Green Certificates and Market Power in the Nordic Power Market

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Outline of presentation

- Provision of renewable energy using GCs
- The basic ideas of a GC- system
- Analytical aspects
- Market structures and first order conditions
- A numerical model
- Results
- Concluding remarks

Provision of renewables using GCs

- Many countries have an objective of increasing the share of renewables in energy supply (e.g. EU wants to raise the share from 14% in 2000 to 22% by 2010).
- An increasing number of countries have decided to or contemplates using GC systems as an alternative to direct subsidies (e.g the Netherlands, Denmark, England, Sweden, Spain, Italy Australia, China, India, USA)
- The Netherlands have had a *voluntary* system functioning for many years. England has introduced an *obligatory* system
- Among the Nordic countries, Sweden introduced an obligatory system in 2003, Norway will introduce a similar system in 2006 and start trading GCs with Sweden, Denmark has designed a system but it is not effectuated, while Finland has no immediate plans

The Nordic GC-system

- **Sellers: producers of green electricity**
  - 1 MWh of green electricity sold at the electricity market gives the right to sell 1 GC at the certificate market
  - For each MWh generated the producer of green electricity thus receives the wholesale price plus the value of a GC
- **Buyers: consumers/retailing companies**
  - Required to hold a minimum percentage of GCs corresponding to total consumption/end-use deliveries
- **Policy variables:**
  - The percentage requirement:
    - Specifies a minimum share of green electricity in end-use consumption. Basically this requirement functions as a constraint on total consumption
  - Price bounds:
    - Lower bound; secures a minimum price for the sellers
    - Upper bound (fine); secures a maximum price for the buyers

Analytical aspects

(Amundsen and Mortensen; 1999, 2001)

- Legend
  - p(x): end-use price of electricity
  - q: wholesale price
  - s : certificate price
  - x: quantity of total electricity
  - y: quantity of ”black” electricity
  - z: quantity of ”green” electricity
  - α: percentage requirement
  - c’(y): marginal cost of “black” electricity
  - h’(z): marginal cost of “green” electricity

Perfect competition: equilibrium conditions

- End-user price: $p\left(x^*\right) = q^* + \alpha s^*$
- Total quantity: $x^* = y^* + z^*$
- Consumption constraint: $x^* = z^* / \alpha$
- Quantity of green electricity: $q^* + s^* = h'\left(z^*\right)$
- Quantity of black electricity: $q^* = c'\left(y^*\right)$
- Implication: $p\left(x^*\right) = (1-\alpha)c'(y^*) + \alpha h'(z^*)$

Perfect competition: Some results

- Increased ”percentage requirement”, may lead to reduced capacity of green power generation
- Harsher CO2 emission constraint may lead to reduced capacity of green power generation
- Increased black generation costs may lead to reduced capacity of green power generation
- Increased price of imported electricity may lead to reduced capacity of green electricity

Market power

- Standard Cournot
  - Market power in the power market, GC-prices perceived as given
  - Market power in both the power market and the GC-market, but separate decisions
- Interactive markets
  - Producers have market power and recognize that an action in one market may influence the price in the other
- Literature:
  - Amundsen and Nese (2002):”Provision of renewable energy using green certificates: market power and price limits”
  - Chen and Hobbs (2003): ”An oligopolistic power market model with tradable NOx-permits”
  - Kolstad and Wolak (2003):” Using environmental emissions permit prices to raise electricity prices: evidence from the California electricity market”

First order conditions

- Standard Cournot:
  - Green electricity:

$$\frac{\partial p\left(x^*\right)}{\partial x} z^* + q^* + s^* = h'\left(z^*\right)$$

  - Black electricity:

$$\frac{\partial p\left(x^*\right)}{\partial x} y^* + q^* = c'\left(y^*\right)$$

- Interactive markets:
  - Green electricity:

$$\left[\frac{\partial p\left(x^*\right)}{\partial x} + (1-\alpha)\frac{\partial s\left(x^*\right)}{\partial z}\right] z^* + q^* + s^* = h'\left(z^*\right)$$

  - Black electricity:

$$\left[\frac{\partial p\left(x^*\right)}{\partial x} - \alpha\,\frac{\partial s\left(x^*\right)}{\partial y}\right] y^* + q^* = c'\left(y^*\right)$$

A numerical model of the Nordic power market

- Major firms (3-5) plus a fringe for each country
- Step-wise increasing linear marginal cost curves, reflecting unit costs and capacity limits for various technologies
- Free-trade in electricity but inter-connector capacity limits
- Autarky or free trade in the certificate market
- Cournot behaviour in the electricity market, perfect competition or Cournot behaviour in the GC-market
- Constant elastic demand curves in each country (price elasticity: -0,3)

A numerical model of the Nordic power market

- Determines equilibrium prices and quantities on, and cross border tariffs between, the electricity markets in Denmark,Finland, Norway and Sweden
- Determines equilibrium prices and trade on the markets for green certificates in Norway and Sweden

Simulations: objectives

- To investigate how a requirement of having a certain percentage of green electricity affects the power market under autharky and under free trade of GCs
- To investigate the possibilities of exercising market power on the GC-market

Simulations: Base case

- The year 2006 is investigated
- Cournot behaviour on the power market
- Free trade in power, but transmission constraints may lead to different prices in the various countries
- No requirements regarding percentage of green electricity in consumption

Table 1. Quantity (TWh) and prices (SEK/MWh) in the base case

	Norway	Sweden
Total electricity consumption	121,3	157,0
Green electricity consumption	0	2,8
Green electricity production	0	2,8
Producer price of electricity	24,0	24,0
Price of green certificates	-	-
Consumer price of electricity	24,0	24,0
Average production costs of el.		3,8

Simulations for Case 1:Only Sweden has a green electricity requirement

- Assumptions:
  - Percentage requirement of **12,8** for Sweden, no percentage requirements in the other Nordic countries
  - Perfect competition on the market for GCs
  - Otherwise, same assumptions as in the base case
- Results:
  - The (common) wholesale price falls
  - The Swedish consumer price increases
  - The average producer cost in Sweden increases
  - The consumer price falls and the consumption increases in Norway

Table 2. Quantity (TWh) and prices (SEK/MWh) in Case 1

	Norway	Sweden
Total electricity consumption	123,9 (121,3)	155,0 (157,0)
Green electricity consumption	0	19,5 (2,8)
Green electricity production	0	19,5 (2,8)
Producer price of electricity	22,4 (24,0)	22,4 (24,0)
Price of green certificates	-	21,6
Consumer price of electricity	22,4 (24,0)	25,1 (24,0)
Average production costs of el.		5,3 (3,8)

Simulations for Case 2: Both Norway and Sweden have green electricity requirements

- Assumptions:
  - Percentage requirement of **2** for Norway and **12,8** for Sweden, no percentage requirements in the other Nordic countries
  - Perfect competition on the market for GCs
  - No trade in GCs
  - Otherwise, same assumptions as in the base case
- Results:
  - The (common) wholesale price falls
  - The Swedish consumer price increases
  - The average producer cost in Sweden increases
  - The consumer price falls and the consumption increases in Norway
  - The price of GC are the same, because the cost of the green technology (wind power) is the same
  - The introduction of a green requirement in Norway leads to larger green production in Sweden

Table 3. Quantity (TWh) and prices (SEK/MWh) in Case 2

	Norway	Sweden
Total electricity consumption	123,7 (121,3)	155,2 (157,0)
Green electricity consumption	2,5	19,6 (2,8)
Green electricity production	2,5	19,6 (2,8)
Producer price of electricity	22,1 (24,0)	22,1 (24,0)
Price of green certificates	22,0	23,0
Consumer price of electricity	22,5 (24,0)	25,0 (24,0)
Average production costs of el.		5,3 (3,8)

Simulations for Case 3: Both Norway and Sweden have green electricity requirements; joint GC markets

- Assumptions:
  - A joint GC market between Norway and Sweden
  - Perfect competition on the market for GCs
  - Otherwise, same assumptions as in Case 2
- Results:
  - The GC price is the same in both Norway and Sweden
  - Otherwise same results as for Case 2 (only minor changes)

Table 4. Quantity (TWh) and prices (SEK/MWh) in Case 3

	Norway	Sweden
Total electricity consumption	123,7 (121,3)	155,2 (157,0)
Green electricity consumption	2,5	19,6 (2,8)
Green electricity production	3,0	19,0 (2,8)
Producer price of electricity	22,1 (24,0)	22,1 (24,0)
Price of green certificates	23,0	23,0
Consumer price of electricity	22,5 (24,0)	25,0 (24,0)
Average production costs of el.		5,3 (3,8)

Simulations for Case 4: Cournot behaviour on the common Norwegian - Swedish GC market

- Assumptions:
  - Trade in GCs
  - Cournot behaviour on the common GC market (Generators are expected but not not obliged to sell the GC:s they receive)
  - All companies have access to the same green technology (same cost and equal opportunity for permission of construction)
  - Otherwise, same assumptions as in Case 2
- Results:
  - The price of GCs is at the upper price bound for Sweden.
  - The generation of green power in Norway and Sweden is well above the percentage requirement
  - In general, not very much market power is needed to drive the GC price to its upper price bound
  - Otherwise same results as for Case 3

Table 5. Quantity (TWh) and prices (SEK/MWh) in Case 4

	Norway	Sweden
Total electricity consumption	124,0 (121,3)	154,0 (157,0)
Green electricity consumption	2,5	19,4 (2,8)
Green electricity production	6,8	17,8 (2,8)
Producer price of electricity	21,7 (24,0)	21,3 (24,0)
Price of green certificates	31,0	31,0
Consumer price of electricity	22,3 (24,0)	25,6 (24,0)
Average production costs of el.		6,4 (3,8)