The Liberalisation process of the German Electricity Market

Strategies and Opportunities

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Content

Non technical abstract

The European liberalised energy market process incorporates challenges and opportunities for all European countries. Germany implemented the EU directive and opened the market for electricity rapidly, guarantied territorial monopolies were cancelled within the German electricity production resulting in a new structure of energy supply firms and products.

Due to competition processes within the energy markets new contests are opened to energy suppliers. Experiences in England and Scandinavia demonstrated several structural and economic development changes inducing employment reactions and industrial and private energy price variations. Owing to the opportunity of European electricity trading firms react strategically like global market players by joining and merging market shares and gains. On the way to perfect competition of the electricity market strategic behaviour like co-operation or refusal of collaboration or of net access will determine the development of market structure and construction of energy suppliers.

Current developments in Germany demonstrate a huge competitive system resulting in immense price decreases and employment reductions within the electricity production firms. Competition can be affected negatively by strategic behaviour of firms resulting for example in a refusal of net access.

This paper compares the opportunity of full competition with monopolistic and oligopolistic games within the German electricity market by a game theoretic modelling tool representing different market actors by regions. In order to investigate the strategic behaviour a game theoretic computational modelling tool was established for Germany. Electricity firms react strategically by optimising their profits with the opportunity to enlarge their market shares influencing prices and demand (Nash- Equilibrium). Due to electricity trading and price influences the market reacts differently by diverse optimal market shares, transport prices or mergers. It turns out that under present market structure and costs situation of energy supplier full competition is no favourable and beneficial solution leading in a substantial decease of firms, an oligopolistic market structure can better of all market actors. Increasing transport prices by distances or as a flat rate and decreasing net capacities result in a more oligopolistic market structure.

Technical Abstract

Within this paper an oligopolistic German electricity market is modelled by a game theoretic modelling tool representing a Nash equilibrium. Due to European electricity market liberalisation electricity producing and trading firms react strategically like global market players by joining and merging market shares and gains. On the way to perfect competition within the electricity market strategic behaviour like co-operation or refusal of collaboration or net access will determine the development of a market and energy suppliers structure. Presently, the German electricity market is determined by strategic behaviour of energy firms so that a full competitive market has not been reached yet.

An oligopolistic market structure emerged and is characterised by a mutual influence of prices due to market shares and power. Computationally, this can be modelled by a Nash equilibrium path based on game theoretic modelling approaches. Within the Nash equilibrium, electricity firms react strategically by optimising their profits with an opportunity to enlarge their market shares influencing prices and demand. A Nash equilibrium is reached by an optimal solution of strategic actions considering strategic behaviour by all other market actors. A non Nash equilibrium or full competition case equals prices and marginal costs in order to determine and optimise profits of firms. The computational game theoretic modelling tool has been developed by the programming language GAMS written as a mixed complementary problem (MCP) solved by the GAMS algorithm MILES resolving non linear complementary problems based on a generalised Newton method iteratively.

It turns out that the Nash equilibrium solution fulfils the optimal criteria of mathematical solution whereas the full competition scenario leads to implausible high market shares resulting though in an oligopolistic market structure characterised by a Nash equilibrium. Within the Nash equilibrium mutual profit maximisation and strategic behaviour leads to regional market shares by firm mergers and establish regional price variations resulting in distinctive net trades.

Key words: Game theoretic modelling; Electricity market liberalisation

JEL- classification: C7, D2, Q4, R3

Introduction

The German electricity market will change due to the liberalisation process of energy markets within the EU. By implementing the EU directive of December 1998 guarantied territorial monopolies were cancelled within the German electricity production resulting in a new structure of energy supply firms. Internal and external competition in production and transmission force energy suppliers towards new production behaviour. In order to provide a sufficient and a long term cost efficient energy supply by previous ”natural monopolies” a guideline was implemented by rules and laws for an undistorted competition in the German electricity market. Within the transformation progress towards a full competition electricity market, electricity suppliers can react strategically influencing prices due to market shares and power by co-operation or merging of firms.

The directive for the internal market of energy passed by the council of the EU in December 1998 had to be implemented into national law in the member states until February 1999. Germany revised the German energy law EnWG (*Energiewirtschaftgesetz*) and modified the law against competition barriers (*GWB: Gesetz gegen Wettbewerbsbeschränkungen*). More precisely, §§ 103 and 103a of GWB are not effective anymore for electricity and gas which means a termination of territorial monopolies. Additionally, the decartelization of the integrated monopolies and the unbundling of energy production, transport and distribution have to guarantee a transparent as well as efficient and well-priced energy supply in Germany.

Moreover, laws had to be modified regarding the equipment safety and the electricity production by renewables (*Stromeinspeisegesetz*) regulating the delivery of electricity produced by renewable energy and the use of cogereration.

In order to guarantee a non-discriminated access to the grid, several alternatives are available permitted by the EnWG. On the one hand the potential was created to feed electricity into the net by the Negotiated Third Party Access (NTPA) or otherwise by the Single Buyer System. In Germany a pragmatic translation of the NTPA is chosen by an organisations agreement of net access, the so called association agreement or contract (*Verbändevereinbarung Durchleitung VVD*) by the BDI, VIK and the VDEW of 22. May 1998 resulting in well defined net access fees or compensations. The VVD creates a basis for future negotiations between suppliers respective owners of the grid and industrial customers assuring a transparentness and planning reliability for the electricity supply. In spite of a basically free access to the grid on an European level, a hedge clause integrated in the EnWG by 31. Dec. 2006 permits the supply by a foreign firm only in case of the hypothetical allowance to the customer firm of concluding a supply contract with a third party in a foreign country.

Due to competition process within the energy markets great chances and new challenges are opened to energy suppliers. Experiences in England and Scandinavia demonstrated several structural and economic development changes inducing employment reactions and industrial and private energy price variations. Due to the opportunity of European electricity trading firms react strategically like global market players by joining and merging market shares and gains. *Day and Bunn (1999)* investigated these aspects by game theoretic approaches representing market power developments and strategic actions of firms in the UK . *Bower and Bunn (1999)* assess trade opportunities within a pool versus bilateral trade system within the UK electricity market. A crucial role plays the treatment of transmission and transport pricing not only for Germany. Experiences in Scandinavia and England demonstrate various results revealing an uniform tariff as an alternative consequence, trade depends significantly on market opportunities and grid owners. *Dawson and Shuttleworth (1997)* studied the transmission pricing in Norway and Sweden and *Green (1997)* examined the illustrated effects for the UK. *Cardell, Hitt and Hogan (1994)* investigated the negative effects of market power and transmission constraints on trade by an imperfect competition model for the North American electricity supplier.

Towards perfect competition of the electricity market strategic behaviour like co-operation or refusal of collaboration or of net access will determine the development of market structure of energy suppliers and the composition of technologies employed. Energy supplier will optimise their production and strategic behaviour by maximising market shares increasing electricity prices and lowering demand or consumption surplus. New energy products like energy services and new market actors electricity broker by exchange firms are and will be established.

The following paper investigates the strategic behaviour of electricity suppliers influencing gains, prices and demand and overall welfare. Especially, maximising market shares results in higher electricity prices (price arrangements), increasing production and decreasing consumption surplus. Full competition warrants lower prices and market gains and an apparent increase of electricity demand.

Main aim of this analysis is to investigate the different strategic behaviour opportunities of market supplier by a computer based game theoretic modelling tool representing the German electricity market within a consistent framework. The paper is structured as follows: part A includes first a brief verbal description of main ideas and interlinkages of the game theoretic modelling tool and second demonstrates the model results and main outcomes concluding with an outlook of possible next investigations. Part B as an Annex comprises the mathematical model description and graphical view of the model surface and interface.

Model description and results

1. Model description

In order to investigate the effects by a further liberalised energy or electricity market in Germany an analyse tool (**LEMI**: Liberalised Energy Market Investigations) was developed including strategic behaviour by firms and market actors. Industrial economics and game theoretic elements were included to illustrate different strategies by market actors.

LEMI is a computational energy market model in order to investigate strategic behaviour by firms within a liberalised energy market in Germany. Firms maximise their profits due to variable production costs, maximum net power, net access costs and transport costs. Market shares due to merges or co-operation play an important role, within a so called Nash equilibrium prices are influenced due to market shares or powers and price elasticities of demand. Within full competition equilibrium market price is equal to marginal costs of production. The electricity market supply structure is specified by natural monopolies established by increasing returns to scale and average costs higher than marginal costs because of high fix cost shares. Main market actors are divided due to their previous regional territories (Figure 1), electricity supply and demand by households and industry determine a regional equilibrium price.

Figure 1: Previous regions of energy suppliers in Germany

Reg1: EnBW+
Reg2: Bayernwerk+
Reg3: BEWAG+
Reg4: HEW+
Reg5: PreussenElektra+
Reg6: RWE+
Reg7: VEAG+
Reg8: VEW+

In total, 28 energy suppliers are distinguished by regions in Germany:

REGION	EVU
South-West	Energie Baden-Württemberg AG Neckarwerke Stuttgart AG Großkraftwerk Mannheim AG Elektrizitäts- und Wasserwerk Rhein-Neckar AG
South-East	Bayernwerk AG Lech-Elektrizitätswerke AG Fränkisches Überlandwerk AG EWAG Energie- und Wasserversorgung AG Stadtwerke Augsburg
Berlin	Berliner Kraft- und Licht (Bewag) AG
Hamburg	Hamburgische Electricitäts-Werke AG
Middle-North	PreussenElektra AG SCHLESWAG AG HASTRA Aktiengesellschaft EWE Aktiengesellschaft Braunschweigische Kohlen-Bergwerke AG (BKB) Überlandwerk Nord-Hannover
West	RWE Energie AG STEAG Geschäftsbereich Energiewirtschaft Wuppertaler Stadtwerke AG Gas-, Elektrizitäts- und Wasserwerke Köln AG ELEKTROMARK Kommunales Elektrizitätswerk Mark AG Stadtwerke Düsseldorf AG
East	VEAG Vereinigte Energiewerke AG
North-West	VEW Energie Aktiengesellschaft VEBA Kraftwerke AG Elektrizitätswerk Minden-Ravensberg GmbH Dortmunder Energie- und Wasserversorgung GmbH

Table 1: Regions and Energy supplier

Examplarily, Figure 2 demonstrates all regional production and demand structure excluding a specific determination of the real position of electricity production and demand. The model structure allows a definition of uniform interregional distances of diverse market actors to calculate transport costs by the association agreement or contract (VVD). Regional diverse demand functions react on price changes due to their price elasticities. Within all regions transmission capacity is assumed as uniform, capacity restrictions are only valid for high voltage areas.

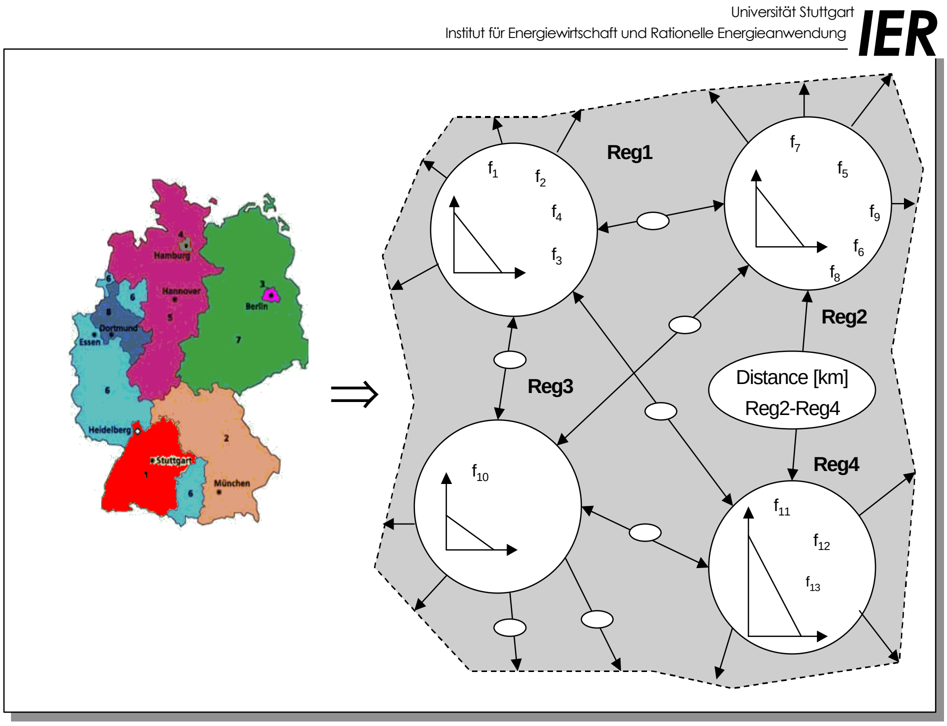

Figure 2: Regional Model Structure

Electricity is produced by six different technologies. Each electricity supplier has different power plants, for example gas, coal, nuclear and water power plants bounded by an upper limit of power capacity. Variable production costs are supposed as constant over time. Produced electricity is disseminated within one region or within interregional trade comprising transportation costs (see Figure 3).

Beside input parameter of electricity production price elasticities of demand, transportation costs by VVD and transmission grid capacity has to be determined exogenously. LEMI determines regional electricity prices, marginal electricity production costs, produced and traded electricity by technology of each firm. Main outcome are the optimal market shares each electricity producer in terms of the Hirschmann- Herfindahl index and interregional trade flows.

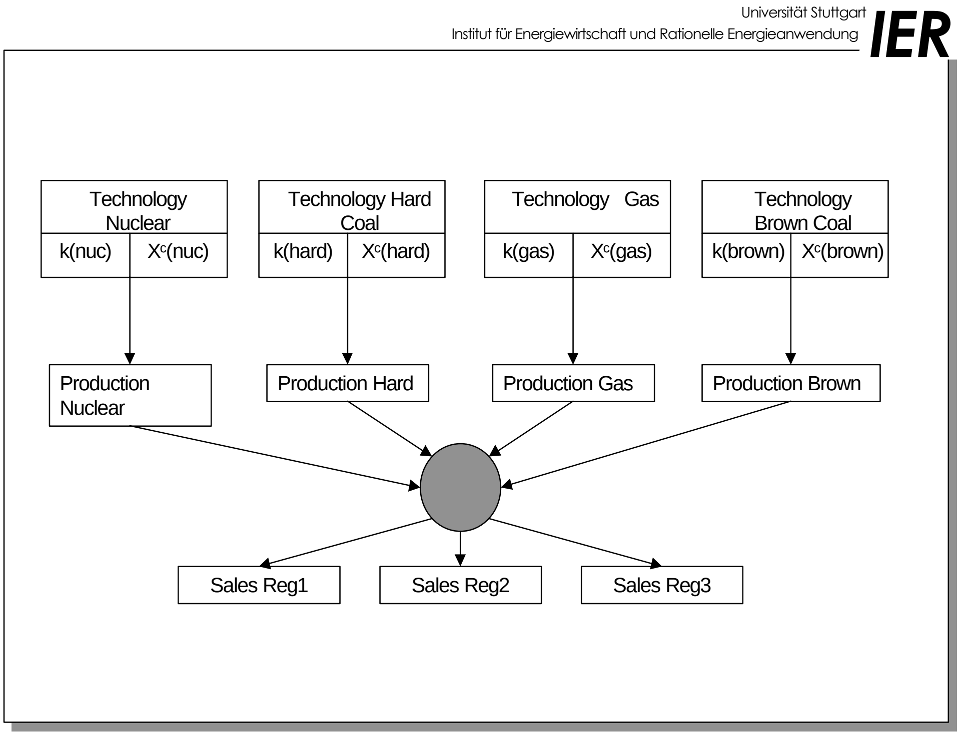

Figure 3: Production Strcuture

Each individual energy supplier reacts as a market player within a non - cooperative oligopolistic game observing a quantity strategy. Each player maximises his / her individual profit assuming that all other player apply a gain maximisation strategy. Produced electricity by each competitive player or market actor influences the sales and trade volumes of each producer interdependently. Each electricity producer and player considers oligopolitic interrelations and correlations operating conjectural (Nash- equilibrium). In order to contrast different strategies of a non cooperative game are compared with a cooperative equilibrium solution considering full competition within the market. In dissimilarity to the Nash equilibrium situation full competition scenario contains no influence on market prices and a profit maximisation by an equalisation of market prices to marginal production costs.

LEMI can be characterised as a static and partial game theoretic model for the electricity market including assumptions about full and perfect information, constant price elasticities within all regions, linear costs functions and a regional electricity production linked by trade flows. Each producer supplies only in one region and capital participation by firms are only considered by accounting acquired capital shares in the individual maximum net power capacity.

Two scenarios are compared:

a) Cournot-Nash behaviour within the oligopolistic game (SA)

b) Full competition (FC)

2. Model results

First, a strategic action scenario (SA) is compared to a full competition case (FC). Following key parameter are supposed:

Price elasticity of demand	0.4
Uniform tariff of 100 km distance	1 Pf/ kWh[1]
Distant component of each additional km	0.02 Pf / kWh
Cost of net utilisation	2 Pf / kWh
Capacity constraint on interregional electricity transport	100 TWh/ year

The adjusted number of market actors, net capacities and constraints, transport costs and different assumptions about net access fees due to association agreement (Verbändevereinbarung Durchleitung (VVD)) variation of power production and technologies resulting in different variable costs is compared within scenarios. Regional prices, supply, demand and exports and imports can be evaluated due to different strategic market games.

An oligopolistic game is determined by a Nash equilibrium measured by an overall HHI index of 0,0771, in order to provide essential model results Table 2 demonstrates Nash equilibrium optimal regional market shares and concentrations, prices, exports and imports:

[1] 1 Pfennig per Kilowatt hour is equal to ca. 0.55 cent per Kilowatt hour

	HHI	Prices in Euro/ KWh	Export in TWh /year	Import in TWh / year
Region 1	0,15	0,077	34	18
Region 2	0,14	0,072	11	35
Region 3	0,16	0,082	12	9,8
Region 4	0,12	0,061	18	8
Region 5	0,13	0,066	28	49
Region 6	0,10	0,051	39	28
Region 7	0,13	0,066	15	29,9
Region 8	0,10	0,051	41	22

Table 2: Regional model results

Regional HHI indicators as a measure of market concentration differ between regions, main market concentrations will occur within the Southern regions resulting in even highest regional prices of electricity and distinctive net trades between regions. Sensitivity analysis by varying transport fees and unified tariffs demonstrates significant changes in electricity prices, trade and market shares. Higher transport fees and unified tariffs result in higher electricity prices with regional deviations. The structure of supply technologies is adjusted due to costs and transport prices. Market shares rise within the ”home” region by increasing transport prices. Price reliant regional demand degenerates due to electricity price increases resulting in lower supply and production and export, respectively. Regional net export suffers most by higher transport prices. A modification of net capacities reveals no significant changes in adaptation because all net capacities are expected to be operated in every region entirely.

Given the exogenous information about variable technology and transport costs structure of German electricity producer an oligopolistic market game expose a non cooperative Nash equilibrium as feasible solution resulting in optimal market shares and profits. The overall HHI index exceeds no critical value. Comparing these results with a full competitive scenario determining mutual profit maximisation by prices equal to marginal production costs demonstrate that the full competition scenario establish no feasible solution for the German electricity market. Previous natural monopolies characterised by high but decreasing fix costs above marginal costs cannot survive within this contestable market and replacement competition. Firm merges and coalitions guarantee a well functioning oligopolistic market, growing transport prices persuade a development towards full competition negatively.

Conclusion and outlook

The current development of the in German electricity market demonstrates a well functioning competitive electricity trading system by transports of electricity between north and south Germany which can be affected negatively by strategic behaviour of firms resulting for example in a refusal of net access. It has to be discussed within the near future whether price or fee observation by an independent authorisation has obliged to be established. Developments of market shares influenced by strategic behaviour of energy suppliers will be most interesting within the near future.

Strategic behaviour is investigated by a game theoretic modelling tool representing market actors like global players optimising their profits mutually due to market shares and a price dependent regional demand structure. Main outcome of this analysis is that the German electricity market is revealed by a natural monopolistic market structure. Within the process towards full competition an oligopolistic market structure is established reducing the overall welfare losses. Previous natural monopolies characterised by high but decreasing fix costs above marginal costs cannot survive within this contestable market and replacement competition . Firm merges and coalitions guarantee a well functioning oligopolistic market, growing transport prices persuade a development towards full competition negatively.

Presently, the German electricity market is characterised by a huge dynamic system resulting in firm merges, decreasing prices, establishment of new products and structure of production technologies. A dynamic market structure can be represented by elastic time periods, a differentiation of time dependent demand reactions by households and industry and by an adequate representation of a stock exchange within the European electricity market.

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References

Bower, J., Bunn, D.: A Model-Based Comparison of Pool and Bilateral Market Mechanisms for Electricity Trading, London, 1999

Cardell, J.; Hitt, C. C.; Hogan, W. W.: Market Power and Strategic Interaction in Electricity Networks, Harvard Electricity Policy, Group, Cambridge, Ma. 1996

Day, C. and Bunn D.: Generation Asset Divestment in the England and Wales Electricity market: A Computational Approach to Analysing Market Power, London, 1999

Dawson, Paul; Shuttleworth, Graham: Efficient Transmission Pricing in Norway and Sweden, Report for NVE, National Economic Research Associates, London, 1997

Energy Modelling Forum: A Competitive Electricity Industry, EMF Report 15, Vol. 1, Stanford University, Stanford, 1998

Fudenberg, Drew; Tirole, Jean: Game Theory, 2. print., MIT Pr., Cambridge, Mass., 1992

Green, Richard: Electricity Transmission Pricing: An Internal Comparison, Department for Applied Economics and Fitzwilliam College, Cambridge, 1997

Hempling, Scott: Making Competition Work: Advice to the New Commission, in: The Electricity Journal, June 1993, S.36-47

Hobbs, B.; Kelly, Kevin A.: Using game theory to analyse electric transmission pricing policies in the United States, in: European Journal of Operational Research 56/1992, S.154-171

Hogan, William W.: Competition in Electricity Markets and Transmission Network Interactions, The Harvard-Japan Project on Energy and the Environment, Working Paper, Cambridge, Ma., 1997

Jensen, Jesper; Rutherford, Thomas F.: The Economic Effects of Electricity Market Reform in Denmark, Presentation at the 18th Annual IAEE conference on “International Energy Markets, Competition and Policy”, 1997

Nordpool (Hrsg.): The Organised Markets at the Nordic Power Exchange: Eltermin, The Financial Market, o.A., 1998

Nordpool (Hrsg.): The organized Markets in Nord Pool, the Nordic Power Exchange: Elspot, The Spot Market, o.A., 1998

Oren, Smuel S.:Preemption of TCCs and Deadweight Loss in Centrally Dispatched Electricity Systems with Competitive Generation, University of California, Berkeley, 1996

Pfaffenberger, W.; Kemfert, C.: Liberalisierung der Energiewirtschaft und Beschäftigung, in: VDI-Berichte 1311, 1997, pp 81-93

Tirole, Jean: The Theory of Industrial Organisation, 6. print., MIT Pr., Cambridge, Mass. 1993

Unipede (Hrsg): Europrog 1998, Programmes and Prospects for the european Electricity Sector, 26th ed., Unipede/Eurelectric, Brussels, 1998

Varian, Hal R.: Microeconomic Analysis, 3rd ed., Norton, New York, N.Y., 1992

Vlahos, K.; Ninios, P.; Bunn, D.: An integrative modelling approach for understanding competitive electricity markets, in: Journal of the Operational Research Society 49/1998, S.187-199

von Weizsäcker, C. C.: Finanzmärkte und Energiemärkte, in: Zeitschrift für Energiewirtschaft 2/98, S.81-85

Watson, Jim: Perspectives of Decentralized Energy Systems in a Liberalised Market: The U.K. Experience, in: Nachhaltige Marktchancen dank dezentraler Energie ? Ein Blick in die Zukunft der Energiedienstleistung (Wüstenhagen, R.; Dyllick, T., Hrsg.), IWÖ-Diskussionsbeitrag Nr.72, St. Gallen, 1999

Zweifel, P.; Beck, K.: Optimal Pricing and Provision of Electricity Markets with Trade, Institut für Empirische Wirtschaftsforschung der Universität Zürich, 1994

ANNEX

Mathematical model description of LEMI

With

F	- Firms
R	- Regions

and

t(*l*(f),r)	- Net access for electricity l(f) to regions incl. taxes
c(i)	- Variable production costs for technology i
de_0(r)	- Reference demand for electricity in region r
pe_0(r)	- Reference price for electricity in region f
s(r)	- Regional price elasticities of electricity demand
scap(r,r*)	- interregionale Netzkapazität
xlim(i,f)	- maximale Nettoleistung der Technologie i bei Firma f

Variables

pe(r)	- Demand price for electricity in region r
w(f)	- Marginal costs of electricity production of form f
t(*l*(f),r)	- Schadow price of electricity transport from region l(f) to region r
J(f,r)	- Market share of firm f in region r
s(f,r)	- Supply of firm f in region r
x(i,f)	- Production of firm f with technology i
netx(r,r*)	- Net export of electricity from region r to region r*

Each producer of electricity maximise their profit due to condition (1). The resulting *Nash Equilibrium* [2] is determined by:

$\forall$ r $\in$ R and $\forall$ f $\in$ F

$$w(\mathrm{f}) + \mathrm{t}\,(l(\mathrm{f}),\mathrm{r}) + t(l(\mathrm{f}),\mathrm{r}) = pe(\mathrm{r})\left(1 - \frac{\mathrm{J}\,(\mathrm{f},\mathrm{r})}{\mathrm{s}\,(\mathrm{r})}\right), \qquad (1)$$

with $\mathrm{t}\,(l(\mathrm{f}),\mathrm{r}) = t(l(\mathrm{f}),\mathrm{r}) = 0$ if l(f) = r

A transport of electricity occurs from region l(f) to region r and l(f) ≠ r, marginal production costs increase due to the shadow price capacity constraints and net access costs incl. taxes. In the case of identical production and delivery regions, l(f) = r, the latest costs components does not appear, only marginal production costs determine profit maximisation.
Within the Nash Equilibrium prices depend on the demand function including price elasticities of demand and the market share of firms.
The individual market share is determined by:

$\forall$ r $\in$ R and $\forall$ f $\in$ F

$$\mathrm{J}\,(\mathrm{f},\mathrm{r}) \cdot \sum_{\mathrm{g} \in \mathrm{F}} s(\mathrm{g},\mathrm{r}) = s(\mathrm{f},\mathrm{r}) \qquad (2)$$

Upper bound of marginal costs is determined by

$\forall$ i $\in$ I and $\forall$ f $\in$ F

$$c(\mathrm{i}) \geq w(\mathrm{f}) \qquad (3)$$

Supply is given by total production of each firm f for all technologies i for all regions r:

[2] Within this context producer can infuence the price due to market shares and price elasticities. In a full competetive

$\forall$ f $\in$ F

$$\sum_{i \in I} x(i,f) = \sum_{r \in R} s(f,r) \qquad (4)$$

Aggregated supply of all firms f in region r is determined by demand of region r, market equilibrium is given by:

$\forall$ r $\in$ R

$$\sum_{f \in F} s(f,r) = de_0(r) \cdot \left(\frac{pe(r)}{pe_0(r)} \right)^{-s(r)} \qquad (5)$$

Net exports of region r to region r* with r $\neq$ r* is determined by:

$\forall$ r and r* $\in$ R and r $\neq$ r*

$$netx(r,r^*) = \sum_{f \in M} s(f,r^*) - \sum_{f^* \in M^*} s(f,r), \qquad (6)$$

with $M = \{ f \mid l(f) = r \}$ and $M^* = \{ f^* \mid l(f^*) = r^* \}$

Net exports are limited quantitatively by net capacity restrictions:

$\forall$ r and r* $\in$ R and r $\neq$ r*

$$scap(r,r^*) \geq netx(r,r^*) \qquad (7)$$

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

$\forall$ i $\in$ I and $\forall$ f $\in$ F

game, prices are given and have to be equal to marginal costs

$$x(\mathrm{i},\mathrm{f}) \leq xlim(\mathrm{i},\mathrm{f}) \qquad (8)$$

Non negative constraints result in:

$$s(\mathrm{f},\mathrm{r}),\ x(\mathrm{i},\mathrm{f}),\ pe(\mathrm{r}),\ w(\mathrm{f}),\ \mathrm{t}(l(\mathrm{f}),\mathrm{r}),\ \mathrm{J}(\mathrm{f},\mathrm{r}) \geq 0 \qquad (9\text{-}14)$$