Designing Environmental Instruments for the Energy Transition

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Policy relevant questions for the energy transition

- How to accelerate the energy transition at least cost?
  - **Multiple renewable technologies** (wind, solar, hydro...)
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Relevant questions:

1. Should the support be **technology-specific** or **technology-neutral**?
2. Should it be set through **quantity** or **price instruments**?
3. What are the **trade-offs involved**?

Renewable Support Instruments

Commonly used renewables support instruments regulate....

- **Quantity:** Auctions, tradable quotas...
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- **Technology specific**: different instruments/levels of support used depending on technology, scale, location, etc.
- **Technology neutral**: all technologies treated equally
- **Hybrid schemes**: corrected technology-neutral approach
  - Auctions: bids of some technologies are deflated
  - Green certificates: some technologies are granted more certificates than others (*banding*)

Renewable Support Instruments in Europe

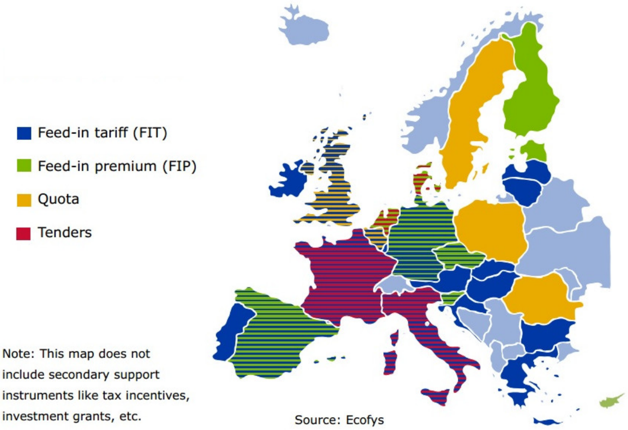
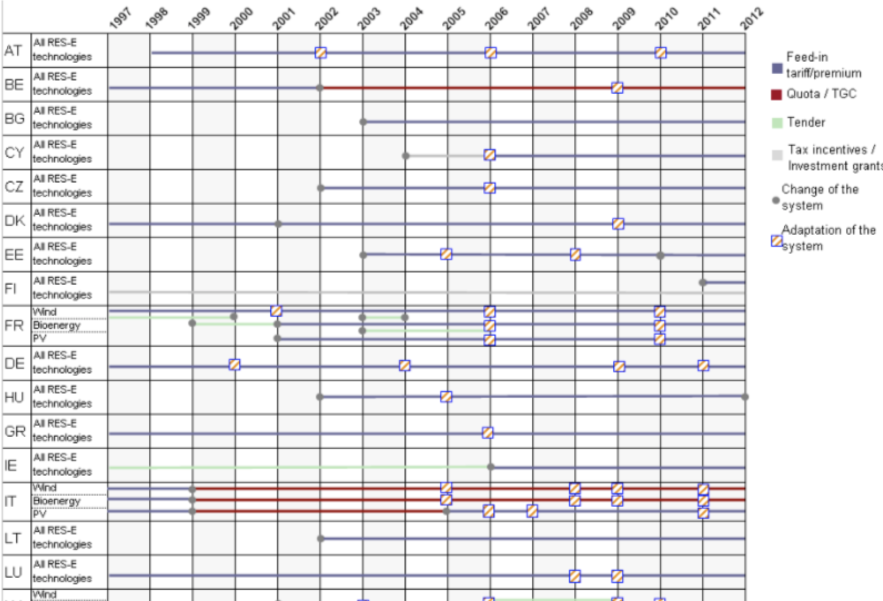
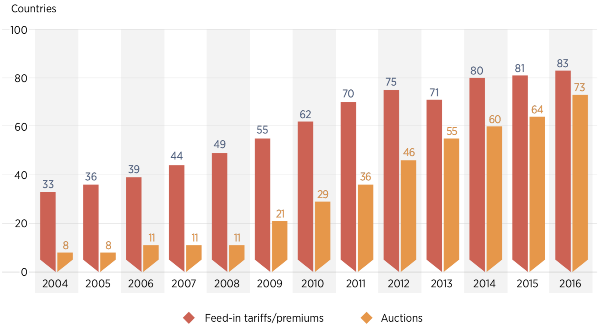


Figure: Renewable Support Instruments

Renewable Support Instruments in Europe



Auctions versus Price regulation (FiTs)



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Renewable auctions, commonly used Europe

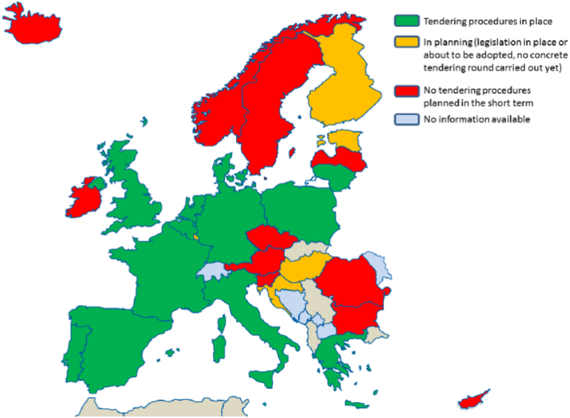

Figure: The use of renewable auctions in Europe

Technology-neutral auctions in Europe

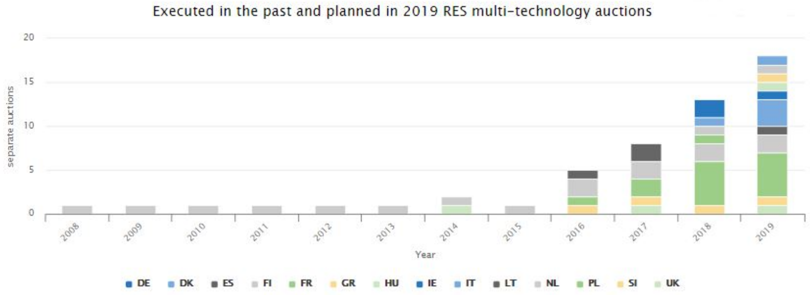

Figure: Increasing number of technology-neutral auctions in Europe

Technology-neutral auctions in Europe

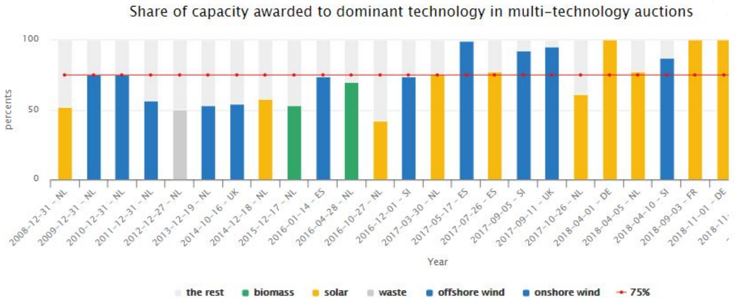

Figure: Share of the dominant technology in technology neutral auctions

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- **Technology neutral instruments are good for efficiency**:
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- **...but might lead to over-compensation, which can be mitigated via banding**
  Technology banding is a means to avoid over compensating cheaper technologies that enter the market at high prices set by more expensive technologies (EC, 2013)

Some (not all) issues are well understood

However, some key issues seem **unanswered**:

1. When does the **risk of over-compensation** dominate over the **cost minimization** objective?
2. Is the balance between **cost efficiency and equity** best resolved through **banding**?
3. **Why quantity** regulation (auctions) and not price regulation?
4. How is the comparison of prices vs quantities affected with **multiple technologies**?

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$$C_t\left(q_t\right) = \left(c_t + \theta_t\right) q_t + \frac{C''}{2} q_t^2$$

  where $c_t \geq 0$ and $C'' > 0$

- Cost shocks: $E[\theta_t] = 0$, $E[\theta_t^2] = \sigma > 0$ and $E[\theta_1 \theta_2] = \rho\sigma \gtrless 0$

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Social Benefits:

- $B(Q)$, where $Q = q_1 + q_2$, with $B' > 0$ and $B'' < 0$
- Ass.: Always optimal to procure units from both technologies

The Planner's Problem

The planner maximizes (expected) **social welfare**:

$$\max W = E\left[B(Q) - \sum_{t=1,2} C_t(q_t) - \lambda T(q_1, q_2)\right]$$

where:

- λ: **shadow cost of public funds**
- $T(q_1, q_2)$: planner's total payment from procuring $Q = q_1 + q_2$

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An instrument design/choice problem: the planner must decide between...

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   - If quantity regulation (auctions): $Q \rightarrow P(Q)$
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2. A **technology-specific** approach:
   - If quantity regulation (auctions): q_1 and $q_2 \rightarrow p_1(q_1)$ and $p_2(q_2)$
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   - If price regulation (tariffs): p_1 and $p_2 \to q_1(p_1)$ and $q_2(p_2)$
3. A **hybrid** approach (banding):
   - **exchange rate** across technologies, α

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Quantities for each technology are given by

$$q_1^N = \frac{Q^N+\Phi^N}{2}+\frac{\Delta\theta}{2C''} > q_2^N = \frac{Q^N-\Phi^N}{2}-\frac{\Delta\theta}{2C''}$$

where

$$\Phi^N \equiv E\left[q_1^N\right]-E\left[q_2^N\right]=\frac{\Delta c}{C''}$$

Technology-Specific Auctions

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- ...at the expense of **increasing costs**:

$$E\left[C^S\right] - E[C^N] = \frac{C''}{4}\left[\left(\Phi^S - \Phi^N\right)^2 + E[(\Delta\theta)^2]\right] > 0$$

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- Tech-neutral auctions are superior to tech-specific auctions iff

$$W_q^N - W_q^S = \frac{1}{4C''}\left[2\sigma(1-\rho) - \frac{\lambda^2}{1+2\lambda}(\Delta c)^2\right] > 0$$

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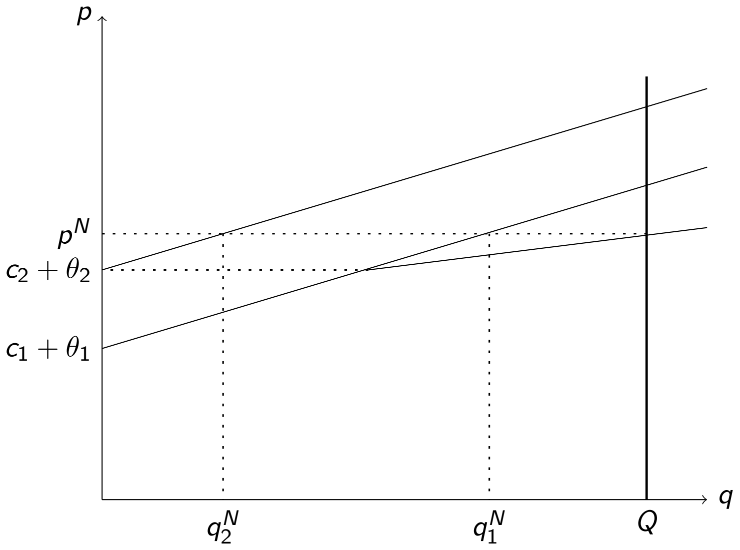
Tech-specificity always dominates if:

- Strong concern for rents: $\lambda \to \infty$
- Perfectly correlated cost shocks: $\rho = 1$

Technology-Neutral *vs* Technology-Specific Procurement



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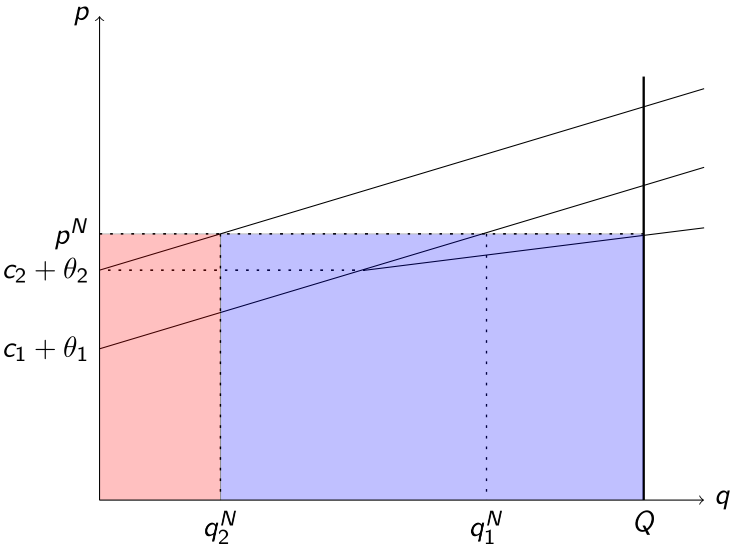

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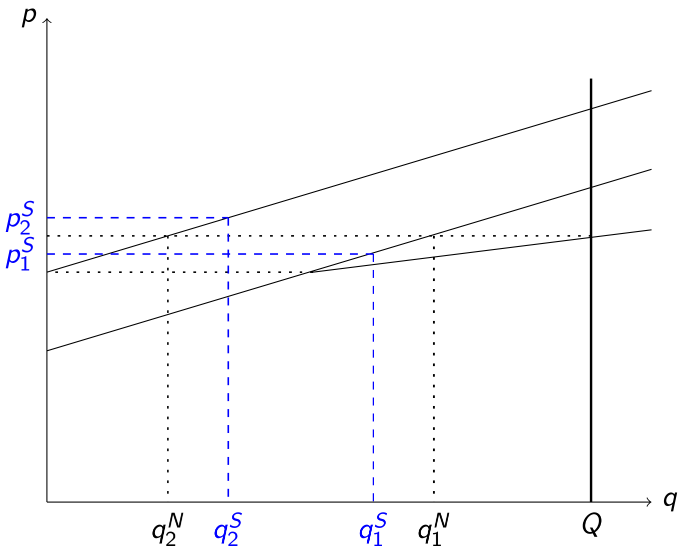

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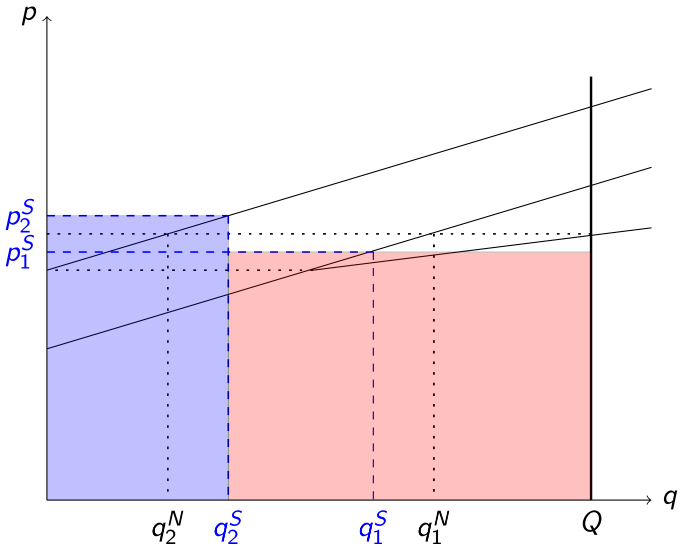

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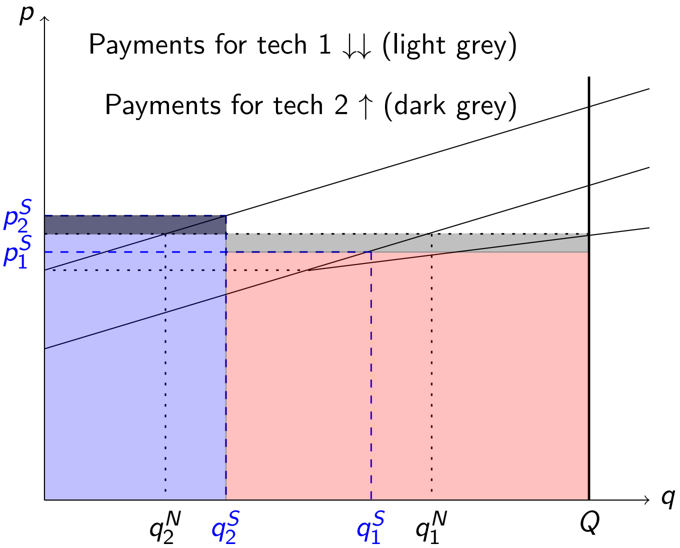

Adding Market Power

- Existing units divided btw dominant firm (d) and fringe (f)
  - Shares $\omega_d = \omega$ and $\omega_f = 1 - \omega$
- Costs for each firm $i = d, f$ are now given by

$$C_{it}(q_{it}, \theta_t) = (c_t + \theta_t)\, q_{it} + \frac{1}{2}\frac{C''}{\omega_i} q_{it}^2$$

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  - **Prices: profit maximization** by dominant firm:

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  - ...resulting in a **higher market share for the fringe**:

$$\begin{aligned} q_f^N - q_d^N &= \frac{1-\omega}{1+\omega} Q^N > 0 \\ q_{ft}^S - q_{dt}^S &= \frac{1-\omega}{1+\omega} q_t > 0 \end{aligned}$$

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- Under separation, market power distorts the **allocation across technologies**:

$$\Phi^S(\omega) = f(\omega, \lambda)\,\Phi^S(0)$$

  - The distortion is increasing in λ
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Welfare:

- Market power reduces welfare under both approaches
- Greater welfare reduction under technology-specific auctions

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$$\max_{p_1, p_2} E\left[B\left(\sum_{t=1,2} q_t(p_t)\right) - \sum_{t=1,2} C_t(q_t(p_t)) - \lambda T(p_1, p_2)\right]$$

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- Quantities adjust so that **each** market price equals the marginal costs of **each** technology:

$$p_t = c_t + \theta_t + C'' q_t(p_t)$$

One price vs. one quantity (Weitzman)

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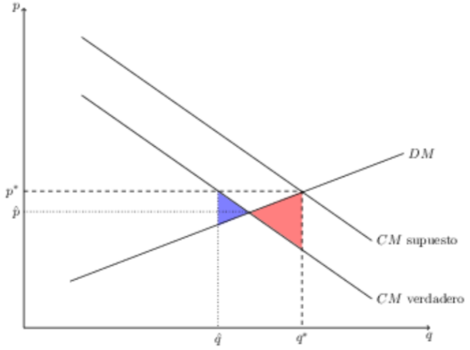

Figure: P vs Q: Price regulation is superior when marginal benefit is relatively flat

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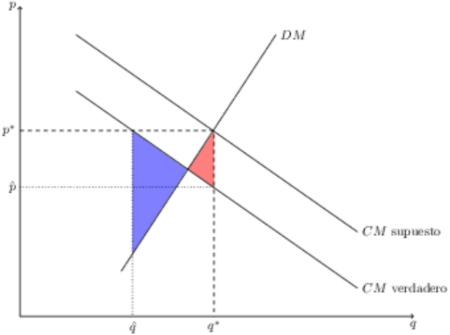

Figure: P vs Q: Quantity regulation is superior when marginal benefit is relatively steep

Two Prices *vs* Two Quantities

- Two prices dominate two quantities iff

$$W_p^S - W_q^S = \frac{\sigma(1+\rho)}{(C'')^2}\left(B'' + \frac{C''}{2}\frac{2}{1+\rho}\right) > 0$$

- **Modified Weitzman (1974)'s formula**
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- **Cost of public funds:**
  - λ does not affect comparison (equal expected payments)

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Note of caution:

- **Constraints when implementing** *optimal* technology separation
- "Bad" technology separation might be worse than neutrality
- ...even in settings where optimal technology separation dominates