Electricity markets: Renewable energy and investments

Lecture 8

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Introduction

We have seen that a price on emissions or a system of tradable emission rights can implement a pollution target. In practice, however, there are multiple additional policies to support carbon-free (renewable) energy technologies, for example:

- feed-in tariffs (FIT)
- upfront subsidies
- green certificate systems

Why do they exist? What do they achieve?

Refreshment, if there is a price on emissions:

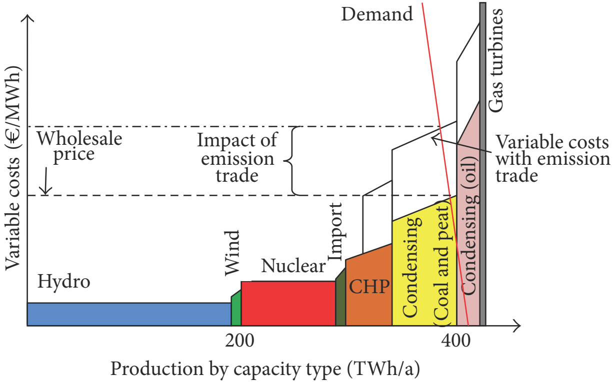

Figure: Pass-through of emissions costs. Why is this not enough?

Pass through in action:

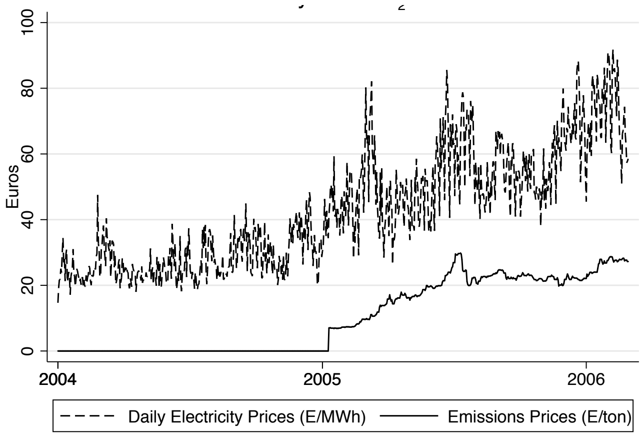

Figure: Reguant&Fabra: Pass-Through of Emissions Costs in Electricity Markets,American Economic Review, 2014, 104(9): 2872-2899.

Simple model for evaluating policies

- $C(Q_R)$ cost of renewable energy Q_R
- $C(Q_F)$ cost of fossil energy Q_F
- $C(Q)$ total cost $Q = Q_F + Q_R$

$$C(Q) = \min_{Q_R, Q_F} \{C(Q_R) + C(Q_F) : Q = Q_F + Q_R\}$$

- $U'(Q) = P(Q)$ consumer price

Absence of regulations: $P(Q) = C'(Q) = C'(Q_R) = C'(Q_F)$

- both technologies contribute up to the point where the marginal costs are equal.

A policy: limit for $\bar{Q}_F$ for fossil energy

If the target is binding, the total cost increases:

- $C'(Q_R) \neq C'(\bar{Q}_F)$, marginal costs no longer equalized
- $C'(Q_R) - C'(\bar{Q}_F) = \lambda > 0$, "the price" of the target
- in equilibrium, $C'(Q_R) = P(Q) = C'(\bar{Q}_F) + \lambda$

Two basic ways of implementing the target:

- If quota $\bar{Q}_F$ is implemented through tradable rights, $\lambda > 0$ will be the market price for the right
- Or, there could be a tax on fossil fuel energy at level $\lambda > 0$

Feed-in-tariff, FIT

In Denmark, Netherlands, and Germany (plus some 60 other countries), the renewable producers receive a guaranteed price, independent of the marker price. In our simple model:

- $\bar{p}$, output price for each renewable producer.
- In equilibrium: $C'(Q_R) = \bar{p}$, and $P(Q) = C'(Q_F)$

Since F receives the final price, it is not paying the proper cost of the policy target (λ above)

- to reach the target $\bar{Q}_F$: subsidize a greater entry of R than what would minimize the cost of the target (achieved when λ is imposed on F)
- technology mix is not optimal

So why is FIT used?

Often seen reasons for using Feed-in-tariffs

- Countries have specific R targets
  - Finland: wind power should increase by 50 % between 2020-2025 (TEM)
  - Denmark: 50 % of all electricity wind by 2020
  - Sweden: 30 TWh wind by 2020. Note, however, that Sweden and Norway use a green certificate system, discussed shortly.
- Can reduce existing rents in the market: distributional argument. I explain in the class.
- Investor risks: society should cover a greater share of the risk of entry.
- Technology spillovers

See *here* for a discussion of the arguments.
See *here* for the political economy reasons

Some alternatives

- green certificates
  - Regulator sets the shares of R and F. Production of R generates rights to produce F. The rights belong to owners of R units: revenue from selling the rights to F units.
  - For the Swedish and Norwegian system: see (*link*).
  - see next Figure
- different versions of the feed-in tariffs: financed by taxes on F production, premium systems, etc.
- Table below

Forms of subsidies

		Price-driven	Quantity-driven
Regulatory	Investment focused	• Investment subsidies • Tax credits • Low interest/Soft loans	• Tendering system for investment grant
	Generation based	• (Fixed) Feed-in-tariffs	• Tendering system for long-term contracts
		• Fixed Premium system	• Tradable Green Certificate system
Voluntary	Investment focused	• Shareholder Programs • Contribution Programs	
	Generation based	• Green tariffs	

Figure: R. Haas et al. / Energy 36 (2011) 2186-2193

Illustration: a market with green certificates

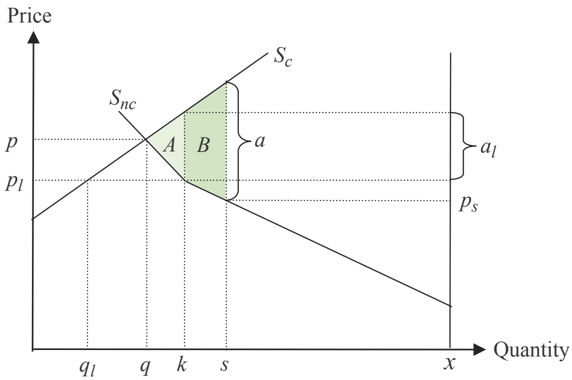

Figure: S.-O. Fridolfsson, T.P. Tangeros / Energy Policy 58 (2013) 57-63

Why investments are risky?

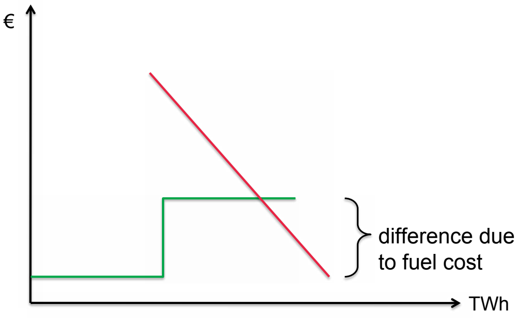

Figure: Demand and supply. Fuel cost includes the cost of emissions

Incentives to invest

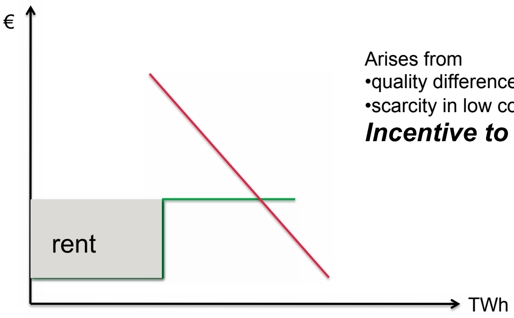

Figure: Technologies that do not use carbon inputs are of higher quality (economically).

Making emissions more costly:

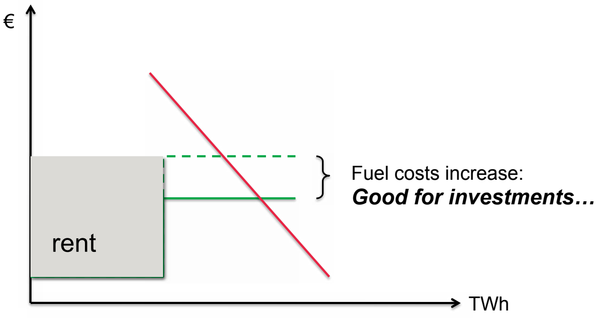

Figure:

But prices can also decline in the future:

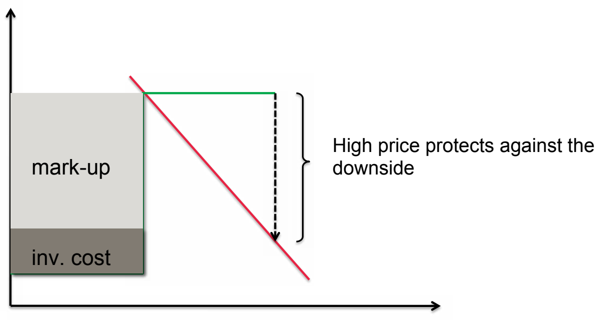

Figure: Thus, in a market equilibrium, there is a mark-up over investment costs. The carbon cost may have to be very high before market-based investments take place. Feed-in tariffs provide a protection for the downside risk.

Nuclear power investments

Plan:

- Institutional background: the Finnish model of ownership
- Tools for analysis: levelized costs and the market impact
- Quantitative Assessment

How important is Nuclear Globally?

The Future of Nuclear Power. An Interdisciplinary MIT Study (2003, *link*)

- ”[..]our study postulates a global growth scenario that by mid-century would see 1000 to 1500 reactors of 1000 megawatt-electric (MWe) capacity each deployed worldwide, compared to a capacity equivalent to 366 such reactors now in service.”

2009 update of the study:

- ”Since 2003 construction costs for all types of large-scale engineered projects have escalated dramatically. The estimated cost of constructing a nuclear power plant has increased at a rate of 15% per year heading into the current economic downturn.”

Construction history

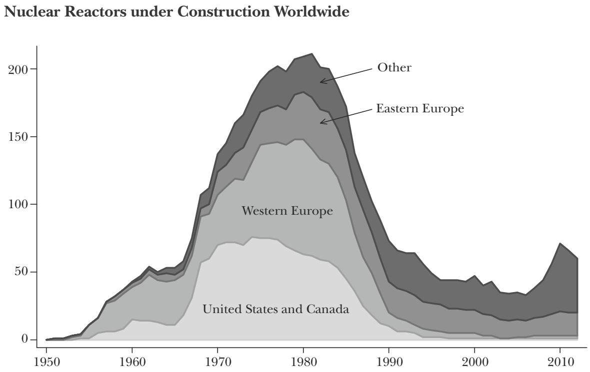

Figure: Source: Davis, see dropbox

How important is Nuclear in Finland?

Finnish electricity key facts (2014):

- Total consumption 83.3 TWh (TeraWatthours). Domestic production 65.4 TWh
- Nuclear is baseload generation: 27.1 % of electricity supply in 2013

Nuclear power plants in Finland

Nuclear power plants in Finland are owned by three companies

1. TVO owns two operating units (Olkiluoto 1 and Olkiluoto 2) and one that is under construction (Olkiluoto3)
2. Fennovoima has been granted a positive decision-in-principle for its unit (Fennovoima 1)
3. Fortum owns two units (Loviisa 1 and Loviisa 2)

First two are ”cooperatives”. This ownership form is the ”Finnish model”

Nuclear power plants in Finland

Cooperatives:

- consortium to joint-finance large investments
- financing share=output share. Also, the running costs are shared in the same proportions
- electricity to shareholders with cost-of-service price
- Majority of nuclear power capacity owned by cooperatives (70 % at the moment, 77 % after OL3 and 82 % after FH1)

Industry, consumer, and wholesale interests are represented

Illustration of ownership

	Series A (OL1+OL2)	Series B (OL3)	Series C (Meri-Pori)	Total
EPV Energia Oy	6.5	6.6	6.5	6.5
Fortum Power and Heat Oy	26.6	25	26.6	25.8
Karhu Voima Oy	0.1	0.1	0.1	0.1
Kemira Oyj	1.9	-	1.9	1
Oy Mankala Ab	8.1	8.1	8.1	8.1
Pohjolan Voima Oy	56.8	60.2	56.8	58.5
Total	100	100	100	100

Figure: Source: TVO

What explains investments in nuclear in Finland?

- Co-operatives
  - No big exposure in individual balance sheets
  - Less equity required and lower risk premiums for loans
- Market risk
  - The plant is a long-term contract
  - Willingness to pay for the contract: industry structure and the retail commitments
- Strategic reasons
  - Capacity share competition

Return requirement

Cost of capital

- r_E, cost of equity, r_D cost of debt
- $A = E + D$, assets=equity+debt
- weighted average cost of capital, WACC:

$$WACC = \frac{E}{A} r_E + \frac{D}{A} r_D$$

- MIT study(2003): WACC=11.5 %
- in Finland, 6% or lower. How?

Cost of capital: typical project

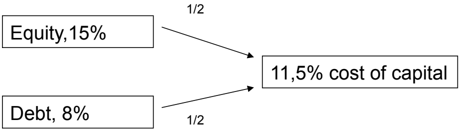

Figure: 50-50 shares of equity and debt

Cost of capital: low equity share for a cooperative

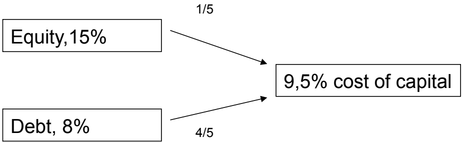

Figure: Cooperative is less exposed to risk

Cost of capital: low cost of debt for a cooperative

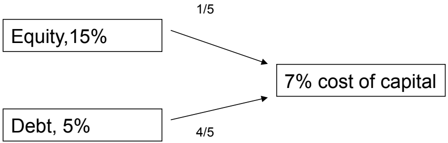

Figure: Cooperative is less exposed to risk

Cost of capital: low return requirement of equity

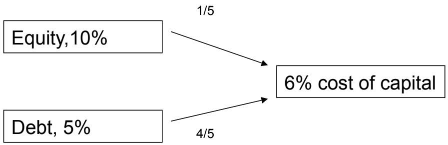

Figure: Non-profits interests in cooperatives

Levelized Cost of Energy, LCOE

LCOE for a given production plant is the constant (in real terms) price for output that would equate the net present value of revenue from the plant's output with the net present value of the cost of production. Formally,

$$\sum_{t=1}^{N} q_t \frac{LCOE}{(1+r)^t} = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$$

$$\Rightarrow$$

$$LCOE = \frac{\sum_{t=0}^{N} \frac{C_t}{(1+r)^t}}{\sum_{t=1}^{N} \frac{q_t}{(1+r)^t}}$$

where C_t is the cost of production at time period t, N is the total number of periods, r is the annual interest rate, and q_t is the quantity of production. To make sure: C_0 captures the fixed costs, and the cost in later periods are the items C_1, C_2, ..., C_N. We will now see how this exactly works using the worksheet for the nuclear case.

Levelized Cost of Energy, LCOE

1. Download the spreadsheet in the lectures folder (see the dropbox folder for the lecture)
2. Look at "results" tab: row 83 gives the total cost of operations for each 5 year period (thus, take this as one period). The first period (2015-19) includes the fixed cost, and the later periods the variable costs. This row identifies the cost items needed for the calculation of LCO
3. Production is somewhat hidden in the spreadsheet so here are the directions for finding it: use D84/D30 to obtain the production (divide revenues by price) for 2020-24 period. Do the same for all 5 year periods and you have the total output in TWh (TeraWatthours) for each period.
4. The discount factor can be found on row 80.
5. Now you are ready to go: calculate the LCO for this plant! It would be nice if you can construct a table that reports this number for different discount rates (change that in row 11) and investment costs (row 12) and also for different variable costs (row 10).
6. The tab "control panel" allows you to change scenarios, and in results you can see when the plant breaks even. Can you explain the relationship between the LCO and the final profitability of the investment?

Some references

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