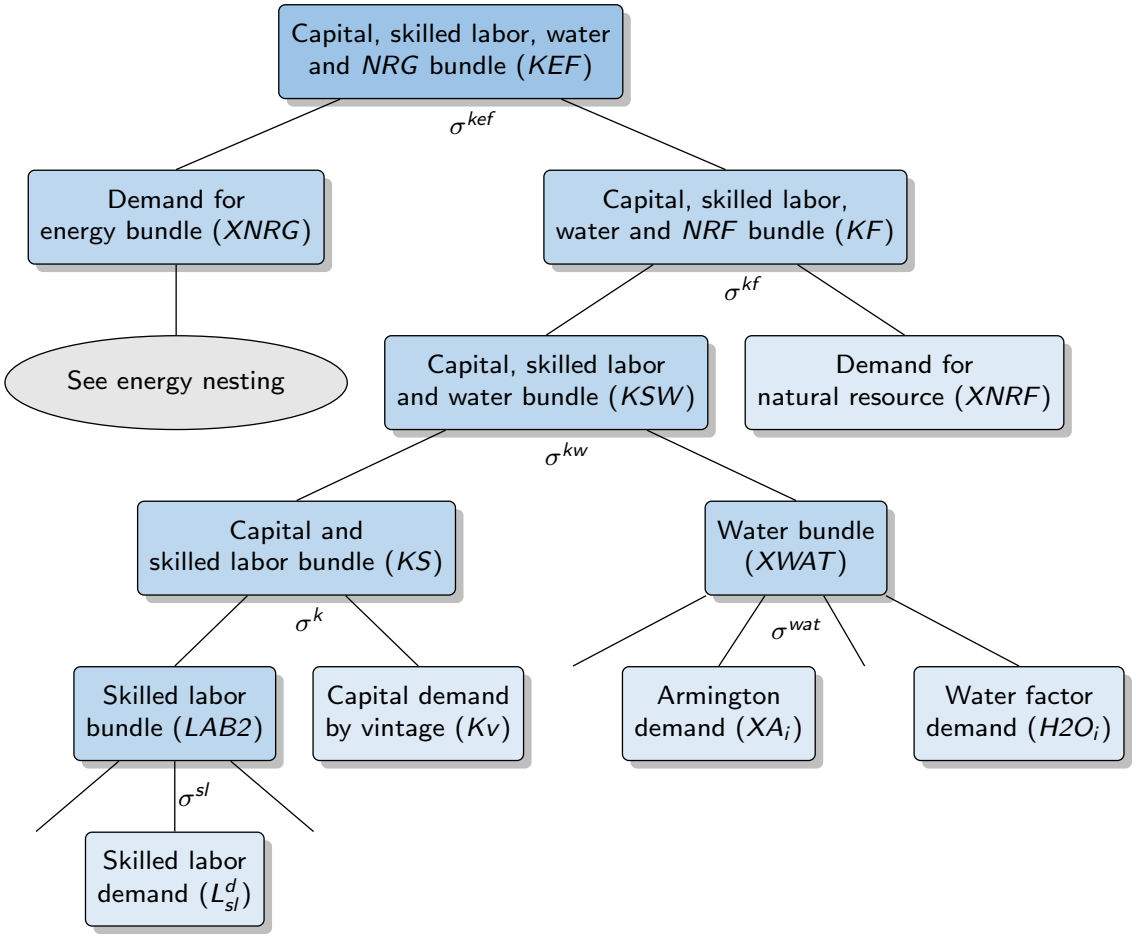
Production module—Livestock Nesting



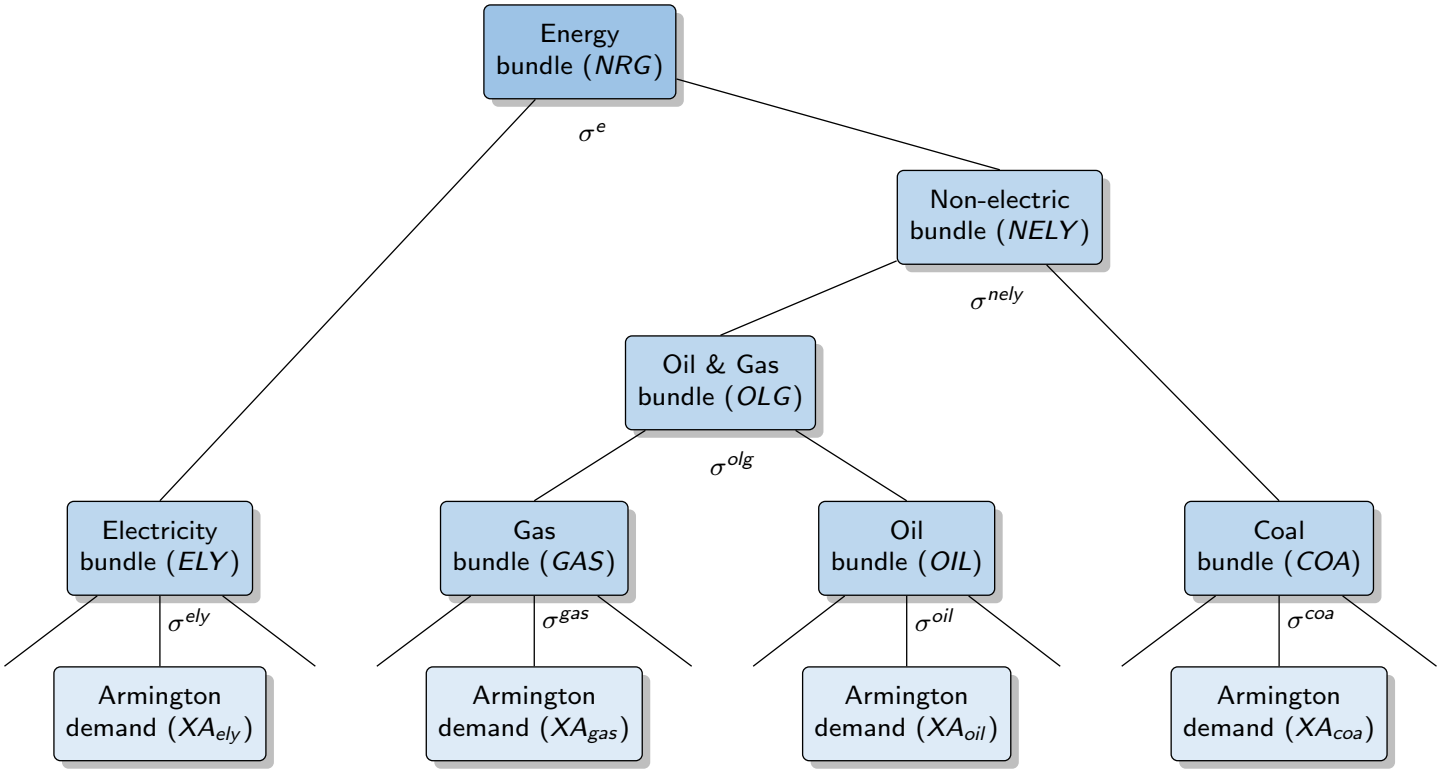
Production module—Standard nesting



Production module—Capital/Energy Nest



Energy Nest


Energy bundle (NRG)
σ^e
Non-electric bundle (NELY)
σ^nely
Oil & Gas bundle (OLG)
σ^olg
Electricity bundle (ELY)
σ^ely
Armington demand (XA_ely)
Gas bundle (GAS)
σ^gas
Armington demand (XA_gas)
Oil bundle (OIL)
σ^oil
Armington demand (XA_oil)
Coal bundle (COA)
σ^coa
Armington demand (XA_coa)

Make module—Standard nest

Figure: Joint production (CET)

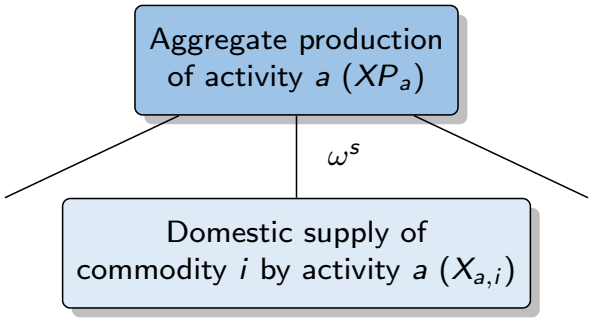
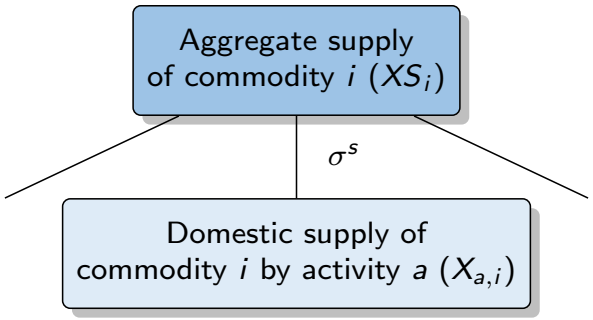
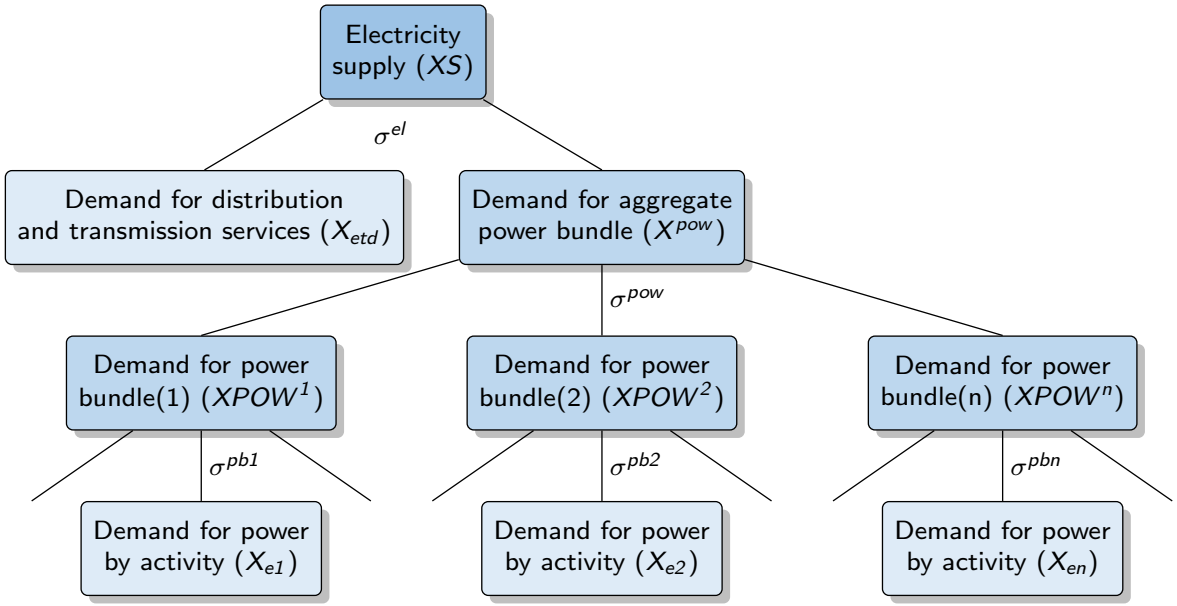


Figure: Commodity supply (CES)



Make module—Power Nest



Income distribution

- Household income
  1. After tax factor income (labor, capital, land, natural resources & water)
  2. Net income from cross-border profits
  3. Net income from cross-border remittances
- Government income
  1. Production tax
  2. Taxes on factor use in production
  3. Taxes on domestic goods demand
  4. Import tariff revenues
  5. Export tax revenues
  6. Emission taxes
  7. Taxes on factor income
  8. Net transfers to households
- Investment income: $Inv = S^h + S^g + S^f + DeprY$

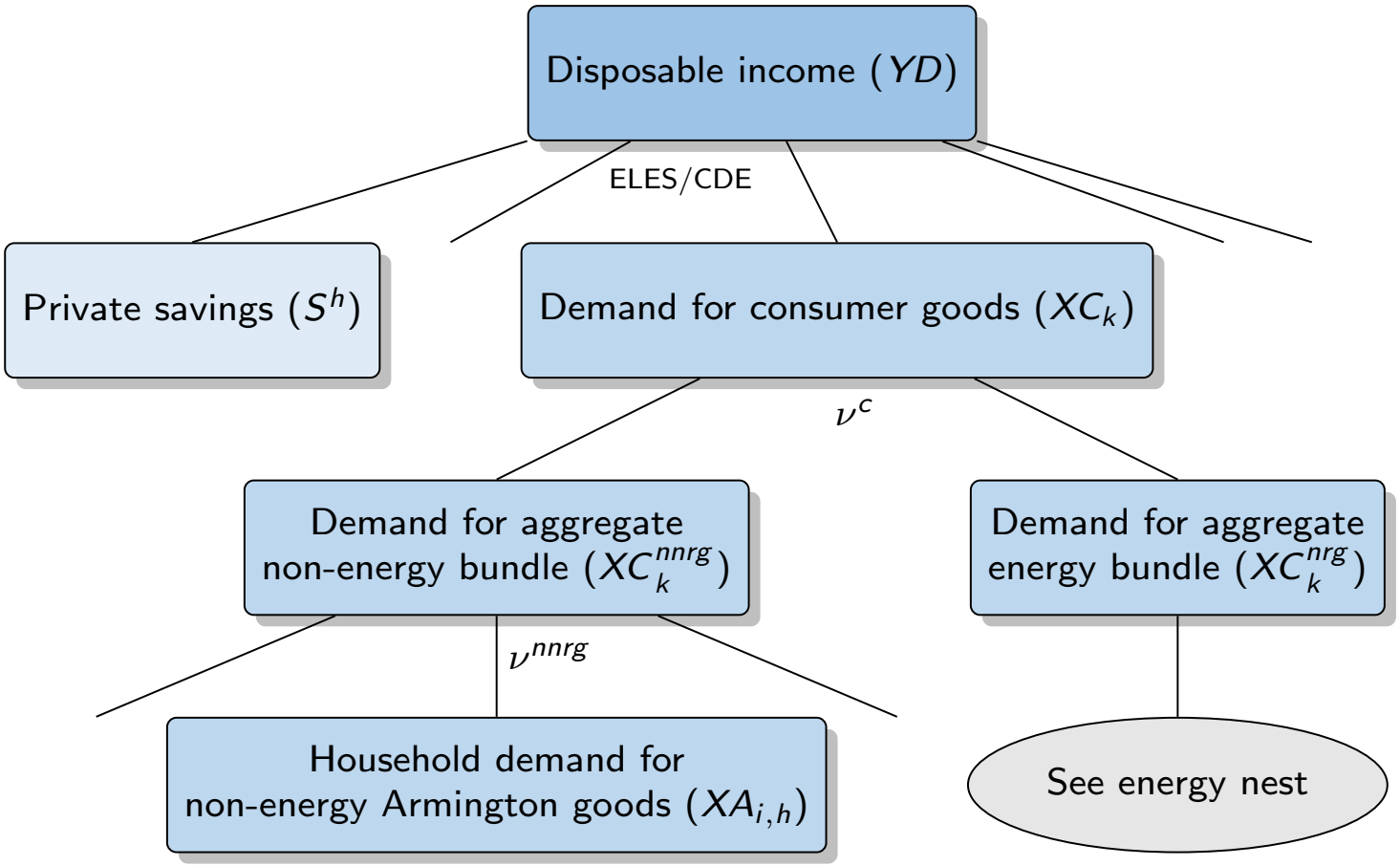
Final demand introduction

- There are typically three domestic final demand agents: households, government and investment.
- Each has a unique expenditure function. Households are assumed to maximize utility subject to a budget constraint.
- Households have a deeply nested structure with a top level utility function and nested CES.
- Possible utility functions include the Constant-differences-in elasticity (GTAP), linear expenditure system (LES), extended LES (ELES), and AIDADS. Also includes Cobb-Douglas as a special version of the LES.
- Expenditure function for other final demand agents is a generic CES—with the possibility of both Leontief and Cobb-Douglas preferences.
- Like production, demand is specified at the Armington level. Decomposition by source follows.

Household demand—Consumer transition matrix

	Food&Bev	Energy	Trp&Comm	Other	Total
Agric	15.9	0.1	0.0	5.2	21.3
Coal	0.0	0.3	0.0	0.0	0.3
Oil	0.0	0.0	0.0	0.0	0.0
Gas	0.0	12.8	0.0	0.0	12.8
Energy int manu	0.0	0.0	0.1	50.8	50.9
Refined oil	0.0	17.5	50.0	0.0	67.5
Electricity	0.0	73.1	0.0	22.9	96.0
Other	347.9	0.1	366.2	1,644.0	2,358.3
Total	363.9	103.8	416.3	1,723.0	2,607.0

Household demand—Nest structure



Household demand—Top level utility

CDE	AIDADS/(E)LES
$V(p,u,Y) = \sum_k \alpha_k u^{e_k b_k} \left(\frac{P_k}{y}\right)^{b_k} \equiv 1$	$u = \prod_k (X_k - \gamma_k)^{\mu_k} \left(\frac{S}{P^s}\right)^{\mu_s}$
$Z_k = \alpha_k b_k u^{e_k b_k} \left(\frac{P_k}{Y}\right)^{b_k}$	$Y^{sup} = Y - \sum_k P_k \gamma_k$
$s_k = \frac{Z_k}{\sum_{k'} Z_{k'}}$	$X_k = \gamma_k + \frac{\mu_k}{P_k} Y^{sup}$
$X_k = s_k Y / P_k$	$s_k = X_k P_k / \mathrm{Y}$
$\sum_k \frac{Z_k}{b_k} \equiv 1$	$\mu_k = \frac{\alpha_k + \beta_k e^u}{1 + e^u}$

Consumer and other final demand

- Each top-level consumer bundle is composed of 1 or more produced goods plus an energy bundle. A CES preference function is assumed.
- The energy bundle is decomposed as above for production activities
- Government and investment expenditure functions use generic CES formulation

Import demand

- Nested structure
  1. Top level allocates domestic absorption between domestic goods and an aggregate import good
  2. Second level allocates aggregate imports by region of origin
- Three options
  1. Both nests use a national preference function. Aggregate absorption is summed across all agents
  2. Top nest uses an agent-specific preference function. Aggregate imports are summed across all agents for second nest that uses a national preference function. (This is the GTAP standard specification)
  3. Both nests use an agent-specific preference function (the MRIO model of trade)

Allocation of domestic output—export supply

- Aggregate domestic supply is allocated across the domestic market and an aggregate export bundle.
- The aggregate export bundle is allocated across destination markets.
- Both allocation nestings use a CET transformation function. Both allow for perfect transformation (i.e. the law-of-one-price)

International trade and transport margins

- A fixed transport margin is implemented to capture the cost of delivering goods from the port of exit to the port of entry. The margin is specific to each bilateral node.
- The transport margins create a demand for services. A 'global' transport sector purchases these services from individual countries based on cost minimization.

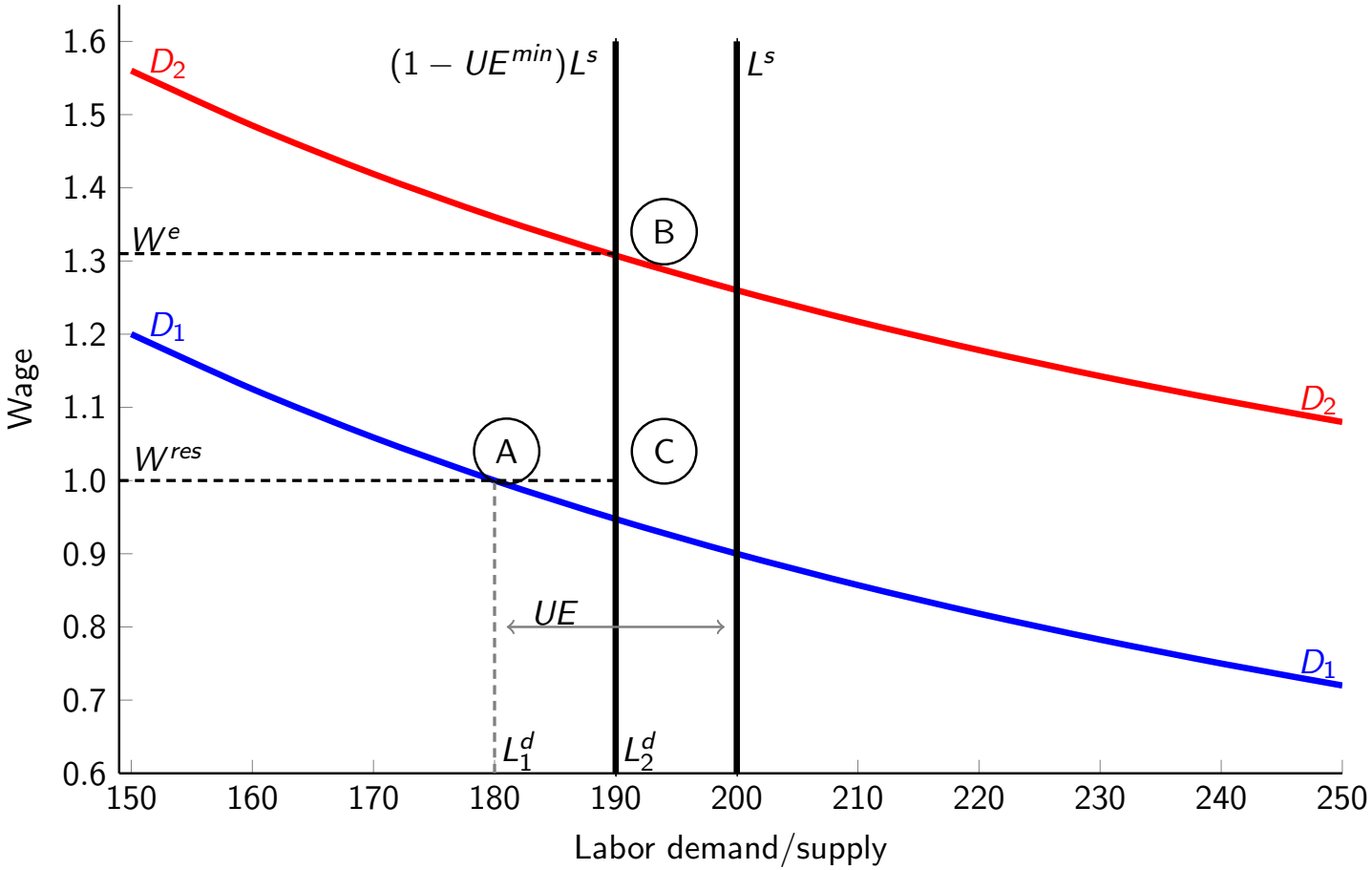
Price linkages from the supply side

PX		Unit cost of production
$\Downarrow$	τ^p	Output tax
PP		Market price of domestic production
$\Downarrow$		'Make' matrix transformation of domestic production
PS		Market price of total domestic supply
$\swarrow$ $\quad$ $\searrow$		Top level CET transformation (ω^x)
PD $\quad$ PET		Market price of domestic & export goods
$\Downarrow$		Second level CET transformation (ω^w)
PE_d		(Bilateral) market price of export goods
$\Downarrow$	τ^e, ζ^e	Taxes on exports
PE_d^{fob}		Border price of exports (FOB)
$\Downarrow$	ζ^{mg}	International trade & transport margins
PM_d^{cif}		Border price of imports (CIF)
$\Downarrow$	τ^m, ζ^m	Taxes on imports
PM_d		(Bilateral) market price of imports

Price linkages from the demand side

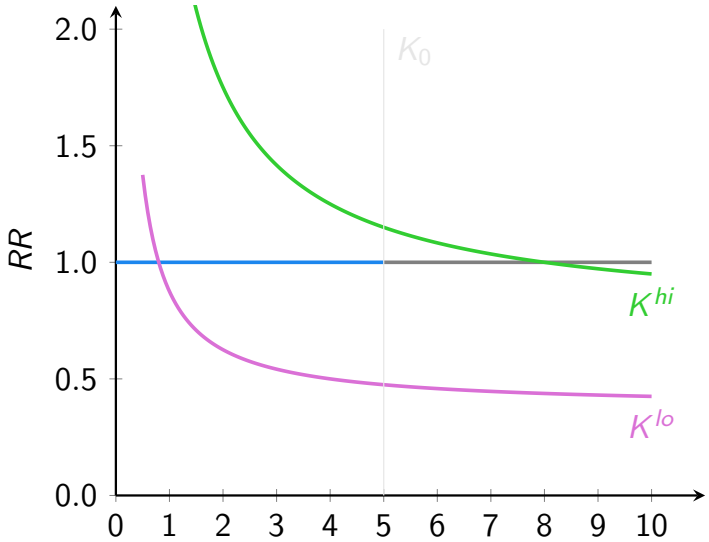
		PM_s^{cif}		Border price of imports (CIF)
		$\Downarrow$	τ^m, ζ^m	Taxes on imports
		PM_s		(Bilateral) market price of imports
		$\Downarrow$		Second level Armington CES (σ^w)
PD		PMT		Market price of domestic & (aggregate) impo
$\Downarrow$		$\Downarrow$	$\tau^{dtx}, \tau^{mtx}, \chi^{tx}$	Sales tax on domestic & imported goods
PD^p		PM^p		End-user price of domestic & (aggregate) imp
	$\searrow$	$\swarrow$		Top level CES aggregation of domestic & imp
	PA			Armington price of goods (by agent)

Labor market closure

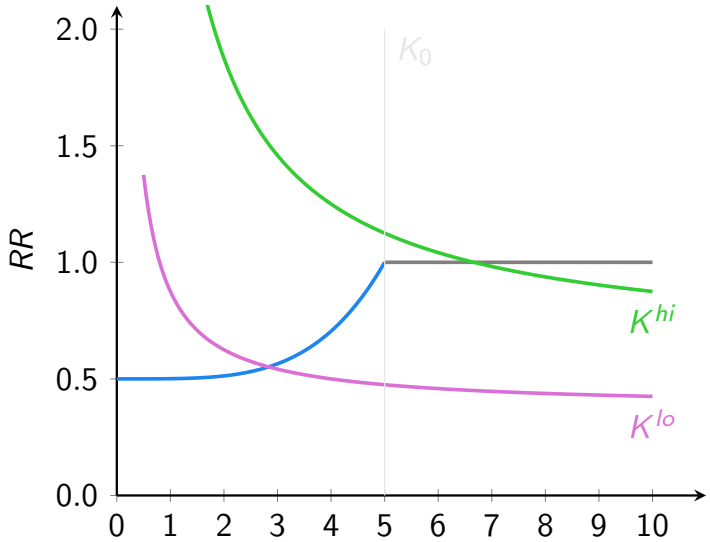


Capital market

- *New* capital is perfectly mobile and clears the capital market.
- In expanding sectors, i.e. sectors that require *New* capital to meet demand, *Old* receives the economy-wide rate of return.
- In contracting sectors, *Old* capital is released using an upward sloping supply curve and the remaining installed capital has a lower rate-of-return determined by equilibrium conditions.



(a) $\eta^I = \infty$



(b) $\eta^I \neq \infty$

Water allocation

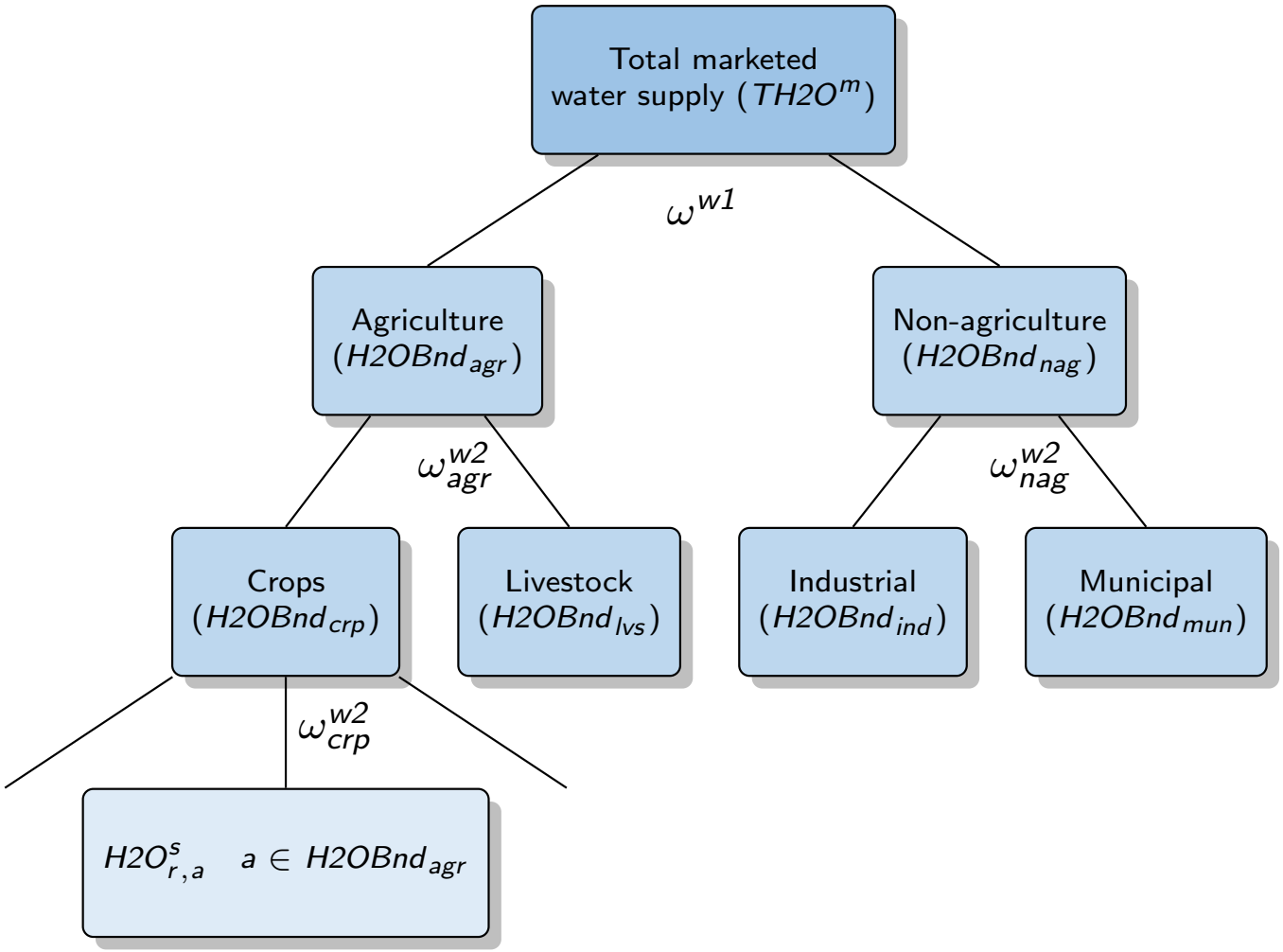


Figure: **CET nest for water allocation**

Natural resource markets

- By default, natural resources are supplied using an upward sloping supply curve.
- We've recently added kinked supply curves—elasticity depends on whether supply is expanding or contracting:

$$\eta = \eta_{lo} + \frac{\eta_{hi} - \eta_{lo}}{1 + e^{-\kappa \dot{s}}}$$

- In some versions of the model, a resource depletion module has been implemented using two reserve pools. Production is given by extracting from 'proven' reserves. New discoveries entail a conversion of 'yet-to-find' reserves into proven reserves. 'Yet-to-find' reserves are initialized in the base year and can only be depleted.

Kinked supply curve

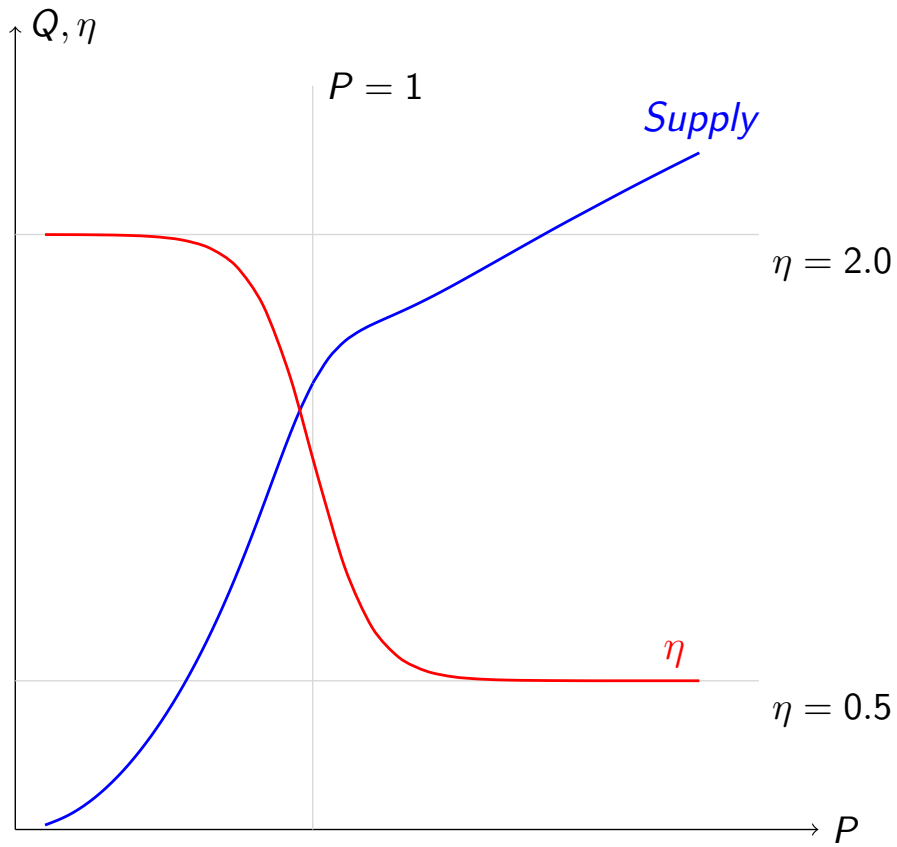


Figure: Example of a kinked supply curve using the sigmoid function

Greenhouse gas emissions

- The current model has four greenhouse gas emissions—the so-called Kyoto gases—carbon, methane, nitrous oxide, and fluoridated gases (of F-gases)
- Carbon, in the current version, is only emitted through the combustion of fuels. The emission coefficients correct for the use of fuels as feedstock such as in refineries and chemicals.
- The other greenhouse gases can be linked to specific inputs, to factors of production (such as land in the case of rice, or herds in the case of livestock), or process emissions such as in the waste management sector.
- The current version of the model does not include any abatement curves. In the case of carbon, there is fuel switching.

Carbon regimes

- A carbon tax is easily implemented. It can be differentiated by region, input and end-user. The model allows for partial to full exemption of specific agents.
- The tax can be endogenously determined with a cap on emissions. The caps can be set for various sets of coalition regions.
- Cap and trade can also be implemented with quota allocation rights assigned to individual regions.
- Some versions of Envisage also allow for border tax adjustments that are applied to regions not participating in a coalition.

Other emissions

Gas	Description
BC	Black carbon
CO	Carbon monoxide
NH_3	Ammonia
NMVB	Non-methane volatile organic compounds (short carbon cycle)
NMVF	Non-methane volatile organic compounds (long carbon cycle)
NO_x	Nitrogen oxides
OC	Organic carbon
PM10	Particulate matter 10
PM2.5	Particulate matter 2.5
SO_2	Sulfur dioxide

Dynamic components

- Labor/population are exogenous. Sources include UN Population Division and IIASA. The latter also includes education projections.
- Capital stock is exogenous within period. It is a function of long-run savings dynamics.
- The baseline scenario is used to calibrate labor productivity. The latter is allowed to differ across sectors.
- Other dynamic factors include improvements in energy efficiency and international trade and transport margins.
- There is ongoing work to provide additional dynamics to other model features—particularly preferences such as household utility and Armington preferences.
- The core baseline scenarios are currently calibrated to the SSP projections provided by the Integrated Assessment community.