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Summary

Nowadays, a process can be observed in Germany where electricity producing and trading firms react to the electricity market liberalisation by merging market shares, since the year 2000, which reduces the number of suppliers and influences production and consumer prices. This paper discusses whether the liberalisation process will have positive or negative impacts on the environmental situation and whether this process together with a phase out of nuclear power can guarantee the intended improvement of environmental conditions without governmental regulation in Germany. This is done by modelling different strategic options of energy suppliers and their impacts on the economic and environmental situation in the liberalised German electricity market by a computational game theoretic model. Calculations with this model show that when German firms act strategically (e.g. a change in action of one firm affects the electricity price and, hence, the payoffs of other firms), the environment is better off at the cost of higher electricity prices. This result is robust to perturbations as shows by performing a sensitivity analysis.

Keywords: Electricity market liberalisation, game theoretic model, environmental effectiveness

JEL: C7, D2, Q4, R3

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1. Introduction

The liberalisation process of the European electricity market initiated in 1996 leads to fundamental and extensive changes within the energy sector. Previous natural monopolies face national and international competition, which is expected to induce a permanent improvement of production, distribution and marketing activities. Presently, expansive price competition can be observed as a result of the changing market situation.

The liberalisation of the German electricity market opened new opportunities for households and industry to choose their energy supplier. By implementing the EU Directive 96/92/EC on the internal market of electricity in December 1998, territorial monopolies were cancelled in German electricity production, resulting in a new structure of energy supply. Internal and external competition in production and transmission, forces energy suppliers towards new production behaviour. In order to provide a sufficient and long-term cost-effective energy supply by the previous “natural monopolies”, a guideline was implemented for an undistorted competition in the German electricity market.

Yet, competition is not guaranteed. While the old situation was characterised by regulated, often state-owned monopolies, the current situation is that the electricity market is dominated by a small number of privatised giants. A first question this paper seeks to answer is whether consumers are better off in the new situation, or whether the electricity companies are able to reap substantial oligopoly rents. A second, related question is how far the oligopoly is removed from perfect competition. A third question relates to the environmental implications of the electricity market liberalisation.

Experiences in England and Scandinavia demonstrated several structural and economic development changes, inducing employment reactions and industrial and private energy price variations. In light of opportunities created by the planned opening of the European electricity market, firms tend to act strategically like global market players, by merging market shares and joining gains. Day and Bunn (1999) investigated these aspects by a game theoretic model of market power and strategic actions of firms in the UK. Bower and Bunn (1999) assess trade opportunities within a pool versus a bilateral trade system in the electricity market of the UK. Admundsen and Bergman (2002) studied these issues for the Norwegian and Swedish power market. Here, transmission and transport pricing plays a crucial role. Experiences in Scandinavia and England suggest that a uniform tariff is preferred over distance charges. Moreover, market opportunities and grid owners significantly influence trade. Dawson and Shuttleworth (1997) studied transmission pricing in Norway and Sweden. Green (1997) examined this effect for the UK. Cardell *et al* (1994) investigated the negative effects of market power and transmission constraints on trading by an imperfect competition model for North American electricity suppliers.

Different non-cooperative games within various markets have been examined by diverse authors. Murphy, Sherali *et al.* (1986) demonstrate mathematical programming approaches in order to determine oligopolistic market equilibria. Salant and Shaffer (1999) illustrate the theoretical impacts on production and social welfare by two stage Cournot-Nash equilibrium solutions by including investments due to learning by doing and R&D determining marginal costs of identical agents differently. For Europe, Jing- Yuan and Smeers (1999) modelled an oligopolistic electricity market within a Nash equilibrium by

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a sophisticated game theoretic model. More generally, Helman et al. (1999) investigated different kind of trade options and strategic price setting within the electricity market. Stern (1998) investigates the liberalisation of the European gas market.

In a liberalised electricity market, electricity suppliers can act strategically, which influences electricity prices, due to changing market shares. Furthermore, it can become attractive to merge with other firms, as it increases the electricity price. While enhancing competition in the electricity market, strategic behaviour (e.g. a change in action of one firm affects the electricity price and, hence, the payoffs of other firms) determines the structure of the market and energy supply network (see also Kemfert (1999) and Kemfert and Tol (2000)).

In this paper, strategic behaviour of energy suppliers and their impacts on the economic and environmental situation in the liberalised German electricity market is studied with the game theoretic modelling tool EMELIE (Electricity Market Liberalisation In Europe). EMELIE is calibrated in Section 5 to the main German energy suppliers, which are linked by capital flows. These firms produce electricity by different technologies, considering others' and their own capacities, operational and marginal costs (including sunk costs). Within this context, the analysis focuses on the impacts of strategic action by firms, which is compared with the case without strategic action where firms are fully competitive. We investigate the electricity prices and the environmental effectiveness of applied technologies.

The outline of this paper is as follows. Section 2 describes Germany's electricity market structure. Section 3 introduces the computational game theoretic model EMELIE, while Section 4 formalises this. EMELIE is calibrated to the German liberalised electricity market in Section 5. Section 6 presents the main model results and a sensitivity analysis on crucial model assumptions. The final section concludes.

2. Germany's electricity market structure

In a liberalised electricity market, strategic behaviour may determine the market structure of energy suppliers and the composition of technologies employed. Energy suppliers can choose among various strategies, e.g. optimise their production, maximising their market shares, increasing electricity prices, and lowering demand or consumption surplus.¹ New energy products, such as energy services, and new market actors, such as electricity brokers through exchange firms are to be established in a liberalised market.

In order to achieve product differentiation and to obtain a competitive advantage, "brand" electricity has been designed, which is a recent trend in the German electricity market. One example is the nation-wide marketing of "green" electricity generated by hydroelectric power plants by BAYERNWERK and RWE (see Table 1 for an overview of 30 German utilities), which has already been feeding the national grid to the same extent as before liberalisation. Due to the liberalisation of the electricity market, the cus-

¹ See Wietschel *et al* (2001). A discussion of recent developments of the German electricity market is given by Pfaffenberger and Haupt (2001)

customer's growing environmental awareness becomes an attractive target for the energy suppliers' marketing activities. In spite of this growing environmental awareness, the share of electricity generated from renewables is only marginal compared to the overall power generation. In 1998, the share of renewable energy in the total electricity production was only 5.2 % (25.3 TWh), of which 68.3 % (17.3 TWh) was produced by hydroelectric power.

The low share of renewable energy including high production and consumer prices indicates that the consumer does not use this as an important parameter in choosing an energy supplier. Their choice, so far, is fairly independent of the kind of technology that is used for electricity generation. Fossil fuels like hard coal (27 %), lignite (25 %), and gas (9 %) represent with approximately 60 % the largest share of Germany's fuel mix. The resulting CO₂ emissions do not play any role in the customer's choice (despite the ecological tax reform), as they do not directly find their way into the electricity price. Nuclear power generation represents with approximately 30 % the largest single production share, which has a positive effect on the overall CO₂ balance of electricity generation, but this has to be faced out due to other environmental objections.

Advertisement of the main utilities has been changed, because consumers are not very flexible in changing utilities, the main electricity supplier decided to enlarge the supply by further product differentiation. However, since 2001 they have already reduced these initiatives. The recent developments of the German electricity market are summarised in Strombasiswissen (2002).

After the electricity market liberalisation in 1998-2000, the capital shares and ownerships have been changed. First all firms per previous supply region merged into one. Second, BAYERNWERK and PREUSSENELEKTRA are acquired by E.ON, the Eastern part Germany including Hamburg by VATTENFALL, RWE acquired VEW, while EnBW did not change owner. Due to these changes, the operating costs of the old firms probably did not change so much, but the capital shares did.

The first result of the liberalised power market is a decrease of the energy price, as an outcome of fierce price competition for increasing market shares by binding clients. Here, the electricity prices are mainly determined by strategic behaviour of energy suppliers, leading to firm mergers, production costs, capital intensities, the extent of overcapacities, and price elasticities of demand. These kind of issues are integrated in EMELIE (Electricity Market Liberalisation In Europe). Furthermore, the new renewable energy law (EEG) and the eco tax, lead to a substantial increase in the electricity price (Oschmann 2000). Because of vertical and horizontal production cooperation and mergers, market shares increase, which increases the electricity price in the long run. Within an oligopolistic electricity market, not only price competition plays an important role, but also additional services offered by energy suppliers for binding customers and gaining market shares.

A conjoint analysis by McKinsey (2001) shows that only 20 to 30 % of all customers are very price sensitive, i.e. they choose their demand only because of price differences. For all other customers, supply reliability, tradition and additional services are more essential, which explains that only 0.5 % of all customers changed their energy supplier (Drake *et al.*, 2000). But, the competition for customer loyalty and market shares has led to a drastic decline in the electricity price, because energy suppliers are trying to enhance

their established clientele and, hence, their market share through their price setting policies. EMELIE compares different reactions of the market, due to price variations.

Price competition in the electricity market forces a development of cheap technologies for electricity production and a reduction of overcapacities, due to the resulting price drop. Energy suppliers act as strategic planners, which leads to mergers by large firms, as the real firm coalitions of VEAG, BAYERNWERK, VEW, EBW and EdF (Energy de France is the main utility in France using nuclear energy) demonstrate. Market concentration would increase consumer prices. Actual market developments show that energy prices indeed increase, but this is also caused by the German eco tax, the renewable energy law and increasing world energy market prices. The electricity market prices determine to a large extent firm's profits and, therefore, the technologies used for electricity production by individual firms. Environmental efficient technologies are more likely to be used, as electricity prices increase, firm's market shares extend, the new renewable energy law (EEG) is implemented and an eco tax is introduced. For Germany, Prognos and EWI (Prognos 2000) predict a decrease of CO₂ emissions by 10.5 % within a time period from 1997 to 2020, caused by an increase of power generation by gas and renewable energy, in order to substitute more environmentally harmful coal and nuclear energy.

3. The Game theoretic Modelling approach

We investigate these market developments by a game theoretic model EMELIE (Electricity Market Liberalisation In Europe). EMELIE can be characterised as a computational model, with which strategic and oligopolistic market behaviour by firms within a liberalised market can be investigated. Each individual energy supplier acts as a market player and observes a quantity strategy within a non-cooperative oligopolistic game. EMELIE includes energy suppliers, producing electricity by different technologies, by considering power plants and their individual capacities, operational and marginal costs (including sunk costs) and their environmental responsiveness. Each player maximises her individual profit assuming that all other players apply a gain maximisation strategy. Profits follow from marginal production costs, variable production costs, maximum net power, net access costs and transport costs and price dependent demand. Electricity produced by one competitive player influences the sales and trade volumes of others producers. Each electricity producer considers oligopolistic interrelations, operating conjecturally in a Nash-equilibrium.

A Cournot-Nash game is characterised by mutual, strategic reactions by individual market players. This leads to a *Nash equilibrium* where all strategies of market actors are optimised as best responses to actions of all other market agents. That means, in an oligopoly, market shares can influence prices. Diverse energy suppliers (market players) are distinguished, corresponding to their previous monopoly territories, classified into a north and south component. In contrast to the oligopolistic market situation, in a fully competitive market, actors behave like price takers, equalising market prices to marginal production costs. Beside input parameter of electricity production, price elasticities of demand, transportation and net utilisation costs and transmission grid capacity are speci-

fied exogenously. EMELIE determines regional electricity prices, marginal electricity production costs, produced and traded electricity per technology per firm.

3.1 MCP Formulation

In solving optimality problems, it is important to recognise that each optimality problem can be defined and decoded as a complementarity problem reflecting all side constraints. Generally speaking, in the framework of a complementarity format, either a non-negative variable is zero or the corresponding inequality constraint is, in fact, an equality. Primarily, by solving a mixed complementarity problem (MCP), the Karush Kuhn Tucker optimality conditions are determined and solved for a decision variable. The MCP format and the Karush Kuhn Tucker conditions are equivalent. So, each MCP problem can be transformed into the classical optimality conditions by consideration of side constraints and vice versa. The idea behind the MCP formulation is to develop a program that permits the classical decomposition method to be obsolete, instead ascertaining the MCP conditions directly. The main advantages of MCP are (1) the simultaneous and parallel determination of decision variables and side constraints and (2) the solution of complex mathematical programmes without an explicit formulation of the objective function. Specially developed solvers detect the MCP format directly and point out, if necessary, whether side constraints are incorrectly defined. Present-day computer technology allows an uncomplicated and fast solution of the MCP problems by mathematical solving algorithms. GAMS provides, at this moment, MILES and PATH as major solvers.² Additionally, applying the MCP method avoids the intricacy of finding a solution by a standard NLP solver if the starting values are distant from the optimal values. Transforming an optimality problem into a MCP formulation requires a specification of the first order conditions and all upper and lower bounds of the decision variables.

The MCP format allows an uncomplicated characterisation of simultaneously solved decision variables (such as in game theory) and a fast solution procedure. GAMS provides this highly efficient formulation mainly in order to solve reciprocal modelling approaches appearing in, for example, game theoretic or applied general equilibrium models.³

4. The model

The computational game theoretic model EMELIE is characterised by following indices, parameters and variables:

² The PATH solver is described in Ferris and Sinaoiromsaran (1998), MILES in Rutherford (1993).

³ For a more complete overview of MCP problems and their application, see Ferris and Pang (1995).

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Indices:

- f - Firms $f \in F$
- r - Regions $r \in R$
- i - Technologies $i \in I$

Parameters:

- c_{r,r^*}^t - Transport cost (including taxes) from region r to region r^*
- c_i^v - Variable production costs for technology i
- d_r^0 - Reference demand for electricity in region r
- p_r^0 - Reference price for electricity in region r
- σ_r - Regional price elasticities of electricity demand
- η_{r,r^*} - Net capacity of transport between region r and region r^*
- $q_{i,f}^{\max}$ - Maximum production capacity with technology i in firm f

Variables :

- p_r - Demand price for electricity in region r
- c_f^m - Marginal and average costs of electricity production of firm f
- τ_{r,r^*} - Shadow price of electricity transport from region r to region r^*
- $\vartheta_{f,r}$ - Market share of firm f in region r
- $s_{f,r}$ - Supply of electricity by firm f to region r
- $q_{i,f}$ - Production of electricity by firm f with technology i

EMELIE is a partial equilibrium model of a liberalised electricity market with multiple actors and is inspired by the theory of industrial organisation (Fudenberg and Tirole, 1992; Tirole, 1988). On the supply side, electricity producing firms maximise their profits. On the regional electricity demand side consumers maximise utility. In equilibrium, prices p_r clear regional markets. Electricity is transported and traded from region $l(f)$ to region r and $l(f) \neq r$. Moreover, firm f is matched to a region by function $l(\cdot): F \rightarrow R$, hence: $\forall f \in F: l(f) \in R$.

Let us first consider the (most difficult) case with *strategic interaction* among firms at the supply side. In this case, electricity producing firms f maximise their net profits. They do this by choosing their strategies as represented by their regional supplies $s_{f,r}$ simultaneously by assuming that other firm do the same. This is equivalent to maximising the profit firm f can obtain by supplying to region r . This profit is the difference between income from supplied electricity minus the cost of production and delivery, where the dependence of the demand function $p_r(\cdot)$ on S constitutes “strategic action”.

$$\text{Maximise } \Pi_{f,r}(S) = p_r(S) \cdot s_{f,r} - c_f^m \cdot s_{f,r} - c_{l(f),r}^t \cdot s_{f,r} \quad (1)$$

where $S = \sum_{f \in F} \sum_{r \in R} s_{f,r}$

Delivery is restricted by a maximum allowable transport capacity (trade constraint) between the region $l(f)=r$ to delivery region r^* . Net exports of region r to region r^* with $r \neq r^*$ is established by taking the difference between the export from region r to region r^* and the import into region r^* from region r .

$$\forall r, r^* \in R, \text{ where } r \neq r^*$$

$$\sum_{\{f|l(f)=r\}} s_{f,r^*} - \sum_{\{g|l(g)=r^*\}} s_{g,r} \leq \eta_{r,r^*} \quad (\tau_{r,r^*}) \quad (2)$$

Note that the shadow price τ_{r,r^*} measures the utilisation of the electricity net between region r and region r^* . The value is zero if the transport constraint η_{r,r^*} is not binding; otherwise a loss is incurred by a foregone trade possibility, where shadow price $\tau_{r1,r2}$ indicates the value of this loss. Then it would make sense for the net owner to make investments for increasing the net capacity between region $r1$ and $r2$. The strict inequality holds when the shadow price $\tau_{r,r^*} = 0$, a result which is well-known from the Karush Kuhn Tucker conditions and is a typical characteristic of a mixed complementarity problem (MCP).

The first order conditions for optimality of strategically acting firms follow from the following Lagrangian:

$$L = p_r(S) \cdot s_{f,r} - c_f^m \cdot s_{f,r} - c_{l(f),r}^t \cdot s_{f,r} - \tau_{l(f),r} \left(\sum_{\{f|l(f)=r\}} s_{f,r^*} - \sum_{\{g|l(g)=r^*\}} s_{g,r} - \eta_{r,r^*} \right) \quad (3)$$

After taking the partial derivatives with respect to $s_{f,r}$ and after rearranging terms, we have:

$$\forall r \in R \text{ and } \forall f \in F$$

$$c_f^m + \tau_{l(f),r} + c_{l(f),r}^t = p_r \cdot \left(1 - \frac{\vartheta_{f,r}}{\sigma_r} \right), \quad (4)$$

$$\text{with } \tau_{l(f),r} = c_{l(f),r}^t = 0 \text{ if } l(f) = r$$

Where the individual market shares in (2) are conveniently determined by:

$$\forall r \in R \text{ and } \forall f \in F$$

$$\vartheta_{f,r} = \frac{s_{f,r}}{\sum_{g \in F} s_{g,r}} \quad (5)$$

Furthermore, for deriving Equation (4), we need a price dependent electricity demand in the case of strategic action by the electricity firms, which is calculated by:

$$\sigma_r = - \frac{dS}{dp_r} \cdot \frac{p_r(S)}{S} \quad (6)$$

Equation (4) is the classical “marginal cost equal to marginal income”. The marginal income in the case of strategic action is reduced by the factor “market share” divided by price elasticity of demand. The market share can also be interpreted as a “monopoly” mark-up.

The partial derivatives of L with respect to $\tau_{l(f),r}$ reproduces equation (2).

Power supply by firm f to region r can be generated with various technologies i , like nuclear, hard coal, brown coal, oil, gas and hydro. We assume here a 3% electricity transport loss.

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$$\forall f \in F$$

$$0.97 \times \sum_{i \in I} q_{i,f} = \sum_{r \in R} s_{f,r} \quad (7)$$

When we substitute (7) into (5), we obtain:

$$s_{f,r} = \vartheta_{f,r} \sum_{g \in F} s_{g,r} = \vartheta_{f,r} \times 0.97 \times \sum_{i \in I} q_{i,f} \quad (8)$$

This means that the supply by firm f to region r is equal to the total production within firm f multiplied with its market share in region r accounting for a loss of 3% in transport. In this way we have linked the actual decision variables in a firm ($\vartheta_{f,r}$ and $q_{i,f}$) to the model.

However, the market needs to be closed on the (consumer) demand side as well. This is achieved by setting up a regional consumer constant elasticity of return (CES) utility function, which consists of the consumer utility of supplied electricity minus the total price they have to pay:

$$\text{Maximise } U_r(s_r) = p_r^0 \cdot d_r^0 \frac{\sigma_r}{1 - \sigma_r} \left(\frac{s_r}{d_r^0} \right)^{\frac{\sigma_r - 1}{\sigma_r}} - p_r \cdot s_r \quad (9)$$

$$\text{where } s_r = \sum_{f \in F} s_{f,r}$$

The related first order conditions are derived directly by taking the partial derivative with respect to regional demand s_r , which leads to the well-known regional inverse demand function:

$$\forall r \in R$$

$$\sum_{f \in F} s_{f,r} = d_r^0 \left(\frac{p_r}{p_r^0} \right)^{-\sigma_r} \quad (10)$$

Model (2), (4), (5), (7) and (10) is completed by putting restrictions on the variables, as shown in equations (11–18). A lower bound of marginal costs is determined by

$$\forall i \in I \text{ and } \forall f \in F, \text{ where } i \text{ is an available technology at firm } f$$

$$c_i^v \leq c_f^m \quad (11)$$

The maximum net production of each individual technology i bounds production of electricity by firm f :

$$\forall i \in I \text{ and } \forall f \in F$$

$$q_{i,f} \leq q_{i,f}^{\max} \quad (12)$$

Non-negativity constraints result in:

$$p_r, \tau_{l(f),r}, \vartheta_{f,r}, s_{f,r}, q_{i,f} \geq 0 \quad (13-18)$$

while the non-negativity of c_f^m is already guaranteed by (11).

Model (2), (4), (5), (7) and (10–18) is used to calculate the *Nash equilibrium* in the case with strategic action, where market information is typically incomplete and we are dealing with the case of imperfect markets. This case shall be referred to as “STRA”.

A model with perfect markets is established by replacing equation (4) by:

$$\begin{aligned} &\forall r \in R \text{ and } \forall f \in F \\ &c_f^m + \tau_{l(f),r} + c_{l(f),r}^t = p_r \end{aligned} \quad (4')$$

with $\tau_{l(f),r} = c_{l(f),r}^t = 0$ if $l(f) = r$

Furthermore, equation (5) should be eliminated as well from the model, as in the case of equation (4'), market share $\vartheta_{f,r}$ is no longer a variable. Of course, the market shares now follow exogenously from the model. Model (2), (4'), (7) and (10–18) is used to calculate the *competitive equilibrium* in the case without strategic action. This case is derived by reducing the demand function to an identity: $p_r(\cdot) = p_r$. Here firms take market prices as given and we are dealing with the case of perfect markets. This case shall be referred to as “COMP”.

These model relations are written by the programming language GAMS, which decomposes the non-linear program as a mixed complementary problem (MCP). This is solved by the non-linear MCP-solving algorithm MILES, which is a mixed inequality and non-linear equation solver. Partially, MILES approximates linear sub-problems by Lemke's algorithm and solves the non-linear program by the generalised Newton algorithm iteratively with a backtracking line search. An optimal solution is found by maximising regional profit conditions reciprocally under all considered constraints.

Main outcomes are regional prices, interregional trade flows and the optimal market shares of each electricity producer from which the regional concentration of the industry can be calculated in terms of the Hirschmann-Herfindahl index (HHI). HHI is a measure for (regional) competitiveness (see also Tirole, 1988, pages 221–223):

$$HHI_r = \sum_{\{r^* | l(f)=r^*\}} (\vartheta_{f,r^*})^2 \quad (19)$$

For the industry as a whole the Hirschmann-Herfindahl index is calculated as follows:

$$HHI = \sum_{f \in F} \left(\frac{\sum_{r \in R} s_{f,r}}{\sum_{r \in R} \sum_{f \in F} s_{f,r}} \right)^2 \quad (20)$$

5. Calibration of EMELIE to the German market

In order to calibrate the model as formulated in the previous section to the case of Germany, we need a wide range of information about the structure of the electricity market, which we sum up below.

- An inventory is needed of power generating firms (f) plants and their geographical location (r), by dividing the country into regions. For that purpose, we have divided Germany into 8 regions (Figure 1) and we included 30 power generating firms into the model (Table 2). However, the model and the model results are based on the German electricity market development until 31-12-1999. In the year 2000, 8 firms remained, where the firms in bold in Table 1 acquired the other firms in the region. This probably did not change the operating costs of the old firms, but it did change the capital shares.
- An inventory is needed of the available technologies. Technology opportunities in Germany. We considered nuclear technology (NUC), hard coal (HC), brown coal (BC), water (HYDRO), gas (GAS) and oil (OIL).
- The (regional) price elasticity of electricity demand is needed (see Table 2).
- The network access and transport costs between region r and region r^* needs to be derived. This is calculated for the case of Germany with the following formula (see Table 2 for the meaning and values of c^{100} , c^{1km} and c^{net}):

$$c_{r,r^*}^t = c^{100} + c^{1km} \cdot (\Delta(r, r^*) - 100) + c^{net}; \text{ with } \Delta(r, r^*) = 100 \text{ if } r = r^* \quad (21)$$

- Here $\Delta(r, r^*)$ represents the distances between region r and region r^* . These are given in Table 3.
- The interregional transport capacity of the network is assumed to be constant and non-binding in Germany as shown in Table 2.
- The regional price p_r^0 (=91.73 €/MWh) and the regional demand d_r^0 (total demand is 270.28 TWh, for regional demand see Table 3) of electricity have to be found for the present situation in order to be able to calibrate the model for the reference case. This case is referred to as “REF”.
- Variable operating costs per technology c_i^v (this is 2.5, 10, 15, 20, 27.5 €/MWh for respectively HYD, NUC, HC/BC, GAS and OIL) have to be assessed, which serves as a lower bound for the marginal production cost c_f^m (equation (11)).
- Finally, the production limit per technology q_{if}^{\max} has to be defined, which serves as an upper bound of production q_{if} (equation (12)).

6. Results

In Section 5, the model has been calibrated to the reference case (REF), while Section 4 gave a formal description of the two cases that can be calculated with the model, namely the case with strategic behaviour (STRA) and the fully competitive case (COMP).

Let us first consider the STRA case in more detail. This case is also known as an oligopolistic game and it is characterised by an overall HHI index of 0.0771, as calculated by Equation (20). Table 4 displays for the STRA case, the regional competitiveness as expressed by HHI_r , consumer prices p_r , exports, imports, the resulting trade balance and regional demand.

Table 4 shows that regional HHI_r indicators differ. The highest concentration emerges in the region around Berlin (3), where we also find the highest regional price of electricity.

The weighted average electricity price has dropped by 32%, while total demand has gone up by 17% as compared to REF.

Let us now consider the COMP case in more detail. This case is characterised by an overall HHI index of 0.1021. Table 5 displays for the COMP case, regional competitiveness as expressed by HHI_r , consumer prices p_r , exports, imports, the resulting trade balance and regional demand.

Table 5 shows that regional HHI_r indicators increase substantially, but now beyond their critical values. For instance, a monopoly emerges in the metropolitan region Hamburg (4). The highest regional prices of electricity are found in southern Germany (1 and 2), which also have the lowest HHI_r value. The weighted average electricity price has dropped by 63%, while total demand has gone up by 49% as compared to REF.

Given the exogenous information about variable technology and transport costs of German electricity producers, an oligopolistic market game shows that the non-cooperative Nash equilibrium is a feasible solution. The overall HHI index does not exceed its critical value. Comparing STRA to COMP, it turns out that COMP leads to an unfeasible solution for the present structure of power supply firms in the German electricity market. As previous natural monopolies, characterised by high but decreasing average costs above marginal costs, cannot survive in this contestable market with fierce replacement competition.

If we take the recent mergers into account, we get a different picture. Table 6 shows the result in the case where firms merge into a single utility per region, which is realised by adding up the production capacities per technology per region. This equal to the result for the most recent mergers between regions in the current model set-up.⁴ Table 6 clearly shows the incentive of firms to merge in a liberalised electricity market, as they can now charge substantially higher electricity prices. This case is characterised by an overall HHI index of 0.1381, while the variation in regional concentration went down. The weighted average electricity price is now only 15% lower, while total demand increased by 7% as compared to REF.

It is also possible to compare REF, STRA and COMP in a different way. Therefore, we calculated the payoff (calculated as the income from power supply minus transport cost minus the cost of produced electricity times the variable costs) for each firm in the three cases. Table 7 shows besides the payoff also the endogenously derived marginal cost (c^m). The larger the difference between the marginal cost and the variable costs (c^v), the higher the payoff. It follows from Table 7 that the payoff is the largest in REF, in-between in STRA and the lowest in COMP. In COMP, however, we find negative payoffs for 8 small firms. A rational agent would rather not supply in such a situation. This shows that COMP is not a realistic outcome, as we already noticed by the too high HHI_r values.

⁴ Admundsen and Bergman (2002) present a different method for dealing with firm mergers. This is omitted here as it substantially changes the model set-up, without changing the point we want to make here.

6.1 Sensitivity analysis

A sensitivity analysis, by varying transport fees and tariffs, demonstrates significant changes in electricity prices, trade and profitability. Crucially, electricity prices are influenced by transport tariffs: higher transport fees and unified tariffs lead to higher electricity prices and a larger regional deviation. Because of that, market shares in the “home” region increases when the transport prices rise. Price-reliant regional demand degenerates, due to growing electricity prices, which induces lower supply, production and export, respectively. Regional net export suffers more by higher transport prices. Trade of electricity includes implicitly also electricity generated by renewable energy, also known as “green electricity”. Model results demonstrate that a modification of net capacities reveal no significant changes in trade adjustments, because all net capacities are found to be operated in every region entirely.

Due to prices, production capacities and market reactions of other players, technologies utilised for electricity production differ significantly in both cases (see Figure 2).

In the case of full competition in the German electricity market, cheap technologies, like old hard and brown coal power plants, are used. Figure 2 compares the shares of technologies to electricity production in Germany in the two different cases. In comparison to the reference case, full competition (COMP) leads to the use of more pollution-intensive but cheaper technologies, like hard and brown coal, whereas strategic behaviour (STRA) leads to an input with more environmental friendly technologies, like gas, and hydro (see Figure 2).

Experiences in other electricity markets in the USA and UK demonstrate, on the contrary, that new additional installed capacity is primarily coming from gas. The main reason for our findings is that we have a static model, which neglects dynamic adjustment processes of future investment decisions. The main purpose of our analysis is to demonstrate, in the current technology mix, the potential implications on utilised technologies of a stronger competition process. The overall amount of domestic electricity production declines in comparison to the reference scenario (electricity production in 1998), which is compensated by an increase of electricity imports.

In continuing the sensitivity analysis, four more cases are compared, namely an increase of renewable energy fostered by the German renewable energy law (EUSTRA, EUCOMP) and a full nuclear phase out (NUCSTRA, NUCCOMP). We detect a much higher increase of the gas technology and renewable energy. But, when the nuclear energy has to be substituted by other technologies, environmental unfriendly technologies, like hard and brown coal have to be used in bigger proportions as well to meet electricity demand. If we compare the case of nuclear phase out with full competition (NUCCOMP) and strategic behaviour (NUCSTRA), we detect, as before, that there is more pollution in NUCCOMP than in NUCSTRA. In the case where the EU promotes renewable energy, by the renewable energy law, strategic behaviour (EUSTRA) also leads to a higher use of renewable energies, than in the competitive case (EUCOMP).

In total, by considering strategic behaviour, an induced rise of production and consumer prices, initiates a preservation of relatively small electricity suppliers. These cannot stay independently, due to the need of mergers with large energy suppliers, in a fully competitive market. Energy suppliers with a low market share use mainly environmental

friendly technologies of which a large part is more expensive than other pollution intensive technologies. Considering full competition, large energy suppliers can enlarge their market shares significantly, whereas small suppliers are losing market shares or have to suffer losses. The environmental situation can be improved by creating a situation, where energy suppliers act strategically. This offers firms the opportunity to expand their relatively more expensive, but environmental friendly, technologies.

7. Conclusions and Outlook

This paper has shown that, while enhancing competition in the electricity market, strategic behaviour (e.g. a change in action of one firm affects the electricity price and, hence, the payoffs of other firms) may determine the structure of the market and the energy supply network. A run with the model, where firms are fully competitive and do not act strategically, shows that gains and market shares increase, while production and consumer prices decrease significantly. Furthermore, more production and lower consumer prices also leads to a need for relatively small electricity suppliers to merge with relatively large suppliers, as they can no longer stay independent. This process has started in the year 2000. However, the environmental situation improves, due to lower carbon emissions, in the case where firms do act strategically, which is also known as an imperfect market. Here energy suppliers with economically inefficient but environmental effective technologies are able to stay in the market. Moreover, when firms act strategically, the environment is better off at the cost of higher electricity prices

Nowadays, the German electricity market is characterised by a huge dynamic system resulting in fusions of firms, varying prices and an establishment of new products and a new structure of production technologies. Comparing a fully competitive market situation with an oligopolistic market, where energy suppliers act strategically, reveals that competition does not only lead to declining prices, but also to higher carbon emissions. It is likely that the privatisation process leads to a strong oligopolistic market, where large energy suppliers with substantial market shares can influence electricity prices. In fact, this development triggers increasing market prices, but additionally avoids the application of economically efficient but environmentally inefficient technologies. The intention of the liberalisation of the German electricity market per se was to guarantee efficient production by abolishing regional energy monopolies, to improve energy services and to reduce electricity prices. From an environmental perspective, the market cannot sort out all this by itself; additional laws and directives are necessary to assure environmental friendly electricity production. This paper has shown that an imperfect market situation is a better breeding ground for environmental effective technologies.

Furthermore, we did not include European trade flows into our model, due to data limitations. This is an area for further research. Our future work focuses on simulating a model of the European-wide electricity market liberalisation. At this stage we can only hint at the possible impact of such an extension. It is likely that due to the German policy to phase out of nuclear power and European policy to increase renewable energy, more and cheaper electricity from Poland and France will be imported.

In the near future, European neighbouring countries may also influence the German electricity market, not only by lower environmental standards and lower production costs, but also by larger construction efficiency, leading to higher electricity imports and a reduction of environmental friendly electricity production. A harmonisation of the liberalisation degree of the European countries will foster competition and also strategic behaviour of all competing firms, which will induce more price competition. Moreover, the development of environmental friendly electricity production will crucially depend on a harmonised agreement of environmental protection policies and standards.

References

- Amundsen, E. and Bergman, L. (2002), Will cross-ownership re-establish market power in the Nordic power market? *The Energy Journal* **23**(2):73–95.
- Bower, J. and Bunn, D. (1999) A Model-Based Comparison of Pool and Bilateral Market Mechanisms for Electricity Trading, London.
- Cardell, J., Hitt, C. C. and Hogan, W. W. (1996) Market Power and Strategic Interaction in Electricity Networks, Harvard Electricity Policy, Group, Cambridge, Mass.
- Dawson, Paul and Shuttleworth, Graham (1997) Efficient Transmission Pricing in Norway and Sweden, Report for NVE, National Economic Research Associates, London.
- Day, C. and Bunn D. (1999) Generation Asset Divestment in the England and Wales Electricity market: A Computational Approach to Analysing Market Power, London.
- Drake, F.-D., T. Ohler, et al. (2000) Vom Preiskrieg zum Servicewettbewerb, *Ener-giewirtschaftliche Tagesfragen* **5**:286–291.
- Ferris, M. and Pang, J. (1995) Engineering and Economic Applications of Complementarity Problems. Wisconsin.
- Ferris, M. and Sinaoiromsaran, K. (1998) Formulating and Solving Nonlinear Programs as Mixed Complementary Problems. Wisconsin.
- Fudenberg, Drew and Tirole, Jean (1992) Game Theory, 2nd print, MIT Press, Cambridge, Mass.
- Green, Richard (1997) Electricity Transmission Pricing An Internal Comparison, Department for Applied Economics and Fitzwilliam College, Cambridge.
- Helman, U., Hobbs, J.B., Cardell, T., Luong, T. and Wander, M.T. (1999) Modelling Strategic Pricing in Bilateral and Poolco Electricity Markets: A Nash- Cournot Approach with Applications to US Eastern Interconnection, INFORMS national meeting, Philadelphia, Npv. 7-10
- Jing- Yuan, W. and Smeers, Y. (1999) Spatial oligopolistic electricity models with Cournot Generators and regulated transmission prices. *Operations Research* **47**(1):102–112.

- Kemfert, C. (1999). "Liberalisation of the German Electricity Market - Strategies and Opportunities." *Nota di Lavoro* **95-1999**.
- Kemfert, C. and Tol, R. S. J. (2000) The Liberalisation of the German Electricity Market - Modelling an Oligopolistic Structure by a Computational Game Theoretic Model. Oldenburg, Working Paper 89/2000.
- Mc Kinsey (2001): Paying a green premium, The McKinsey Quarterly, 2001 Number 3.
- Murphy, F. H., H. D. Sherali, et al. (1986) A mathematical programming approach for determining oligopolistic market equilibrium. *Mathematical Programming* **24**:92–106.
- Oschmann, V. (2000) Das Gesetz für den Vorrang Erneuerbarer Energien. *Energiewirtschaftliche Tagesfragen* **6**:460–464.
- Prognos (2000) Energiereport III: Die längerfristige Entwicklung der Energiemärkte im Zeichen von Wettbewerb und Umwelt. Stuttgart, Schäffer-Poeschel Verlag Stuttgart.
- Pfaffenberger, W. and Haupt, U. (2001) Wettbewerb auf dem deutschen Strommarkt- Zwei Jahre nach der Liberalisierung, 2. IEWT 2001, Strategien und Instrumente für den Wettbewerb in der Energiewirtschaft.
- Rutherford, T. (1993) MILES, A Mixed Inequality and non Linear Equation Solver
- Salant, S. W. and Shaffer, G. (1999) Unequal treatment of Identical Agents in Cournot Equilibrium. *The American Economic Review* **89(3)**:585–604.
- Stern, J (1998) Competition and Liberalisation in the European Gas Market: A Diversity of Models, London.
- Strombasiswissen (2002), Kooperationen und Fusionen verändern die Stromlandschaft. Available from: <http://strombasiswissen.bei.t-online.de/SB115-04.htm>
- Tirole, Jean (1988) The Theory of Industrial Organisation, MIT Press, Cambridge, Massachusetts.
- Verbändevereinbarung (2001): Verbändevereinbarung über Kriterien zur Bestimmung von Netznutzungsentgelten für elektrische Energie und über Prinzipien der Netznutzung.
- Wietschel, M., Dreher, M. and Rentz, O. (2001) Grüne Angebote in Deutschland: Stand und Perspektiven; 2. IEWT 2001, Strategien und Instrumente für den Wettbewerb in der Energiewirtschaft.

Tables

Table 1 The considered 30 energy suppliers in Germany, their main production technology and total production capacity.

Region	EVU, Electricity generating plant	Main technology	Total capacity (MW)
1. South-West	Energie Baden-Württemberg AG (EnBW)	Nuclear	4,776
	Neckarwerke Stuttgart AG (NWS)	Nuclear	2,920
	Großkraftwerk MANNHEIM AG	Hard Coal	1,497
	Kraftwerk LAUFENBURG	Hydro	151
	Elektrizitäts- und Wasserwerk Rhein-Neckar AG (EWRN)	Hard Coal	376
2. South-East	BAYERNWERK AG	Nuclear	4,787
	LECH Elektrizitätswerke AG	Hydro	241
	Fränkisches Überlandwerk AG (FUW)	Gas	1
	EWAG Energie- und Wasserversorgung AG	Hard Coal	101
	Stadtwerke AUGSBURG	Gas	21
3. Berlin	Berliner Kraft- und Licht AG (BEWAG)	Hard Coal	2,493
4. Hamburg	Hamburgische Electricitäts-Werke AG (HEW)	Nuclear	3,272
5. Middle-North	PREUSSENELEKTRA AG	Nuclear	9,884
	SCHLESWAG AG	Hydro	14
	HASTRA AG	Gas	20
	EWE AG	Gas	14
	Braunschweigische Kohlen-Bergwerke AG (BKB)	Brown Coal	525
	Überlandwerk Nord-Hannover (UNH)	Gas	3
6. West	RWE Energie AG	Brown Coal	17,134
	STEAG Geschäftsbereich Energiewirtschaft	Hard Coal	1,122
	Wuppertaler Stadtwerke AG (WSW)	Gas	160
	Gas-, Elektrizitäts- und Wasserwerke Köln AG (GEW)	Brown Coal	425
	ELEKTROMARK Kommunales Elektrizitätswerk Mark AG	Hard Coal	977
	Stadtwerke Düsseldorf AG (SWD)	Hard Coal	848
7. East	VEAG Vereinigte Energiewerke AG	Brown Coal	9,247
8. North-West	VEW Energie AG	Gas	4,002
	VEBA Kraftwerke AG	Hard Coal	3,469
	Elektrizitätswerk Minden-Ravensberg GmbH (EMR)	Gas	664
	PESAG	Gas	0.2
	Dortmunder Energie- und Wasserversorgung GmbH (DEW)	Gas	12
Total:			69,158

Note: AG = aktiengesellschaft. Main utilities are in bold face, they took over the other utilities within their region in 2000.

Source: Verbändevereinbarung (2001).

Table 2 Parameters of EMELIE for Germany.

Description	Value and unit
Price elasticity of demand, $\sigma_r = \sigma$	0.4
Uniform tariff of 100 km distance (c^{100})	5.50 €/MWh
Tariff per km (above 100 km) (c^{1km})	0.10 €/MWh/km
Cost of net utilisation (c^{net})	10 €/MWh
Capacity constraint on interregional electricity transport, $\eta_{r,r^*} = \eta$	100 TWh/year

Source: Verbändevereinbarung (2001).

Table 3 The average distances between the regions and regional electricity demand in Germany.

	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Demand (TWh/year)
Region 1	0	164	508	536	400	265	429	372	37.26
Region 2	164	0	436	543	422	379	365	443	43.47
Region 3	508	436	0	257	250	486	79	400	11.34
Region 4	536	543	275	0	136	379	272	243	8.91
Region 5	400	422	250	136	0	265	222	150	55.94
Region 6	265	379	486	379	265	0	429	143	49.50
Region 7	429	365	79	272	222	429	0	365	34.02
Region 8	372	443	400	243	150	143	365	0	29.84

Source: Verbändevereinbarung (2001).

Table 4 Regional model results where firms behave strategically (STRA).

	HHI _r	Prices (€/MWh)	Export (TWh/year)	Import (TWh/year)	Trade balance	Demand (TWh/year)
Region 1	0.151	63.18	33.97	17.21	16.76	43.25
Region 2	0.144	67.98	10.97	34.95	-23.99	49.01
Region 3	0.157	74.67	12.61	9.73	2.88	12.31
Region 4	0.132	66.51	16.30	8.24	8.06	10.13
Region 5	0.136	60.05	28.92	49.05	-20.13	66.27
Region 6	0.115	56.31	38.99	27.11	11.88	60.17
Region 7	0.145	69.79	14.99	29.41	-14.42	37.95
Region 8	0.133	57.41	41.88	22.93	18.95	35.99
Total	0.0771	62.65	198.63	198.63	0	315.09

Source: Model calculations.

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Table 5 Regional model results in competitive equilibrium (COMP).

	HHI _r	Prices (€/MWh)	Export (TWh/year)	Import (TWh/year)	Trade bal- ance	Demand (TWh/year)
Region 1	0.324	36.60	21.93	0	21.93	53.81
Region 2	0.387	43.00	0	21.93	-21.93	58.86
Region 3	0.968	30.50	13.01	17.33	-4.32	17.62
Region 4	1.000	31.90	3.14	0	3.14	13.59
Region 5	0.817	35.50	0	3.42	-3.42	81.78
Region 6	0.546	30.50	0	0	0	76.89
Region 7	0.629	30.50	17.33	13.02	4.31	52.85
Region 8	0.446	30.50	0.29	0	0.29	46.35
Total	0.1021	34.21	55.70	55.70	0	401.75

Source: Model calculations.

Table 6 Regional model results with firm mergers to 8 utilities, where firms behave strategically (STRA).

	HHI _r	Prices (€/MWh)	Export (TWh/year)	Import (TWh/year)	Trade bal- ance	Demand (TWh/year)
Region 1	0.186	84.32	27.83	28.70	-0.87	38.54
Region 2	0.175	85.89	20.90	33.43	-12.53	44.63
Region 3	0.160	80.51	13.68	9.72	3.96	11.95
Region 4	0.166	78.90	18.64	7.68	10.96	9.46
Region 5	0.159	69.42	34.96	48.51	-13.55	62.54
Region 6	0.179	77.85	34.21	39.41	-5.19	52.86
Region 7	0.152	75.55	30.88	28.00	2.88	36.77
Region 8	0.177	74.35	39.20	24.85	14.34	32.46
Total	0.1381	77.59	220.29	220.29	0	289.19

Source: Model calculations.

Table 7 Firm's payoff and marginal production cost for three cases.

Firm	Payoff			Marginal cost	
	REF	STRA	COMP	STRA	COMP
EnBW	2303.12	728.77	319.77	15.00	21.10
NWS	0.00	597.71	177.20	18.29	21.10
MANNHEIM	0.00	375.72	48.14	24.26	21.10
LAUFENBURG	38.22	52.83	19.33	44.57	21.10
EWRN	0.00	99.22	16.56	41.17	21.10
BAYERNWERK	2446.80	751.11	470.38	14.48	27.50
LECH	109.42	82.99	31.84	45.38	27.50
FUW	0.35	0.20	0.04	52.45	27.50
EWAG	52.20	31.80	10.36	49.50	27.50
AUGSBURG	10.09	5.80	1.28	51.85	27.50
BEWAG	689.09	475.45	-6.17	20.00	15.00
HEW	525.19	512.14	91.37	20.00	16.40
PREUSSENELEKTRA	3491.89	1194.34	574.36	11.70	20.00
SCHLESWAG	0.73	5.23	1.90	45.41	20.00
HASTRA	9.49	4.57	-0.04	44.61	20.00
EWE	0.00	2.83	-0.01	45.39	20.00
BKB	0.00	129.12	20.22	38.39	20.00
UNH	1.38	0.66	0.00	47.01	20.00
RWE	2796.52	983.25	239.23	10.00	15.00
STEAG	0.00	220.26	-4.32	27.46	15.00
WSW	0.00	30.82	-0.21	37.63	15.00
GEW	0.00	88.83	-1.53	34.30	15.00
ELEKTROMARK	248.53	195.29	12.74	28.48	15.00
SWD	204.94	147.49	-1.47	29.62	15.00
VEAG	2243.82	844.31	174.98	15.00	15.00
VEW	493.43	563.05	29.73	20.00	15.00
VEBA	1319.83	552.06	-11.36	20.03	15.00
EMR	0.00	133.38	7.95	34.03	15.00
PESAG	0.00	0.04	0.00	41.91	20.00
DEW	0.00	2.53	0.33	41.50	15.00
total	16985.04	8811.80	2222.60		

Note: Payoff = $\sum_r (p_r - c_{l(f,r)}^1) s_{f,r} - \sum_i q_{i,f} c_i^v$ and the marginal cost is derived endogenously with model calculations.

Source: Model calculations.

Figures

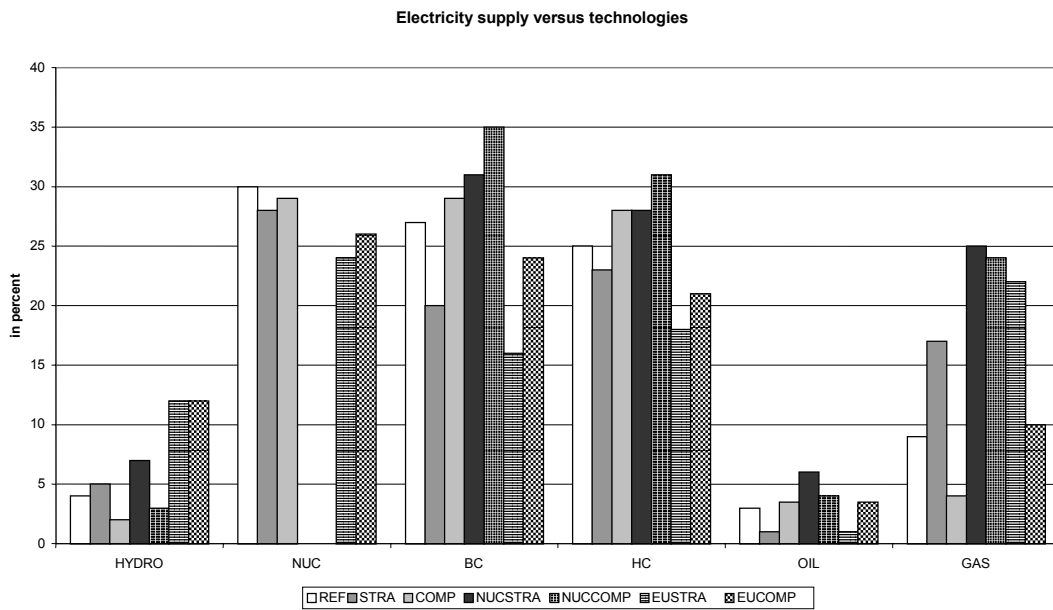
Figure 1: A map of the considered 8 regions in Germany.

- Region 1: South-West
- Region 2: South-East
- Region 3: Berlin
- Region 4: Hamburg
- Region 5: Middle-North
- Region 6: West
- Region 7: East
- Region 8: North-West



Source: Verbändevereinbarung (2001)

Figure 2: Utilisation of electricity supply technologies in seven cases.



Source: Model calculations.

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