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GREEN CERTIFICATES AND MARKET POWER ON THE NORDIC POWER MARKET

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Green Certificates and Market Power on the Nordic Power Market

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Abstract:
The purpose of this study is to elucidate under which circumstances, how, and to what extent market power on the TGC market can be used to affect the entire electricity market. There are basically two reasons for being concerned with market power in TGC markets. One is that a small number of companies may have exclusive access to first rate sites for wind power generation. The other is that withdrawal of a small number of TGCs implies a multiple reduction of electricity consumption, with corresponding increases of end user prices. For the purpose of investigating the principles by which market power may be exercised in this setting a simple analytical model is designed and analytical results are derived. To investigate matters further a numerical model, based on the analytical model, is constructed for the Nordic countries. Among the Nordic countries only Sweden has a TGC market but there is a common Nordic electricity market with free trade of electricity. The analysis shows that Swedish companies possessing capacity for green electricity generation, indeed, have the ability to exercise market power on the common Nordic power market by withholding TGCs. However, the analysis reveals that an opening of TGC trade between the the Nordic countries to a large extent achieves the objective of eliminating the use of market power that would otherwise be established. Also, this may have a cushioning effect on the volatility of TGC prices.

JEL classifications: C7; Q28; Q42; Q48
Key words: Renewable energy, electricity, green certificates, market power, Nordic power market.

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1. Introduction[3]

In Sweden a market for Tradable Green Certificates (TGCs) was introduced in 2003. The purpose was to stimulate investments in electricity generation based on renewable energy sources without using direct governmental subsidies to renewable energy. More precisely the aim is to create a market where different types of renewable electricity can compete on equal terms, thus relieving governments and public agencies from being directly involved in power industry investment decisions.

Like any other market a TGC market consists of sellers and buyers. The sellers are the generators of "green" electricity[4]. The generators obtain an amount of TGCs corresponding to the amount of green electricity they feed into the network i.e. one MWh of green electricity generated gives rise to one TGC. The sellers thus get revenues both from selling the electricity on the electricity wholesale market and from immediately selling the TGCs received from the issuing body on the TGC market. However, they may also decide to sell the certificates at a later date, or even not at all.

The buyers of TGCs are the consumers and retailing companies that are required to acquire certificates corresponding to a certain percentage of the total consumption of electricity ("the percentage requirement"). In other words the demand for TGCs is directly derived from the demand for electricity. A market clearing price of TGCs is determined by the interplay of supply and demand.

An important aspect of a TGC system is that the percentage requirement creates a direct link between the electricity market and the TGC market. What happens in the electricity market has a direct impact on the TGC market and vice versa. Moreover, as the demand for electricity tends to be inelastic, the derived demand for TGCs is even more inelastic. Several studies have focused on various implications of the direct link between the two markets[5].

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[4] By "green" electricity is meant electricity produced by means of wind-, sun-, wave- and geothermal energy as well as by biomass and peat and (new) small hydropower plants.

[5] Amundsen and Mortensen (2001), as well as Amundsen and Nese (2004) show that an increase of the percentage requirement does not necessarily lead to an increase of the generation of green electricity

It seems to us that many of the problems discussed in these studies were not well understood when TGC markets were designed and introduced. Another issue that also seems to have been overlooked is the risk for and impact of market power in the TGC market.

The purpose of this study is to elucidate under which circumstances, how, and to what extent market power in the TGC market can be used to affect the entire electricity market. There are basically two reasons for being concerned with market power in TGC markets.

The first is the fact that the industry average cost curve for green electricity tends to be upward sloping. This is because the cost of wind power, one important source of green electricity, depends on the wind conditions at the site of the plant, and that different sites differ significantly in this respect. The situation is similar for environmentally friendly hydro power, and, to some extent, for other types of green electricity. In the short and medium term the location of suitable sites in relation to the existing power grid implies that investments in green electricity generation, to a varying extent, should include investments in transmission capacity connecting the power plant to the existing grid. In the case of biomass and peat other kinds of transportation infrastructure investments may be needed.

Thus, given the state of technology and the upward sloping cost curve, there is a limit on the amount of green electricity that can be produced within a country. This means that some generators, by getting access to the suitable sites, will become dominating producers of green electricity and thus may be able to exercise market power in the TGC market. Currently the number of "green electricity" producers in Sweden is very large, but 96 percent of them produce less than 50 GWh per annum (18 percent of the total production of green electricity). On the other hand the three major power com-

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and that harsher CO2 constraints (tax or permits) will definitely lead to less green electricity with this TGC system. (See also Bye (2003) and Fischer (2009) on the effects on electricity prices with a TGC system). Amundsen, Baldursson and Mortensen (2004) analysed the volatility of TGC price stemming from the annual variations of wind power. Several specific features of multi-country TGC markets have been studied by Finon and Menanteau (2003), Bergman and Radetzki (2003), Nese (2003) and Unger and Ahlgren (2003), Butler and Neuhoff (2004), Amundsen and Nese (2009), panies produce around 25 percent of all green electricity, and on the basis of current investment plans this share is likely to increase significantly in the near future.

The second reason for being concerned with market power in a TGC market is that, as a result of the percentage requirement, the withdrawal of a given number of TGCs from the market forces a much larger reduction of electricity consumption (e.g. if the percentage requirement is 10 the withdrawal of one certificate will induce a reduction of 10 MWh of consumption). Thus, relatively modest exercise of market power in the TGC market may have a significant impact on the price of electricity and the allocation of resources in the power industry. Moreover, by having access to a large share of the best sites for generation of green electricity a "small" power producer may be able to exercise market power in the electricity market by exercising market power in the TGC market.

In order to elucidate the interplay between the electricity and TGC markets a simple analytical model is presented. Then a numerical version of the model, depicting the Nordic electricity market and the Norwegian-Swedish market for TGCs is used to quantify the impact of TGC market power under various assumptions about the distribution of the essential resources for green electricity production.

2. An analytical model

The following model is designed to capture the interplay between the electricity and TGC markets. The following variables will be applied

p : End-use price of electricity

s : TGC price

q : Wholesale price of electricity

x : Quantity of total electricity

y : Quantity of "black" electricity

z : Quantity of "green" electricity

w : Number of TGCs sold

v : Number of TGCs used

α : Percentage requirement

The inverse demand function for electricity is assumed given by

$$p(x)\text{, with } \frac{\partial p}{\partial x} = p'(x) < 0$$

The cost function for black electricity for a given producer, i (i = 1,…,n) is assumed given by

$$c_i = c_i(y_i)\text{, with } c_i'(y_i) > 0$$

and

$$c_i''(y_i) \geq 0$$

The cost function for green electricity is assumed given by

$$h_i(z_i)\text{, with } h_i'(z_i) > 0$$

and

$$h_i''(z_i) > 0$$

Both black and green electricity are delivered to a common wholesale market, from where profit maximizing retailing companies purchase electricity for end-use deliveries. In addition to the wholesale market there is also a market for TGCs.

We consider two cases with respect to the functioning of the electricity and TGC markets. In the first we assume that the electricity market is an oligopoly market where agents behave in accordance with the Cournot model, while there is perfect competition on the TGC market. In the second case both markets are oligopolistic, and Cournot behavior is assumed.

In the first case we assume that the producers take the TGC price as given and maximize profits as a Cournot player on the electricity market. Clearly, the implication of this is that the producers will sell all TGCs generated. Hence, the objective function may be formulated as in the competitive case

$$\Pi_i(y_i + z_i) = qy_i + [q+s]z_i - c_i(y_i) - h_i(z_i)$$

The first order conditions read

$$\frac{\partial \Pi_i}{\partial y_i} = \frac{\partial p(x)}{\partial x} x_i + q - c_i'(y_i) = 0$$

$$\frac{\partial \Pi_i}{\partial z_i} = \frac{\partial p(x)}{\partial x} x_i + q + s - h_i'(z_i) = 0$$

In deriving these conditions, observe that

$\frac{\partial q}{\partial y_i} = \frac{\partial q}{\partial z_i} = \frac{\partial q}{\partial x} = \frac{\partial (p - \alpha s)}{\partial x} = \frac{\partial p}{\partial x}$, as s is considered as given by the agents

Equilibrium conditions are

$$p^* = q^* + \alpha s^*$$

$$x^* = y^* + z^* = \frac{z^*}{\alpha}, \text{ where } x^* = \sum_i x_i^*, \; y^* = \sum_i y_i^*, z^* = \sum_i z_i^*$$

$$\frac{\partial p(x)}{\partial x} x_i^* + q^* = c_i'(y_i^*), \forall i$$

$$\frac{\partial p(x)}{\partial x} x_i^* + q^* + s^* = h_i'(z_i^*), \forall i$$

A more compact way of characterizing the competitive solution may be obtained by successive substitution of the above conditions i.e.

$$p(x^*) + \frac{\partial p}{\partial x} x_i^* = (1-\alpha)c_i'(y_i^*) + \alpha h_i'(z_i^*), \forall i$$

This condition states that the producer's marginal revenue is equal to a linear combination of the individual producer's marginal cost of providing black and green electricity, with the percentage requirement as the combination weight. Moreover, by solving this equation the price of electricity, *p*, can be expressed as a function of *y* and *z*. In other words, by choosing the level of output of black and green electricity a generator can influence the market price of electricity.

We then turn to the second case and consider an electricity producer that behaves as a Cournot player in both markets. In the formulation to follow, however, we assume that the electricity producer does not game on the simultaneous functioning of the two markets[6]. Rather we assume that the producer in determining the generation of green and black electricity only considers the electricity market and thus takes the TGC price as given.

Likewise, we assume that the producer in determining the amount of TGCs to sell, w_i only takes the TGC market into account and thus takes the wholesale price as given. This formulation may be considered as a standard Cournot formulation with multiple markets. It is however, necessary to take into account that the producer is constrained by the amount of TGCs generated, i.e. we must have

$$w_i \le z_i$$

The electricity producer, thus, faces the following optimization problem

$$\begin{aligned} &\text{Max } \Pi_i(y_i, z_i, w_i) = q[y_i + z_i] + sw_i - c(y_i) - h(z_i), \\ &\quad \text{s.t.} \quad w_i \le z_i \end{aligned}$$

To solve this problem, formulate the Lagrangian function

$$L_i(y_i, z_i, w_i) = q[y_i + z_i] + sw_i - c(y_i) - h(z_i) - \lambda_i[w_i - z_i]$$

The first order conditions are

$$\frac{\partial L_i}{\partial y_i} = \frac{\partial p(x)}{\partial x} x_i + q - c_i'(y_i) = 0$$

[6] For a discussion of this problem, see Amundsen and Nese (2004). For market power of interconnected markets (e.g. emission permit markets and energy markets) see Montero (2009). Furthermore, Traber and Kemfert (2009) analyze the impacts of the German Feed-in tariffs on both electricity prices, emissions and firms while taking account of market power and oligopolistic behaviour.

$$\frac{\partial L_i}{\partial z_i} = \frac{\partial p(x)}{\partial x} x_i + q + \lambda_i - h_i'(z_i) = 0$$

$$\frac{\partial L_i}{\partial w_i} = \frac{1}{\alpha}\frac{\partial p(x)}{\partial x} w_i + s - \lambda_i = 0$$

In deriving these conditions observe that

$$\frac{\partial s}{\partial w_i} = \frac{\partial(\frac{p-q}{\alpha})}{\partial w_i} = \frac{1}{\alpha}\frac{\partial p(x)}{\partial x},$$

as q, by assumption, is considered as given by the agents as they sell TGCs.

Eliminating $\lambda_i *$ the equilibrium conditions may be expressed as[7]

$$p^* = q^* + \alpha s^*$$
$$x^* = y^* + z^* = \frac{z^*}{\alpha}$$
$$\frac{\partial p(x^*)}{\partial x} x_i^* + q^* = c_i'(y_i^*),\ \forall i$$
$$\frac{\partial p(x^*)}{\partial x}[x_i^* + \frac{w_i^*}{\alpha}]^* + q^* + s^* = h_i'(z_i^*),\ \forall i$$

Upon successive substitution of the above conditions, the following compact relationship appears

$$p(x^*) + \frac{\partial p(x^*)}{\partial x}[x_i^* + w_i^*] = (1-\alpha)c_i'(y_i^*) + \alpha h_i'(z_i^*),\ \forall i$$

This condition states that the producer's marginal revenue from the electricity and the TGC markets is equal to a linear combination of the individual producer's marginal

[7] Observe that condition 15) assumes an interior solution for the TGC price. The reason for this is that the change of the TGC price following from a change in the sale of TGCs is equal to zero if the TGC price is at any price bounds. In such a case there would be no difference between optimality conditions of the present market setting and the market setting considered above (i.e. market power in the electricity market only).

cost of providing black and green electricity, with the percentage requirement as the combination weight. By solving the equation above the price of electricity can be expressed as a function of *y, z* and *w*. In other words, a generator affects the price of electricity not only by his output decisions, but also by selling or not selling the TGCs he has received.

3. A two- country model

Next we consider two countries, A and B, (such as Norway and Sweden) that trade both electricity and green certificates with each other. In this setting policy measures taken in one country may effect the decisions made in the other country.

Under autarky each country will have to satisfy the same general set of equilibrium conditions as discussed above. Prices and quantities will, however, be specific to each country as determined by the demand function, the cost functions and the policy measure applied (percentage requirement).

Opening for trade in electricity while still keeping separate TGC markets, the electricity wholesale price will become the same in both countries. Thus it holds that $q_A{*} = q_B{*} = q{*}$. Considering the most general case of Cournot behavior in both markets the following conditions apply:

$$p_j{*} = q{*} + \alpha_j s_j{*},\ j = A, B$$

$$x_A{*} + x_B{*} = y_A{*} + z_A{*} + y_B{*} + z_B{*}$$

$$x_j{*} = y_j{*} + z_j{*},\ j = A, B$$

$$\frac{\partial p(x^*)}{\partial x} x_{ij}{*} + q^* = c_{ij}'(y_{ij}^*),\ \forall i, j,\ \ j = A, B$$

$$\frac{\partial p(x^*)}{\partial x}[x_{ij}{*} + \frac{w_{ij}{*}}{\alpha_j}] + q{*} + s_j{*} = h_{ij}'(z_{ij}{*}),\ \forall i, j\ \ j = A, B$$

Observe that the common wholesale market implies that the derivatives of end-user prices will be the same for both countries even though end user prices may be different. This follows from the fact that

$$q^* = p_A(x_A^*) - \alpha_A s_A^* = p_B(x_B^*) - \alpha_B s_B^*$$

and the assumption that the TGC price is considered as given when operating in the electricity market.

Opening for trade in certificates, the TGC prices will be equated and become the same for both countries. Thus, it holds that $s_A^* = s_B^* = s^*$ at a level intermediate to the initial TGC prices of the two countries.

In this setting there is a need for an additional variable and an additional equation (stating that total certificates applied must be equal to total certificates sold) to describe the equilibrium solution. Hence, we describe the number of certificates used in country j by v_j. Net import of certificates for country j is then equal to $v_j - w_j$. The set of equilibrium conditions now reads

$$\mathrm{p}_j^* = \mathrm{q}^* + \alpha_j \mathrm{s}^*,\ \mathrm{j} = \mathrm{A}, \mathrm{B}$$

$$x_A^* + x_B^* = y_A^* + z_A^* + y_B^* + z_B^*$$

$$\mathrm{x}_j^* = \mathrm{y}_j^* + \mathrm{v}_j^*,\ \mathrm{j} = \mathrm{A}, \mathrm{B}$$

$$v_A^* + v_B^* = w_A^* + w_B^*$$

$$\frac{\partial p(x^*)}{\partial x} x_{ij}^* + q^* = c_{ij}'(y_{ij}^*),\ \forall i, j,\ \ j = A, B$$

$$\frac{\partial \mathrm{p}(\mathrm{x}^*)}{\partial \mathrm{x}}[\mathrm{x}_{ij}^* + \frac{\mathrm{w}_{ij}^*}{\alpha_j}] + \mathrm{q}^* + \mathrm{s}^* = \mathrm{h}_{ij}'(\mathrm{z}_{ij}^*),\ \forall \mathrm{i}, \mathrm{j},\ \ j = A, B$$

A special case applies if only one of the two countries has a TGC system and generators in the other country are allowed to participate in that system. For instance, Norwegian generators of green electricity could receive Swedish TGCs and be allowed to participate in the Swedish market for TGCs.

4. A numerical model

In order to shed some light on the real world situation a numerical model with the same basic structure as the analytical model has been used. The model is an updated version of the static model of the Nordic electricity market, i.e. the integrated electricity market of Denmark, Finland, Norway and Sweden, initially used in Bergman and Radetzki (2003).

The basic features and assumptions of the numerical model are as follow:

- In each country there are 3-5 major electricity generation firms, acting as Cournot players, and a number of small generation firms forming a competitive fringe. There is no entry of new firms, but the incumbent firms may invest in new capacity.
- Marginal cost curves are step-wise increasing and linear, reflecting unit costs and capacity limits for various technologies.[8]
- Green electricity encompasses electricity generated by wind, water and biomass. However, only electricity generation in new small hydropower plants are considered green, whereas electricity generation in existing hydropower plants are considered black[9] just as electricity generated in nuclear-, gas-, coal-, and oil power plants.
- Free-trade in electricity between the four Nordic countries, but inter-connector capacity limits may lead to different wholesale prices in the various countries
- Two alternative trade regimes for the TGC market: Autarky or free trade between the four Nordic countries
- Two alternative assumptions about the behavior of the major firms in the TGC market: Price taking (perfect competition) or Cournot behavior. The fringe firms always behave as price takers both in the electricity and the TGC market.
- Constant elastic demand curves in each country (price elasticity: -0,3)

Using 2001 as its base year the model projects annual equilibrium prices and quantities in, and cross border tariffs between, the electricity markets in Denmark, Finland,

[8] The cost of production in an electricity generation unit is equal to the variable cost in existing units and the sum of the variable cost and the annualized capital cost in a new unit.
[9] For Norway black electricity generation is almost exclusively taking place in water power plants whereas black electricity generation in Sweden also includes electricity from nuclear-, gas- and coal power plants.

Norway and Sweden. It also projects equilibrium prices and trade in the markets for TGCs in Norway and Sweden.

In the model it is assumed that the rights to exploit the most favorable sites for wind power production has been acquired by the major power generators. Thus a “fringe” power producer who wants to enter the market for green electricity only has access to more costly wind power sites, i.e. sites where wind conditions and/or the cost of connecting to the grid is higher than for the sites available for the major generators.

In the following we will use the numerical model to analyze to what extent a requirement to have a certain percentage of green electricity in Sweden affects the Nordic electricity market. We consider both autarky and free trade of TGCs. Moreover we analyze to what extent that market power in the TGC market affects the electricity market. The case of no TGC market is considered as a benchmark. The focus is on the year 2010. As the effects of the Swedish TGC system are similar in the three other Nordic countries we only present the results for Norway (being a significantly larger national electricity market than Denmark and Finland together).

5. Simulation results

Using the numerical model we have considered three alternative cases, or projections, for 2010, and compared the outcome for prices and quantities with the corresponding data for the benchmark case (denoted Base 2010). Note that the Base case is also a projection, and that “electricity consumption” includes transmission and distribution losses. In the tables prices are expressed in € per MWh. The different cases are defined in the following way:

<u>Base 2010</u>

In this case there is free trade in electricity between the Nordic countries, i.e. Denmark, Finland, Norway and Sweden. There is no TGC system in Sweden or in any other Nordic country.

Case 1

Again free trade in electricity between the Nordic countries is assumed, but now a TGC system with the percentage requirement equal to 12.7[10] is introduced in Sweden. Perfect competition in the Swedish TGC market is assumed, but there is no cross-border trade in TGCs.

Case 2

This case is like Case 1, except that the major generators act as Cournot players in the market for TGCs

Case 3

This case is like Case 2, except that generators in Denmark, Finland and Norway are allowed to participate in the Swedish TGC system, and to trade TGCs across the Nordic borders.

We present the simulation results by pair-wise comparisons of the four alternatives. In order to analyze the impact of a TGC system on the electricity market we compare Base 2010 and Case 1. Note that in Case 1 the Swedish TGC market is assumed to be perfectly competitive, i.e. no generator can, or decides to, exercise market power on the TGC market. Also note that producer prices are equal to producer prices in Norway. The key results are summarized in Table 1 below.

Table 1. Base 2010 vs. Case 1

	Base 2010	Case 1
Electricity consumption in Norway, TWh	128.2	131.4
Electricity consumption in Sweden, TWh	165.9	163.0
Producer price of electricity in Sweden, €/MWh	26.5	24.4

[10] The official percentage requirement for 2010 is 17.9 percent. However, as electricity intensive industries are exempt from the requirement to use a certain fraction of “green” electricity the average percentage requirement on all electricity consumption is 12.7.

Producer price of electricity in Norway, €/MWh	26.6	24.4
Price of TGCs, €/MWh	-	29.0
Consumer price in Sweden, €/MWh	26.6	28.1

As can be seen in the table the introduction of a TGC system leads to a reduction of the producer prices of electricity, i.e. the system and area prices determined at the common Nordic power exchange Nord Pool. The reason for this is that the TGC system induces additional investments in generation capacity. As a result the supply of electricity increases, and the equilibrium producer price falls.

The consumer price of electricity in Sweden, however, increases as a result of the percentage requirement and the positive price of TGCs. Thus electricity consumption increases in Norway (where producer and consumer prices are the same in the model) and decreases in Sweden.

The price of TGCs in Case 1 is somewhat lower than the actual TGC prices observed 2008-2009, which varied within the range 30-35 €/MWh. For the period 2004-2006, when the percentage requirement was lower, the prices projected by the model were very close to the observed prices. The somewhat higher prices in 2008 and 2009 could be a result of market power being exercised, but it could also reflect relevant costs not fully taken into account by the model.

Next we analyze the potential impact of market power on the Swedish market for TGCs, i.e. we compare Case 1 and Case 2. The results are summarized in Table 2. As can be seen in the table there is considerable potential market power on the TGC market. If this market power is fully exercised the equilibrium prices of TGCs would be several times higher than the prices hitherto observed.

Moreover, the impact on the electricity market would be significant, reducing electricity consumption in Sweden by around 15 percent. The numbers may seem unrealistic, but they clearly indicate that the percentage requirement, which is the core feature of a TGC system, opens up a new possibility to exercise market power in the electricity market.

Table 2. Case 1 vs. Case 2

	Case 1	Case 2
Electricity consumption in Norway, TWh	131.4	132.5
Electricity consumption in Sweden, TWh	163.0	140.7
Producer price of electricity in Sweden, €/MWh	24.4	23.8
Producer price of electricity in Norway, €/MWh	24.4	23.8
Price of TGCs, €/MWh	29.0	174.7
Consumer price in Sweden, €/MWh	28.1	46.0

One reason for the significant potential market power created by the TGC system is that the TGC market is a quite small national market with a small number of relatively large players. Consequently it is an oligopolistic market in which each player has significant market power. One way of dealing with that problem is to enlarge the market and open up for international trade in TGCs. Case 3, where generators in the other Nordic countries are allowed to participate in the Swedish TGC market, represents one possibility along these lines.

Case 3 implies that, from a Swedish policy perspective, green electricity generated in Denmark, Finland and Norway is seen as a perfect substitute for green electricity generated in Sweden. Consequently TGCs are allocated to generators in the other Nordic countries on the basis of the same principles as TGCs are allocated to Swedish generators. Moreover, all generators in the Nordic countries can sell their TGCs in the Swedish market for TGCs. Needless to say the Case 3 “model” has not been seriously considered by policy makers in the Nordic countries. However, it illustrates a serious drawback of the current Swedish TGC market. The simulation results are summarized in Table 3, where the results for Case 1 also are included.

Table 3. Case 2 vs. Case 3

	Case 2	Case 3	Case 1
Electricity consumption in Norway, TWh	132.5	132.8	131.4
Electricity consumption in Sweden, TWh	140.7	162.6	163.0
Producer price of electricity in Sweden, €/MWh	23.8	23.6	24.4
Producer price of electricity in Norway, €/MWh	23.8	23.6	24.4
Price of TGCs, €/MWh	174.7	37.8	29.0
Consumer price in Sweden, €/MWh	46.0	28.4	28.1

As can be seen in the table the addition of new participants on the Swedish TGC market increases competition and significantly reduces the possibilities to exercise market power. In fact, opening up for cross-border trade with TGCs (Case 3) essentially has the same effect on the electricity market as perfect competition in a national Swedish market for TGCs (Case 1).

6. Concluding remarks

In connection with the restructuring of the electricity markets in the Nordic countries market power was seen as a major potential problem. The reason was that each one of the national (in Denmark two disconnected regional markets) was dominated by one major power company. However, by integrating the national markets this problem was significantly mitigated. Our results indicate that market power is a potential problem in the Swedish market for TGCs, but again the solution seems to be market integration. That is, to open up the Swedish market for green power producers in the other

Nordic countries. The argument for doing this becomes even stronger if a TGC system is introduced in the other Nordic countries.

In concluding this paper it should be noted that the success of introducing TGC markets not only depends on the ability to mitigate market power but also on other factors. One potential problem is the volatility, both short term and on an annual basis, of TGC prices resulting from natural variations in wind conditions (see Amundsen, Baldursson and Mortensen (2006)). In Denmark, for instance, the supply of wind power may vary by 25 percent (compared with the annual average) between windy and calm years.

As the marginal cost of wind power generation is close to zero for existing capacities competitive wind power generators will at all times produce what is feasible and thus generate erratic and price inelastic supply. Hence, the number of TGCs issued and available for sale will also be highly volatile and this will lead to a considerable uncertainty with respect to the remuneration (i.e. the sum of the TGC price and the wholesale price) of investment in green technologies. This in its turn may also influence the required rate of return for investors in renewable electricity i.e. the required rate of return would be higher as compared with what would be necessary if subsidies were stable and certain.

However, an integration of the Swedish TGC market with other Nordic TGC markets would be a solution, or at least a remedy, to this problem. This is because wind variations in various parts of the Nordic area probably are not closely correlated. Hence, an extension of the TGC market would stabilize TGC prices.

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