The impact of increased efficiency in the use of energy: A computable general equilibrium analysis for Spain

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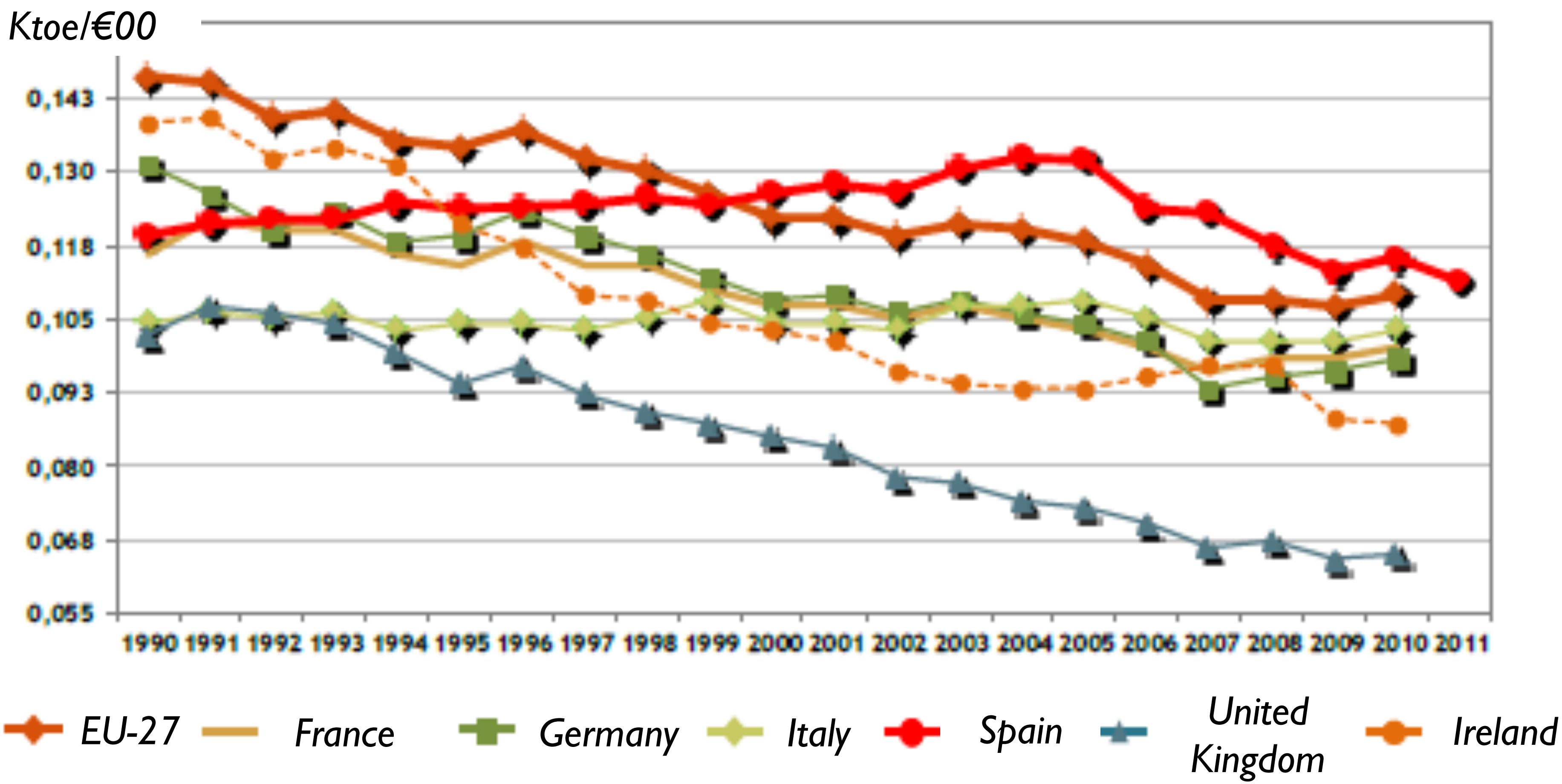
OUTLINE

- Motivation: the twofold economic challenge of energy efficiency and energy savings
- The foundations of the rebound effect
- The magnitude of the rebound effect. How much to worry? What suggests the empirical literature?
- An estimation of the economy-wide rebound for Spain by means of a CGE model
- Conclusions and policy implications

Motivation

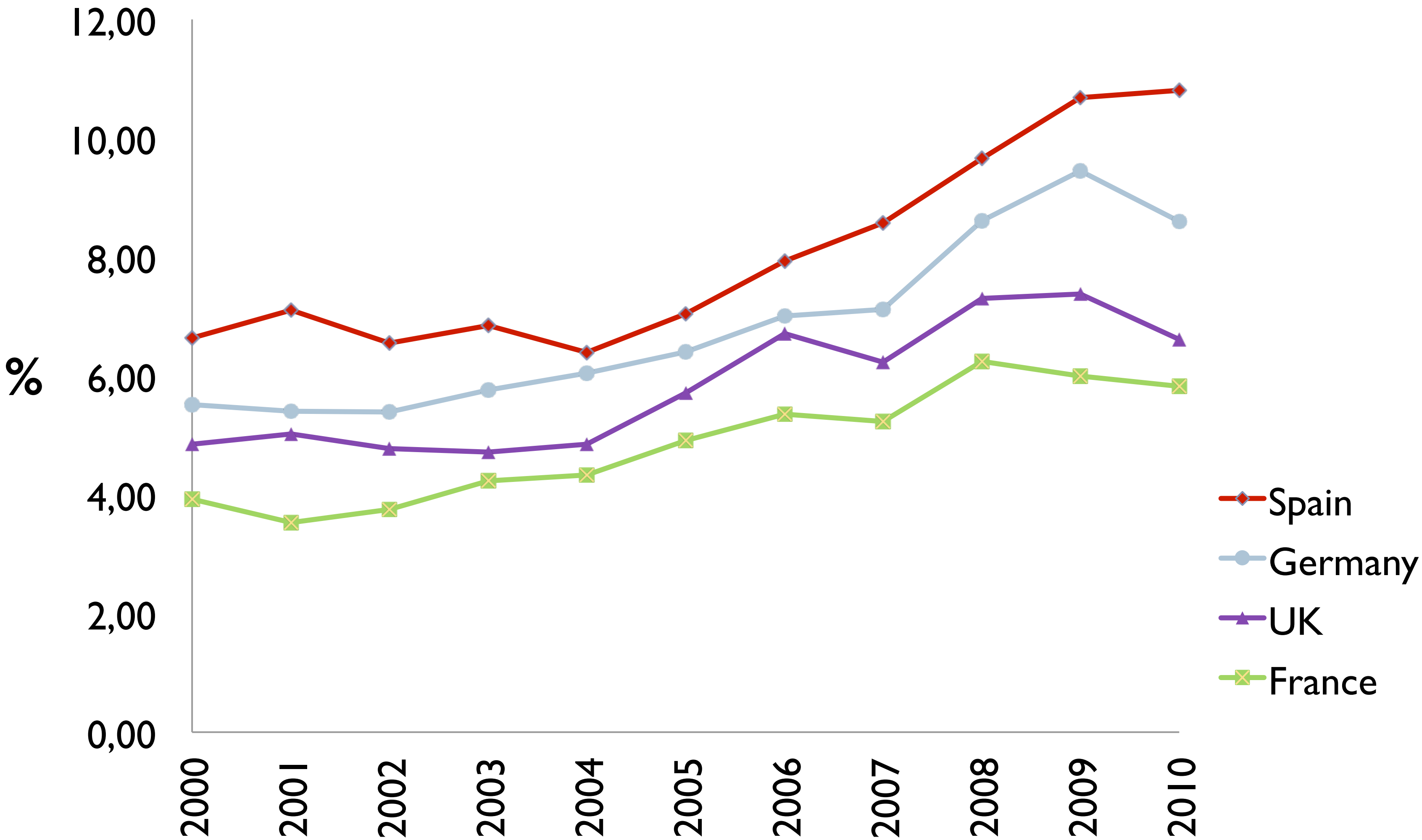
- Energy efficiency and energy savings as major economic challenge.
- Particularly, for Spain:
  - High energy intensity rate (Energy consumption/GDP)
  - The rise of energy prices and the increasing impact of energy costs on economic competitiveness
  - High energy dependency rate (Net imports/Gross consumption).

Energy Intensity (Energy consumption/GDP)



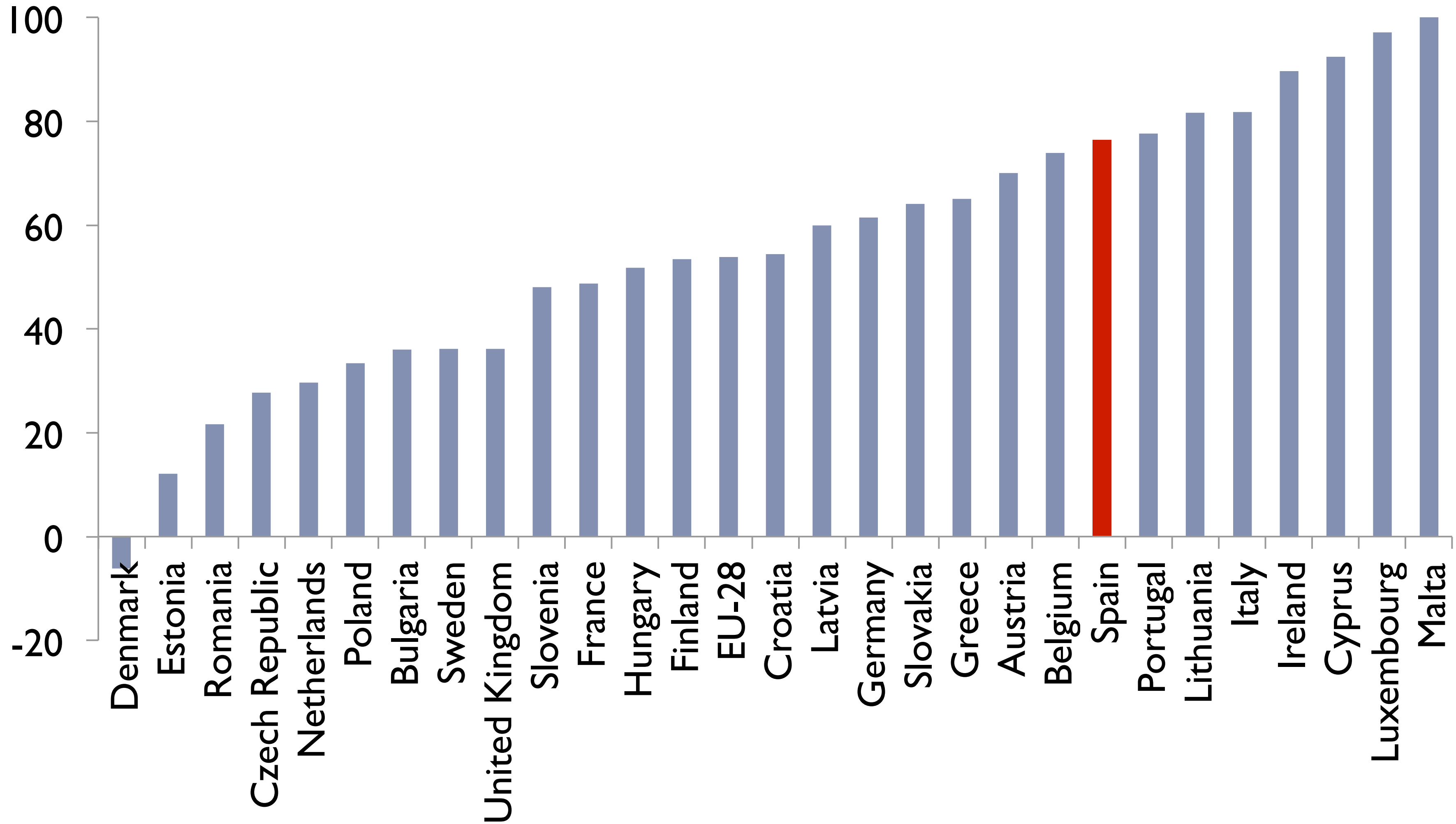
Source: IDAE. Ministry of Industry, Energy and Tourism

Energy Costs/Value Added (manufacturing)



Source: Arocena and Díaz 2013 (Eurostat data)

Energy dependence (Net imports/Gross consumption)



Energy efficiency challenge

- The quest for energy savings and energy efficiency: National Energy Efficiency Action Plan 2011-2020
  - Energy savings estimates result from improvements in technology and processes: 2% reduction of the aggregate energy intensity in 2010-2020 (2.52% in manufacturing)
- The question is whether improvements in the technical efficiency of energy use can be expected to reduce energy consumption by the amount predicted by engineering calculations.
- Improvements in energy efficiency can lead to reductions in energy consumption lower than expected because of rebound effects

The rebound effect

- Rebound effect is the umbrella term for a variety of economic mechanisms that reduce the energy savings from improved energy efficiency.
- Effective price change: If you increase efficiency of any factor of production, its price / unit of service (i.e. the effective/ implicit price) is reduced. This triggers a positive demand response – directly (by the producer or consumer whose efficiency has improved) and also economy wide through knock on effects. The strength of this demand is what causes the rebound effect. The effective price change is the source of the rebound effect. How this is impacted by the efficiency improvement and associated factors needs to be considered to measure rebound (Turner, 2010).

The drivers of the economy-wide rebound effect

- Substitution Effect: An incentive to use more energy inputs since their effective price has fallen.
- Output Effect: Producers may use the cost savings from EE improvements to increase output, increasing consumption of capital, labor and materials, which themselves require energy to provide.
- Compositional Effect: relatively energy-intensive products benefit more from the fall in the effective energy prices
- Competitiveness effect: results from the fall in supply prices of commodities that use energy as an input to production
- Income effect: increased real household incomes will impact on household consumption of all commodities, including the direct and indirect consumption of energy.

What the rebound effect is?

- RE tend to be ignored in official analysis of the potential energy savings from energy efficiency improvements (with the UK being the only exception)
- Potential energy savings are typically estimated by engineering models that assume no economic responses to improved energy efficiency.
- Actual energy savings are estimated by energy-economic models that simulate those responses.
- The rebound effect is commonly defined as the percentage of PES that are offset by the rebound mechanisms:

$$RE = [1 - AES/PES] \times 100$$

Ranges of rebound effect and their implication for energy consumption

RE (in %)	Types of RE	Energy use
RE < 0	Superconservation/negative rebound	EE improvement is over realized
0	No rebound/zero rebound	EE improvement is fully realized
0 < RE< 100	Partial rebound	EE improvement is partially offset by increased demand for energy
100	Full rebound	EE improvement is exactly offset
> 100	Backfire	EE improvement is outweighed by increased demand for energy

Empirical evidence of RE

Many empirical studies on RE estimates for particular sectors.

They provide consistent evidence for the presence of RE:

- Household sector: EE for space heating/cooling, white goods, lighting results in 10-40% RE in developed countries
- Commercial road transport: fuel efficiency 30-80% for fuel efficiency in.
- Manufacturing.
  - A USA study investigating 30 industry sectors shows long term direct rebound effects of 20-60% (Saunders 2010)
  - The UK: 15-27%
  - India: 43-96% in energy intensive manufacturing industries

Estimates of economy-wide rebound effect (CGE studies)

Authors	Country	Assumed energy efficiency improvements	Rebound estimates
Grepperud & Rasmussen (2004)	Norway	100% in six sectors	Small rebound for oil > 100% for electricity
Vikstrom (2004)	Sweden	15% in non-energy sectors and 12% in energy sectors	50-60%
Washida (2004)	Japan	1% in each sector	35-70%
Hanley et al (2005)	Scotland	5% in each production sector	>100%
Allan et al (2007)	UK	5% in each production sector	30-50%
Turner (2009)	UK	5% in each production sector	23% for electricity 30% for non-electric
Guerra & Sancho (2010)	Spain	5% in each production sector	90%
Broberg et al (2014)	Sweden	5% in each production sector	40-70%

A CGE model for the analysis of rebound effect in Spain

Work in progress:

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(Universidad Pública de Navarra)

- We construct a Computable General Equilibrium (CGE) model to study the economy-wide effects of an increase of energy efficiency.
- It is a static CGE model describing an open economy disaggregated into 27 production sectors, with 27 consumer goods, a representative consumer, the public sector and a simplified rest of the world.

A CGE model for the Spanish economy

- Equilibrium conditions:
  - Zero profits are made in all sectors.
  - Equilibrium in the goods and capital markets.
  - Other constraints:
    - The available income is equal to the expenditure executed by all agents.
    - Macroeconomic closure (investments = savings)
    - Unemployment in labour markets.

- The unemployment rule

$$w=(1-u/1-u\ )^{1/\beta}$$

w = real wage

u =unemployment rate

u = unemployment rate in the benchmark year

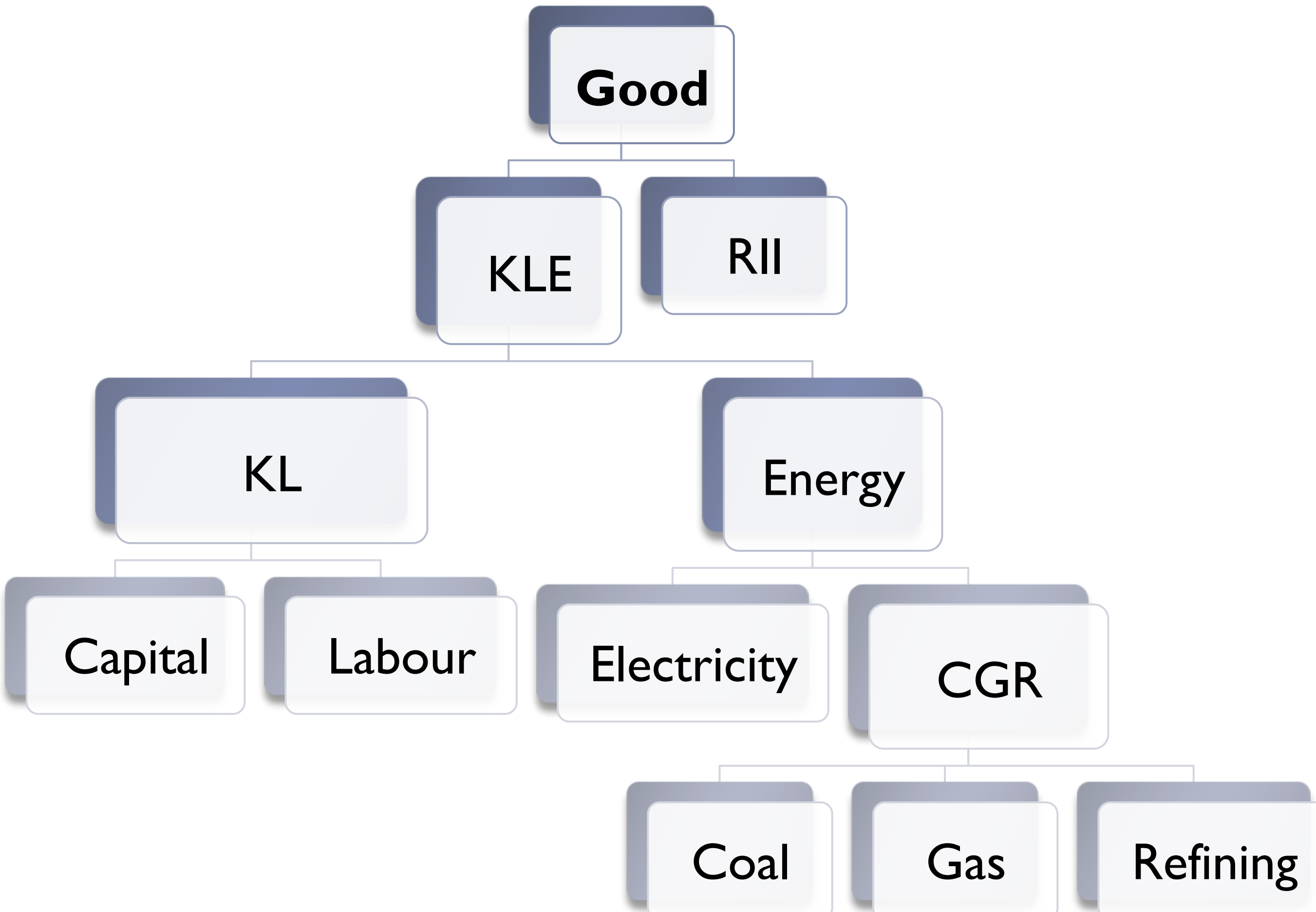
β = parameter that measures the flexibility of real wages with respect to the unemployment rate.

When $\beta\to\infty$; $\Delta w\to 0$ Rigid wages: real wage does not vary when the unemployment rate does

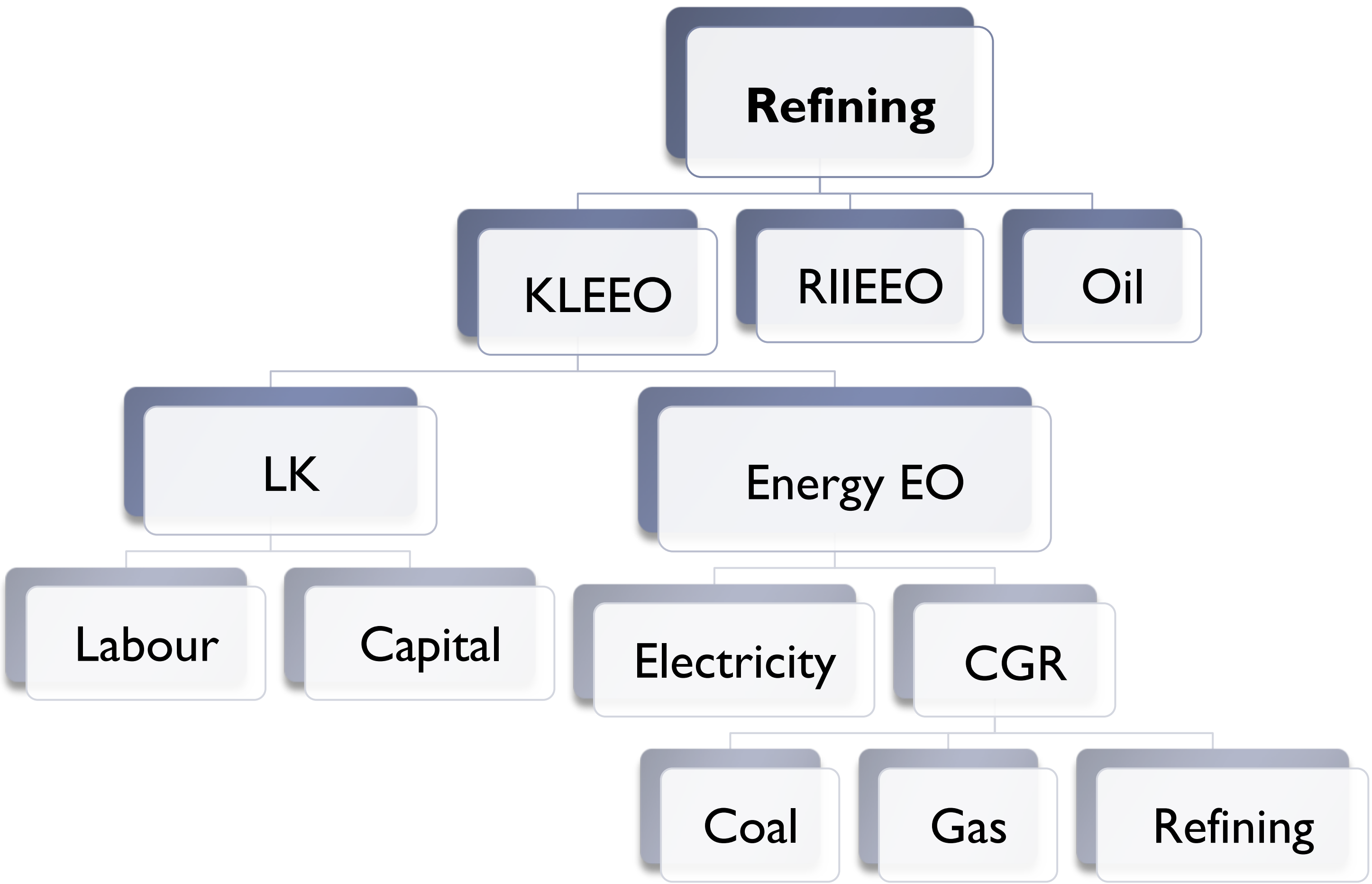
When $\beta\to 0$ Flexible wages: the unemployment rate is close to the benchmark year

- Nested (CES) production and utility functions
  - Nested technology of K, L, Energy inputs and rest of intermediate inputs
  - Treatment of energy in the production function based on the nestings on MIT Emissions Prediction and Policy Analysis (EPPA) model.
  - Elasticity values drawn from previous papers widely used in the empirical literature.

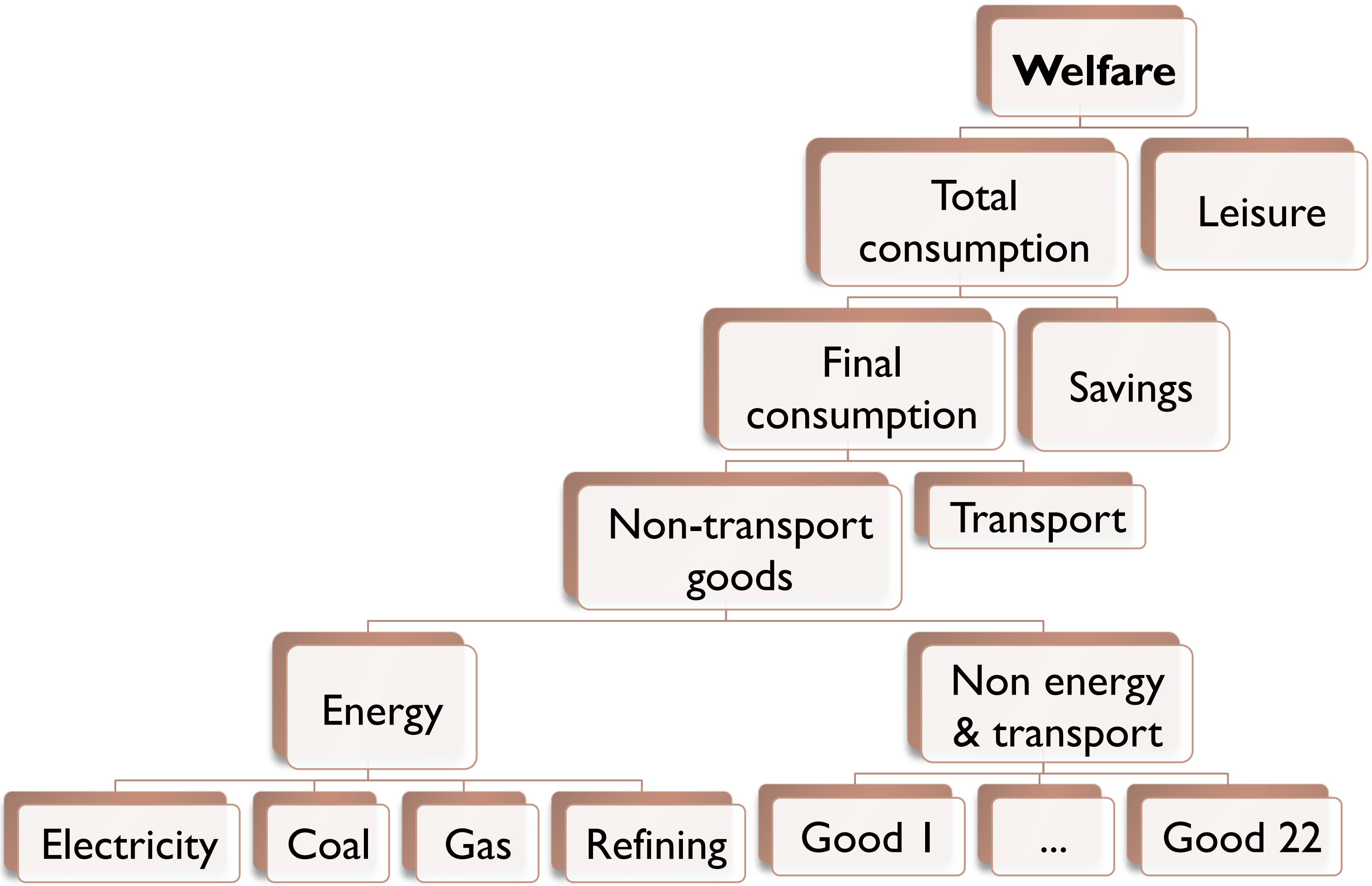
Nested production function for non-energy sectors



Example: nested production function for the oil refining sector

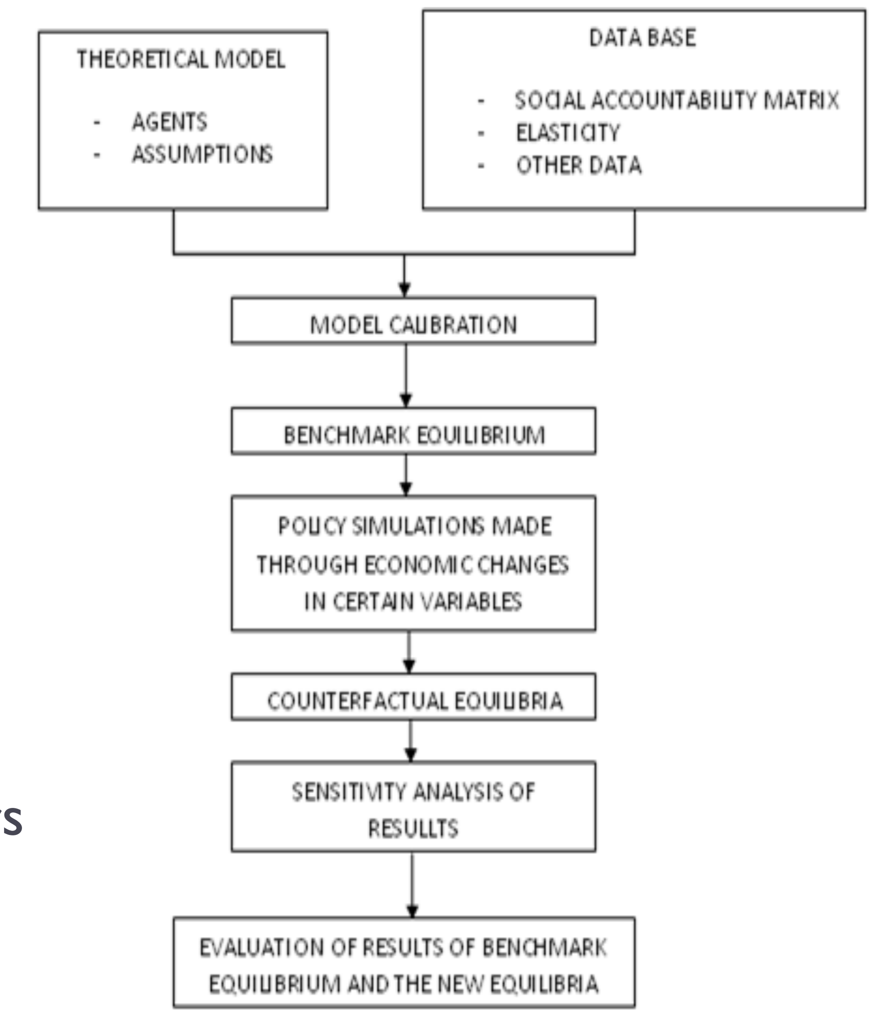


Nested utility function



The model: a CGE analysis

- Data:
  - Social Accounting Matrix (SAM) from the last available (2005) Symmetric Table for the Input-Output Framework of Spanish economy (National Institute of Statistics)
- Calibration:
  - The method for the functional forms assumed that fixed the value of the unknown parameters so that the equation system replicates the database as an equilibrium solution of the model.



Simulation

- It is simulated a 5% increase in the productivity of energy-related inputs i.e. the reduction in the use of energy inputs by unit of output produced.
- The four energy intermediate inputs correspond with the following sectors:
  1. **Coal** (extraction of coal, lignite and peat)
  2. **Refining** (Refined petroleum products)
  3. **Electricity** (production and distribution of electricity)
  4. **Gas** (production and distribution of gas)

Aggregate results: Energy consumption

- Base case: 5% energy productivity improvement in the use of all four energies in all production sectors

	AES (%)	Rebound Effect (%)
Coal	-4.20	16,1
Oil	-2.52	49,6
Electricity	-1.85	63,0
Gas	-3.95	21,0

Rebound effects across sectors (%)

	Coal	Oil refined	Electricity	Gas
Mining of coal	-11,7		-66,4	-66,4
Extraction of oil and gas		41,4	41,4	41,4
Other mining & quarrying	46,6	64,3	72,8	38,7
Refined oil products	-1,1	15,7	25,8	-8,6
Electricity	4,1	9,1	17,0	-10,5
Gas	-57,8		-57,8	-57,8
Water		76,2	87,1	
Food and drink		79,5	81,5	53,5
Textiles		79,4	80,0	53,4
Chemical	74,0	92,3	101,7	65,9
Rubber and plastic		79,9	84,4	53,9
Cement		72,7	83,1	46,9
Glass and glass products		84,9	85,1	58,7
Ceramic goods		87,9	85,6	61,7
Manuf. of basic metals	57,9	75,9	79,3	50,0
Metal products		78,5	82,2	52,5
Equipment	55,4	73,3	78,3	47,4
Paper		82,7	81,7	56,7
Wholesale and retail trade		68,5	75,4	42,8
Transport	46,0	63,7	72,3	38,2
Market services	49,2	67,0	74,0	41,3
Non-market services		54,9	62,3	29,6

Results: macroeconomic variables

Base case: 5% energy productivity improvement in the use of all four energies in all production sectors

	(% change from the base year)
GDP (at factor cost)	0.93
Welfare	0.86
Employment	0.67
Unemployment rate	-6.69
Real wage	0.44
Real rent of capital	0.68

Sensitivity analysis

- Functional forms: CES vs Cobb-Douglas vs Leontieff
- Capital closure:

  We change the perfect mobility across sectors assumption to the immobility across sectors.

- Treatment of the labour market:

  We assume two different wage flexibility:

  1. Less rigid wages
  2. More rigid wages

- Range of elasticity values

Sensitivity analysis

	Benchmark	CD production	CD utility	Leontief production	Leontief utility	CET = 0	$\sigma_{KL}/2$	$\sigma_{KL}*2$	K specific
Welfare	0.812	0.800	0.789	0.662	0.834	0.806	0.762	0.859	0.837
Employment	0.581	0.504	0.646	0.210	0.512	0.576	0.448	0.707	0.641
Unemployment rate	-6.017	-5.575	-5.520	-3.523	-6.445	-5.970	-5.139	-6.853	-6.420
Real wage	0.404	0.374	0.371	0.237	0.433	0.401	0.345	0.460	0.431
Capital real rent	0.720	0.788	0.753	0.859	0.691	0.711	0.777	0.665	0.689

CET: elasticity between national and foreign sales

σ_{KL}: elasticities of substitution between labour and capital

K-specific assumption (i.e. immobility of capital across sectors)

Sensitivity analysis

- Sensitivity analysis:
  - Different elasticities of substitution between capital and labour do not affect the overall results.
  - Specific capital instead of perfect capital mobility does not seem to affect the results.
  - In the flexibility of labour market, a relative great range is allowed without affecting the results.
  - The choice of functional forms do not significantly at macro level (but affects results at sectoral level, particularly the choice of production functions)

Final considerations

- Rebound effect exist and may be significant in many industries.
- Recognising and accounting for rebound effects in the design and Evaluation of Policy: reconsider energy efficiency targets
- Efficiency gains are the result of an exogenous and costless energy productivity increase. These productivity gains completely transfer to reductions of energy prices (potential upward bias rebound estimates).
- Results are dependent on the structure and assumptions of the model. More sensitivity analysis is needed (e.g. alternative nesting structures and elasticity values)

Policy implications:

- Measures to address/counteract RE:
  - Recognising and accounting for rebound effects in the design and Evaluation of Policy
  - Fiscal instruments
  - Other non-tax increases of the effective energy price
  - Sustainable Lifestyle Behaviour Change
  - Mixed instruments
  - Development of new business models