World Bank and TGO

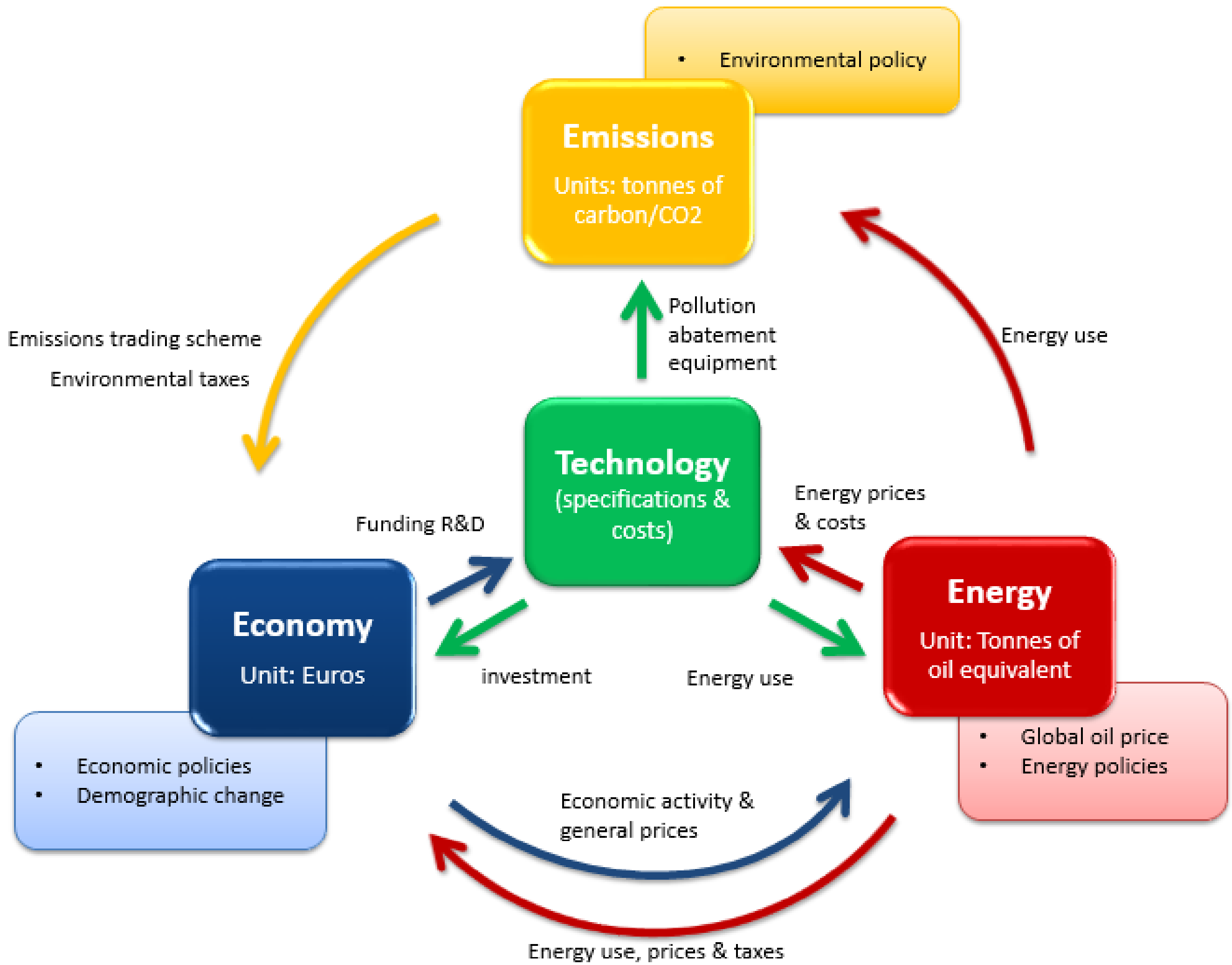
Energy-Environment-Economy links in E3-Thailand

Project: Impacts of carbon pricing instruments on national economy and contribution to NDC – Thailand

Unnada Chewpreecha and
Sophie Heald

14 February 2018

Energy-Environment-Economy interactions in E3-Thailand



The Energy Sub-model

- Determines final energy demand (by fuel and user) and prices of fuel use
- Provides feedback to main economic framework
- This 'top-down' approach is intended to be supplemented by a set of 'bottom-up' engineering sub-models
  – a detailed treatment of the electricity supply industry (FTT)

Aggregate energy demand functions

- No explicit production function
- Energy demand as derived from demand for heat, power etc. and in turn from demand for products
- 2-level hierarchy: aggregate energy demand equations and fuel share equations
- Aggregate demand affected by industrial output of user industry, household spending in total, relative prices, technical progress

Econometric equation	Main explanatory variables
Total energy demand (by sector)	economic activity, weighted price of energy, investment, technology
Disaggregated energy demand (by fuel by sectors	economic activity, relative price of specific fuel, investment, technology

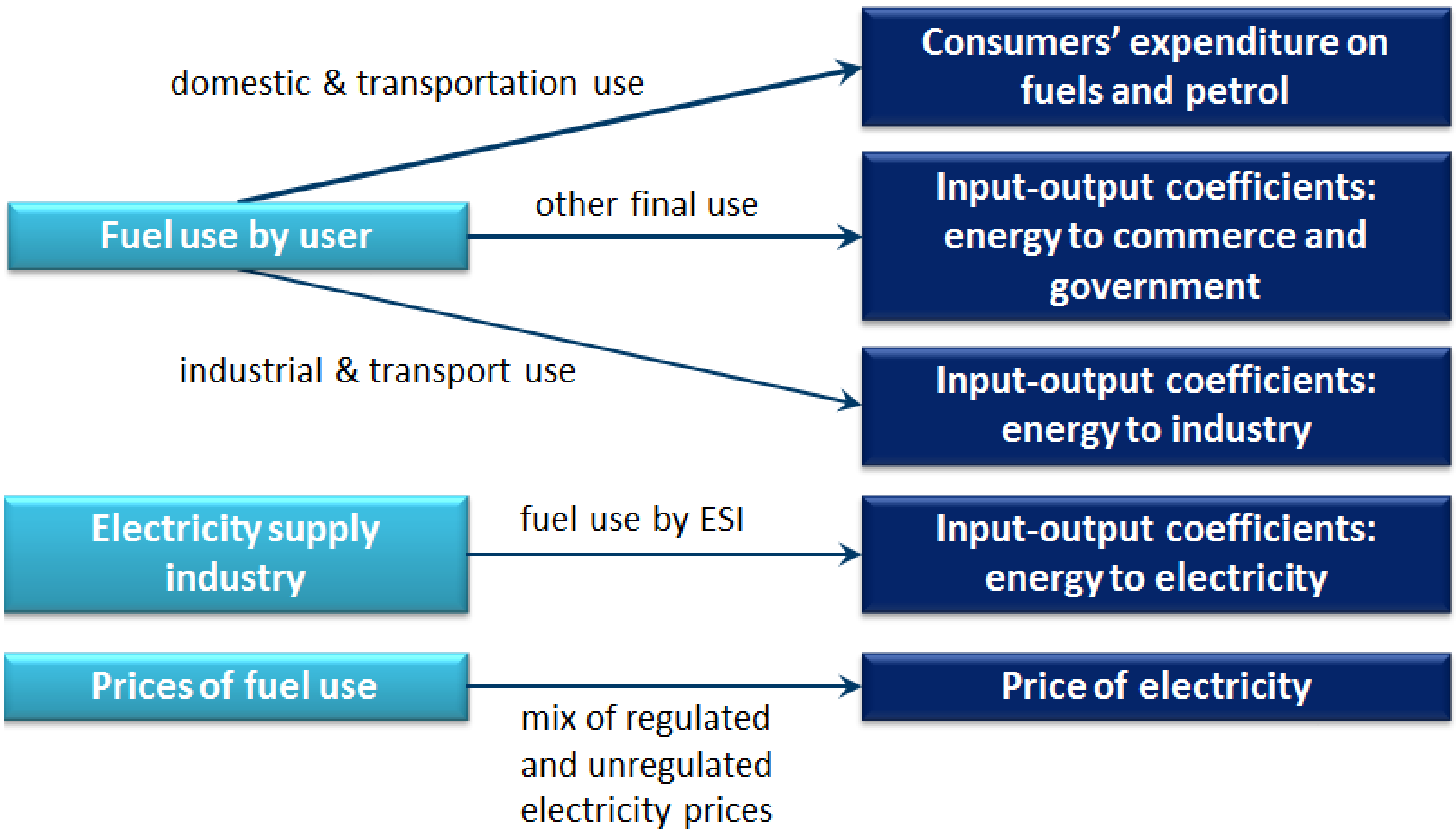
cambridge econometrics

Fuel share equations

- This aggregate demand then shared out among main fuel types (coal, fuel oil, gas and electricity)
- Fuel share equations depend upon:
  - activity, technology, relative price effects
- Total demand is scaled to match the results from the aggregate demand equation

cambridge econometrics

Feedback from the Energy Sub-model



FTT-Power Sub Model

- FTT:Power uses a decision-making core for investors wanting to build new electrical capacity, facing several options.
- The decision-making core takes place by pairwise levelised cost (LCOE) comparisons, conceptually equivalent to a binary logit model, parameterised by measured technology cost distributions.
- This part of the model is set to exogenous, allowing users to fix the power generation mix

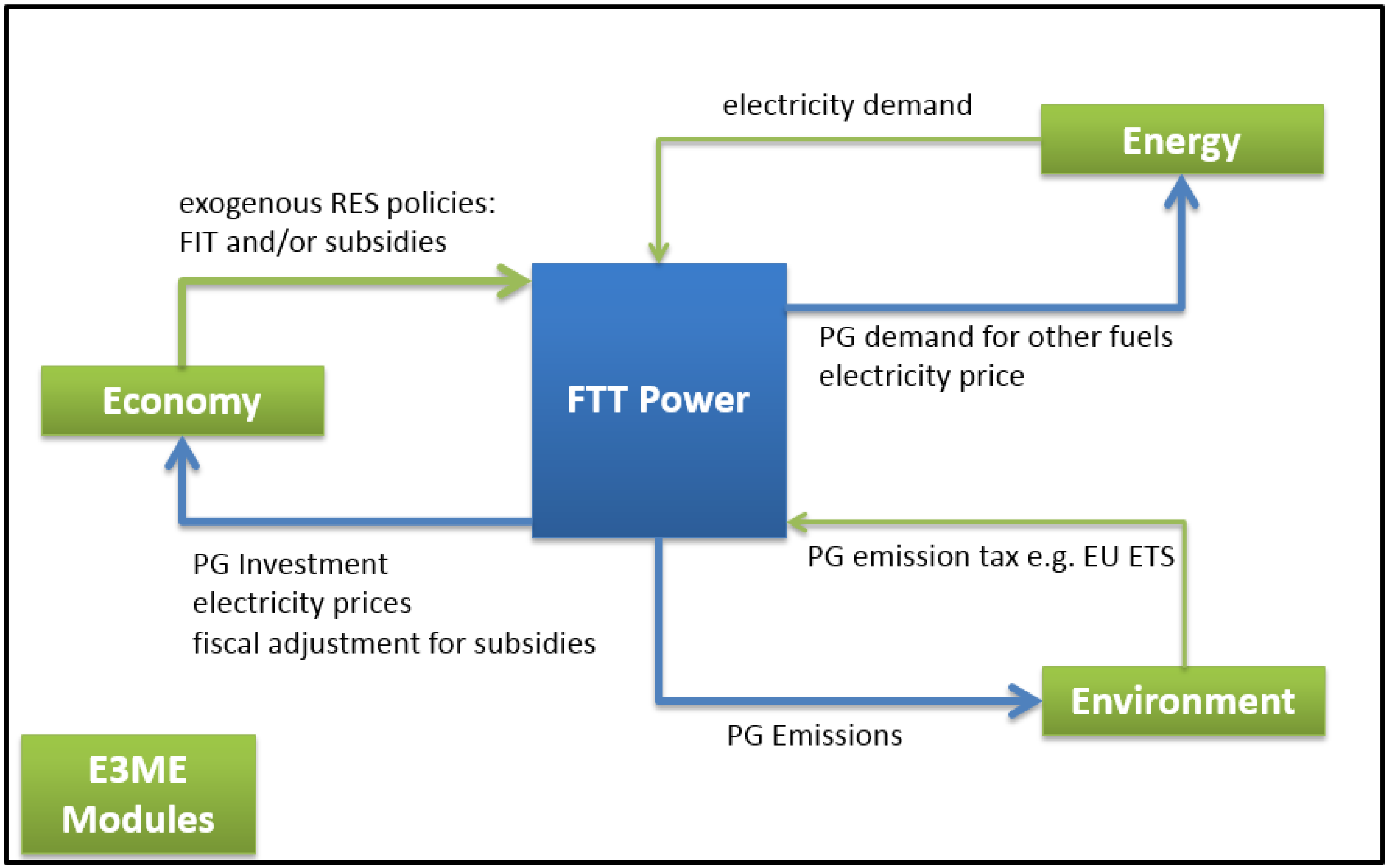
FTT:Power technologies, parameters and costs

0	From: IEA Projected costs of generating electricity																	
	p.103	p. 62-63							p.43									
	Discount rate	10%	Rate increase price of carbon		1%	Starting price of carbon ($/t)			22.10	dD/D	15%	Es/D:	1%	Upeak/Utot	30%	Us/Utot	1%	Negative allow
	Carbon Costs	std	Overnight	std	Fuel	std	O&M	std	Lifetime	Lead Time	Load Factoı	Type	LCOE	std	Fuel CO2	Efficiency	Emissions	Learning rates
	$/MWh	$/MWh	$/kW	$/MWh	$/MWh	$/MWh	$/MWh	$/MWh	years	years		0,1,2,3	$/MWh	$/MWh	kgCO2/GJ	%	tCO2/GWh	b
Nuclear	0	0	3739.50	1396.74	9.33	1.38	14.23	5.49	60	7	85%	1	91.80	31.15	0.0	100%	0.0	-0.086 No
Oil	0	0	1139.00	958.84	207.48	222.19	20.53	5.28	40	4	85%	1	246.14	237.52	73.3	45%	586.4	-0.014 No
Coal	0	0	2133.50	762.70	20.01	11.12	6.38	6.28	40	4	85%	1	60.36	24.92	99.4	42%	852.0	-0.044 Re
Coal + CCS	0	0	3919.00	1087.70	20.81	9.49	13.93	4.23	40	4	85%	1	97.14	27.71	99.4	37%	96.7	-0.074
IGCC	0	0	3552.00	1582.50	18.60	1.46	9.36	1.40	40	4	85%	1	84.52	27.22	99.4	42%	852.0	-0.044 SBi
IGCC + CCS	0	0	4194.00	1412.84	18.52	6.96	11.94	0.48	40	4	85%	1	97.24	29.47	99.4	37%	96.7	-0.074 BIC
CCGT	0	0	1047.00	365.21	60.08	12.25	4.51	1.67	30	2	85%	1	80.23	17.82	56.1	57%	354.3	-0.059 BIC
CCGT + CCS	0	0	2269.50	482.95	66.05	1.36	5.96	0.37	30	2	85%	1	105.93	8.63	56.1	47%	43.0	-0.074
Solid Biomass	0	0	4491.50	2021.84	44.10	34.52	10.09	10.44	40	4	85%	2	125.70	68.26	0.0	42%	0.0	-0.074 Bic
S Biomass CCS	0	0	6277.00	2346.85	44.10	34.52	10.09	10.44	40	4	85%	2	154.14	73.44	-112.0	37%	-980.8	-0.105
BIGCC	0	0	3552.00	1582.50	44.10	34.52	9.36	1.40	40	4	85%	2	110.01	59.75	0.0	42%	0.0	-0.074 Em
BIGCC + CCS	0	0	4194.00	1412.84	44.10	34.52	11.94	0.48	40	4	85%	2	122.82	57.02	-112.0	37%	-980.8	-0.105
Biogas	0	0	2604.00	2817.37	26.50	42.45	24.84	18.38	30	2	85%	2	66.42	88.38	0.0	57%	0.0	-0.074 Bic
Biogas + CCS	0	0	3826.50	2935.11	26.50	42.45	24.84	18.38	30	2	85%	2	108.54	90.14	-54.6	47%	-376.4	-0.105
Small Hydro	0	0	4254.00	4314.95	0.00	0.00	6.97	31.28	80	7	85%	3	84.39	109.80	0.0	100%	0.0	-0.020 No
Large Hydro	0	0	1995.50	5747.63	0.00	0.00	5.11	10.54	80	7	85%	3	41.42	115.13	0.0	100%	0.0	-0.020
Onshore	0	0	1962.50	632.81	0.00	0.00	21.26	9.10	25	1	27%	0	114.33	39.11	0.0	100%	0.0	-0.105
Offshore	0	0	4453.50	919.09	0.00	0.00	39.40	15.13	25	1	39%	0	182.91	44.74	0.0	100%	0.0	-0.136 No
Solar PV	0	0	5153.00	1602.55	0.00	0.00	23.73	21.96	25	1	16%	0	428.49	147.83	0.0	100%	0.0	-0.269
CSP	0	0	5141.00	494.62	0.00	0.00	27.59	5.44	25	1	32%	0	229.50	24.86	0.0	100%	0.0	-0.152 No
Geothermal	0	0	3901.00	5906.98	0.00	0.00	18.21	7.60	40	4	85%	3	80.33	101.66	0.0	100%	0.0	-0.074
Wave	0	0	4770.00	2240.11	0.00	0.00	51.87	33.93	20	1	46%	0	192.34	99.90	0.0	100%	0.0	-0.218 Ty
Fuel Cells	0	0	5459.00	5459.00	54.46	54.56	49.81	49.81	20	2	85%	1	190.33	159.93	15.3	80%	68.9	-0.234
CHP	0	0	1528.50	4568.36	55.84	10.16	9.20	36.31	40	2	85%	1	59.15	115.42	15.3	80%	68.9	-0.044
																	1 GWh = 3600 GJ	

IEA, 2015

cambridge econometrics

FTT:Power and E3-Thailand Model



cambridge econometrics

Prices in the Energy Sub-model

- Prices are determined as follows:
  - exogenous global fossil fuel prices: oil, gas and coal production prices
  - electricity prices from the FTT linked to cost of generation, transmission, distribution, and supply
- Policy measures affect the prices e.g.:
  - environmental taxes/charges
  - revenue from any energy tax may be used in main model, depending on the assumptions:
  - recycle carbon tax revenues as reduction in employer taxes
  - reduce direct/indirect tax burden

cambridge econometrics

Treatment of Environmental Emissions

- Energy-related CO_2 derived from energy demand
- Projections of fuel use by user and type determine much of the emissions, allowing for different fuel quality/combustion processes

Energy and emission classifications

Fuel users classification

1 Power own use & trans.
2 Other energy own use & transformation
3 Iron & steel
4 Non-ferrous metals
5 Chemicals
6 Cement
7 Other non-metallics
8 Ore-extra.(non-energy)
9 Food, drink & tobacco
10 Tex., cloth. & footwear
11 Paper & pulp
12 Plastic
13 Engineering etc
14 Other industry
15 Construction
16 Rail transport

Fuels type classification

1 Coal
2 Oil
3 Gas
4 Electricity
5 Biofuels

Power technology

1 Nuclear
2 Oil
3 Coal
4 Coal + CCS
5 IGCC
6 IGCC + CCS
7 CCGT
8 CCGT + CCS
9 Solid Biomass
10 S Biomass CCS
11 BIGCC
12 BIGCC + CCS
13 Biogas
14 Biogas + CCS
15 Tidal
16 Large Hydro
17 Onshore
18 Offshore
19 Solar PV
20 CSP
21 Geothermal
22 Wave
23 Fuel Cells
24 CHP

cambridge econometrics

Mitigation options modelled in E3-Thailand

- Carbon taxes and emission trading schemes
  - with alternative recycling options, i.e. via reductions in income taxes, labour taxes or indirect taxes
  - covering different areas
  - allowing exemption/lower rates for energy-intensive industries
- Regulations
- Energy efficiency
- Renewable mix
- Environmentally harmful subsidies removal
- Funding/support of R&D
  - general R&D support
  - support for energy saving and low-carbon processes

cambridge econometrics

ETS Options in the model

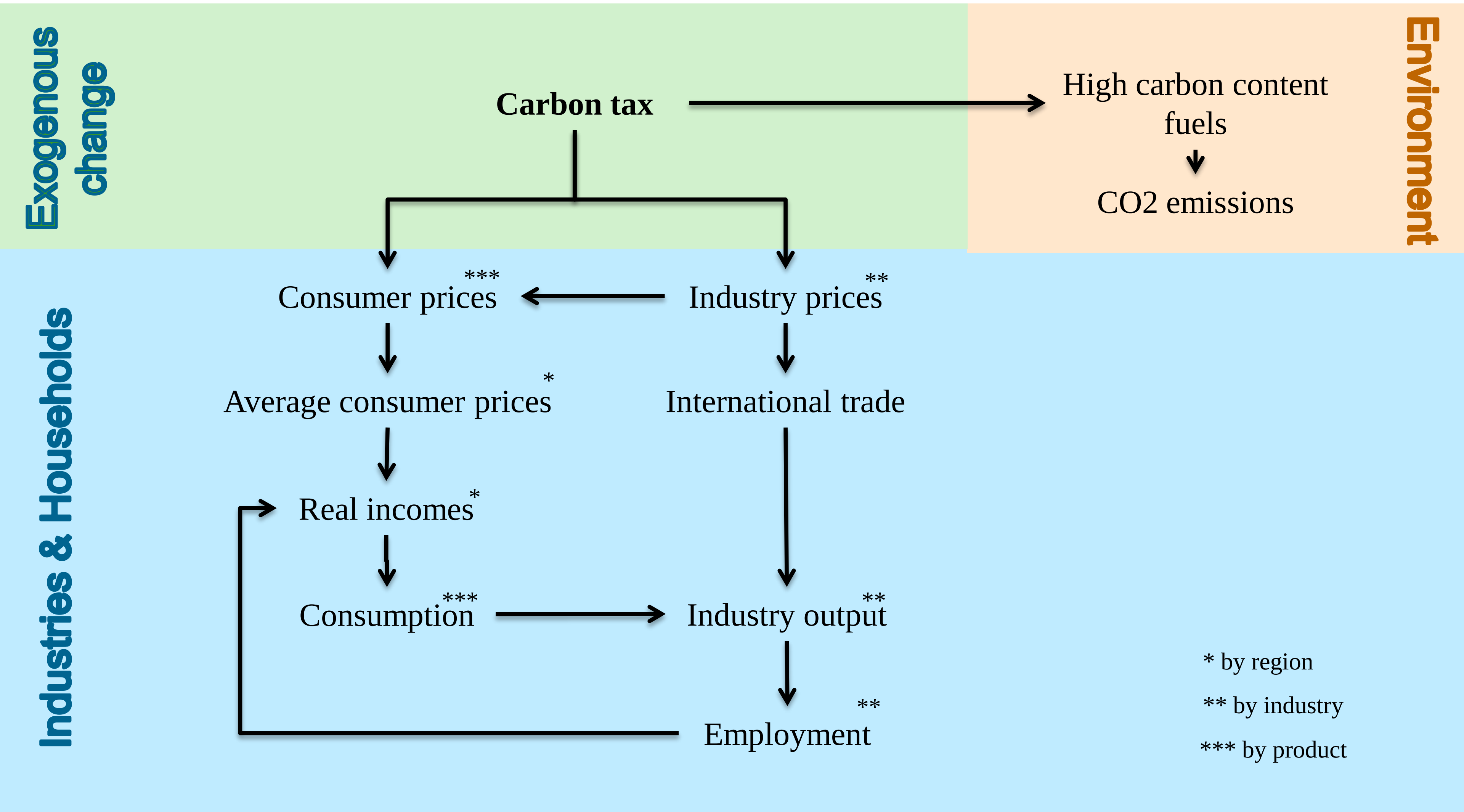
- Price can be entered exogenously or calculated by the model for a given level of caps
  - market clearing is assumed
  - yearly caps or prices
- Sectoral coverages and within sector coverages
- Permits are allocated or auctioned
- Offsets
- Auctioned revenues can be used for revenue recycling
- Indirect emissions

cambridge econometrics

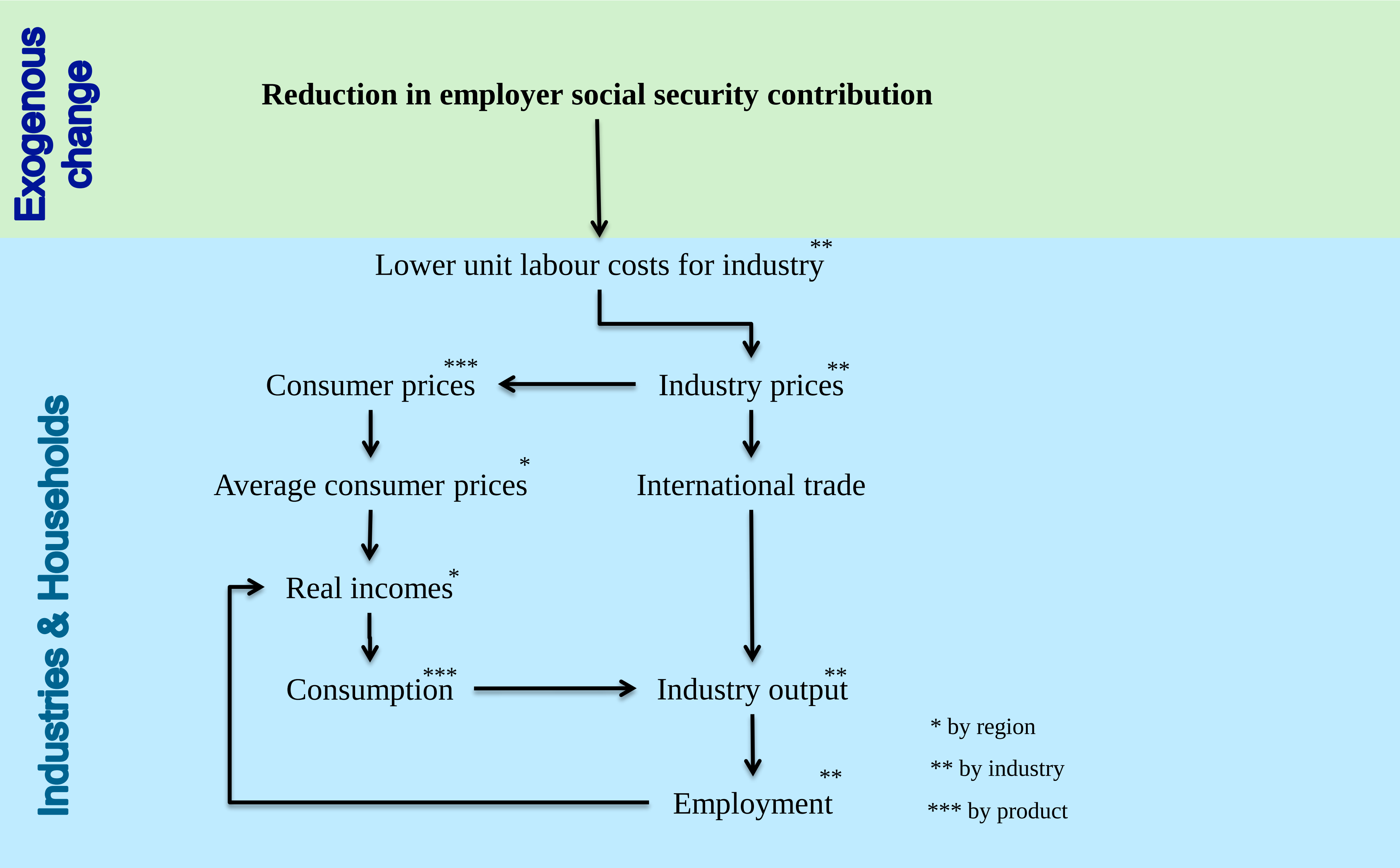
Carbon tax options in the model

- Sectoral coverage and within sector coverage (exemptions)
- Revenue recycling options
- Varying rates between sectors
- Varying rates between years
- Indirect emissions
- Revenue recycling

Impact of an carbon tax



Impact of revenue recycling



Energy efficiency

What is required for macro modelling

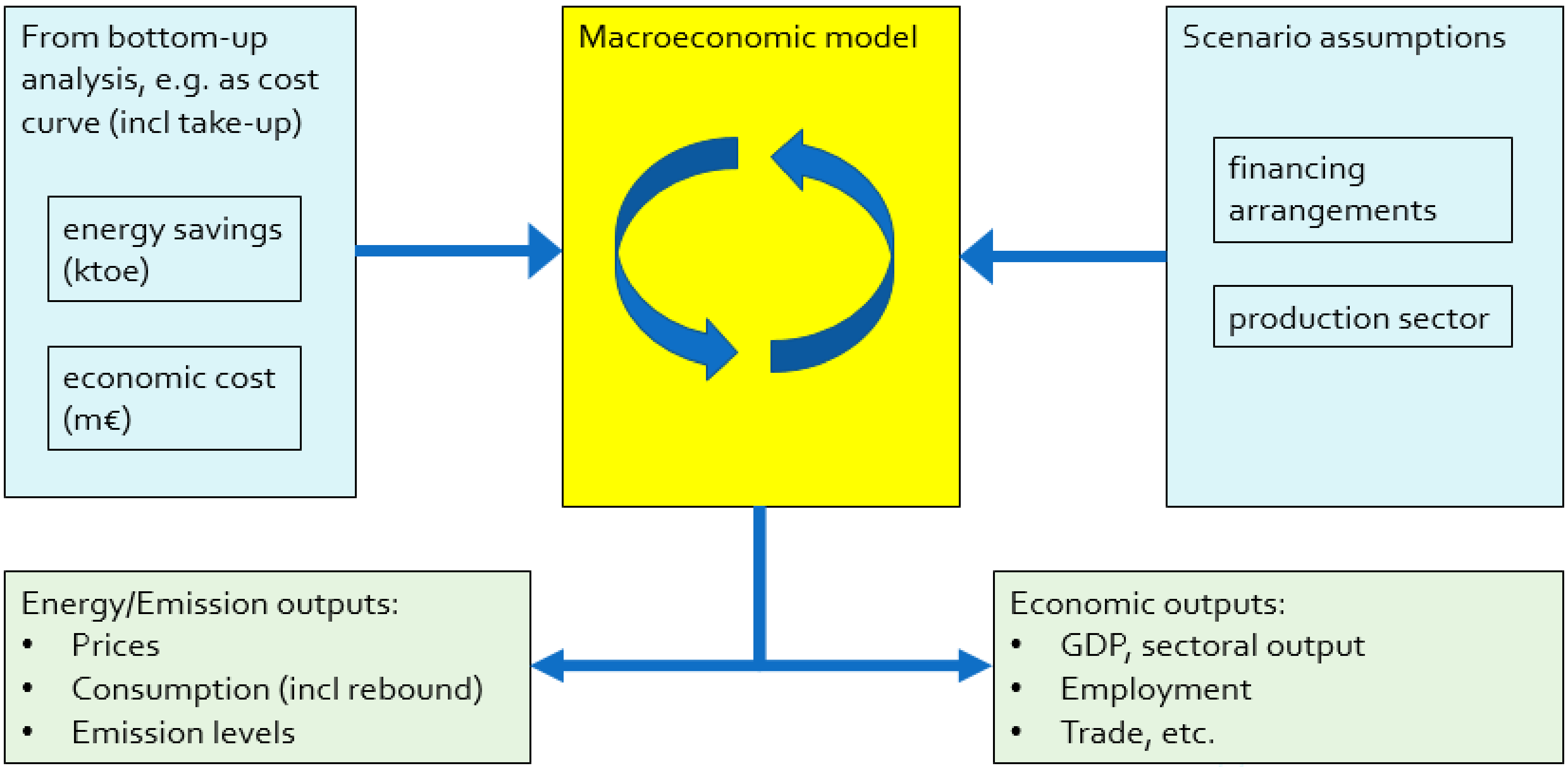
- A scenario approach is usually applied – either ex ante or ex post, if it is ex ante then a baseline case is required
- The scenarios are then defined in terms of:
  - amount of energy savings
  - cost of these savings
  - who pays for the measures
  - who receives the payment
- Each of these inputs must be defined by sector and time period

cambridge econometrics

What can macro-modelling tell you?

- A macroeconomic model could be able to tell you:
  - supply chain effects of energy efficiency programmes
  - macro-level impacts, like GDP
  - employment effects
  - indirect rebound effects
  - interaction with other policy
- It would not generally be able to tell you:
  - the individual energy savings for a particular measure
  - rates of uptake for particular technologies
- A comprehensive economic analysis therefore requires a combination of bottom-up and macroeconomic modelling

Model Inputs and outputs



Rebound effects

- A macroeconomic model is required to estimate indirect and induced rebound effects
  - the economic benefits of greater efficiency lead to higher rates of economic activity, meaning more energy consumption
  - some models (both energy and economic) will also include fossil fuel price feedback effects, with lower initial demand leading to lower prices and rebounds in consumption
- Estimates for the scale of rebound effects vary considerably – it is clear that they depend on sector, location, time period and several other factors

Impacts of energy efficiency