Second-Best Analysis of European Climate and Energy Policy: Is One Bird in the Hand Worth Two in the Bush?

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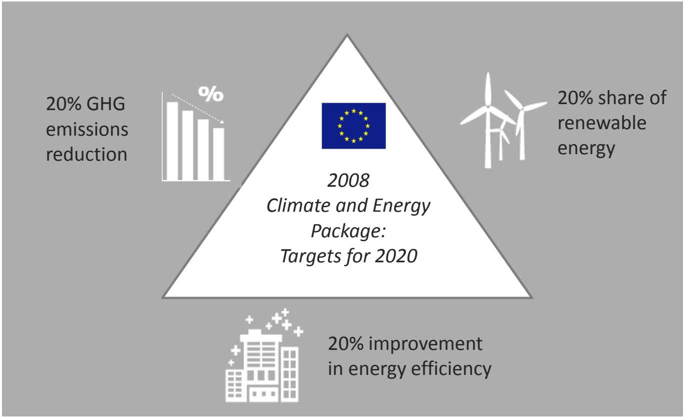
Motivation

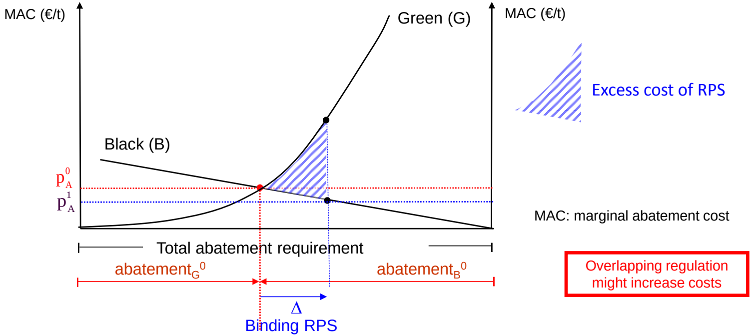
- In economic analysis, we often examine isolated single instruments and look for the single policy 1st-best solutions
- But in reality, policies have to work in an environment with multiple distortions and where multiple policies are in place
- The EU climate and energy policy is a typical and relevant example where a multitude of instruments is implemented on multiple levels of governance

EU Climate and Energy Policy - Targets for 2020



The economist's straight advice

Basic economics tells us: Equalizing marginal abatement costs leads to the least-cost solution. Additional instruments just cause distortions:



Source: Böhringer et al., 2009

but ...

There are additional market failures beyond the GHG externality:

- Knowledge spillovers of learning-by-doing for low-carbon technologies
- Knowledge spillovers of research and development (R&D)
- Consumers' imperfect perception of benefits of energy efficiency improvements

$\Rightarrow$ 1st best policy portfolio: One policy instrument for each market failure (Bennear & Stavins, 2007)

The 2nd but... we are living in an second (or n-th) best world

- 1st best can often not be implemented because imperfect institutions, political constraints, incomplete information, transaction & compliance costs (Rodrik, 2008)
- Lipsey & Lancaster (1956): With multiple market failures remedy of one market failure doesn't necessarily improve welfare
  - It can either reduce the welfare losses created by the other market failures, exacerbate them, or not affect them
- If more externalities than instruments: How to adjust policy instruments?

Literature

- **2nd-Best environmental policy**
  - Parry et al. (1999), Goulder et al. (1999): *Pre-existing taxes raise tcosts of market-based env policies.*
  - Cremer & Gahvari (1999): *Pigouvian taxes can be re-adjusted.*
- **Overlapping policies**
  - Böhringer et al. (2008/2009), Böhringer & Rosendahl (2010), Fankhauser et al. (2010), Boeters & Koorneef (2011), Requate (2015): *Overlapping policies have significant adverse (welfare) effects*.
  - Bennear & Stavins (2007), Fischer & Newell (2008): *1st best includes overlapping policies.*

Paper in a nutshell

- We examine how policy instruments need to be adjusted if number of instruments is insufficient
- with a theoretical and a numerical electricity market model that takes into account several market failures
- Our calibrated model shows that policy costs of reducing EU carbon emssions by 40% are about 30% lower if additional market failures are adressed vs. a sole carbon price
- If one instrument is missing, adjusting the remaining ones can reduce up to 50% of your additional costs

Model Setup

A simplified electricity sector model as in Fischer et al. (2013):

- Two stages
- Three types of tech for electricity generation: (i) mature fossil-fuel-based, (ii) mature non-fossil-fuel-based, (iii) “new” renewables
- New renewables are subject to endogenous tech change:
  - LbD: Quantities in stage 1 affect costs in stage 2
  - R&D investments in 1 reduce generation costs in 2
- But producers have not full appropriation of the benefits from tech change $\Rightarrow$ Too low rates of tech change

Model Setup: Consumers

- Consumers gain utility from energy services
- Energy efficiency investments increase the utility per unit of energy
- Two types of energy efficiency investments: Short and long term investments
- But consumers perceive only a fraction of the realized energy savings $\Rightarrow$ Under-investment in energy efficiency

Model Setup: Interventions

The government can intervene and implement policy instruments to address market failures:

(i) Carbon price such that emissions are equal to the socially desired level

(ii) Subsidy per unit of produced REN to correct for LbD spillovers

(iii) Subsidy of REN R&D investments

(iv) Subsidy of energy efficiency investments

1st-Best implementation

Four 1st best policy instruments correct the four market failures (Tinbergen rule):

(i) Carbon price 1 = Discounted carbon price 2

(ii) REN output subsidy = Not internalized REN cost reduction in stage 2

(iii) R&D subsidy rate = Not internalized REN cost reduction in stage 2

(iv) Energy efficiency subsidy rate = Not percieved benefits from EE investments

2nd-best Adjustment: Theoretical predictions

How to adjust remaining instruments?

Missing instrument	REN Output Subsidy: Stage 1	REN Output Subsidy: Stage 2	R&D Subsidy	Energy Efficency Subsidy: Stage 1	Energy Efficency Subsidy: Stage 2
REN Output Subsidy			$\uparrow/\downarrow$	$\downarrow$	$\downarrow$
R&D Subsidy	$\downarrow$	$\uparrow$		$\downarrow$	$\downarrow$
EE Subsidy	$\downarrow$	$\downarrow$	$\downarrow$		

Parametrization

Functional forms as in Fischer, Preonas & Newell:

- Non-renewables: $C_{it} = c^i_{ot} + c^i_{1t}(q^i_t - \bar{q}^i_t) + \frac{c^1_{2t}}{2}(q^i_t - \bar{q}^i_t)^2$
- Renewables:
  $G_{rt} = \left(g^r_{ot} + g^r_{1t}(q^r_t - \bar{q}^r_t) + \frac{g^r_{2t}}{2}(q^r_t - \bar{q}^r_t)^2\right)\left(\frac{\bar{K}^r_t}{K^r_t}\right)$
- Knowledge stock: $K^r_t = \left(\frac{Q^r_t}{Q^r_1}\right)^{k^r_1}\left(\frac{H^r_t}{H^r_1}\right)^{k^r_2}$
- R&D investment: $R^r = \gamma^r_0 h^{r\,\gamma_1}_1$; $H^r_2 = H^r_1 + h^r_1$
- Energy efficiency investment: $Z^j = z^j_1\theta^j_t + \frac{z^j_2}{2}\theta^{j\,2}_t$

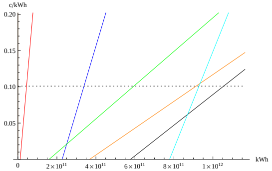
Calibration

- Stage 1 ($n1$): 2015-2020; Stage 2 ($n2$): 2021-2040
- Discount rate δ: 0.025
- Degree of knowledge appopriability (R&D)ρ_{rd}: 0.5
- Degree of knowledge appopriability (LbD)ρ_{ld}: 0.3
- Energy efficiency appropriation rate β: 0.9
- Learning rates: Wind: 3.1% (Solar: 14%)
- R&D rates: Wind: 13.2%, (Solar: 20%) (Klaassen & Söderholm, 2007)

Calibration

	Period 1 supply slope $[EUR/kWh^2]$	Period 2 supply slope $[EUR/kWh^2]$	CO_2 intensity $[t/kWh]$
Coal	2.4×10^{-13}	6.6×10^{-14}	0.91×10^{-03}
Natural gas	1.2×10^{-09}	6.2×10^{-10}	0.36×10^{-03}
Oil	1.9×10^{-13}	2.7×10^{-13}	0.88×10^{-03}
Nuclear	6.7×10^{-13}	2.3×10^{-13}	0
Hydro	9.0×10^{-13}	7.4×10^{-13}	0
Wind	2.3×10^{-13}	3.8×10^{-13}	0
Solar	3.0×10^{-12}	2.4×10^{-12}	0

Table: Based on EU Energy Trends 2030 (2009)



Scenarios

(i) *CO_2-Price:* only available instrument is cap & trade. Cap: -40% in 2030 relative 1990

(ii) *1st-Best:* full availability of all instruments

(iii) *No-R&D-Sub:* 2nd-best without R&D subsidy

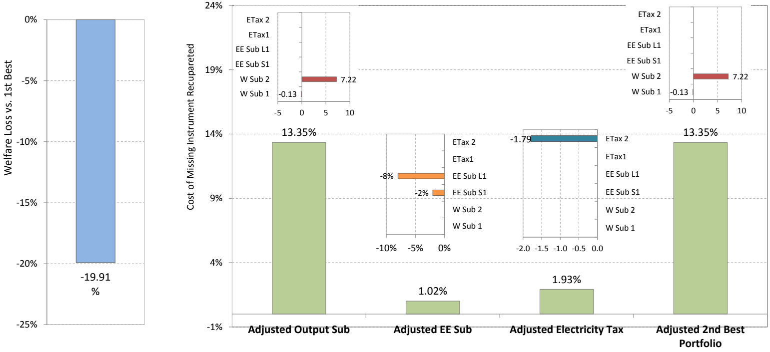
(iv) *No-Effic-Sub:* 2nd-best without subsidies for energy effiency investments

(v) *No-Output-Sub:* 2nd-best without output (learning) subsidies

1st Best

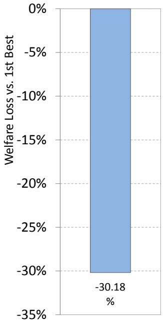
		CO_2 Price only	1st Best
Policy costs	[% welf CO_2]	100	69.77
Wind out sub	[EUR/MWh]		1.13
PV out sub	[EUR/MWh]		7.76
EE sub s1	[EUR/MWh]		0.03
EE sub l	[EUR/MWh]		0.16
R&D sub	rate		0.5
Elec price 2	[EUR/MWh]	95.9	88.8
CO_2 price 2	[EUR/tCO2]	32.8	24.6

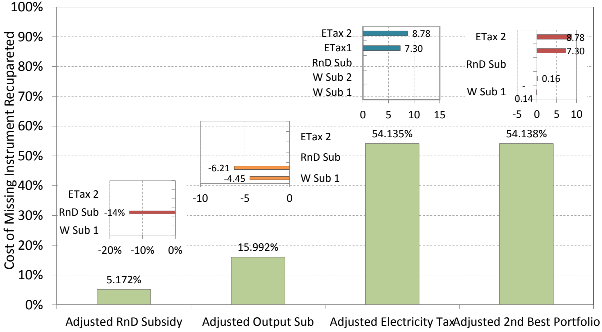
No R&D Subsidy



		1st Best	No R&D Subsidy	Adjusted Output Subsidy	Adjusted EE Subsidy	Adjusted Electrictiy Tax	Adjusted Portfolio
Electrictiy Price 2	[EUR/MWh]	96.78	89.99	89.30	90.52	89.33	89.30
CO2 Price 2	[EUR/tCO2]	18.25	25.91	25.17	26.53	27.17	25.17

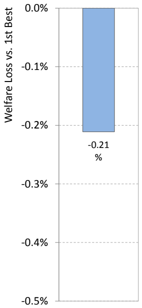
No Energy Efficiency Subsidy

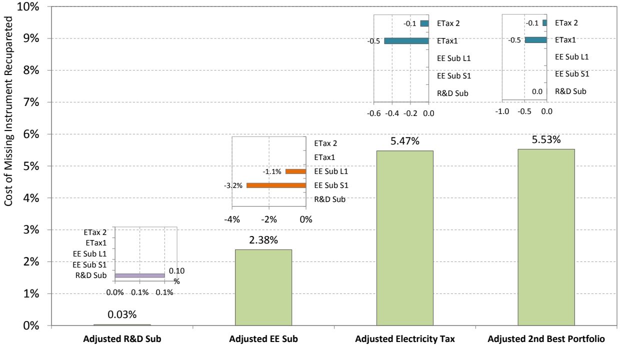




		1st Best	No EE Subsidy	Adjusted RnD Subsidy	Adjusted Output Subsidy	Adjusted Electrictiy Tax	Adjusted Portfolio
Electrictiy Price 2	[EUR/MWh]	96.78	94.33	94.70	95.22	97.53	97.50
CO2 Price 2	[EUR/tCO2]	18.25	31.09	31.49	32.167	24.59	24.57

No Output Subsidy





		1st Best	No Output Subsidy	Adjusted R&D Subsidy	Adjusted EE Subsidy	Adjusted Electrictiy Tax	Adjusted Portfolio
Electrictiy Price 2	[EUR/MWh]	96.797	97.104	97.104	97.175	96.790	96.790
CO2 Price 2	[EUR/tCO2]	18.252	18.285	18.283	18.329	18.368	18.370

Conclusions

- 1st-best portfolio reduces policy costs by about 30%
- But not every instrument has the same importance: larger benefits from energy efficiency than from R&D and than from output subsidies
- We provide a recipe for policy makers to achieve this cost reduction via appropriate re-adjustments (policy fine-tuning)
- We show that “policy fine tuning” when moving from 3rd to 2nd best can reduce up to 50% of additional costs
- However, relationship between instruments and market failures is complex and not fully understood

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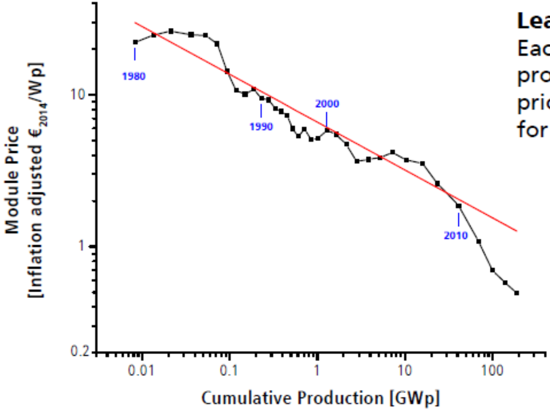
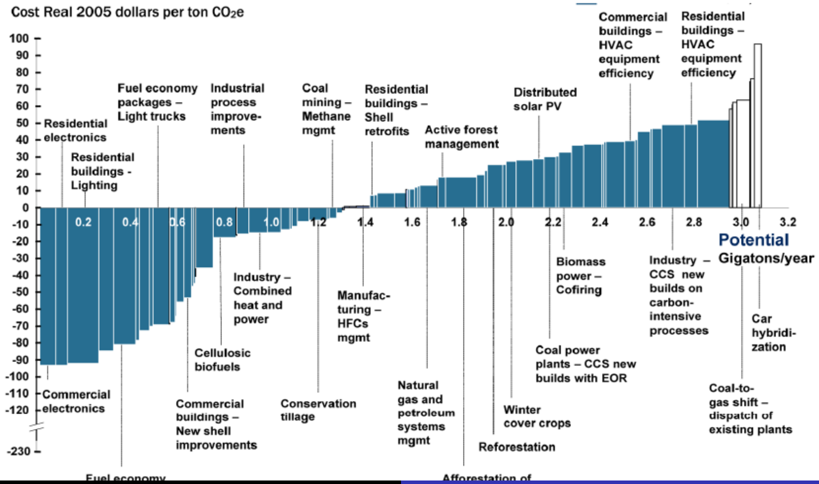
Learning Rates



Learning Rate:
Each time the cumulative production doubled, the price went down by 19.6% for the last 34 years.

McKinsey MACs



Consumer Behavior

- The representative consumer experiences money-metric utility:

$$\max_{v^1,v^2,e^{S1},e^{L1},e^{S2}} U = n^1[v^1 - p^1 d^1(v^1, e^{S1}, e^{L1}) \\ -(1-\lambda^{S1})Z^{S1}(e^{S1} \mid \beta^{S1}) - (1-\lambda^{L})Z^{L1}(e^{L1} \mid \beta^{L}] \\ +\delta n^2[v^2 - p^2 d^2(v^2, e^{S2}, e^{L1}) - (1-\lambda^{S2})Z^{S2}(e^{S2} \mid \beta^{S2})] \quad (1)$$

- *Indexes: St*: short-term in each period; *SL*: short- & long-term over both periods
- *Parameters:* β: fraction of perceived energy efficiency improvements
- *Control variables:* v^t: value of elec. services; $e^{(S/L)t}$: energy

Producer Behavior

- The representative producer of each electricity technology max. profits:

$$\max_{q^{i1},q^{i2},h^{i1}} \Pi^i = n^1[(p^1+\phi^{i1})q^{i1} - C^{i1}(q^{i1}) - \tau^1\mu^i q^{i1} - (1-\sigma^{i1})R^{i1}(h^{i1})]$$
$$+\delta n^2[(p^2+\phi^{i2})q^{i2} - C^{i2}(q^{i2} \mid \rho n^1 q^{i1}, \rho n^1 h^{i1}) - \tau^2\mu^i q^{i2}]$$

- *Indexes:* i: elec. technology; $t = \{1;2\}$: 2 model periods with n years per period
- *Parameters:* μ^i: carbon emissions intensity; ρ: fraction of private knowledge;

  δ: discount rate

Welfare Effects

$$
\begin{aligned}
\frac{dW}{d\Psi} = {} & n^1 \sum_{i \in r} \left[-C^{i2}_{q^{i1}} \delta n^2 (1-\rho) - \phi^{i1} \right] \frac{dq^{i1}}{d\Psi} \\
& + n^1 \sum_{i \in r} (-C^{i2}_{h^{i1}}) \delta n^2 \frac{1-\rho-\sigma}{1-\sigma} \frac{dh^{i1}}{d\Psi} \\
& + n^1 p^1 d^1 \left(\frac{1-\beta^{S1}-\lambda^{S1}}{1-\lambda^{S1}} \frac{de^{S1}}{d\Psi} + \frac{1-\beta^{L}-\lambda^{L}}{1-\lambda^{L}} \frac{de^{L}}{d\Psi} \right) \\
& + \delta n^2 p^2 d^2 \left(\frac{1-\beta^{S2}-\lambda^{S2}}{1-\lambda^{S2}} \frac{de^{S2}}{d\Psi} + \frac{1-\beta^{L}-\lambda^{L}}{1-\lambda^{L}} \frac{de^{L}}{d\Psi} \right) \\
& + n^1 \sum_{i} \tau^1 \mu^i \frac{dq^{i1}}{d\Psi} + \delta n^2 \sum_{i} \tau^2 \mu^i \frac{dq^{i2}}{d\Psi}
\end{aligned}
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Energy Mix in Baseline

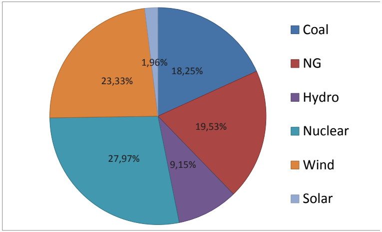

Figure: EU Electricity mix in in 2020, EU Energy Trends 2030 (2009)