Incorporating Bottom-up Technological and Behavioural change information into a Top-down Computable General Equilibrium Model

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Important GHG sectors

- CGE models are often used for the study of economic impacts of climate change policies on the economy.
- Most modern economies consist of two sectors which are significant in terms of GHG emissions: electricity generation and transport sectors.

Important issues

- Electricity generation sector is dominated by issues of technological change; transport sector is concerned with issues about behavioural change
- How to model these types of issues in a CGE model?

ELECTRICITY SECTOR

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Technologies in the Electricity sector

- Electricity is produced from a combination of different technologies using coal, oil, gas, nuclear energy, biomass, wind/solar energy, etc.
- Each technology can be represented (in a top-down CGE model) by a production function/process describing the various combinations of fuels, labour, capital, and other inputs into its production

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Technology substitution

- The question is: how to model the ‘substitution’ between these production (functions/processes):
  - Mathematical programming
  - Aggregate production function approach
  - Strategic behaviour of industry suppliers

Mathematical programming

- Mathematical programming seeks to explain ‘substitution’ between technological processes by relying on the principle of material (energy) balance and the imposition of physical (capacity) constraints:
  - The method is elegant, powerful but often extremely difficult and cumbersome to be integrated into a large scale top-down model

Aggregate production function

- Aggregate production function approach (CRESH, Logit functions as used in MEGABARE, GTEM, SGM models, etc.) relies on the assumption of *imperfect* substitution between alternative technology outputs:
  - The method is simple and can easily be incorporated into a CGE model, but it is often artificial, arbitrary, and can be highly inaccurate in describing reality.

Strategic behaviour

- Strategic behaviour of industry suppliers can be used to explain different shares of technologies in the electricity market, based on the assumption of product heterogeneity on the cost side, even if the outputs of all technologies are homogeneous from the demand side.

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Strategic behaviour in CGE

- Conventional CGE models do not adopt this approach because of the assumption of perfect competition (PC) in the electricity.
- But PC is highly unrealistic, given that electricity production is often characterised by a mixture of constant and increasing returns to scale (IRTS) production processes, in many cases with large fixed costs.

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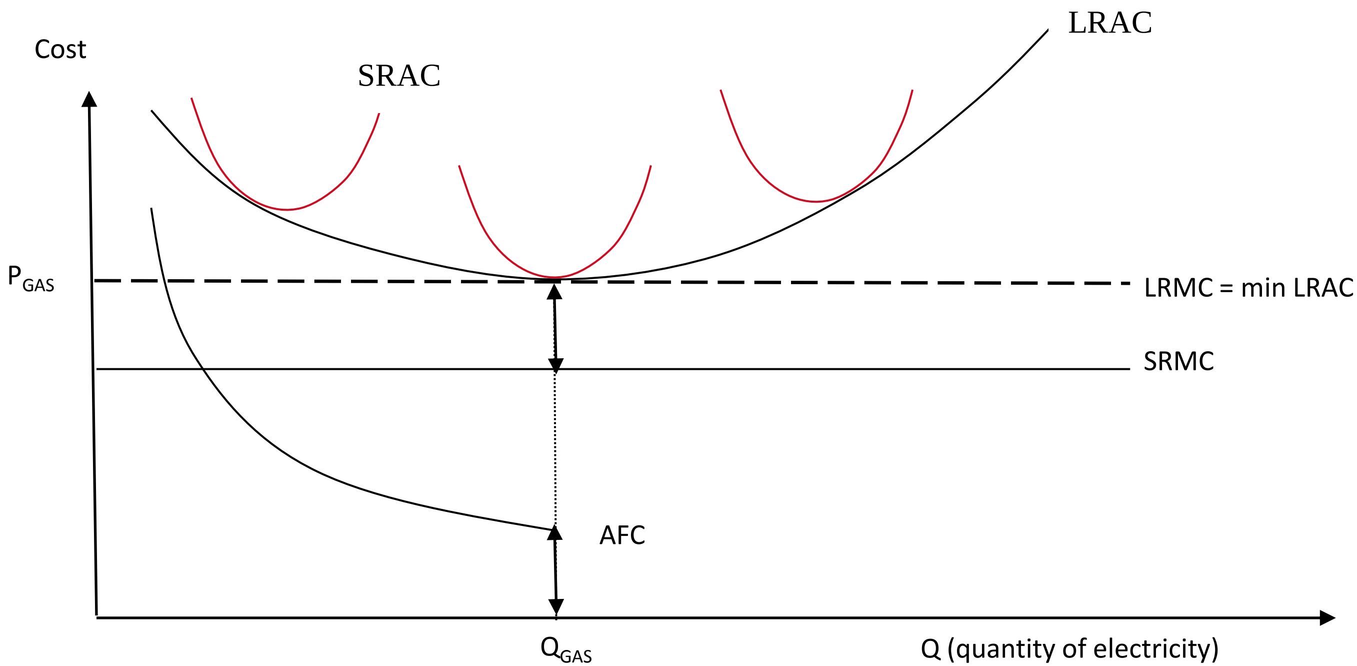
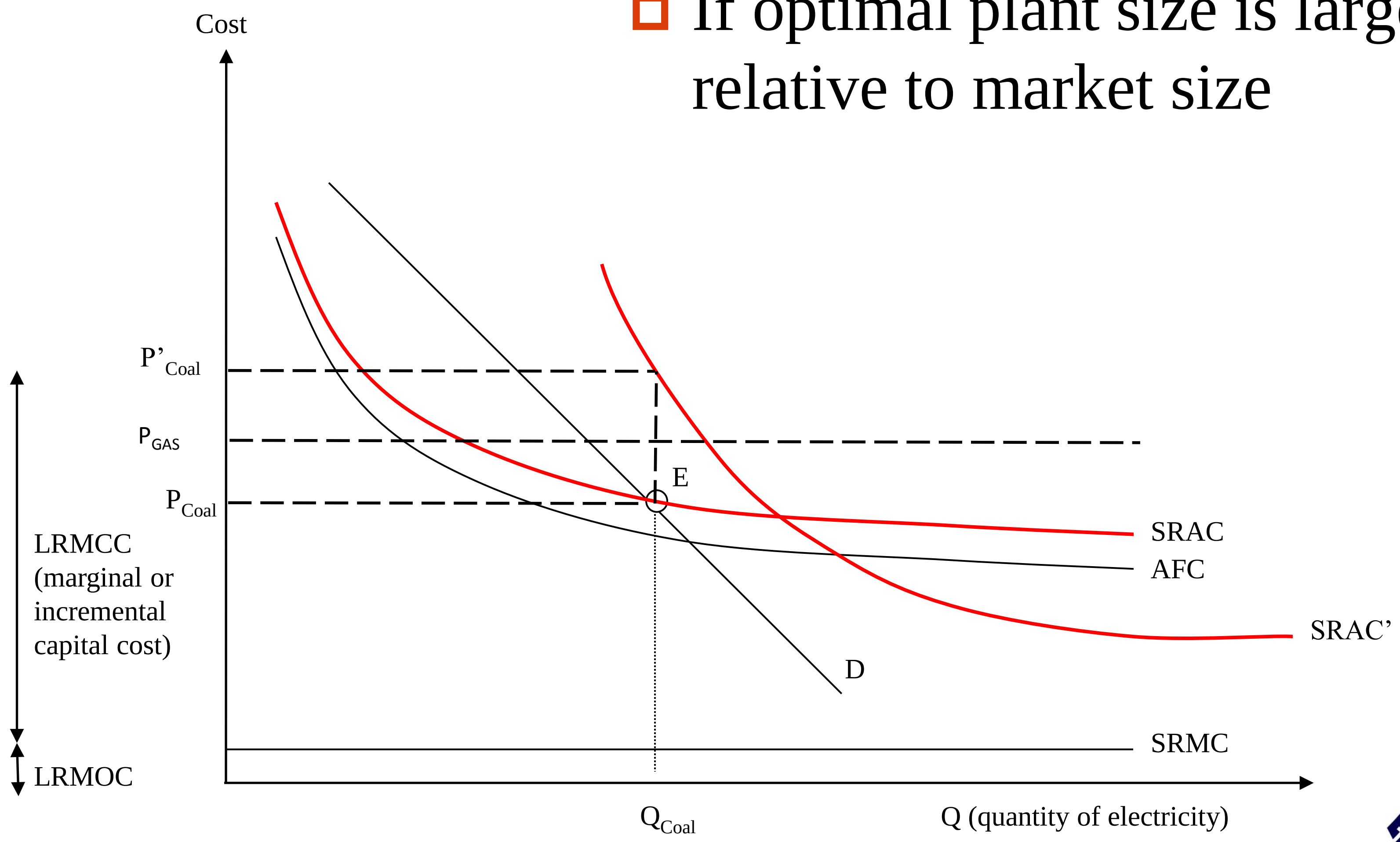
Constant returns to scale

- If optimal plant size is small relative to the size of demand for the product.

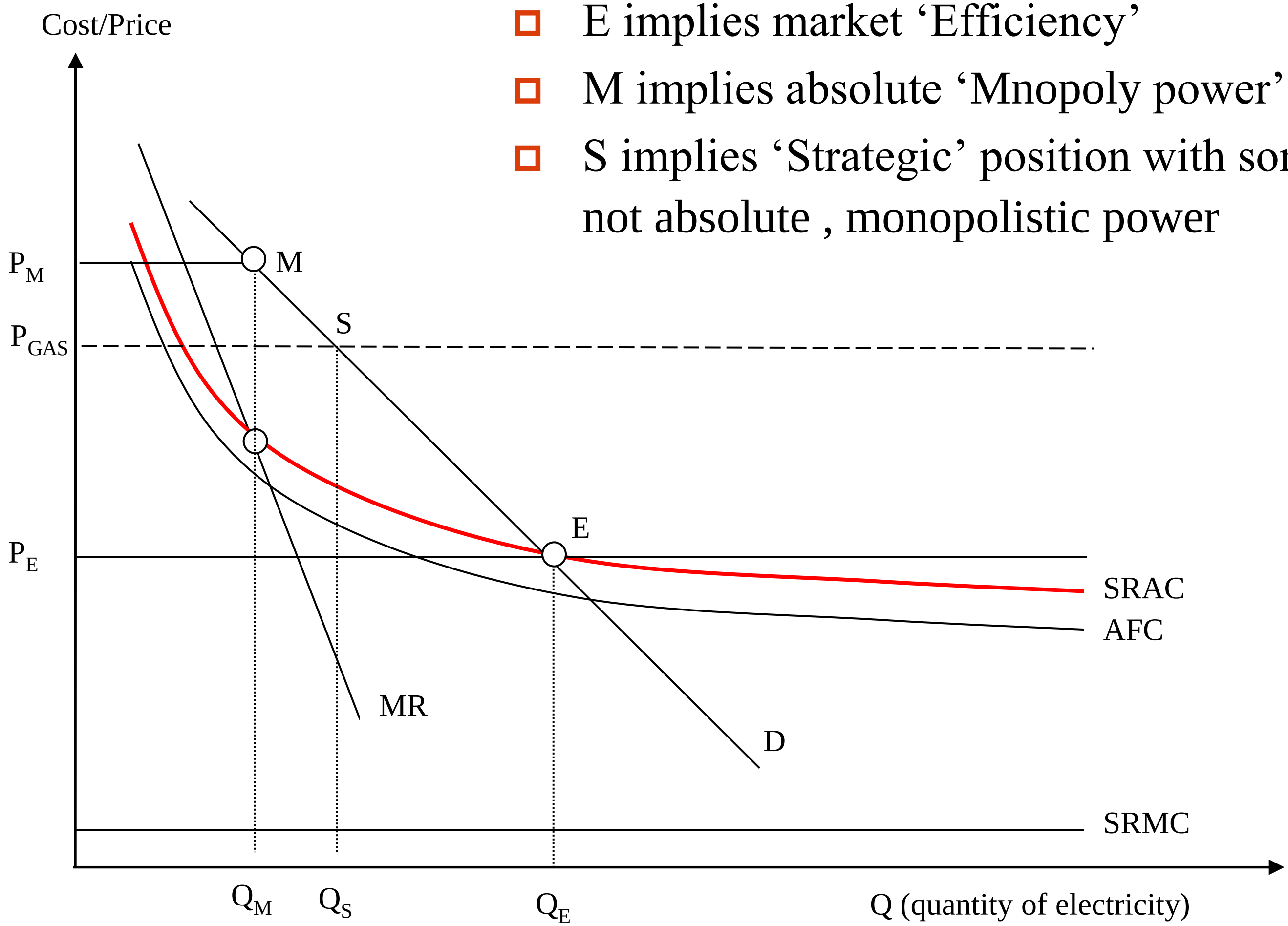


Increasing returns to scale

- If optimal plant size is large relative to market size

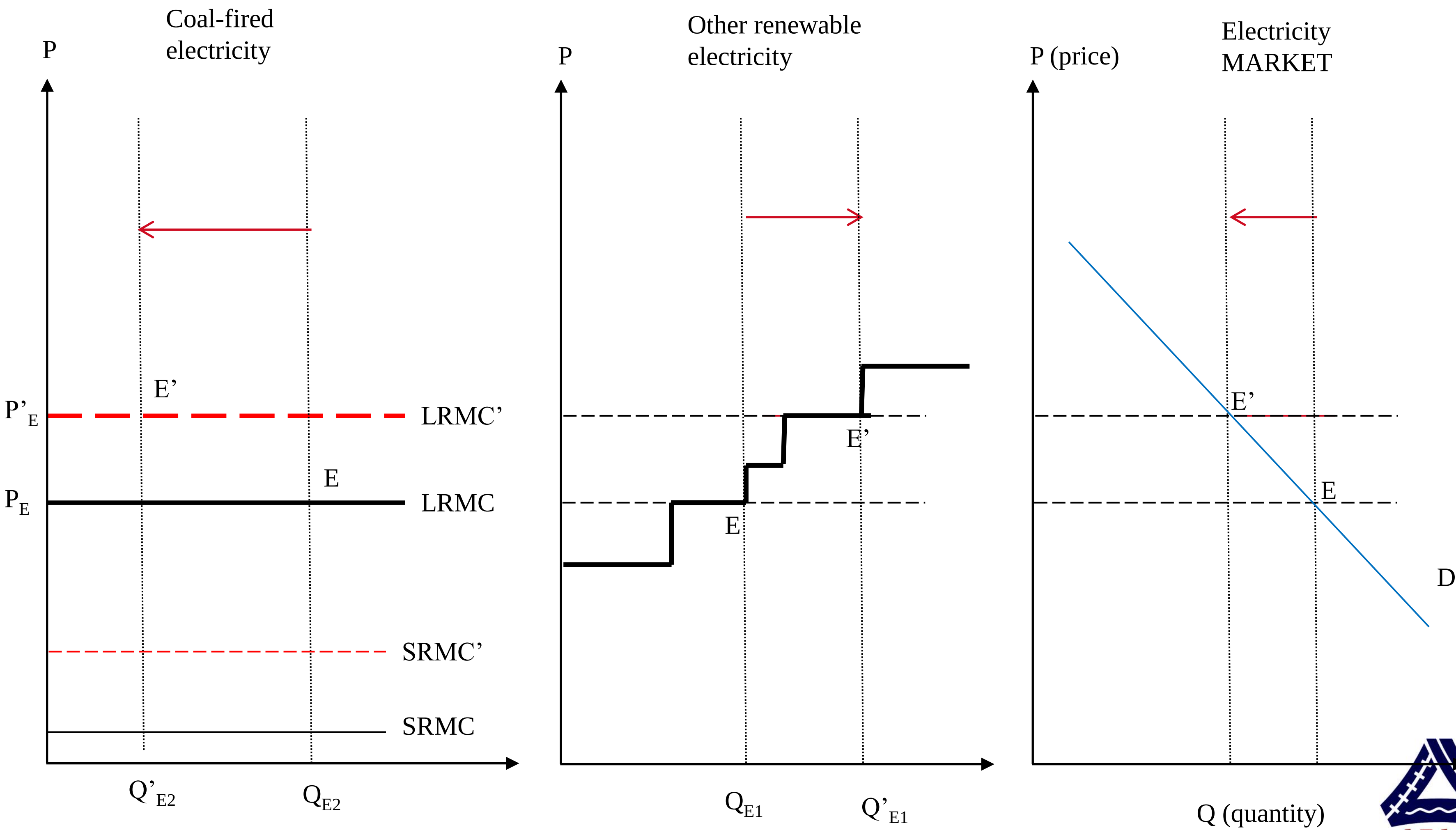


Increasing returns to scale & monopolistic power

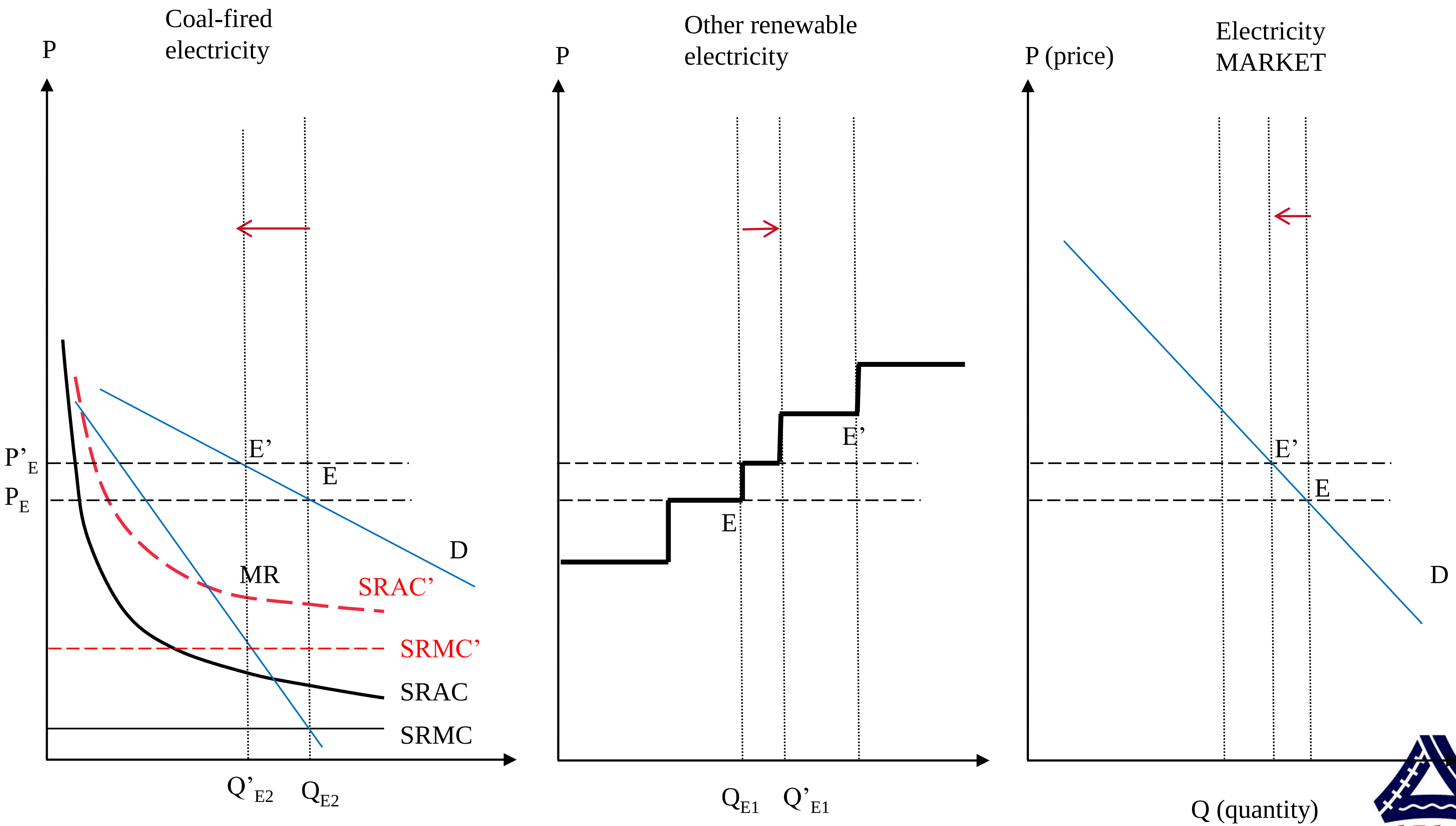


- E implies market ‘Efficiency’
- M implies absolute ‘Mnopoly power’
- S implies ‘Strategic’ position with some, but not absolute , monopolistic power

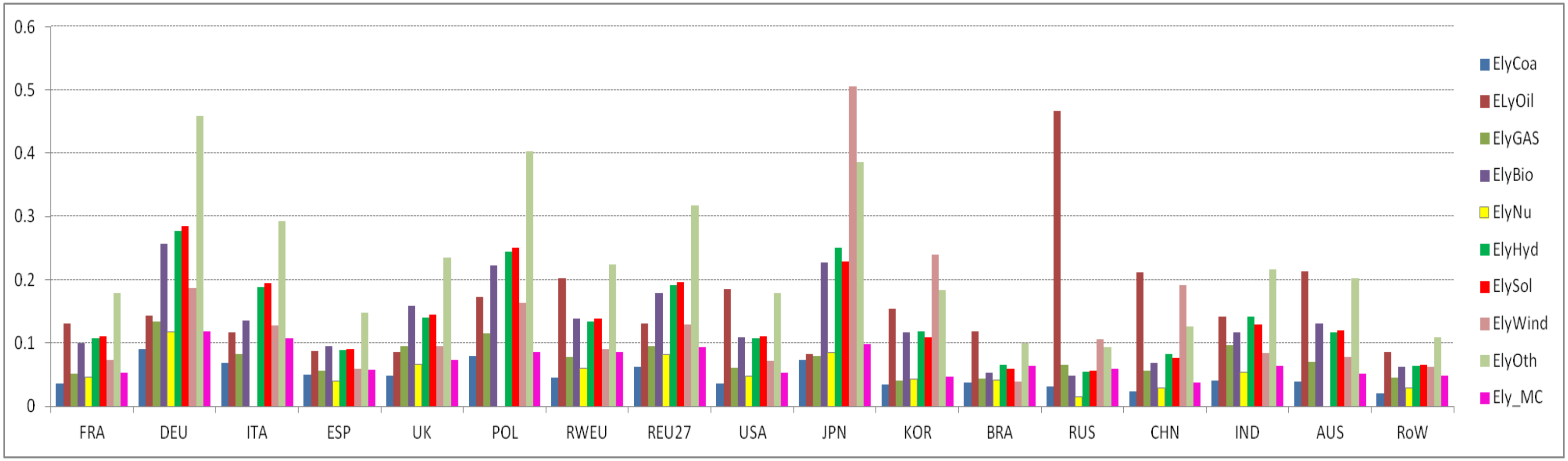
Quantity responses under perfect competition assumption

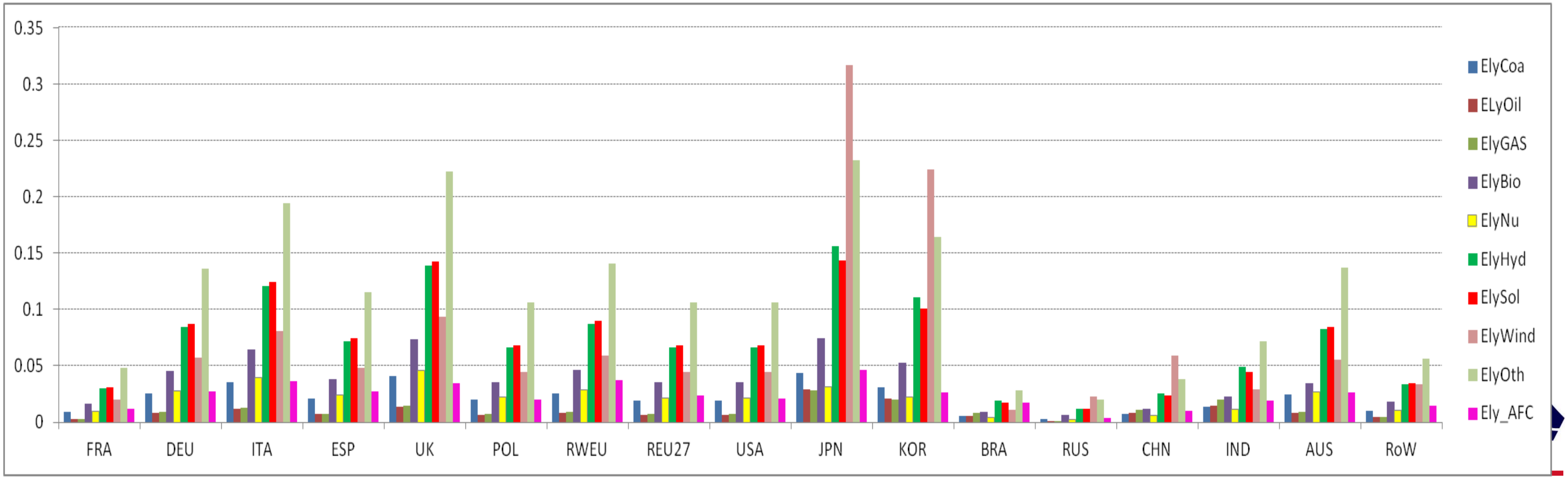


Quantity responses under assumption of monopolistic power



Marginal cost (MC) and average fixed cost (AFC) for various technologies in different countries





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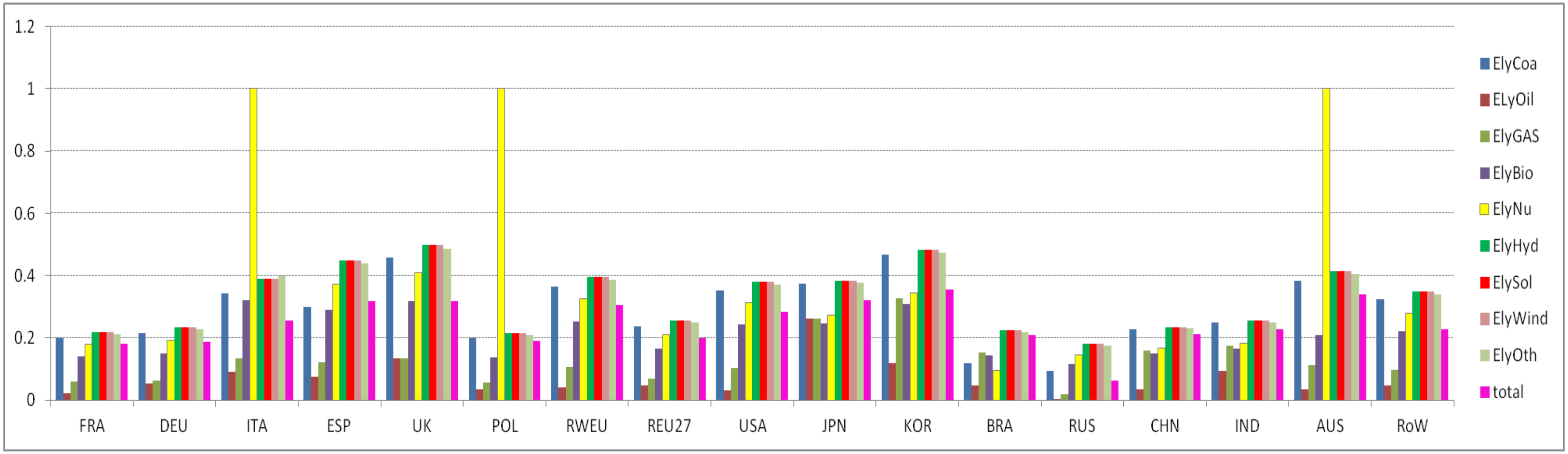
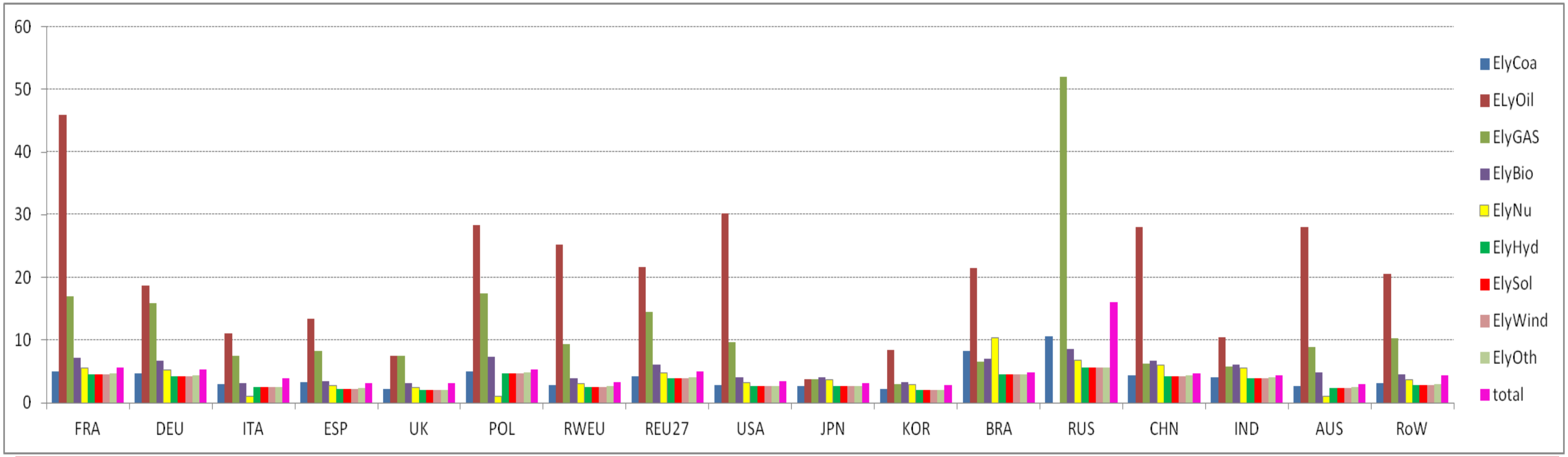
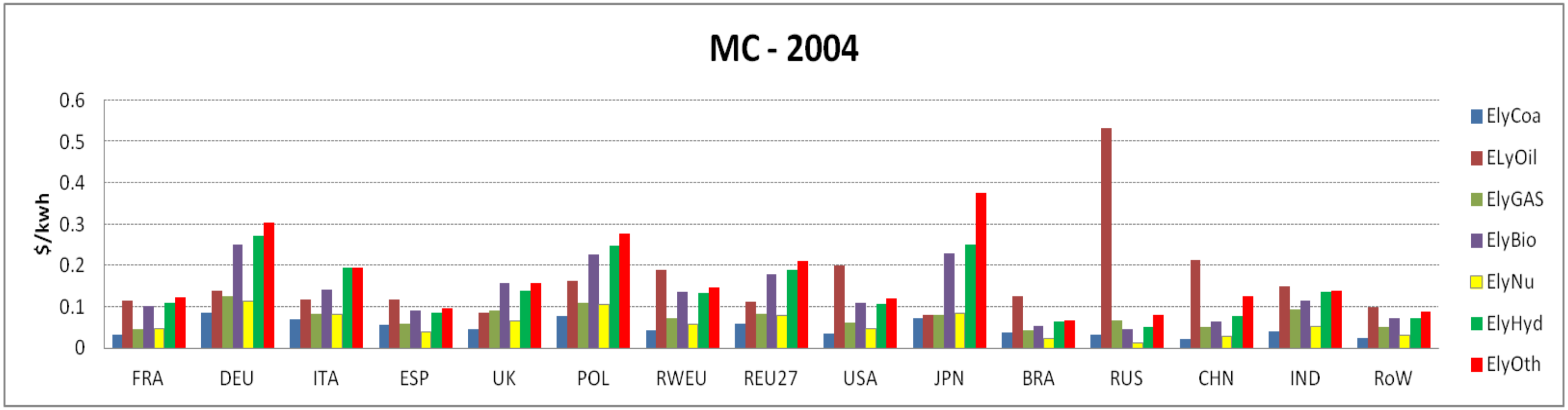
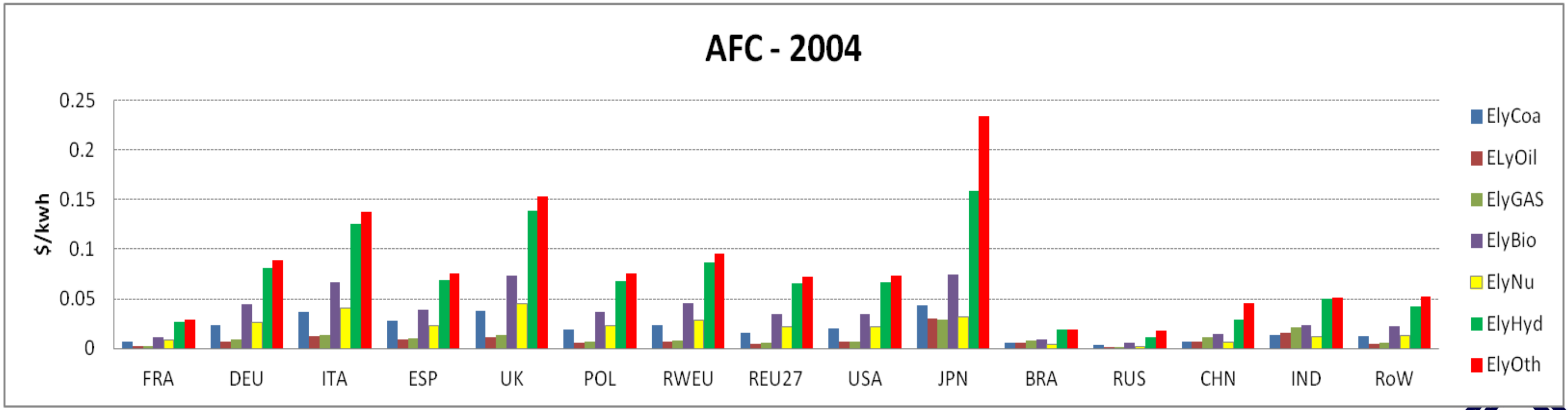
Mark-up = AFC/(AFC+MC)
elasticity = 1/mark-up



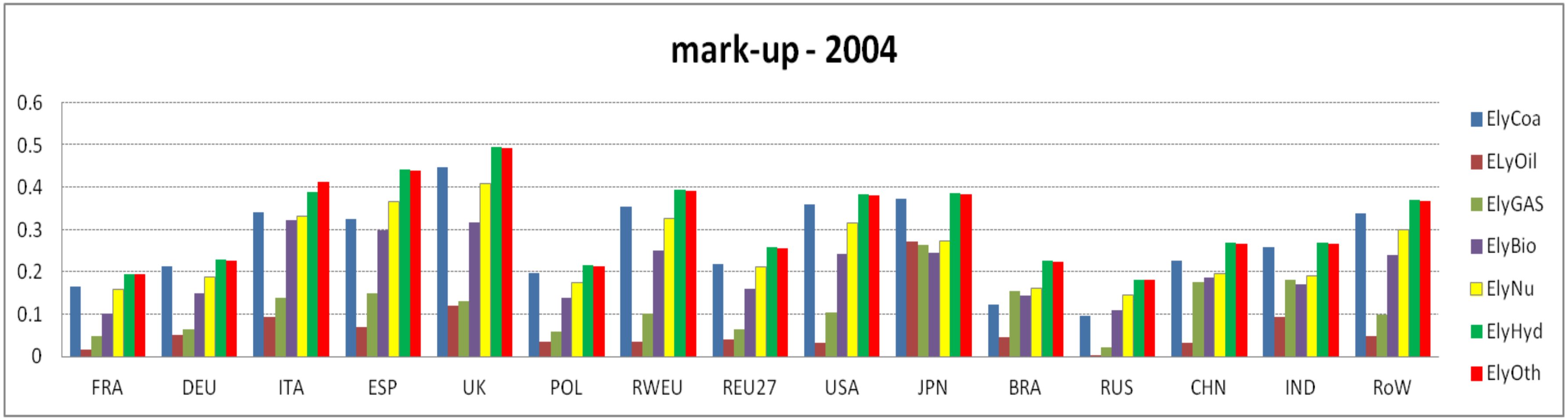


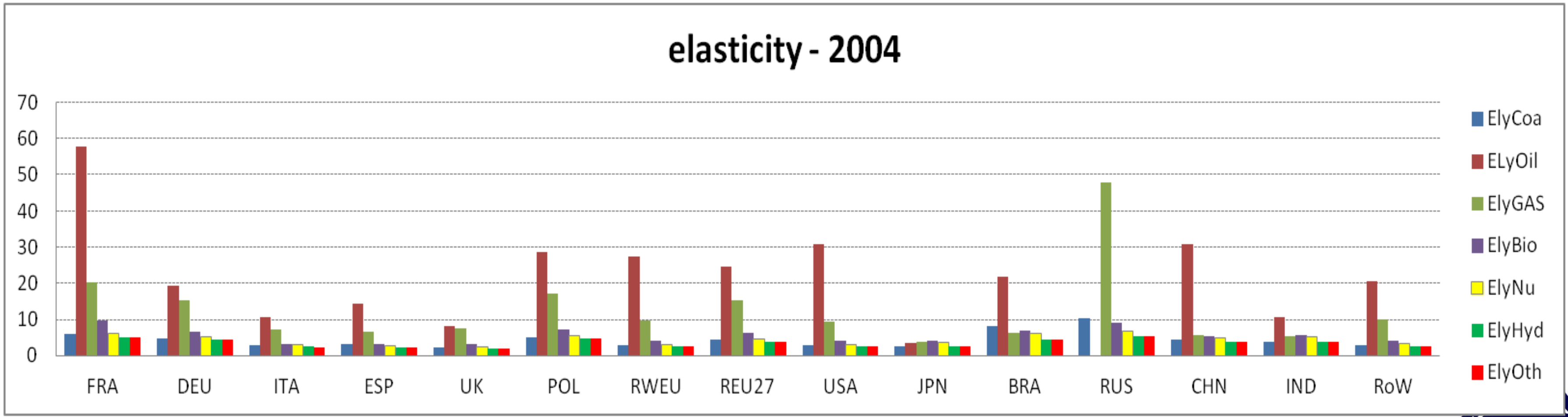
Base data (2004) – GTAP7, IEA



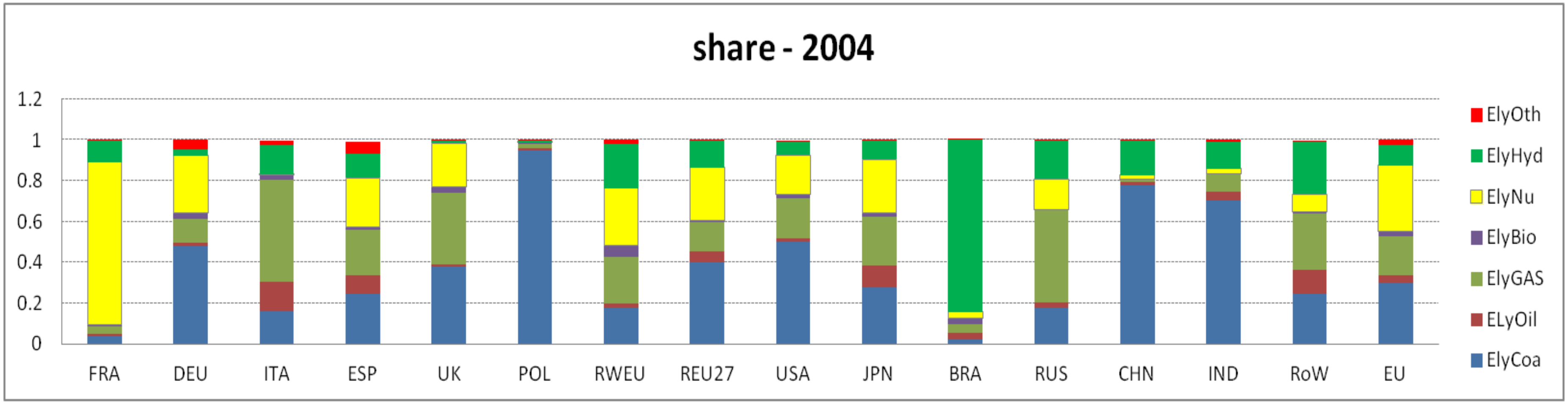


Base data (2004) – GTAP7, IEA

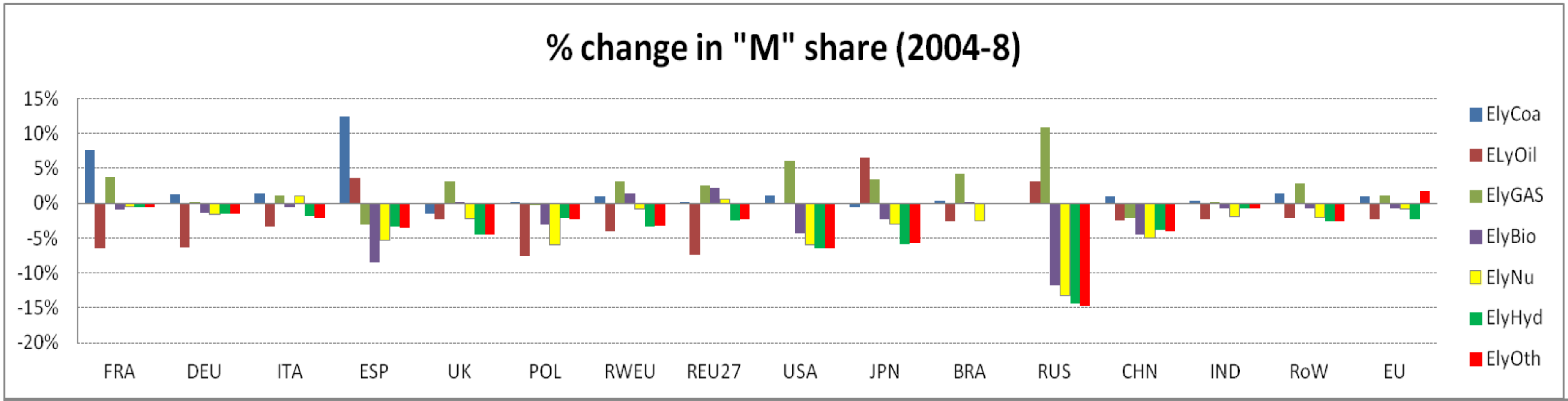


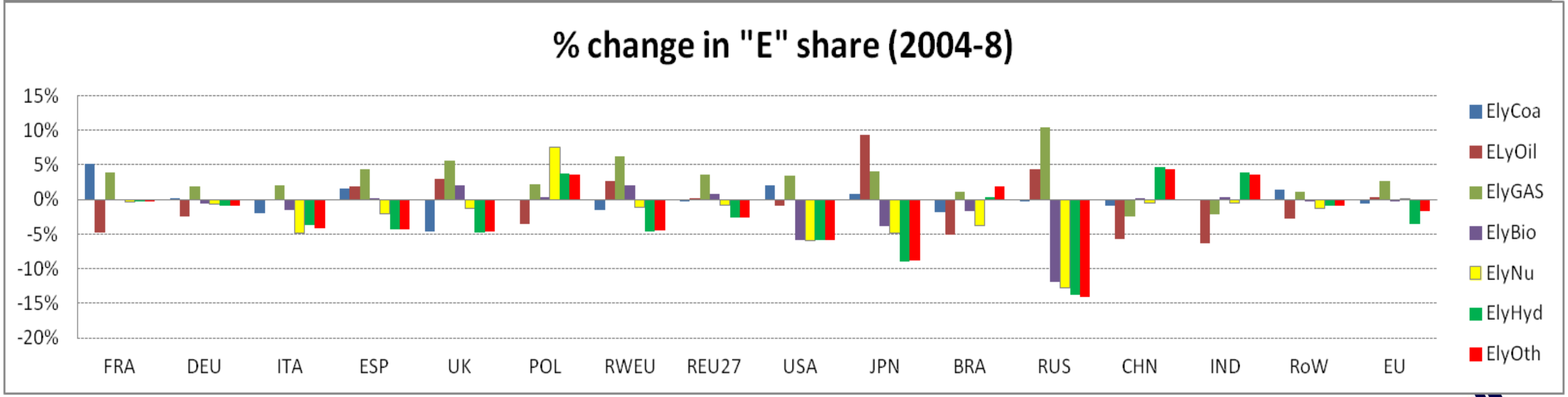


Base data (2004) – GTAP7, IEA



Experiment – effects of European Emission Trading Scheme for the Electricity sector





TRANSPORT SECTOR

Transport sector is characterised by behavioural decisions at a disaggregate level

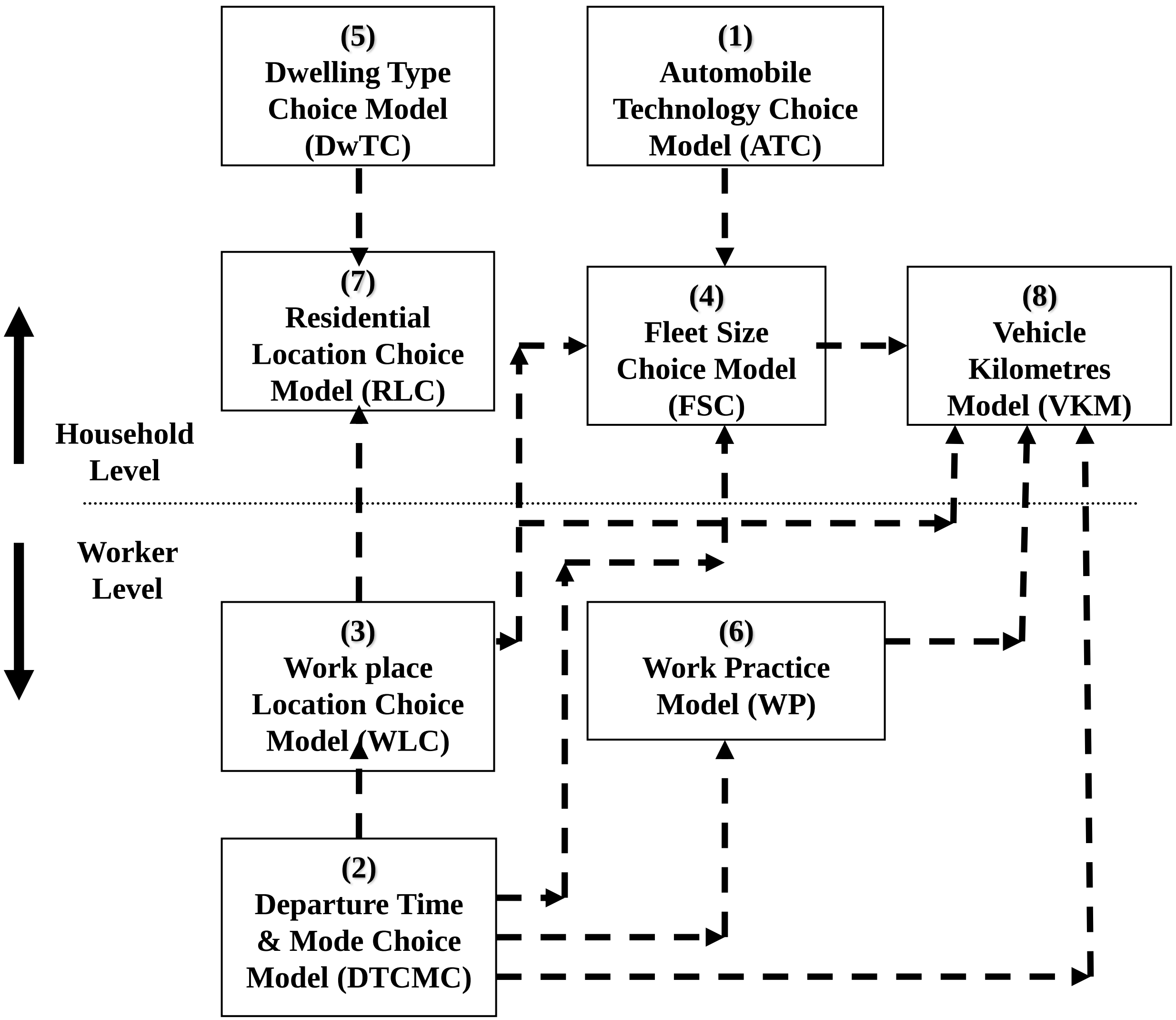
- Discrete choice (DC) modules are often used in bottom-up transport-land use models to look at issues of behavioural change
- They are rich in details at a disaggregate (individual) level, but weak in details concerning economy wide-linkages, the latter are better handled by continuous aggregate demand (CD) model

Link between transport behavioural decisions and economy wide policies

- There have been studies which look at the conceptual link between DC and CD models within the neoclassical framework.
- However, none so far has actually incorporated a “true” DC module (one estimated based on disaggregate data) within a CGE framework with links to CD modules

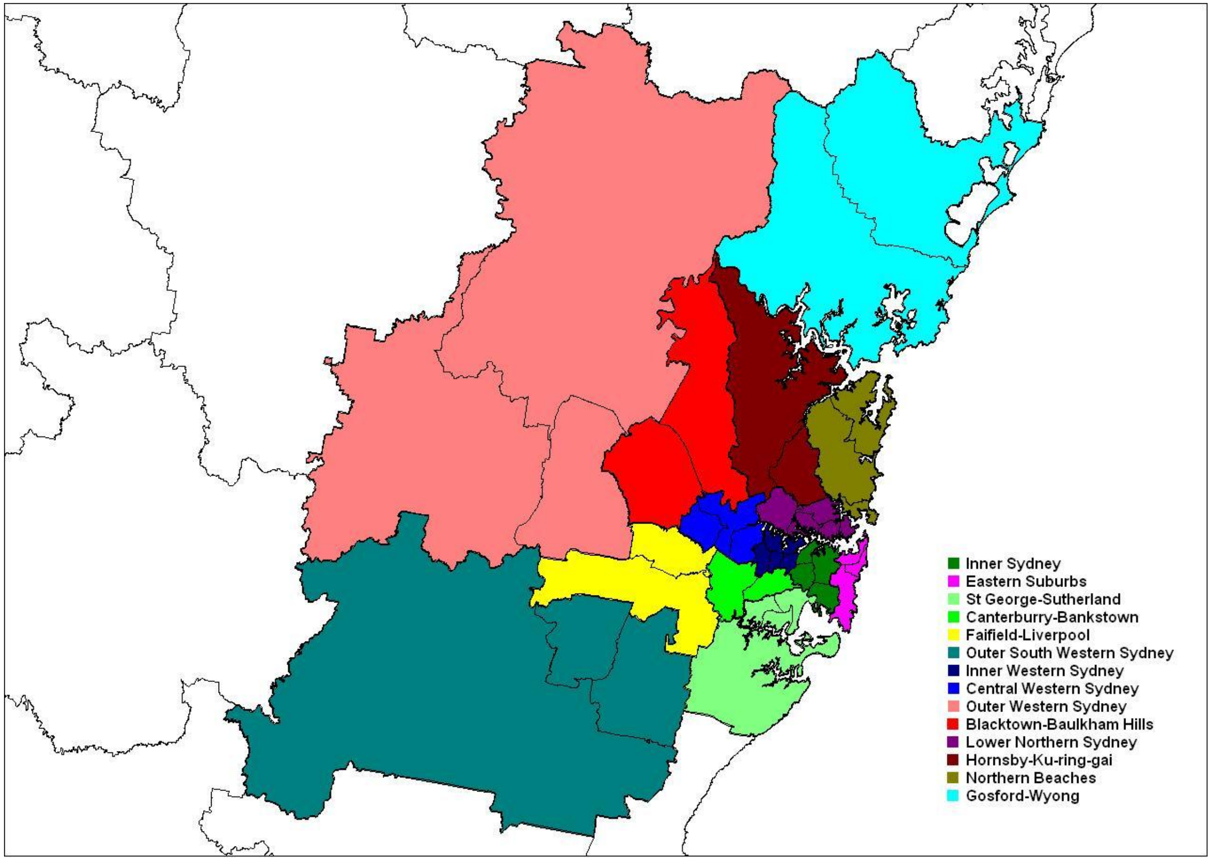
(3)

TRESIS – a bottom-up transport land-use model for Sydney

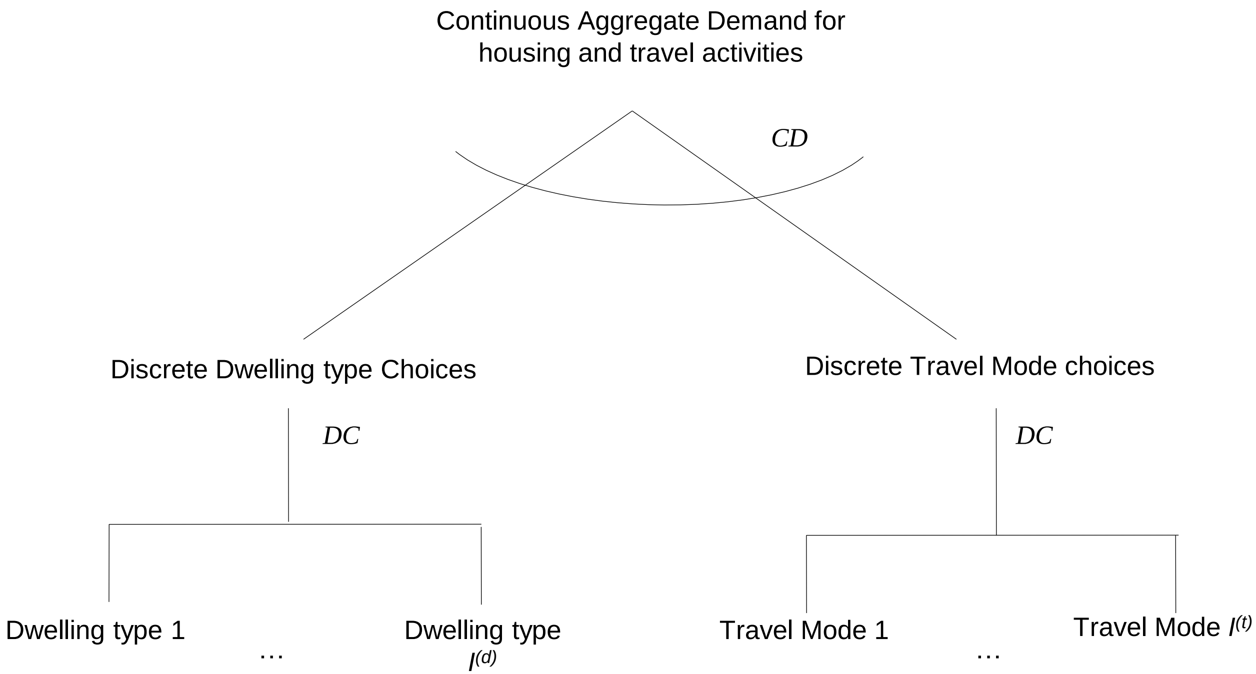


<u>Note</u>:
i) Number in brackets indicates the order of evaluating model in a sequence
ii) Dashed arrows indicate inter-dependency among related models

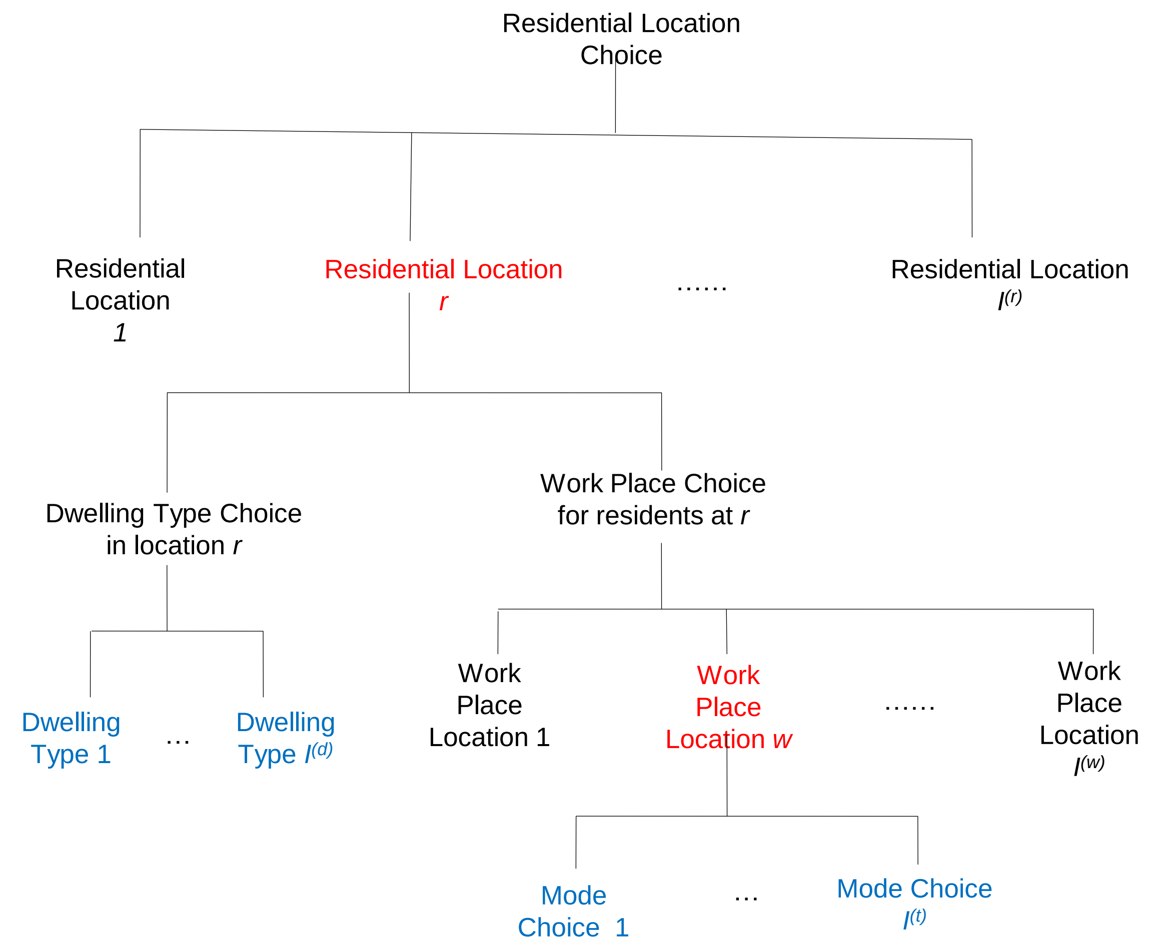
SGEM is a top-down CGE model for the Sydney Metropolitan Area (SMA)



A simple linkage between DC and CD modules within TRESIS-SGEM



Linkages between DC decisions with a spatial (location) element



Mathematical formulation of a nested DC module

$$Prob_i^{(t/wr)} = \frac{\exp(V_i^{(t/wr)})}{\sum_{j \in I^{(t/wr)}} \exp(V_j^{(t/wr)})}; \quad i \in I^{(t/wr)}.$$

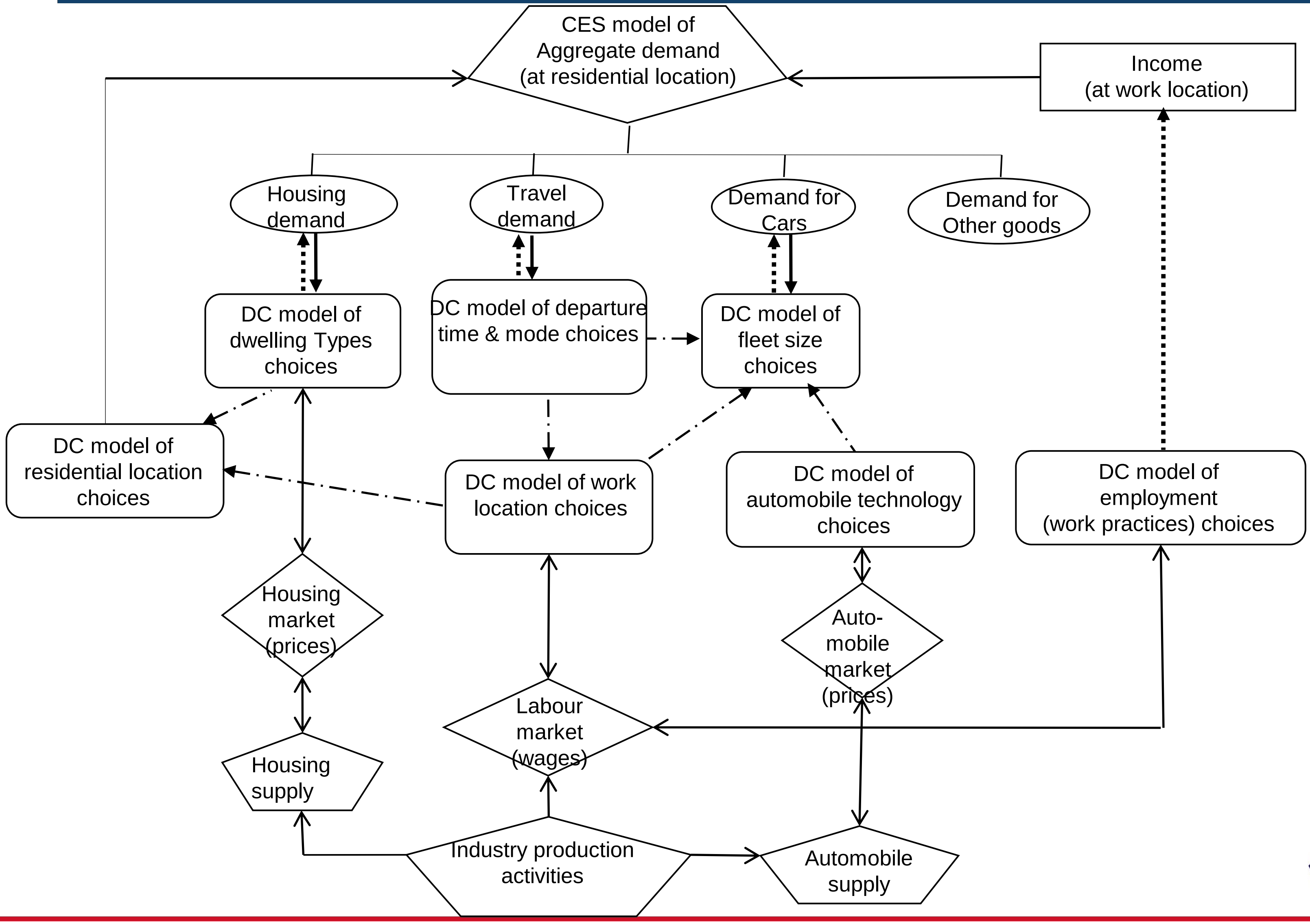
$$V_i^{(t/wr)} = \sum_{m \in M^{(t)}} \alpha_m^{(t)} A_{im}^{(t/wr)} + \sum_{n \in N^{(t)}} \beta_n^{(t)} B_{in}^{(t/wr)}$$

$$\overline{V}^{(t/wr)} = \ln \sum_{j \in I^{(t/wr)}} \exp(V_j^{(t/wr)}) = \sum_{i \in I^{(t/wr)}} \frac{\exp(V_i^{(t/wr)})}{\sum_{j \in I} \exp(V_j^{(t/wr)})} \ln(\exp(V_j^{(t/wr)}))$$

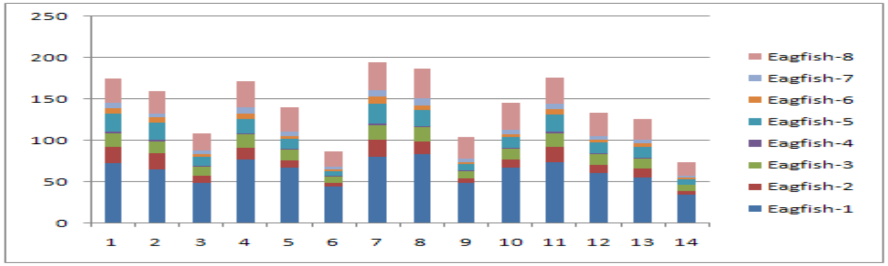
$$= \sum_{j \in I^{(t/wr)}} Prob_j^{(t/wr)} (V_j^{(t/wr)})$$

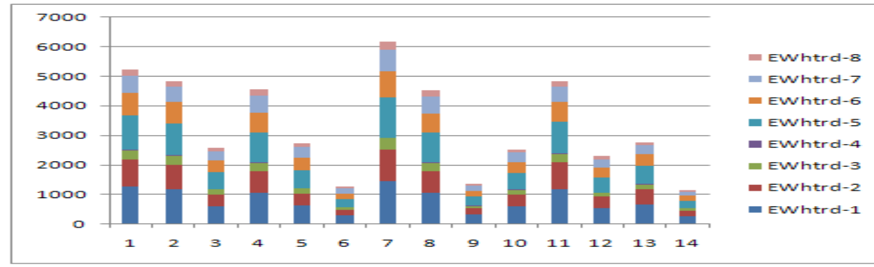
$$d\ln(Prob_i^{(t)}) = dV_i^{(t)} - d\overline{V}^{(t)}$$

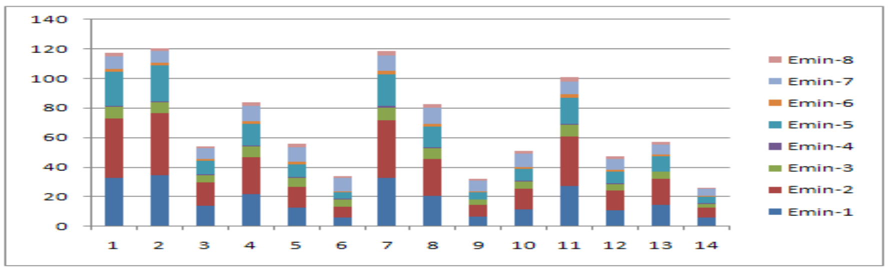
More complex linkages

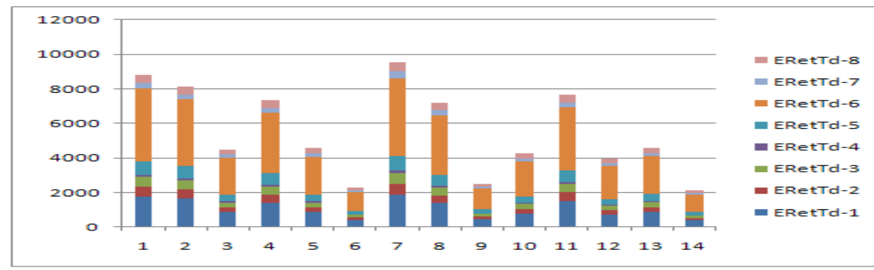


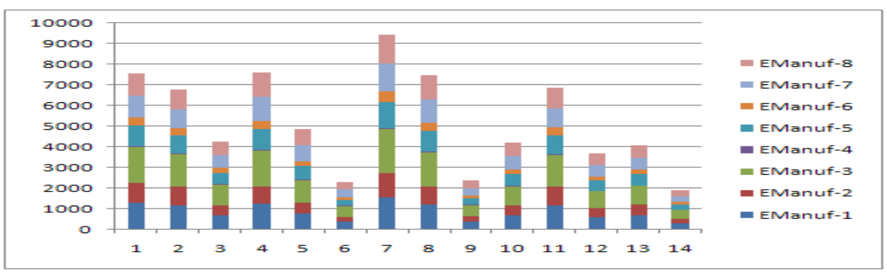
Effective Employment Density in each of the 14 zones by Occupation categories (ABS 2006 Journey to Work))

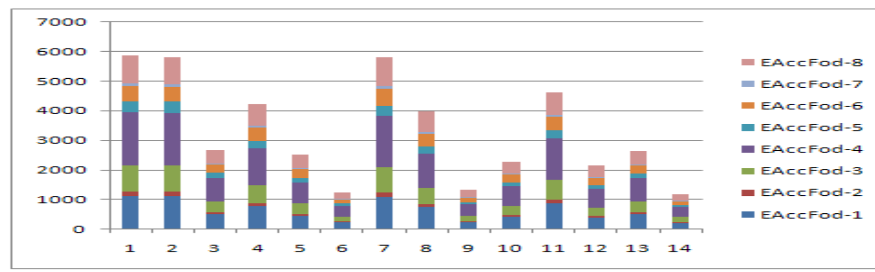


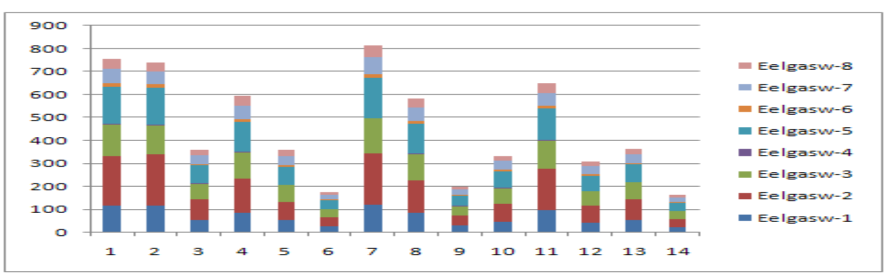


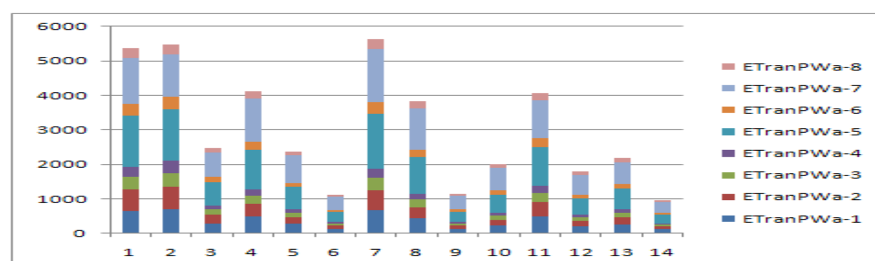












An Illustative experiment
North-West Rail Link (NWRL) Project

Table 1 Percentage change in the total number of work trips by TRAIN between Origin-Destination zones following the improvement in the rail ink between zone 1 and zone 10.

Origin Zone		Destination Zone No.														
No.	Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Average over all destinations
		Inner_Sydney	Eastern_Subs	StGge_Suther	Canter_Banks	Fairfd_Livrp	Outer_SW_Syd	Inner_W_Syd	Centrl_W_Syd	Outer_W_Syd	Blck_Baulk_H	Lower_N_Syd	Horns_Kuring	Nth_Beaches	Gosfrd_Wyong	
1	Inner_Sydney	0.00	0.00	0.15	0.82	-0.70	0.20	-2.31	1.83	0.25	3.96	0.00	0.29	0.15	0.21	0.38
2	Eastern_Subs	0.00	0.00	0.05	0.71	-0.73	0.14	-2.31	1.72	0.14	12.43	0.00	0.21	0.14	0.03	0.05
3	StGge_Suther	0.00	0.00	-0.03	0.64	-0.90	0.06	-2.60	1.73	0.02	18.82	0.00	0.10	-0.01	-0.03	0.05
4	Canter_Banks	0.00	0.00	-0.22	0.48	-1.06	-0.11	-2.74	1.55	-0.17	1.12	0.00	-0.11	-0.17	-0.21	0.13
5	Fairfd_Livrp	0.00	0.00	0.18	0.83	-0.60	0.31	-2.41	1.90	0.28	17.30	0.00	0.35	0.22	0.19	0.50
6	Outer_SW_Syd	0.00	0.00	-0.08	0.63	-0.87	0.09	-2.62	1.71	0.03	18.84	0.00	0.11	-0.02	-0.08	0.01
7	Inner_W_Syd	0.00	0.00	0.97	1.69	0.08	0.99	-1.30	2.67	1.03	14.55	0.00	1.27	1.15	0.90	0.85
8	Centrl_W_Syd	0.00	0.00	-0.66	0.10	-1.45	-0.47	-3.22	1.11	-0.53	17.75	0.00	-0.52	-0.58	-0.67	0.22
9	Outer_W_Syd	0.00	0.00	-0.08	0.67	-0.85	0.14	-2.64	1.71	0.04	18.53	0.00	0.11	0.00	-0.03	1.56
10	Blck_Baulk_H	4.77	13.30	20.16	3.18	17.13	20.40	11.11	21.06	19.15	-13.54	6.24	9.70	20.28	17.29	5.65
11	Lower_N_Syd	0.00	0.00	0.00	0.73	-0.80	0.20	-2.45	1.78	0.10	4.28	0.00	0.25	0.11	-0.01	0.40
12	Horns_Kuring	0.00	0.00	-0.11	0.61	-0.93	0.05	-2.64	1.69	-0.02	8.20	0.00	0.08	-0.04	-0.11	0.12
13	Nth_Beaches	0.00	0.00	-0.06	0.65	-0.88	0.10	-2.61	1.75	0.04	18.86	0.00	0.11	0.00	-0.05	-0.38
14	Gosfrd_Wyong	0.00	0.00	-0.06	0.66	-0.86	0.11	-2.60	1.76	0.05	19.61	0.00	0.11	0.00	-0.01	-0.17
	Average over all origins	0.25	0.00	0.06	0.07	0.67	0.03	0.62	1.05	2.57	4.00	0.47	0.28	0.13	0.15	0.58

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Work location choice results

Table 3 Percentage change in choice probability for a work place location (destination zone) given a residential location (origin zone) following the improvement in the rail ink between zone 1 and zone 10.

Origin Zone		Destination Zone No.													
No.	Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Inner_Sydney	Eastern_Subs	StGge_Suther	Canter_Banks	Fairfd_Livrp	Outer_SW_Syd	Inner_W_Syd	Centrl_W_Syd	Outer_W_Syd	Blck_Baulk_H	Lower_N_Syd	Horns_Kuring	Nth_Beaches	Gosfrd_Wyong
1	Inner_Sydney	0.00	0.00	0.08	0.71	-0.59	0.08	-2.13	1.59	0.07	-0.79	0.00	0.27	-0.05	0.30
2	Eastern_Subs	0.00	0.00	-0.03	0.51	-0.51	-0.31	-1.98	1.47	0.57	-0.54	0.00	0.14	-0.05	-0.02
3	StGge_Suther	0.00	0.00	-0.02	0.57	-0.94	0.03	-2.48	1.62	0.14	-0.97	0.00	0.11	0.01	-0.04
4	Canter_Banks	0.00	0.00	-0.21	0.46	-1.04	-0.05	-2.59	1.50	0.06	-0.92	0.00	-0.16	-0.16	-0.05
5	Fairfd_Livrp	0.01	0.00	0.22	0.71	-0.50	0.29	-2.38	1.77	0.37	-1.03	0.00	0.31	0.30	0.19
6	Outer_SW_Syd	0.01	0.00	-0.10	0.57	-0.85	0.10	-2.48	1.62	0.07	-0.84	0.01	0.13	0.00	-0.07
7	Inner_W_Syd	0.00	0.00	0.62	1.45	-0.20	0.42	-1.06	2.18	0.86	-1.49	0.00	1.23	1.13	-0.24
8	Centrl_W_Syd	0.00	0.00	-0.67	0.14	-1.35	-0.45	-3.15	1.07	-0.23	-1.39	0.00	-0.50	-0.18	-0.68
9	Outer_W_Syd	0.01	0.00	-0.08	0.60	-0.83	0.17	-2.67	1.63	0.06	-0.89	0.01	0.18	0.04	-0.03
10	Blck_Baulk_H	0.00	0.00	0.14	0.74	-1.04	0.31	-3.62	1.71	0.12	-0.51	0.00	0.27	0.17	0.32
11	Lower_N_Syd	0.00	0.00	-0.03	0.60	-0.82	0.40	-2.35	1.57	0.05	-1.09	0.00	0.30	0.09	-0.59
12	Horns_Kuring	0.00	0.00	-0.13	0.53	-0.97	-0.05	-2.46	1.61	0.00	-1.10	0.00	0.09	-0.02	-0.04
13	Nth_Beaches	0.00	0.00	-0.07	0.60	-0.87	0.03	-2.43	1.69	0.18	-0.67	0.00	0.13	0.00	0.08
14	Gosfrd_Wyong	0.01	0.00	-0.19	0.58	-0.82	0.08	-2.56	1.69	0.03	-0.88	0.01	0.10	-0.03	-0.01

Household fleet size choices

Table 5 Fleet size choice for households living in different zones before and after the NWRL Project

Residential Zone		Before project Shares of Fleet sizes		After Project Shares of Fleet sizes		% change in Shares of Fleet sizes	
No.	Name	Single car	Multi-cars	Single car	Multi-car	Single car	Multi-car
1	Inner_Sydney	0.99	0.01	1.00	0.00	0.57	-56.89
2	Eastern_Subs	0.98	0.02	0.98	0.02	-0.10	5.50
3	StGge_Suther	0.81	0.19	0.91	0.09	12.67	-52.83
4	Canter_Banks	0.82	0.18	0.93	0.07	14.18	-63.84
5	Fairfd_Livrp	0.76	0.24	0.82	0.18	8.36	-26.39
6	Outer_SW_Syd	0.61	0.39	0.79	0.21	30.26	-47.00
7	Inner_W_Syd	0.77	0.23	0.74	0.26	-4.81	16.43
8	Centrl_W_Syd	0.73	0.27	0.97	0.03	32.60	-89.42
9	Outer_W_Syd	0.60	0.40	0.24	0.76	-59.57	87.74
10	Blck_Baulk_H	0.71	0.29	0.96	0.04	34.51	-85.01
11	Lower_N_Syd	0.78	0.22	0.92	0.09	16.90	-60.85
12	Horns_Kuring	0.66	0.34	0.61	0.39	-7.72	15.05
13	Nth_Beaches	0.72	0.28	0.80	0.20	11.85	-29.86
14	Gosfrd_Wyong	0.60	0.40	0.88	0.12	47.22	-69.70

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Household vehicle type choices

Table 6 Vehicle type choice before and after the NWRL Project

Residential Zone		Before project Shares of vehicle types			After Project Shares of vehicle types			% change in Shares of vehicle types		
No.	Name	small	Medium	large	small	Medium	large	small	Medium	large
1	Inner_Sydney	0.202	0.455	0.343	0.173	0.468	0.359	-0.029	0.014	0.016
2	Eastern_Subs	0.202	0.455	0.343	0.205	0.453	0.342	0.002	-0.001	-0.001
3	StGge_Suther	0.202	0.455	0.343	0.177	0.466	0.357	-0.025	0.012	0.013
4	Canter_Banks	0.202	0.455	0.343	0.159	0.475	0.366	-0.043	0.020	0.023
5	Fairfd_Livrp	0.202	0.455	0.343	0.188	0.461	0.351	-0.014	0.006	0.008
6	Outer_SW_Syd	0.202	0.455	0.343	0.185	0.462	0.353	-0.017	0.008	0.009
7	Inner_W_Syd	0.202	0.455	0.343	0.214	0.448	0.338	0.012	-0.006	-0.005
8	Centrl_W_Syd	0.202	0.455	0.343	0.121	0.492	0.386	-0.081	0.038	0.043
9	Outer_W_Syd	0.202	0.455	0.343	0.236	0.439	0.325	0.034	-0.016	-0.018
10	Blck_Baulk_H	0.202	0.455	0.343	0.041	0.529	0.430	-0.161	0.074	0.086
11	Lower_N_Syd	0.202	0.455	0.343	0.160	0.474	0.366	-0.042	0.019	0.022
12	Horns_Kuring	0.202	0.455	0.343	0.210	0.451	0.339	0.008	-0.004	-0.004
13	Nth_Beaches	0.202	0.455	0.343	0.185	0.462	0.352	-0.017	0.008	0.009
14	Gosfrd_Wyong	0.202	0.455	0.343	0.179	0.465	0.356	-0.023	0.011	0.012

Conventional users benefits and wider economy impacts.

Table 7 Conventional transport -land use impacts (TLUIs) and wider economic impacts (WEIs) of the NWRL transport improvement project. ($2006/per annum)

Type of impacts	Description	Scenarios(*)		
		Base Case NO (new) Agglomeration effects and NO change in total employment	A WITH (new) Agglomeration effect but NO change in total employment	B WITH (new) Agglomeration and WITH change in total employment
WEI	Changes in total wage bill ($mill)	3.860	4.379	4.792
TLUI	Changes in total (imputed) rent ($mill)	(3.860)		
	Changes in the logsum (converted to $mill) of the residential location choices.	-	27.644	27.373
	mark-up of WEIs over TLUIs (%)	0%	0-15.8%	0-17.5%
	Explanation	WEI is *not* additional to but overlapping with TLUI	WEI is additional to TLUI	WEI is additional to TLUI

(*) Notes:

Base Case: no (new) agglomeration effects and no change in total employment for the Sydney Metropolitan Area (SMA) as a whole, only a *redistribution* of existing employment and housing locations between zones assuming the transport project will allow the local economy of the SMA to reach a new equilibrium to take advantage of any *existing* wage differentials between locations following the changes in generalised transport costs between zones as a result of the project ;

Conclusions

- Significant policy impacts are evaluated at the aggregate economy wide level, but effective policy designs are often set at the disaggregate individual consumer/producer level.
- To inform policy makers with well designed policy studies, therefore, it is essential to be able to combine the uses of both bottom-up and top-down models within a common framework, such as a CGE model

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Thank you