Market Power in Joint Markets for Power and Green Certificates

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Outline

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The Scandinavian GC system

- Sellers: producers of green electricity
  - 1 kWh of green electricity sold at the electricity market gives the right to sell 1 GC at the certificate market
- Buyers: consumers/distribution 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
    - Constraint on total consumption
  - Price bounds:
    - Lower bound; secures a minimum price for the sellers
    - Upper bound; secures a maximum price for the buyers

Motivation

- GC-systems have been implemented, or are under consideration, in a number of countries: Australia, The Netherlands, Denmark, Norway, Sweden and the US (Texas, New England, Wisconsin)
- Literature:
  - Amundsen and Mortensen (2001, 2002):”The Danish green certificate system: some simple analytical results”, *Energy Economics*
  - 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”

The model

- Static analytical equilibrium model
- Increasing LRMC for both generation technologies
- No capacity constraints
- No transmission limits
- No transaction costs

Market structures

- Perfect competition
- Market power, using standard Cournot assumptions
  - Market power among both kinds of generation technologies, i.e. both producers of green and black electricity enjoys market power
  - The GC price is treated as exogenous by both the producers of black and green electricity, i.e. neither of the producers realize that their quantity decisions in the electricity market affect the GC price and thereby the resulting wholesale price of electricity through the interaction between the electricity and the GC market

Market structures

- Market power in interactive markets
  - The producers now realize that their quantity decisions in the electricity market affects the GC price and thus the wholesale price received by the producers.
  - Each producer conjectures the effects on both markets of decisions made in one market.
  - We include therefore an endogenous treatment of the interaction between the electricity and the GC market

First order conditions (Nash-Cournot)

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

First order conditions

- Standard Cournot:
  - Green electricity:

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

  - Black electricity:

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

- Interactive markets:
  - Green electricity:

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

  - Black electricity:

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

Results

- Perfect competition and standard Cournot:
  - There may be established an equilibrium GC-price at the price bounds or at an intermediate level
- Interactive markets:
  - The GC market **collapses** in the sense that the GC price will never be established at an intermediate level. It may, however, be established at the lower or upper price bound.

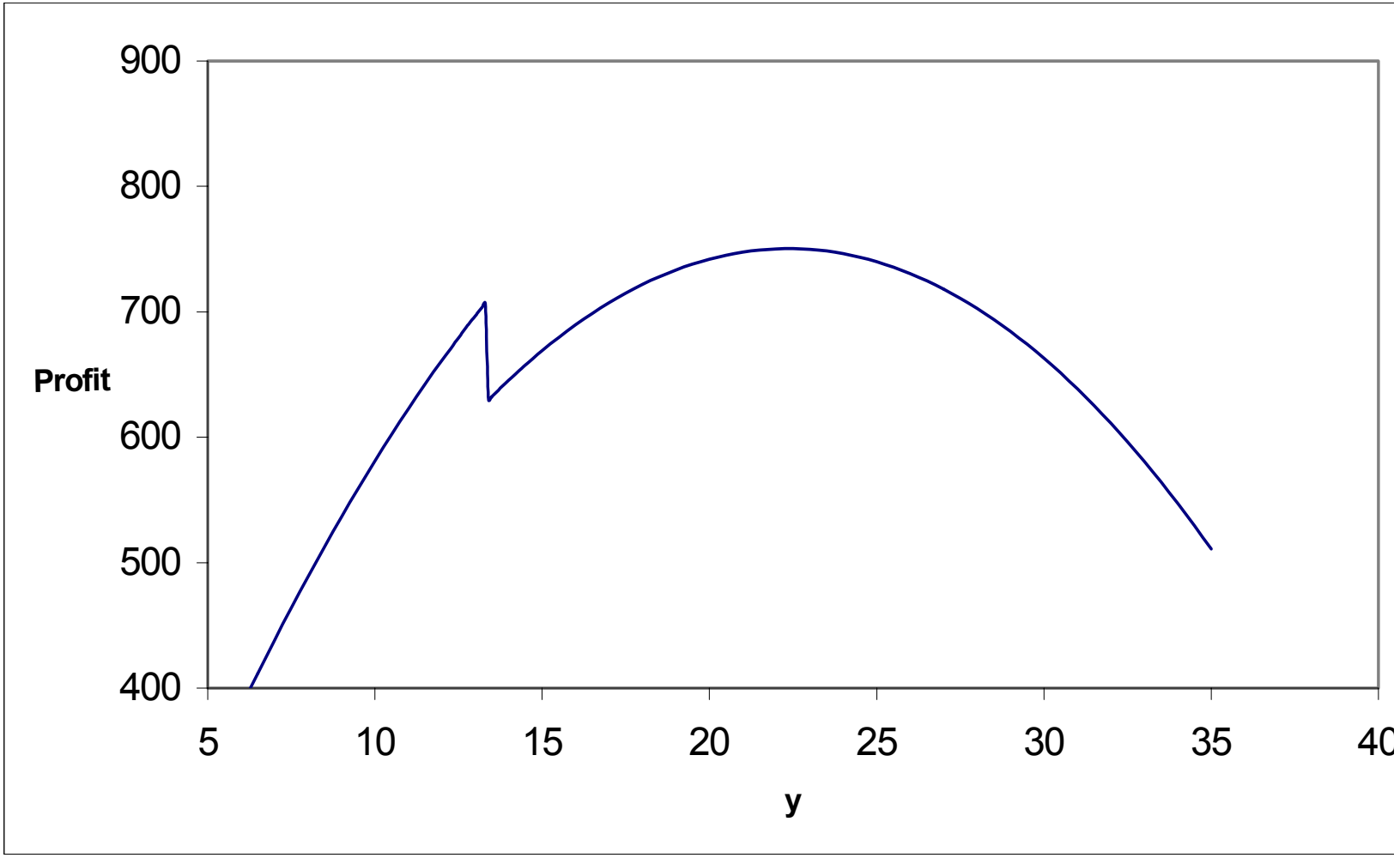

Figure 2: Profit curve for the oligopolistic producers of black electricity in the interactive market power case, illustrating an equilibrium GC-price at the upper price bound.

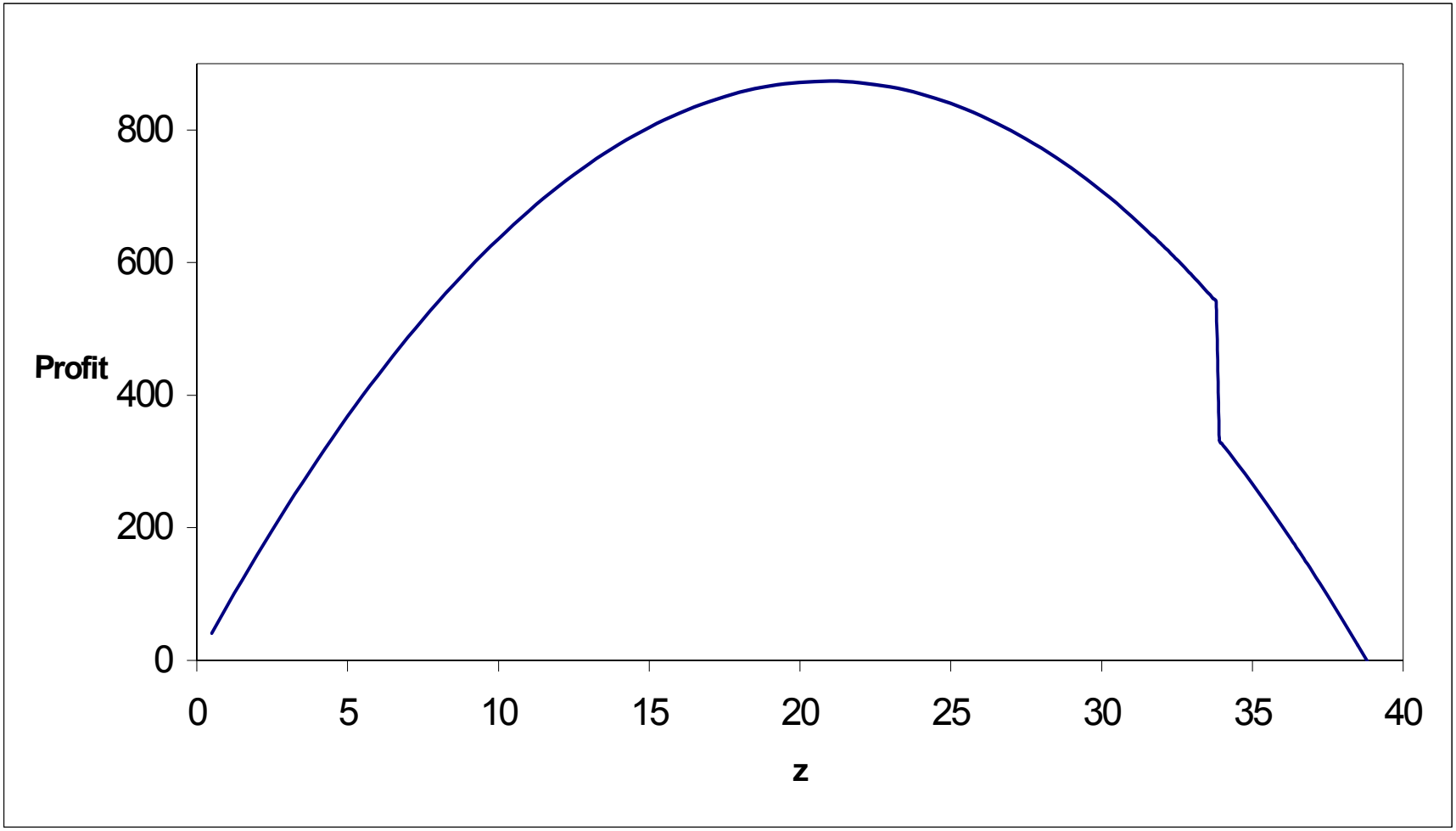

Figure 3: Profit curve for the oligopolistic producers of green electricity in the interactive market power, illustrating an equilibrium GC-price at the upper price bound.

Concluding remarks

- Market power makes the GC system collapse, given that we consider interactive electricity and GC markets.
- Market power may also affect produced quantities in unexpected ways.
- The results are valid also if assuming market power among only one of the generation technologies.
- The problems revealed in this paper clearly call for caution in the design and implementation of GC systems.
- Experiences from Sweden:
  - GC system established 1 May 2003
  - GCs frequently traded at the upper price bound

The model (cont.)

- Variables
  - p(x): consumer price of electricity
  - x: consumption of electricity
  - q: wholesale price of electricity
  - s: certificate price
  - α: percentage requirement
  - y: quantity of black electricity
  - z: quantity of green electricity
  - c'(y): marginal cost of black electricity
  - h'(z): marginal cost of green electricity

Results (interactive markets)

- Example: the producer of black electricity:
  - The black producer knows the electricity demand function and determines electricity price by the supply of black electricity taking the supply of green electricity as given (Cournot assumption)
  - Furthermore, the black producer knows the demand function for GCs and determines GC price by the supply of black electricity taking the supply of GCs as given (Cournot assumption).
  - Observe that the GC demand is a derived demand in a fixed proportion to electricity demand (i.e. not a separate demand function) The GC demand is a function of *p* not of *s* separately

Results (interactive markets)

- As noted, the first order condition for the black producer is:

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

- i.e. the black producer equates marginal cost to marginal revenue in the wholesale market
- Observe, however, that the marginal revenue function is discontinuous at the GC price bounds, i.e. $\frac{\partial s}{\partial y}$ is not defined.

Results (interactive markets)

- For this reason the black producer will always drive an intermediate GC- price to its lower or upper bound by a marginal reduction or increase of his production and thereby increase profit.
- Correspondingly, the producers of green electricity may use their market power to reduce or increase their generation of electricity marginally and thus create an excess or deficit demand for GCs. This leads to a jump of the GC price to its upper or lower bound.