Residential energy demand elasticities: what lessons can be learned from bottom-up and top-down methodologies

International Energy Workshop

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VITO,
Stanford , July 6, 2011

Outline

- Background - developing guidelines
- Energy demand elasticity ⇔ Energy service elasticity
- Conceptual differences: optimisation models⇔ econometrics
- Bottom-up model
- Econometric approach
- Comparing results and conclusions
- Guidelines

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Background

- Energy optimisation models:
  - representing supply structure of energy service
  - in early nineties complemented with demand characteristics => service demand elasticities
  - energy service elasticities not observable

- Econometric methodology
  - Coïntegration analysis: methodology for determining long term elasticities.
  - New estimation methods

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Objective

- ➔ Providing guidance in quantifying energy service elasticities

- Indirect methodology
  - Developing relationship between energy demand and energy service elasticities
  - Comparing energy demand elasticities from state of the art optimisation model and econometric analysis

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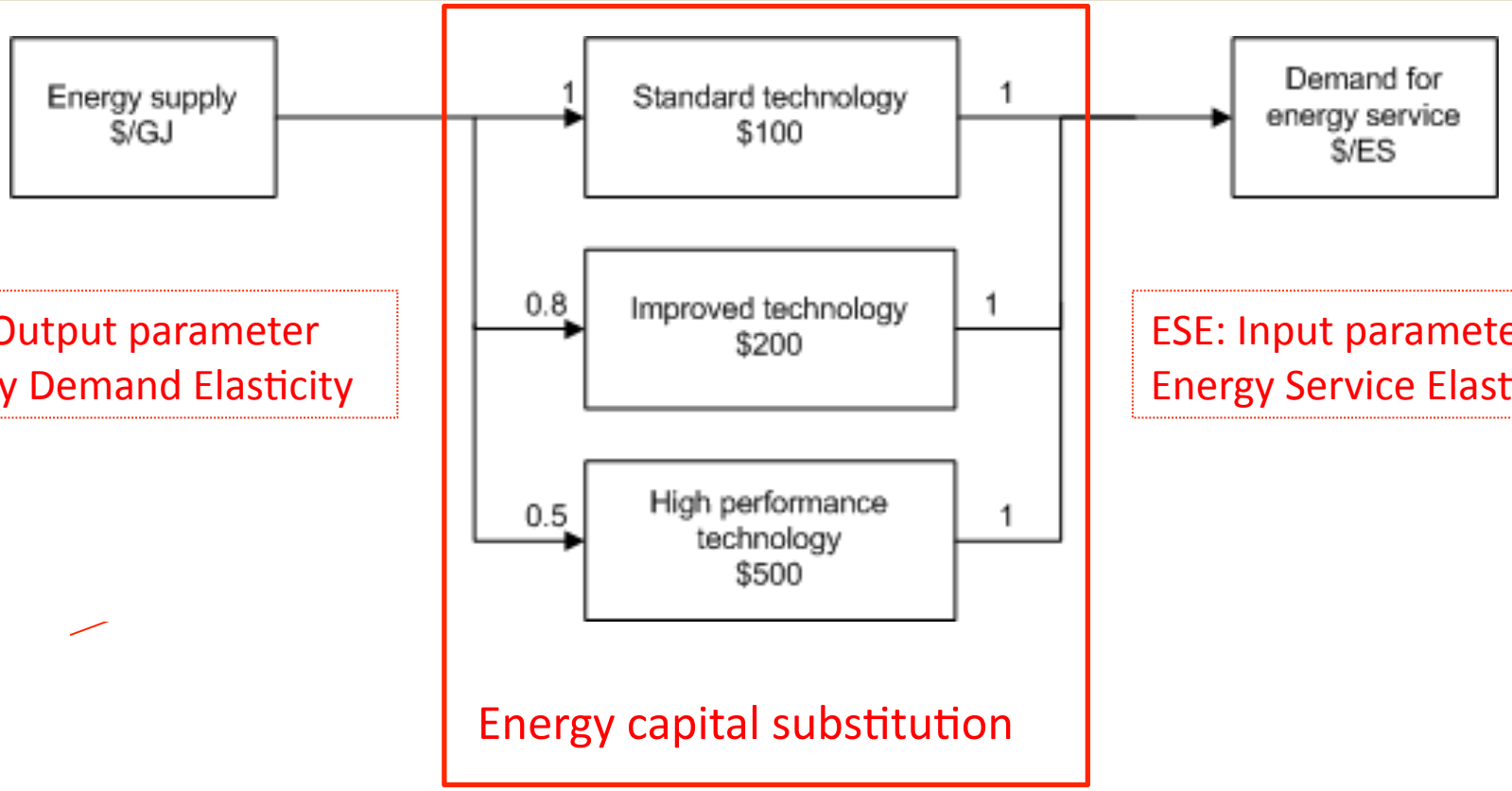
Energy demand elasticity ⇔ Energy service elasticity



EDE: Output parameter
Energy Demand Elasticity

ESE: Input parameter
Energy Service Elasticity

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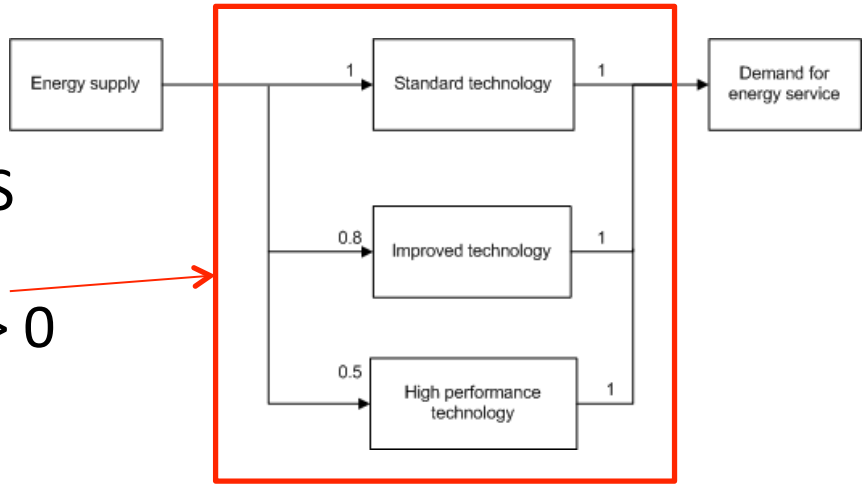
Energy demand elasticity ⇔ Energy service elasticity

PES = f(PK,PE)
δ = Qe.Pe /(Qk.Pk+Qe.Pe)
=budget share of energy in ES
0 < δ < 1
σ : elasticity of substitution > 0



$$EDE = -\sigma (1-\delta) + \delta\, ESE$$

EDE < ESE < 0 if σ big
ESE < EDE < 0 if σ small
ESE ↗ then EDE ↗

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Conceptual differences

- Optimisation models
  - Economic reasoning
  - Price induced technology shifts
  - Future technology deployment
  - Competitive market
- Econometric models
  - Historical observations
  - Single parameter
  - Derived from historical (=paste) data
  - Historical market imperfections

Looks like we are comparing the incomparable

However

Both types of models used for similar policy analysis

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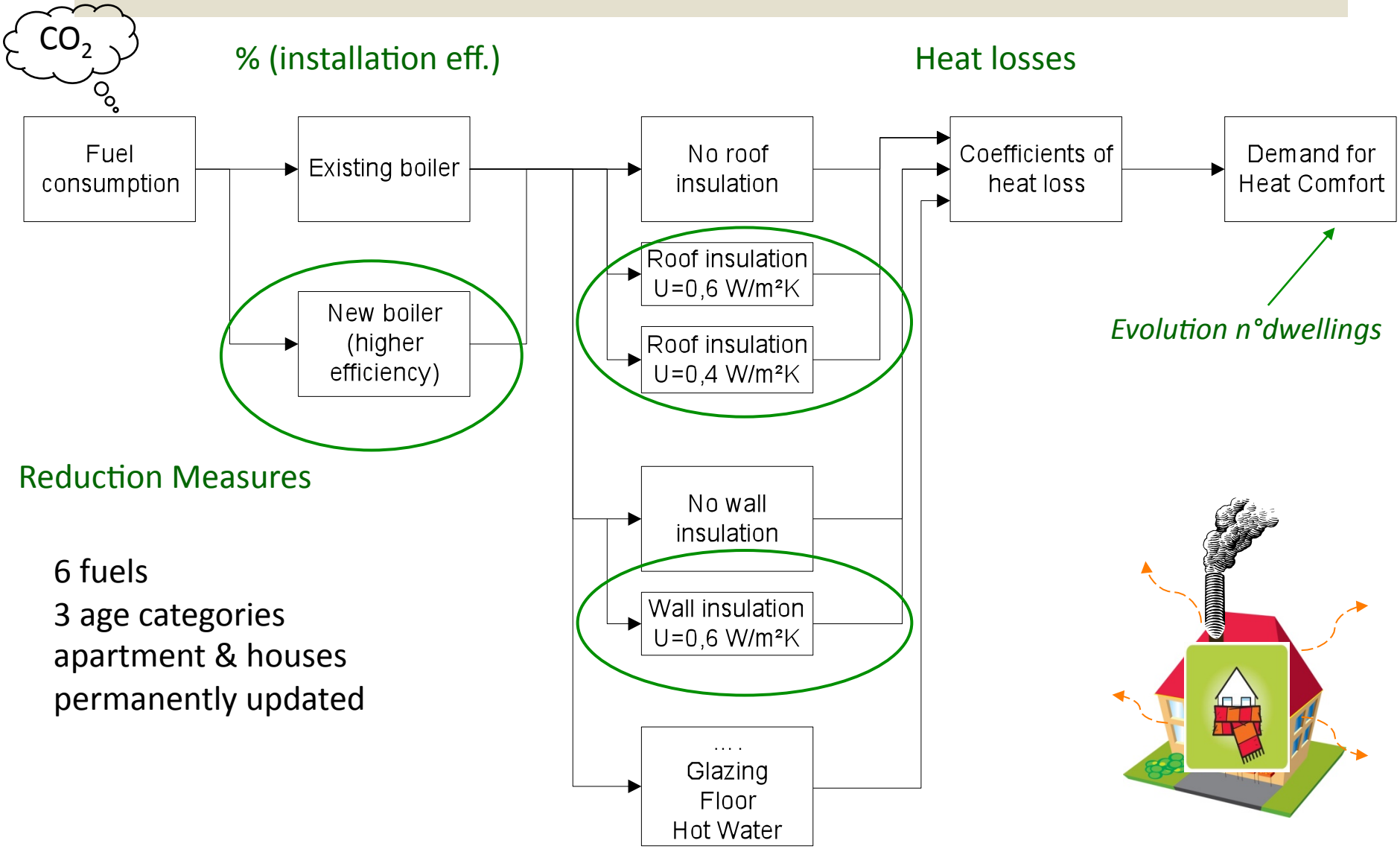
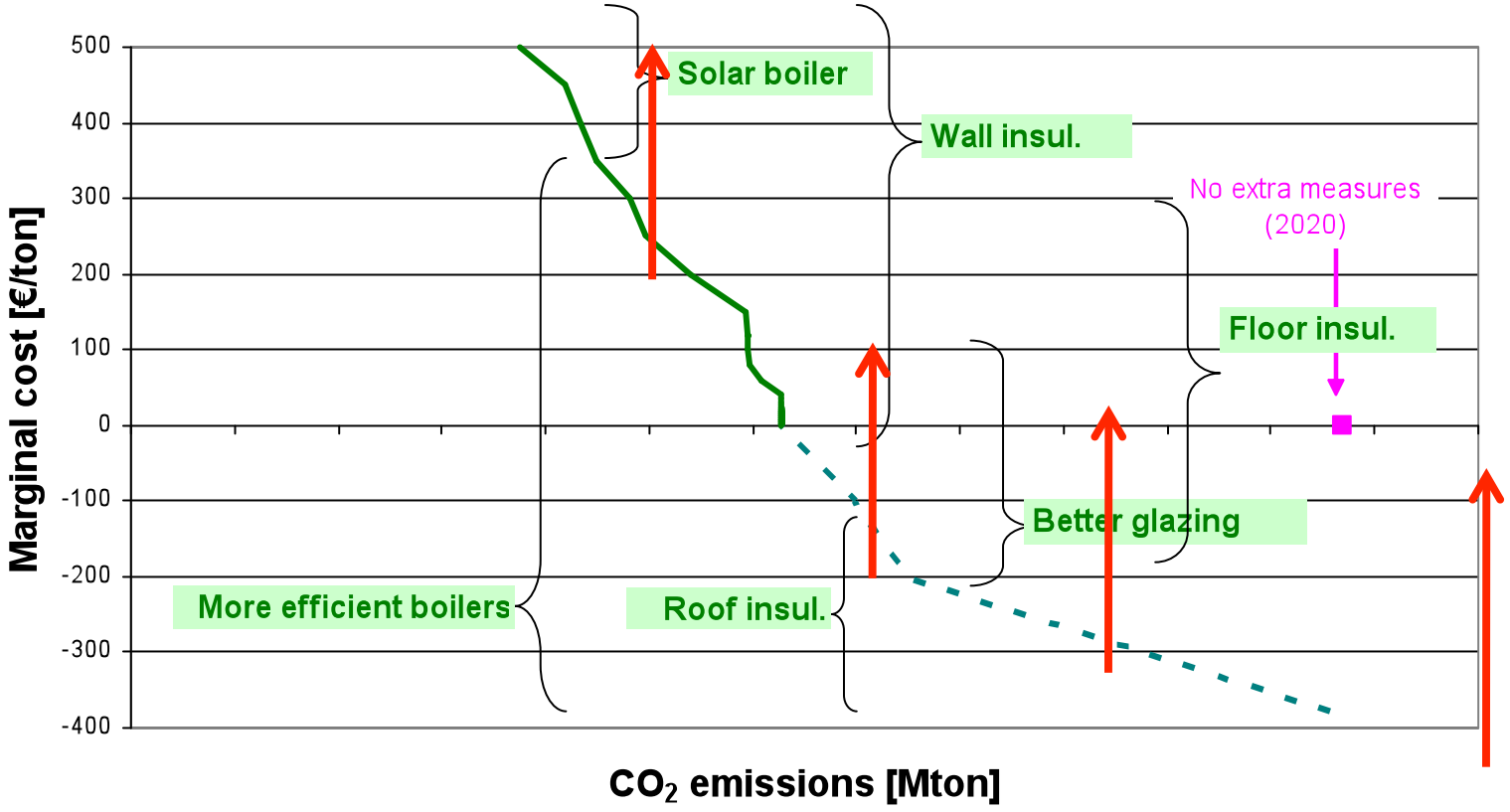
Model Structure in Markal (1)



6 fuels
3 age categories
apartment & houses
permanently updated

Overview of reduction measures



15 % Hurdle rate

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Results

Hurdle rate: 15 %, Energy price increase: 20 %				
		Total	Existing	New
ESE = 0	EDE	-0.63	-0.25	-1.43
ESE =-0.2	EDE	-0.78	-0.42	-1.53
	δ	0.75	0.86	0.50
	σ	2.52	1.76	2.84
Hurdle rate: 15 %, Energy price increase: 100%				
		Total	Existing	New
ESE = 0	EDE	-0.23	-0.16	-0.38
ESE = -0.2	EDE	-0.39	-0.31	-0.54
	δ	0.78	0.76	0.82
	σ	1.04	0.65	2.13

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Panel coïntegration approach

- Coïntegration
  - Long term property of non-stationary time series.
  - Many economic time series are non-stationary
  - Appropriate methodology for long term elasticities
  - Avoiding spurious regressions
- Panel data
  - Short time dimension in the data
  - Panel dimension partly replaces time dimension in tests
  - Panel unit root tests: stationary character of panel time series
  - Panel coïntegration tests: spurious character of regressions

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Panel coïntegration approach

- Yearly observations
  - Q: Log (fuel consumption)
  - Y: Log (real income)
  - P: Log (Price fuels /consumer price index)
  - hdd: Log (Heating degree days)

- Data from EUROSTAT
  - DK,FR,DE,IT,NL,ES,UK 1991-2008
  - SI 1992-2008
  - FI,HU,IE,PT 1995-2008
  - AT 1996-2008
- Homogeneous panel estimates: identical elasticities
- Heterogeneous panel estimates: country specific elasticities

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Model specification - proposal

$$Q_{i,t} = \alpha_i + \beta_i Y_{i,t} + \gamma_i P_{i,t} + \theta_i hdd_{i,t} + \varepsilon_{i,t}$$

Unit root tests

	Q		Y		P		hdd	
DK	-2.747	(0)	-0.561	(0)	-1.628	(1)	-2.316	(0)
FR	-2.693	(0)	-0.088	(0)	0.124	(0)	-4.208	(0)
DE	-3.770	(0)	-1.790	(0)	0.422	(0)	-3.027	(0)
IT	-1.822	(0)	-1.615	(0)	-2.141	(0)	-2.670	(2)
NL	-1.397	(0)	-1.335	(0)	0.787	(0)	-2.944	(0)
ES	-1.450	(2)	-0.661	(1)	-0.851	(0)	-3.542	(0)
UK	-2.492	(0)	-1.610	(0)	-0.192	(2)	-2.844	(0)
Panel Levin-Lin	-1.922		-1.300		3.533		-4.514	
N observations	117		118		116		117	

Critical values: ADF -t- test 10 % -2.64, 5% -2.99, 1% -3.75 for 25 observations

Panel Levin-Lin test: 10 % -1.282, 5% -1.645, 1% -2.326

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Unit root tests

- Conclusion:
  - Y: Log(real income): non-stationary
  - P: Log(real price): non-stationary
  - Hdd: Log(heating degree days): stationary
  - Q: Log(fuel consumption): ???

- ➔ Coïntegration analysis requires all variables to be non-stationary

New approach

Step 1 : regression to determine elasticity of hdd

$$\Delta Q_{i,t} = \gamma_i + \theta_i^* \Delta\, hdd_{i,t} + \varepsilon_{i,t}$$

Step 2: Derive new time series, removing noise from hdd and perform new unit root test

$$Q_{i,t}^* = Q_{i,t} - \theta_i^* \left(hdd_{i,t} - \overline{hdd}_{\,i} \right)$$

Step 3: New model specification

$$Q_{i,t}^* = \alpha_i + \beta_i Y_{i,t} + \gamma_i P_{i,t} + \varepsilon_{i,t}$$

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New model specification

$$Q^{*}_{i,t} = \alpha_i + \beta_i Y_{i,t} + \gamma_i P_{i,t} + \varepsilon_{i,t}$$

	θ* estimate	Q* Unit root test	
DK	0.567	-1.685	(0)
FR	0.474	-2.008	(2)
DE	0.597	-2.339	(0)
IT	0.613	-1.261	(0)
NL	0.745	0.515	(0)
ES	0.126	-0.793	(0)
UK	0.734	-1.861	(2)
Panel Levin-Lin		1.221	
N observations		115	

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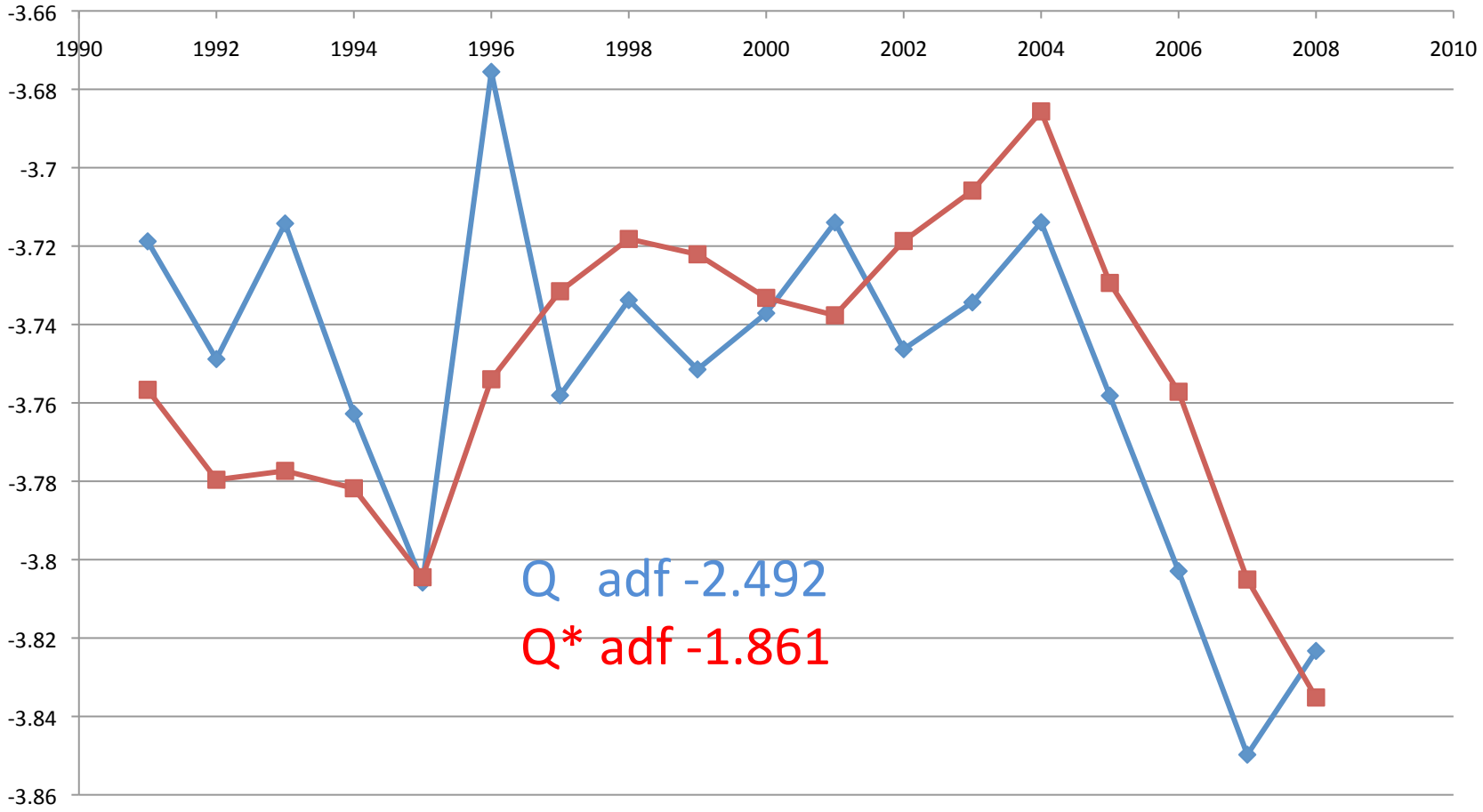
Q – Q* : example



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Regressions: results

	OLS		DOLS	
	Income	Price	Income	Price
AT	0.32	-0.20		
DK	0.09	0.00	0.17	0.00
FI	0.00	-0.14		
FR	0.04	-0.07	0.64	-0.51
DE	0.57	0.00	0.96	-0.07
HU	0.43	-0.14		
IE	0.22	-0.01		
IT	1.59	-0.34	2.70	-0.02
NL	0.00	-0.30	0.05	-0.30
PT	0.28	-0.06		
SI	0.10	-0.08		
ES	0.59	0.00	0.96	-0.35
UK	0.08	-0.18	0.36	-0.02
Homogenous N=7	0.31	-0.10	0.56	-0.10
Homogenous N=13	0.25	-0.11	0.46	-0.10

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Pedroni coïntegration tests

		heterogeneous-slope (N=7)		homogeneous-slope (N=7)		Full sample (N=13)
		OLS	DOLS	OLS	DOLS	OLS
Panel v		0.202	-1.508	-1.795	-2.280	0.129
Panel ρ		-0.154	-0.258	1.496	1.352	-0.661
Panel *t*		-1.959**	-2.885***	1.364	0.906	-4.138 ***
Panel *t* parametric		-2.238**	-3.023***	1.510	1.225	-4.368 ***
Group ρ		0.223	0.625	2.832	2.523	0.345
Group *t*		-6.562***	-4.311***	2.844	2.441	-8.738***
Group *t parametric*		-3.845***	-2.898***	2.482	1.694	-5.095***
Critical values		Panel v	Other			
	10%	1.282	-1.282	*		
	5%	1.645	-1.645	**		
	1%	2.326	-2.326	***		

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Conclusions from econometric analysis

- DOLS slightly better than OLS
  - Higher income and price elasticities
- Energy price elasticity between - 0.5 and 0.
  - average -0.18
  - Values above -0.3 not exceptional
- Significant differences between countries
  - Homogeneous estimates rejected

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Comparing results and conclusions

- Optimisation model
  - Elasticity not constant
    - 20 % -> -0.63 100 % -> -0.23
  - *EDE* < econometric result

    ➔ suggesting *ESE* = 0 in this particular case
- Econometric analysis
  - Differences between countries suggesting that elasticities are not constant in time
- Some (expert) judgement still required

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Guidelines for ESE quantification

- Assume *EDE is known*
- Determine δ and σ (3 model runs)
  - Price increase and ESE = 0 ➔ EDE1
  - Arbitrary ESE2 ➔ ED2
  - δ = (ED1-ED2)/ES2 , σ = ED1/ (δ – 1)
- $A A A = (A A A + A(1 - A))/A$

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Thank you for your attention

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