university of groningen
faculty of economics and business

13003-EEF

Decomposing changes in competition in the Dutch electricity market through the Residual Supply Index

Machiel Mulder
Lambert Schoonbeek

university of groningen / faculty of economics and business

SOM is the research institute of the Faculty of Economics & Business at the University of Groningen. SOM has six programmes:
- Economics, Econometrics and Finance
- Global Economics & Management
- Human Resource Management & Organizational Behaviour
- Innovation & Organization
- Marketing
- Operations Management & Operations Research

Research Institute SOM
Faculty of Economics & Business
University of Groningen

Visiting address:
Nettelbosje 2
9747 AE Groningen
The Netherlands

Postal address:
P.O. Box 800
9700 AV Groningen
The Netherlands

T +31 50 363 7068/3815

www.rug.nl/feb/research

Decomposing changes in competition in the Dutch electricity market through the Residual Supply Index

Machiel Mulder
Netherlands Competition Authority (NMa) and University of Groningen
Machiel.mulder@nma.nl

Lambert Schoonbeek
University of Groningen

Decomposing changes in competition in the Dutch electricity market through the Residual Supply Index

MACHIEL MULDER[1] and LAMBERT SCHOONBEEK[2]

Abstract

We propose to assess the influence of a number of events on the degree of competition in the Dutch electricity wholesale market over the period 2006-2011 through a decomposition method based on the Residual Supply Index. We distinguish regulatory market-integration events, firm-level events and changes in the level of residual demand. We conclude that market-integration measures to improve competition have been effective, but that the changes in residual demand appear to have been equally important. Firm-level events have only had a minor impact on the intensity of competition.

JEL-codes: L1, Q41, Q48

Keywords: electricity market; competition; regulation; residual supply index

---

[1] Machiel Mulder (corresponding author), Netherlands Competition Authority (NMa), and Department of Economics, Econometrics and Finance, University of Groningen, The Netherlands.
Corresponding address: NMa, PO Box 16326, 2500 BH The Hague, The Netherlands; Fax + 31 70 330 3370; Tel +31 70 330 3321; e-mail: machiel.mulder@nma.nl.

[2] Lambert Schoonbeek, Department of Economics, Econometrics and Finance, University of Groningen, The Netherlands; e-mail: l.schoonbeek@rug.nl.

1. Introduction

The intensity of competition in markets is generally not constant as competitive conditions might change over time. Firms may gain (more) market power by, for instance, increasing the heterogeneity of their products, raising consumer switching costs or mergers and acquisitions. Market power might also change as a result of investments in additional capacity by firms or changes in the level of demand. Moreover, in some markets governments implement measures enhancing integration of regional markets into larger geographic markets, which might raise the number of competitors and, hence, reduce market power (Shapiro, 1989; Farrell and Shapiro, 1990). The ultimate net effect of these influences determines how competition evolves.

In order to better understand the development of competition over time, one should analyze the relative contribution of factors affecting competitive conditions. In this paper we develop a method for this decomposition analysis and apply it to the Dutch electricity (wholesale) market. We focus on this market over the period 2006-2011, as here a number of events occurred in this period. Several incumbent electricity (wholesale) companies have been taken over by foreign competitors, the companies changed their generation portfolios, while extension of the cross-border capacity has enlarged the relevant geographic market substantially. In addition, the demand for electricity decreased as a result of the economic downturn since 2008, while the residual demand for the major centralized power companies declined even stronger because of the growth in decentralized production resulting in a decreasing share of centralized production in the total Dutch electricity generation (CBS, 2012).

We propose to assess the relative strength of several influences on competition in the Dutch electricity market through a decomposition method based on the Residual Supply Index (RSI). The RSI is broadly viewed as an appropriate measure for potential market power in electricity markets (Sheffrin, 2002; Bergman, 2005; Twomey et al., 2005; Swinand et al., 2008; Gianfreda and Grossi, 2012). It can be shown that the RSI is related to the Lerner index which more directly measures allocative efficiency (Newbery, 2009). The Lerner index, however, cannot directly be decomposed into factors which contributed to its development as is the case with the RSI. The RSI of firm *i* is measured by the ratio of the aggregate supply capacity remaining in the market after subtracting firm *i*'s capacity, relative to total demand. If the RSI of a firm is below 1, that firm is needed to meet demand, which makes it a so-called pivotal player.

Our paper is related to studies which use structural indicators to analyze the impact of specific factors on competition. Most of these studies are forward looking, formulating scenarios on exogenous events. Küpper et al. (2008), for instance, estimate how an expected increase in cross-border transmission capacity would change the Herfindahl-Hirschman index and RSI. To the best of our knowledge our paper is the first that applies a backward-looking perspective on competition in electricity markets by assessing the impact of *all* major past events on competition through estimating the development of the RSI in a number of counterfactual situations.

By using hourly data over the period 2006–2011, we are able to determine how the different events affected the RSI in the Dutch electricity market in this period. The data refer to production levels, capacities and marginal costs of all centralized production units in this market (NMa, 2007). After determining the hourly merit order we are able to find the system-marginal plant, i.e. the plant with the highest marginal costs which is needed to produce the quantity of electricity demanded by electricity users. For the firm owning the system-marginal plant, we calculate the RSI, which we call the 'market RSI'. Next, we determine how this market RSI would have changed if certain events would not have happened. We define three types of events: market-integration events, firm-level events and changes in the level of residual demand (faced by the major power companies). The market-integration events consist of regulatory extensions of the relevant geographic market. We focus on the following measures: physical extensions of cross-border capacity, market coupling and netting. The firm-level events consist of mergers and acquisitions and changes in the plant portfolio of companies. The demand events capture not only the development in aggregated domestic demand, but also the supply from decentralized generation units. The analysis is conducted for super peak hours, as especially during these hours pivotality plays a role (Borenstein et al., 2002). Super peak hours are defined as 10 am to 7 pm during working days.

Keeping all else equal, we find that the impact of the market-integration events in the Dutch electricity market on the market RSI was approximately 5 times as big (in absolute terms) as the impact of the firm-level events. We further find that another major factor behind competition was the decline in the residual demand, which partly resulted from the growth in decentralized production.

The remaining of this paper is structured as follows. Section 2 describes more extensively the events which have taken place in the European electricity market, focusing on market integration, firm-level events and developments within demand. Section 3 presents the theoretical approach to measure market power, while Section 4 describes the events which have taken place in the Dutch electricity market and how we measure these events. The results are presented in Section 5, while Section 6 concludes.

2. Electricity markets

Electricity markets have a number of characteristics which have to be taken into account in order to understand how competition evolves (Tamaschke et al., 2005). The product is homogeneous, but in the short and medium term, electricity can hardly be substituted by other products, implying that the product market consists only of electricity. More particular, as electricity cannot (efficiently) be stored, the product market consists of a range of consecutive markets in which supply has to be equal to demand. Generation capacity is fixed in the short and medium term because of dynamic constraints on the dispatch of power plants, environmental restrictions and the long lead time of investments. Especially during super peak hours, capacity constraints may occur affecting the intensity of competition (Borenstein et al., 2002). In addition, the relevant geographic market depends on the network characteristics, in particular the capacity of connections with neighbouring networks.

Because of these characteristics, the response of supply to changes in demand is mainly determined by the merit order of power plants. Plants with relatively high marginal costs are only used during super peak hours, while plants having relatively low marginal costs can be used for supplying base load. Note that plants with relatively high marginal costs need to have relatively low fixed costs in order to be able to generate sufficient profits to recoup the investment costs. Plants with relatively low marginal costs may have relatively high fixed costs as they are more often dispatched enabling them to generate sufficient compensation for investment costs. As a consequence of the volatile demand and rather fixed generation capacity, the tightness of the market as well as the positions of individual firms in the merit order change continuously. The position of a firm in the merit order and the steepness of the latter influence both the incentive and possibility of this firm to withhold generation capacity in order to exercise market power and, hence, increase its profits (Green, 2011).

Until the mid1990s, electricity markets in most European countries where characterized by publicly owned, vertically integrated companies operating in isolated regions, exempted from competitive pressure. With the introduction of competition, firms were often split into network operators (both for transmission and distribution) subject to regulatory supervision and commercial electricity companies operating on markets. Together with the introduction of competition, the European Commission pursued integration of national markets into (regional) European markets. One perceived benefit of this integration is that it raises the security of energy supply as a larger variety of energy sources becomes available. For electricity specifically holds that connection of countries using different generation techniques and having different demand profiles, improves productive efficiency. The connection between the Nordic markets and the Dutch market (through the NorNed line), for instance, implies that a mainly hydro-driven system is coupled with a mainly thermal-driven system, which has a different production technique. Integration is also seen as beneficial for competition as it increases the size of the relevant geographic markets and possibly also the number of competitors. A number of regulatory measures have been taken to realize this integration (EC, 2007). Cross-border barriers within the EU have been significantly reduced over the past decade through harmonization of trade conditions, extension of physical connections and more efficient utilization of existing connections.

Simultaneously with the process of integrating national markets, a number of events happened at the firm level. Green (2006) saw an ‘unprecedented wave’ of cross-border mergers and acquisitions. During 1998-2007, the annual number of mergers and acquisitions within the European energy sector increased, while also the average size of the deals grew. In this respect 2007 was a striking year as a number of deals between major energy firms took place (Leveque and Monturus, 2008). In the beginning, most of the deals were domestic, but later on cross-border deals became dominant. Most of the mergers and acquisitions between energy firms took place in the United Kingdom, Italy and Germany. In the former two countries, privatization was a big trigger of this process, while in Germany significant efficiencies could be achieved owing to an industry structure which was highly fragmented. Also the Netherlands showed a relatively high activity of mergers and acquisitions in the energy industry, where foreign firms acquired Dutch firms (Leveque and Monturus, 2008).

The concentration tendencies on firm level may have reduced the intensity of competition in the electricity market. The deals in Germany, for instance, resulted in four companies (E.ON, RWE, Vattenfall Europe and EnBW) having about 80% of the generation capacity, raising the Herfindahl-Hirschman index to about 2,500 (Brunekreeft and Twelemann, 2005) and creating serious concerns about (abuse of) market power (Möst and Genoese, 2009; Bundeskartellamt, 2011; Liebau and Ströbele, 2011). Note, however, that the impact of mergers on consumer welfare is not straightforward as efficiency effects might (partly) compensate for negative effects on competition (Morris and Oska, 2008; Keller, 2010).

More recently, electricity markets are affected by a significant growth in decentralized generation capacity, in particular renewable generation capacity. Wind-powered generation has grown strongly in many countries as it is increasingly becoming economically attractive, partly because of supporting schemes. This holds in particular for Germany, where it has almost doubled to about 25 GW nowadays, but less so for the Netherlands (EWEA, 2012). Solar cell capacity has also strongly increased, in particular in Germany where it grew from about 3 GW a number of years ago to almost 25 GW in 2012. This increase in renewable generation capacity reduces the residual demand for the conventional power plants.

3. Measuring market power

In studies of market power in the electricity market, Cournot models are widely used (e.g. Borenstein et al., 2002; Joskow and Kahn, 2002; Müsgens, 2006; Puller, 2007). These models are in particular useful for short-term analysis when firms face capacity constraints (Willems et al., 2009). In order to decompose the development of market power we use a measure which is related to this type of model.

Let us take a market with n electricity firms. Let C_i be the capacity of firm i and mc_i its constant marginal costs, where $mc_1 \leq mc_2 \leq \dots \leq mc_n$. The system-marginal firm (s) denotes the firm with the largest marginal costs (mc_s) that is used to meet demand. The standard measure for market power of firm i is the Lerner index $L_i = (p-mc_i)/p$, where p is the market price. The Lerner index measures the intensity of competition by the degree to which price exceeds marginal costs. As a benchmark, we first consider perfect competition. The market supply curve (merit order) is then given by a piecewise linear step function such that firms with smaller marginal costs are dispatched first. The system-marginal firm is determined by the point of intersection of the market demand and supply curve. The Lerner index of the system-marginal firm is equal to zero, i.e. under perfect competition this firm has no market power.[3] We notice that the Lerner index of each (capacity-constrained) inframarginal firm with marginal costs smaller than mc_s is positive. This does not reflect some allocative inefficiency, but rather that such a firm can produce more efficiently than the system-marginal firm, i.e. with marginal costs below the competitive equilibrium price. Hence, in order to analyze market power the Lerner index of the system-marginal firm is relevant.

Returning to the Cournot case, we recall that in the equilibrium of the standard model (without capacity constraints) the Lerner index of firm i can be written as $L_i = s_i / \varepsilon$, where s_i is the market share of firm i and ε the (absolute value of the) elasticity of market demand. Hence, the degree of market power of firm i is determined by its market share and the elasticity of demand. The relationship between the Lerner index and market share, however, is not straightforward for the electricity industry where market power strongly depends on the magnitude of demand, given the non-storability of electricity, and the short-term inflexibility of both supply (capacity) and demand (Borenstein et al., 1999; Willems et al., 2009). Therefore, for this industry it is common to relate the market power of a firm to an indicator for its pivotality.

[3] It might happen that the demand curve intersects the supply curve at a point where the latter jumps from level mc_s to mc_{s+1}. In that case $p \in (mc_s, mc_{s+1}]$. For brevity we disregard that case here.

The generally used measure for pivotality is the Residual Supply Index (RSI), which was first introduced by Sheffrin (2002) for the Californian electricity market. The basic formula for the RSI of firm *i* is:

$$RSI_i = \frac{\sum_{j=1}^{n} C_j - C_i}{D}, \qquad (1)$$

where *D* is total demand. The RSI is a dimensionless variable as generation capacity is measured in MW, while demand is measured in MWh/h. As this indicator is a continuous variable, its size indicates the degree of pivotality. The RSI_i measures the aggregate supply capacity remaining in the market after subtracting firm *i*'s capacity, relative to total demand. If the RSI_i is below 1, firm *i* is needed to meet demand, which makes it a pivotal player. Usually a value slightly above 1 (e.g. 1.1) is used as a threshold to determine whether a firm is pivotal because of the need of reserve margins (Twomey et al., 2005). Sheffrin (2002) argues that an electricity market can be viewed as competitive if the RSI is not below 1.1 during more than 5% of all hours. The advantage of the RSI over other structural indicators is that it takes into account the relative position of a firm compared to other producers while also including the magnitude of total demand (Twomey et al., 2005; Gianfreda and Grossi, 2012). The RSI, for instance, acknowledges the fact that not only large, but also small firms can be pivotal, implying that pivotality is not unambiguously related to market shares (Bergman, 2005). For an appropriate measurement of the RSI, it is important to control for contractual commitments of a firm. Hence, the variable C_i should only measure flexible capacity, i.e. the capacity that can be used strategically to exercise market power. Moreover, the RSI should also include the capacity of foreign firms to supply to the market, acknowledging the fact that the relevant geographic market can exceed the domestic market (Arnedillo, 2011).

Newbery (2009) demonstrates that if exactly one firm i is pivotal and all other (non-pivotal) firms $j \neq i$ produce at full capacity, we have

$$L_i = \frac{1}{\varepsilon} - \frac{1}{\varepsilon} RSI_i \,, \qquad (2)$$

i.e. the Lerner index of the pivotal firm is linearly and negatively related to its RSI. We see that in that case the pivotality of firm i determines its potential to raise price above its marginal costs (Bergman, 2005). Newbery further shows that in the equilibrium of a symmetric Cournot oligopoly (where all firms have the same capacity and identical cost functions) in case all firms produce near full capacity, we have

$$L_i \approx \frac{1}{\varepsilon} - \frac{1}{\varepsilon} RSI_i \qquad (3)$$

for all i, i.e. the Lerner index of each firm is approximately linearly and negatively related to its RSI. Because of the symmetry in this case, we have $L_i = L$ and $RSI_i = RSI$ for all i. Finally, Newbery (2009) also considers an asymmetric oligopoly, where firms have different capacities and/or different cost functions, demand is linear and contractual commitments are determined endogenously. In that case, in equilibrium, the Lerner index of each firm remains linearly and negatively related to its RSI. In this relationship both the intercept and coefficient associated with the firm’s RSI are still a decreasing function of ε. However, now their magnitudes are firm-specific since they also depend on other factors, in particular the capacities and marginal costs of firms as well as the number of firms.

In our empirical analysis we focus on the residual supply index of the system-marginal firm (RSI_s), which we call the market RSI. This index can be seen as a key determinant of the intensity of competition in the electricity market, since it can be related to the Lerner index on the system level (L_s). Note, however, that the impact of the market RSI on competition changes if the price elasticity of demand changes. Therefore, in our empirical analysis we will check whether our general findings using the market RSI are consistent with the development of the Lerner index L_s.

In order to determine the effect of specific events on the market RSI, we calculate its value for different counterfactuals. To illustrate this, let us write the market RSI in period t as

$$RSI_s(t) = \frac{X(t)}{D(t)}, \tag{4}$$

where $X(t) = \sum_{j=1}^{n} C_j(t) - C_s(t)$. In each counterfactual we suppose that specific changes have not occurred. First, consider the counterfactual in which X remains at the initial level of period t, while D is allowed to move to its level of period $t + \Delta t$. Hence, we suppose that the past change in X has not taken place. The difference between the actual market RSI in period $t + \Delta t$ and the market RSI under this counterfactual is given by

$$B_{X|D(t+\Delta t)} = \frac{X(t+\Delta t)}{D(t+\Delta t)} - \frac{X(t)}{D(t+\Delta t)}. \tag{5}$$

We call this difference the basic effect (*B*) of the change in *X*, while *D* is allowed to move to its level of period $t + \Delta t$. Next, consider the counterfactual where *D* stays at the level of period *t*, while *X* is allowed to move to its level of period $t + \Delta t$. Now we suppose that the past change in *D* has not taken place. In that case the basic effect of the change in *D*, while *X* moves to its level of period $t + \Delta t$, reads

$$B_{D|X\,(t+\Delta t)} = \frac{X\,(t+\Delta\, t)}{D(t+\Delta\, t)} - \frac{X\,(t+\Delta\, t)}{D(t)}. \tag{6}$$

Using this, we obtain the decomposition

$$RSI_s(t+\Delta\, t) \;\; - \;\; RSI_s\,(t) = B_{X|D(t+\Delta t)} + B_{D|X\,(t+\Delta t)} \;\; - \;\; F\,, \tag{7}$$

where

$$F = B_{X|D(t+\Delta t)} \;\; - \;\; B_{X|D(t)} \tag{8}$$

and

$$B_{X|D(t)} = \frac{X(t+\Delta t)}{D(t)} \;\; - \;\; \frac{X(t)}{D(t)}. \tag{9}$$

Hence, the difference between the market RSI in periods *t* and $t + \Delta t$ can be decomposed as the summation of the basic effects (5) and (6) minus a correction term *F*. The presence of *F* reflects that, contrary to what has been assumed in each of the counterfactuals associated with (5) and (6), *X* and *D* in fact have changed simultaneously. Notice that *F* is equal to the difference between the basic effects of the change in *X*, while *D* is allowed to move to its level in period $t + \Delta t$ or stays at the level of period *t*, respectively (see (5) and (9)).

4. Events in the Dutch electricity market

We distinguish three types of influences on competition in the Dutch electricity market: enlarged connection with other markets, firm-level events (in particular changes in the generation portfolio and mergers and acquisitions) and, finally, changes in the magnitude of residual demand (which is total demand minus the supply from decentralized generation units). Including these three factors, we obtain the following modified formula for the RSI of firm *i*:

$$RSI_i = \frac{TC + IC - C_i}{TP + I - E}, \qquad (10)$$

where *TC* is total domestic (flexible) generation capacity, *IC* available import capacity, *TP* total domestic production, *I* import and *E* export. We define the available import capacity as the available transfer capacity, which is equal to total technical capacity minus the transmission reliability margin and minus the already allocated capacity.

4.1 Market-integration events

As a part of the broader EU market integration project, the Dutch electricity market has become more integrated with the neighbouring markets. This integration is reflected in enlarged cross-border transport capacity. The total size of the technical (nominal) import capacity grew from 3.9 GW in 2006 to 5.6 GW in 2011, which is more than 20% of the total domestic generation capacity of 26.6 GW (TenneT, 2012a). This increase resulted from NorNed, the connection with the Nordic electricity market of 0.7 MW which was realized in 2008, and BritNed, the connection with the UK market of 1 GW which was realized in 2011. Fig. 1 depicts the available import capacity (i.e. the capacity which can be used for commercial transactions) for each super hour in 2006-2011. The available capacity can be below the technical import capacity as a result of loop flows, technical disturbances and maintenance activities (TenneT, 2012a).

Besides these measures directly raising the available cross-border transmission capacity, a number of other regulatory measures were taken to increase the efficiency of the utilization of the capacity, in particular market coupling and netting. Market coupling means that traders which are active in each of the coupled markets (i.e. having programme responsibility in each market) are able to submit orders to the commodity markets (i.e. power exchanges) without paying attention to the availability of cross-border capacity. The power exchanges set the clearing price given these orders and the available day-ahead transport capacity (Küpper et al., 2008). This allocation scheme of cross-border capacity is also referred to as implicit auctioning, compared to the explicit auctioning process where traders have to buy transport capacity in advance. Note that market coupling refers to the day-ahead markets only. For monthly and yearly contracts, the capacity is still allocated explicitly. In the near future, market coupling will be introduced for the intraday markets as well.

In November 2006, market coupling was introduced in the market with France and Belgium (the so-called Trilateral Market Coupling) while in November 2010 market coupling was realized on the German-Dutch border. In November 2010, an intermediate form of volume coupling was introduced at NorNed, meaning that the traded quantities are calculated first, while afterward the prices are calculated. This interim form of market coupling will be replaced by full market coupling in the near future.

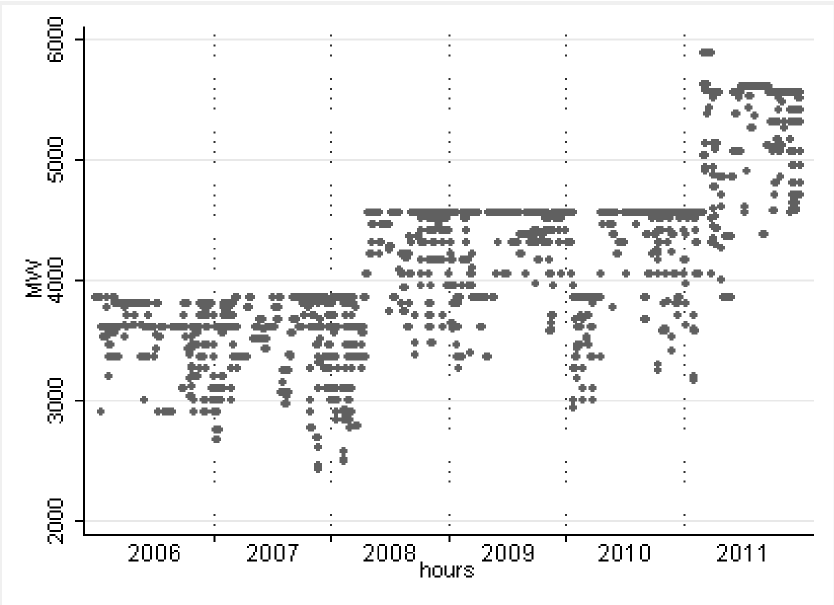

Fig. 1. Available import capacity (MW) in the Dutch electricity market, 2006-2011 (super peak hours).

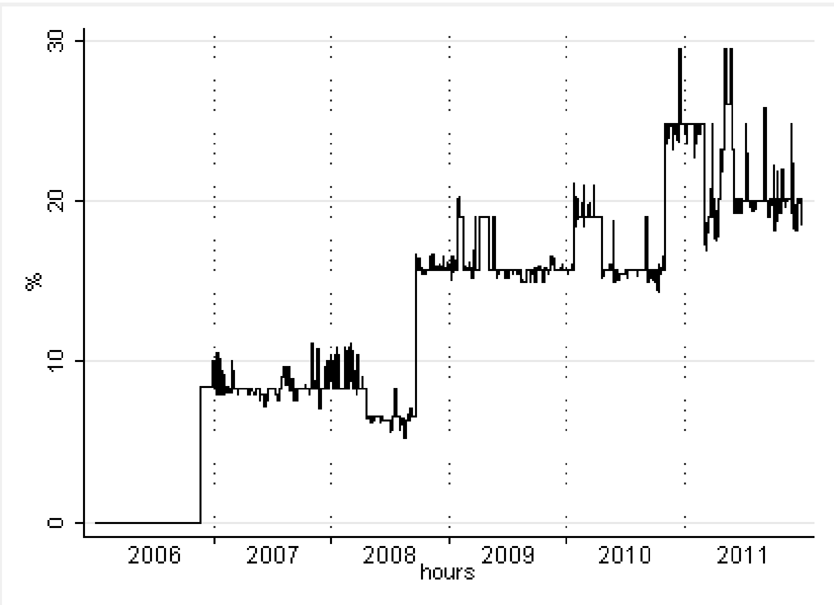

Fig. 2. Effect of market coupling and netting on the available import capacity, in % of the technical import capacity, in the Dutch electricity market, 2006-2011 (super peak hours).

The direct result of market coupling is that the transmission capacity is utilized more efficiently (Küpper et al., 2008; Jullien et al., 2011). A more efficiently used transmission line can be viewed as an increase in the available cross-border capacity. We estimate the impact of market coupling on the utilization of the cross-border infrastructure through the occurrence of inefficient cross-border flows before and after market coupling (see Appendix A).

Another measure which increases the interconnection capacity is netting. With netting, the Transmission System Operator (TSO) nets out bidirectional long-term contracts. As a result, electricity can be exported or imported commercially, but physically it stays in the country where it is generated. This measure effectively increases the import capacity available on the day-ahead market by the net size of the bidirectional long-term export contracts (see Appendix A). In November 2008, netting was introduced on the connections with Belgium and Germany. On NorNed, netting is not possible as here only a short-term market exists, while netting is implemented by making the difference between long-term export and import contracts available for short-term trade.

It appears that the introduction of market coupling on the Dutch-Belgian border (November 2006) and Dutch-German border (November 2010) and netting (November 2008) had a significant impact on the availability of import capacity (Fig. 2). The brief decline in 2008 results from the realization of the NorNed line, which increased the total amount of import capacity and, hence, reduced the relative effect of market coupling. The same holds for the decline in 2011 which resulted from the realization of the BritNed line.

4.2 Firm-level events

We distinguish two types of firm-level events: changes in generation portfolio and financial deals between firms resulting in mergers and acquisitions. The former type of events is taken into account by using time-series data on generation capacity per firm, based on data from (NMa, 2007). The same holds for mergers and acquisitions between domestic firms. Table 1 shows that the major six firms in the market have different portfolios. Some firms have a relatively large number of plants, while others only have one or two plants.

Table 1

Characteristics of plant portfolio per firm in the Dutch electricity market, on average over 2006-2011.

	Number of plants	Average available capacity per plant (MW)	Average maximum (technical) capacity per plant (MW)
Firm 1	11	318	382
Firm 2	14	198	223
Firm 3	7	216	236
Firm 4	13	160	258
Firm 5	1	713	810
Firm 6	2	257	435

Fig. 3 depicts how the generation capacity of the major electricity companies evolved over 2006-2011. Most of these firms changed their generation portfolio by investments or divestments: some firms enlarged the generation capacity, while other firms had a stable or even declining portfolio.

During the period that the national markets became more integrated, electricity firms became more international as well. Before 2001, the Dutch electricity wholesale market was dominated by four large national players: Electriciteitsbedrijf Zuid Holland (EZH), Utrecht, Noord-Holland, Amsterdam (UNA), Electriciteits Produktiemaatschappij Oost- en Noord-Nederland (EPON), and Electriciteits Produktiemaatschappij Zuid-Nederland (EPZ). Since then, a restructuring process started resulting in the new Dutch companies Essent, Nuon, Eneco and Delta. The former two companies have been taken over by the German company RWE and the Swedish company Vattenfall, respectively. The German company E.ON and the Belgian company Electrabel also entered the Dutch market.

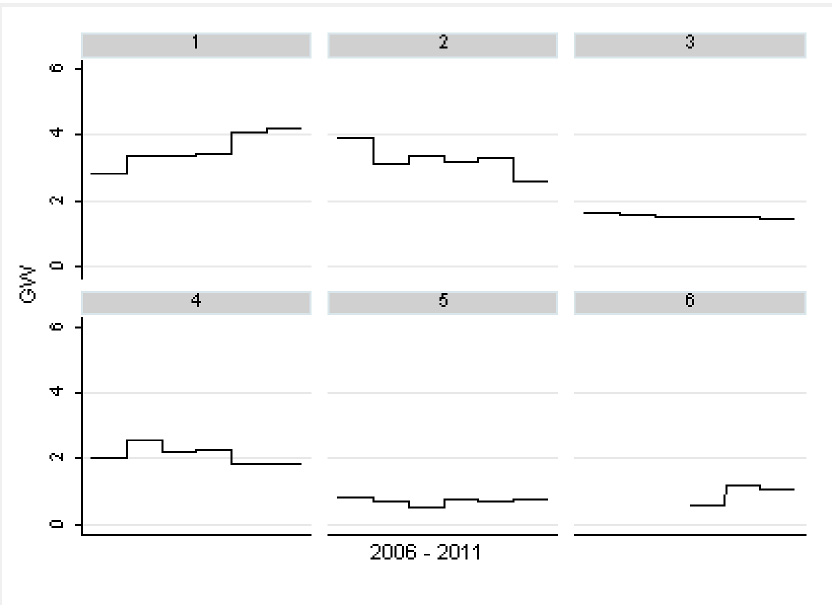

Fig. 3. Generation capacity (GW) per firm in the Dutch electricity market, 2006-2011.

The impact of cross-border mergers and acquisitions on the market RSI depends on the availability of import capacity. If a domestic firm is acquired by a company in a neighbouring country, this can be seen as if it obtains access to generation capacity in that neighbouring country. The access to that capacity can be restricted by the available import capacity. Hence, the import capacity influences the total volume the firm can sell at the domestic market, and, hence, the incentives to withhold electricity in order to increase spot prices (Gilbert et al., 2002). In the Dutch electricity market the amount of long-term cross-border capacity one firm may obtain was legally constrained at 400 MW until 2012 (Elektriciteitswet, 1998). This implies that the effect of a cross-border merger on a firm's capacity was also limited by that constraint. In other words, if a domestic electricity company was acquired by a company in a neighboring country, the available generation capacity of the new (merged) firm for the domestic market was increased by the firm-level constraint on import capacity (which was 400 MW). Notice, however, that using cross-border capacity is not free of charge. Therefore, owning generation capacity on the other side of the border is not fully equal to having extra capacity in the domestic market.

4.3 Changes in residual demand

Finally, changes in residual demand directly affect the market RSI. The higher the residual demand, the more the centralized units are needed which is reflected by a lower RSI. The relevant demand can be based on the net load of the Dutch system, which is equal to actual domestic generation by the centralized production units plus import minus export. Over the period 2006-2011, the net load on this network shows a declining trend (Fig. 4), which can be partly attributed to the general economic downturn after the outbreak of the financial crisis (TenneT, 2012b) .

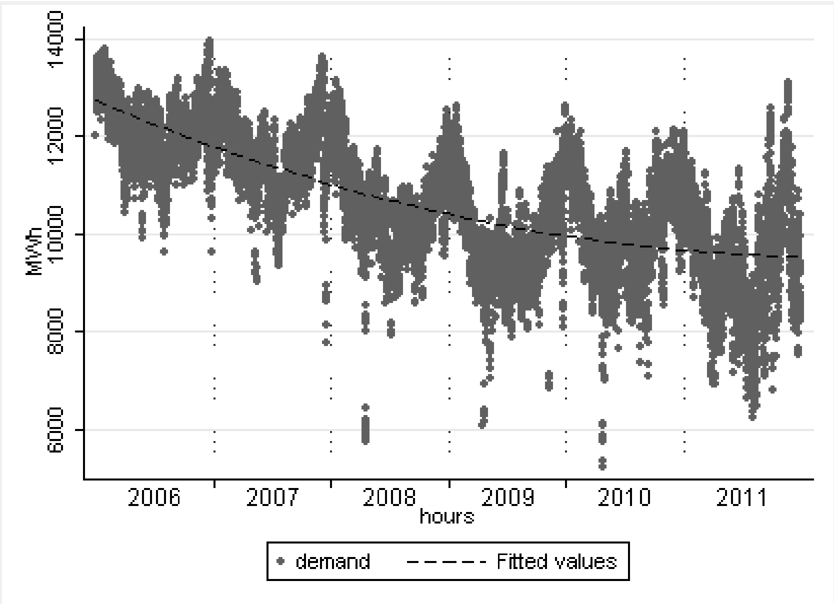

Fig. 4 Residual demand for electricity (MW/h) in the Dutch electricity market, 2006-2011 (super peak hours).

To some extent, the decline in residual demand is caused by an increase in decentralized production: on annual basis, the production by decentralized units increased from 31.7 TWh in 2006 to 42.2 TWh in 2011, while the production by the centralized units remained about the same (CBS, 2012). As a result the share of centralized generation in total domestic generation decreased from 68% in 2006 to 64% in 2011. The demand for electricity also shows a seasonal pattern as electricity is relatively strongly used for lightning.

5. Results

5.1 Counterfactuals

The decomposition of the changes in competition in the Dutch electricity market is done by defining a number of variants in which we exclude one or more events (Table 2). In variant A all events are included, which means that this variant describes the actual development of the market RSI. All other variants refer to counterfactuals in which one or more events are excluded. For each variant, the market RSI is calculated for each hour over the period 2006-2011.[4] The differences in the market RSI between variant A and the other variants indicate the effect of the respective events.

The counterfactuals of no market coupling or netting are determined by not correcting the physical import capacity for the impact of these regulatory measures (see Appendix A). The counterfactual of no NorNed line and no BritNed line is defined as the actual available import capacity minus the respective sizes of these lines. As the counterfactual of the changes in the generation portfolio, we use the average firm capacity in 2006. The counterfactual of the acquisitions of Nuon by Vattenfall and Essent by RWE is that the former Dutch companies do not see a rise in access to foreign generation capacity which resulted from these events. For the demand events, finally, we set the counterfactual by correcting the hourly demand values for the change in the average annual values compared to 2006. For instance, if the average 2006-level is x% lower than the average 2007 level, we decrease the hourly values in 2007 by x%.

[4] See Appendix B for descriptive statistics of the market RSI per variant per year. Note that variant (I) shows some fluctuations in the RSI over time, while this variant does not include any of the three events. These fluctuations follow from remaining changes within separate years.

Table 2

Definitions of variants: which events are (not) included?

Variant	Market-integration events			Firm-level events		Demand events
	Market coupling	Netting	NorNed and BritNed	Changes in generation capacity	Mergers and acquisitions	
A	+	+	+	+	+	+
B	-	-	+	+	+	+
C	+	+	-	+	+	+
D	-	-	-	+	+	+
E	+	+	+	+	-	+
F	+	+	+	-	+	+
G	+	+	+	-	-	+
H	+	+	+	+	+	-
I	-	-	-	-	-	-

Note: + (-) means (not) included.

5.2 Findings

The market-integration events increased the market RSI in 2011 by 0.26, hence they reduced the potential market power in the Dutch electricity market (Fig. 5 and Table 3). The impact of the connection with the Nordic power market (the NorNed line) and the UK market (the BritNed line) is about equal to the combined impact of market coupling and netting.

Table 3

Difference of the mean of the market RSI per variant, 2011 (super peak hours).

Comparison of RSI	Comparison refers to effect of:	Mean	St. error	t-test
Market-integration events				
RSI (A) - RSI (B)	Market coupling and netting	0.11	0.0003	335
RSI (A) - RSI (C)	NorNed and BritNed	0.15	0.001	112
RSI (A) - RSI (D)	Market coupling, netting, NorNed and BritNed	0.26	0.002	177
Firm-level events				
RSI (A) - RSI (E)	Mergers and acquisitions	-0.02	0.0004	-39
RSI (A) - RSI (F)	Changes in generation portfolio	-0.03	0.002	-15
RSI (A) - RSI (G)	Mergers and acquisitions and changes in generation portfolio	-0.05	0.002	-26
Demand events				
RSI (A) - RSI (H)	Changes in average annual level of demand	0.35	0.001	313
All events				
RSI (A) – RSI (I)		0.52	0.002	199

Note: the sum of the market-integration events (0.26), firm-level events (-0.05) and demand events (0.35) equals 0.56, which is 0.04 higher than the overall effect (0.52). This difference results from the interaction between the events (which is *F* in equation (7)).

The firm-level events had a relatively small impact on the market RSI (Fig. 6 and Table 3). On average, the firm-level events reduced the market RSI in 2011 by 0.05. The impact of mergers and acquisitions on the RSI is about equal to the impact of changes in the size of the generation capacity per firm. In the years 2006–2008, the firm-level events hardly had an effect on the market RSI, but in more recent years these events resulted in firms obtaining more market power. This follows from the fact that one major power firm increased its generation capacity significantly, while another major firm showed a decreasing level of capacity.

The changes in the residual demand caused a relatively large effect on the market RSI. (Fig. 7 and Table 3). On average, they raised the market RSI in 2011 by 0.35.

The overall effect of the market-integration, firm-level and demand events is shown in Fig. 8. Without these events the market RSI would be 1.03 in 2011, while it actually was 1.55 (see Appendix B), which gives an overall effect in 2011 of 0.52. This indicates that the intensity of competition has strongly increased. The relative contributions of the three types of events can also be seen from the duration curves in Fig. 9. The firm-level events have a small downward effect on the market RSI, as the duration curve excluding these events (variant G) is above the duration curve including all events (variant A). Both the market-integration events and the demand events have a strong upwards effect on the market RSI, as the duration curve excluding these events (variant D and variant H, respectively) is significantly below the RSI of variant A, which includes all events. The duration curve belonging to variant I shows that without each of the events, 2011 would have had many super peak hours with a pivotal player.

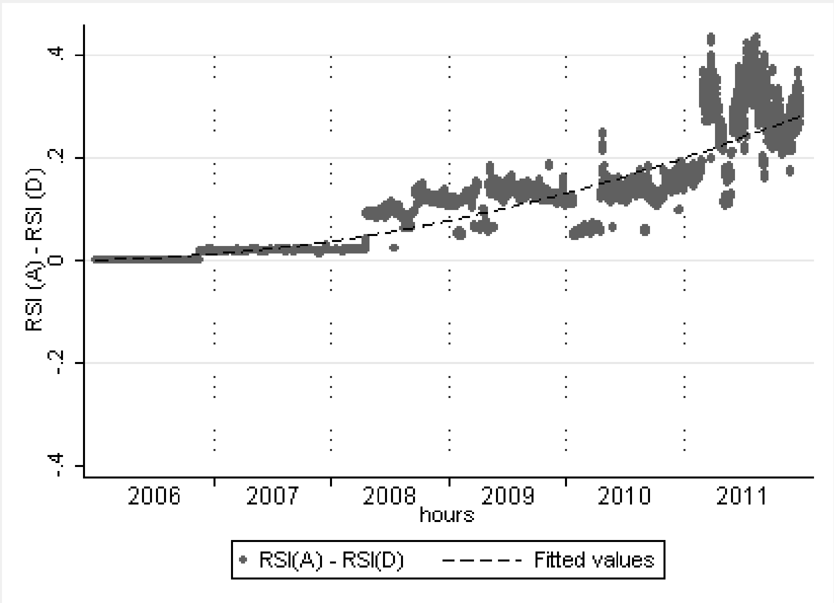

Fig. 5. Effect of market-integration events on the market RSI in the Dutch electricity market, 2006-2011 (super peak hours).

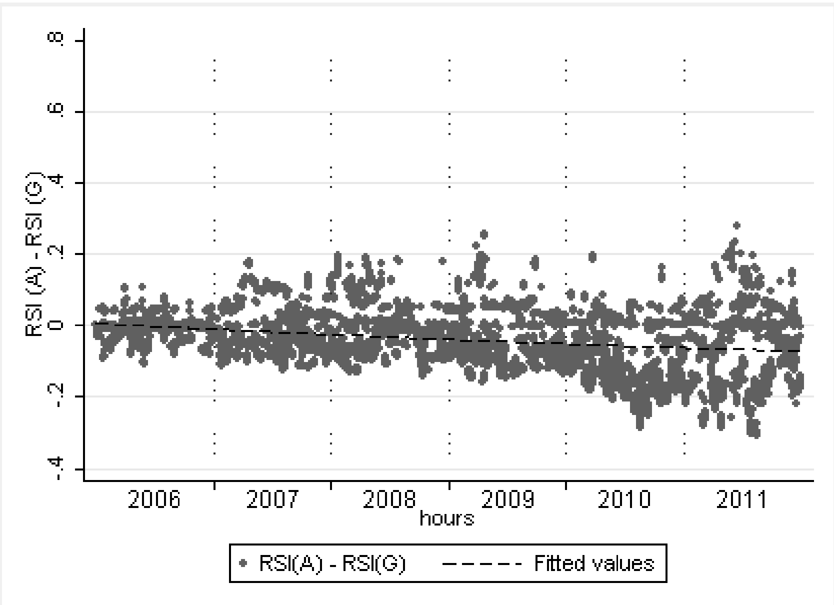

Fig. 6. Effect of firm-level events on the market RSI in the Dutch electricity market, 2006-2011 (super peak hours).

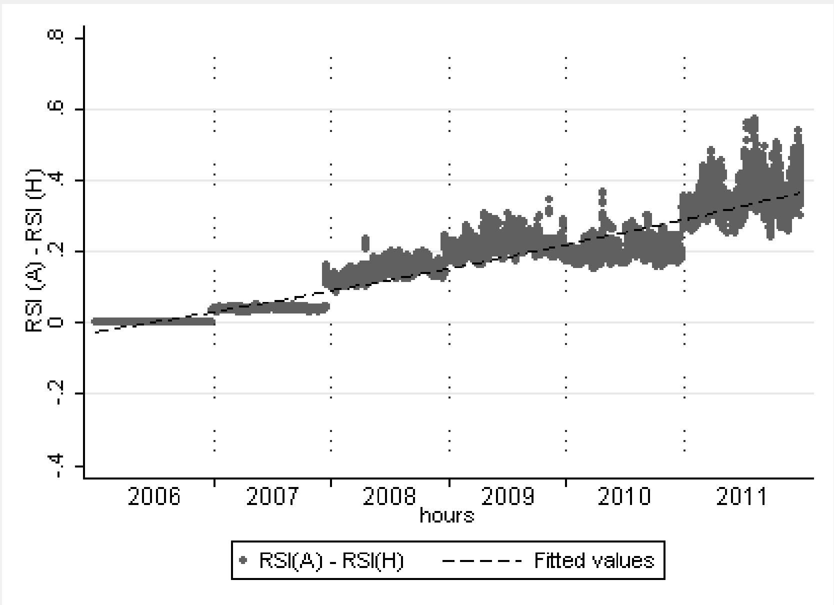

Fig. 7. Effect of demand events on the market RSI in the Dutch electricity market, 2006-2011 (super peak hours).

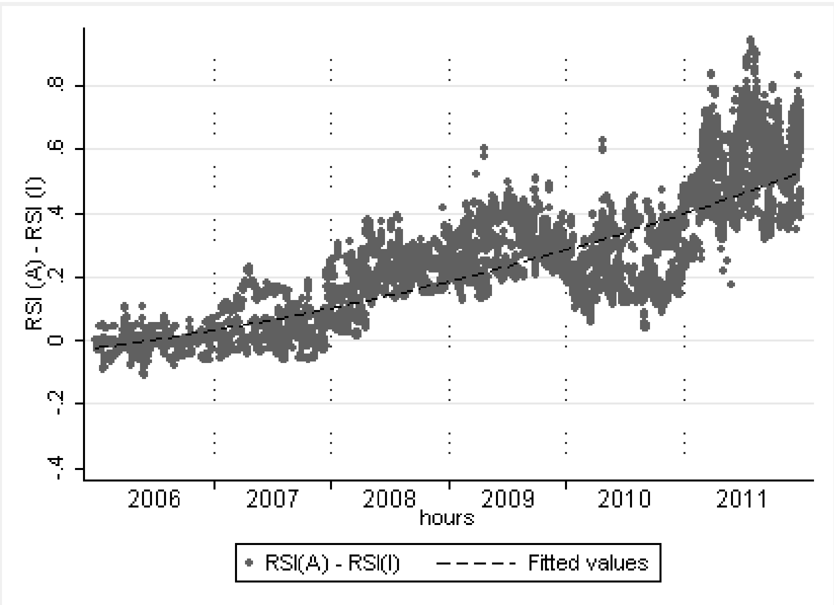

Fig. 8. Overall effect of all events on the market RSI in the Dutch electricity market, 2006-2011 (super peak hours).

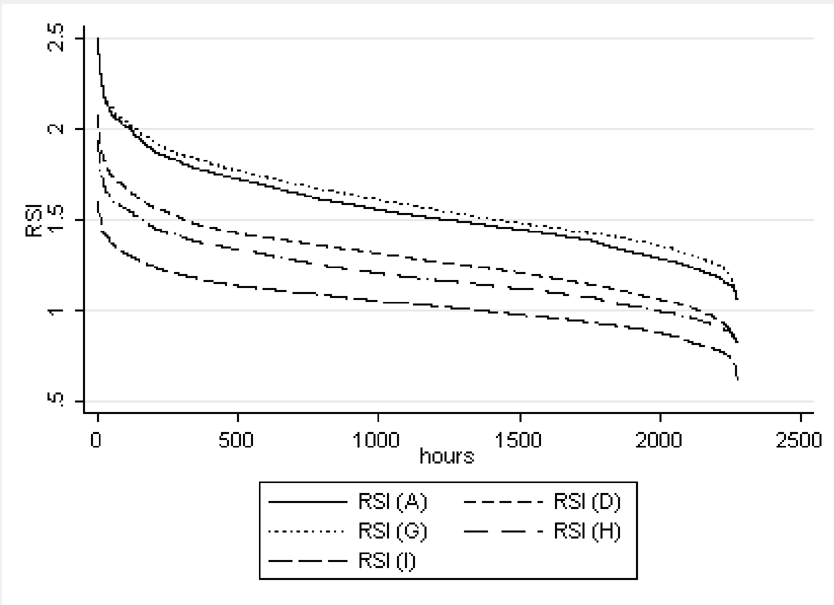

Fig. 9. Duration curves of the market RSI in the Dutch electricity market in five variants, 2011 (super peak hours).

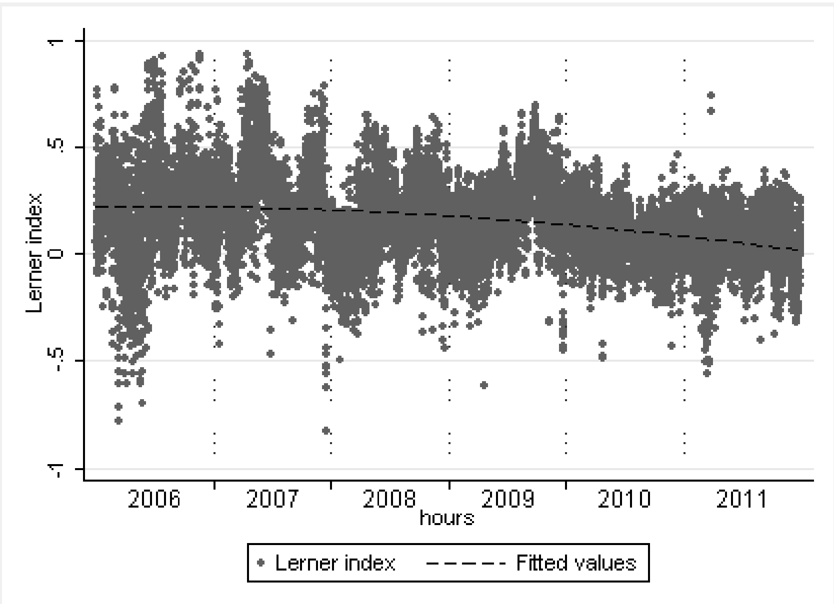

Fig. 10. Lerner index of the system-marginal firm in the Dutch electricity market, 2006-2011 (super peak hours).

Because of the relationship between the market RSI and the Lerner index (L_s) of the system-marginal firm, the L_s should have declined given the increase in the market RSI. In order to check for this, we present Fig. 10. It shows that L_s has a declining trend. The average annual values of this Lerner index in the period 2006-2011 are equal to 0.22, 0.26, 0.15, 0.19, 0.08, 0.06, respectively. Hence, at the end of this period the average annual Lerner index has approached the value which belongs to competitive markets, i.e. 0. The correlation coefficient between the market RSI and L_s is equal to -0.22, which confirms the negative relationship between these two variables.

6. Conclusion

We find that the regulatory market-integration events have more than eliminated the negative effects of firm-level events on competition in the Dutch electricity market. The latter have only had a minor impact on the intensity of competition, which results from the fact that no major mergers between domestic companies have occurred during the period of analysis while the plant portfolios stayed relatively stable. Regarding the market-integration events we find that the impact of the virtual cross-border extensions (market coupling and netting) almost equals the impact of the physical extensions of the cross-border grid (the NorNed line and BritNed line). Another important factor behind the market RSI appears to be the development of the residual demand. The decrease in overall domestic electricity consumption as a result of the economic downturn after the outbreak of the financial crisis as well as the increase in decentralized generation have reduced the demand for the centralized production units, making them less pivotal. We conclude, therefore, that regulatory measures to improve competition in the Dutch electricity market have been effective, but that changes in the residual demand appear to be equally important.

These general findings appear to be consistent with the development of the Lerner index of the system-marginal firm. While the market RSI shows an increasing trend during the period of analysis, the Lerner index shows a decreasing trend: both developments indicate that the intensity of competition in the Dutch electricity market has risen. From both the market RSI and Lerner index we conclude that the Dutch electricity market has become fairly competitive. Given the intended further increase in cross-border capacity and the continuing growth in renewable generation capacity, we expect that the intensity of competition in the Dutch market will remain high.

We conclude that the market RSI is a useful measure for determining with hindsight the contribution of the major factors behind the intensity of competition in electricity markets. Our findings regarding the relative importance of several factors affecting competition helps to determine effective policy measures to improve competition in electricity markets.

In applying this method, one should notice a few caveats. Our decomposition method implicitly assumes that the different type of events are not mutually related. This assumption holds for some events, such as the development in the residual demand and the market-integration events. The firm-level events, however, might to some extent be related to the other types of events, insofar they affect the expected profitability of investments in power plants, and mergers and acquisitions. Stated differently, if the market-integration events would not have taken place, electricity companies might have had stronger incentives to extend generation capacity in the Dutch market. Moreover, one should be aware of the fact that increasing interconnection with neighbouring countries not necessarily results in more intensive competition, as the precise impact on competition also depends on the industry structure and relative magnitude of the generation capacity in these countries.

ACKNOWLEDGEMENTS

The authors are grateful for comments received from colleagues at the NMa and RUG and for the research assistance provided by Michiel Dotinga and Mark Hartog van Banda. The authors are, however, fully responsible for any remaining shortcomings. The contents of this paper do not constitute any obligation on the NMa.

References

Arnedillo, O., 2011. What does the evidence really say about the residual supply index? The Electricity Journal. 24, 57-64.

Bergman, L., 2005. Addressing market power and industry restructuring. Paper presented at the Conference 'Implementing the internal market of electricity: proposals and time-tables', Brussels, 9 September.

Borenstein, S., Bushnell, J., Knittel, C.R., 1999. Market power in electricity markets: beyond concentration measures. The Energy Journal. 20, 65-88.

Borenstein, S., Bushnell, J.B., Wolak, F.A., 2002. Measuring market inefficiencies in California's restructured wholesale electricity market. American Economic Review. 92, 1376-1405.

Brunekreeft, G., Twelemann, S., 2005. Regulation, competition and investment in the German electricity market: RegTP or REGTP. The Energy Journal. 26, 9-126.

Bundeskartellamt, 2011. Sector inquiry into electricity generation and wholesale markets. Bonn, January.

CBS, 2012. http://statline.cbs.nl/StatWeb/default.aspx.

EC (European Commission), 2007. DG Competition report on energy sector inquiry, Brussels.

Elektriciteitswet, 1998. http://wetten.overheid.nl/BWBR0009755/geldigheidsdatum_14-11-2012/informatie (November 2012).

EWEA (European Wind Energy Association), 2012. Wind in power: 2011. European Statistics, February.

Farrell, J. , Shapiro, C., 1990. Horizontal mergers: an equilibrium analysis. American

Economic Review. 80, 107-126.

Gianfreda, A., Grossi, L., 2012. Forecasting Italian electricity zonal prices with exogenous variables. Energy Economics. 34, 2228-2239.

Gilbert, R., Neuhoff, K., Newbery, D.M., 2002. Allocating transmission to mitigate market power in electricity networks. Harvard Electricity Policy Group, Cambridge (MA).

Green, R., 2006. Electricity liberalisation in Europe—how competitive will it be? Energy Policy. 34, 2532-2541.

Green, R. 2011. Did English generators play Cournot? Capacity withholding in the electricity pool. Imperial College Business School, October.

Joskow, P.L., Kahn. E., 2002. A quantitative analysis of pricing behaviour in California's wholesale electricity market during summer 2000. The Energy Journal. 23, 1-36.

Jullien, C., Pignon, V., Robin, S., Starapoli, C., 2011. Coordinating cross-border congestion management through auctions: an experimental approach to European solutions. Energy Economics. 34, 1-13.

Keller, A., 2010. Competition effects of mergers: an event study of the German electricity market. Energy Policy. 38, 5264-5271.

Küpper, G., Delarue, E., Delvaux, B., Meeus, L., Bekaert, D., Willems, B., Proost, S., D'Haeseleer, W., Deketelaere, K., Belmans, R., 2008. Does more international transmission capacity increase competition in the Belgian electricity market? Katholieke Universiteit Leuven, TME Working Paper EN2008-010.

Leveque, F., Monturus, R., 2008. Mergers & Acquisitions within the European power and gas sectors; cases and patterns. CERNA, Ecole des Mines de Paris, January.

Liebau, B., Ströbele, W.J., 2011. The shortcomings of the architecture of the German electricity market. The Electricity Journal. 25, 21-28.

Morris, J., Oska, D., 2008. The likely effect of the proposed Exelon-PSEG merger on the wholesale electricity prices. The Electricity Journal. 21, 45-54.

Möst, D., Genoese, M., 2009. Market power in the German wholesale electricity market. The Journal of Energy Markets. 2, 47-74.

Müsgens, F., 2006. Quantifying market power in the German wholesale electricity market using a dynamic multi-regional dispatch model. The Journal of Industrial Economics. 4, 471-498.

Newbery, D.M., 2009. Predicting market power in wholesale electricity markets. Cambridge working papers in economics 0837.

NMa (Netherlands Competition Authority), 2007. Monitor energy markets 2007; an analysis of developments in the Dutch wholesale markets for gas and electricity. The Hague.

Puller, S.L., 2007. Pricing and firm conduct in California's deregulated electricity market. Review of Economics and Statistics. 89, 75-87.

Shapiro, C., 1989. Theories of oligopoly behaviour. In: Schmalensee R.,Willig, R., (Eds.), Handbook of industrial organization, volume 1. North-Holland, Amsterdam, pp. 329-414.

Sheffrin, A., 2002. Predicting market power using the residual supply index. Presented to FERC market monitoring workshop, December 3-4 2002.

Swinand, G., Scully, D., Ffoulkes, S., Kesller, B., 2008. Modelling EU electricity market competition using the Residual Supply Index. London Economics, 1-22.

Tamaschke, R., Docwra, G., Stillman, R., 2005. Measuring market power in electricity generation: a long-term perspective using a programming model. Energy Economics. 27. 317-335.

TenneT, 2012a. Rapport monitoring leveringszekerheid 2011-2027. RGE 2012-155.

TenneT, 2012b. http://www.tennet.org/tennet/publicaties/Elektriciteitsverbruik.aspx. November 2012.

TenneT, 2012c. http://energieinfo.tennet.org/. November 2012.

Twomey, T., Green, R., Neuhoff, K., Newbery, M.D., 2005. A review of the monitoring of market power: the possible roles of transmission system operators in monitoring market power issues in congested transmission systems. Journal of Energy Literature. 11, 3-54.

Willems, B., Rumiantseva, I., Weigt, H., 2009. Cournot versus supply functions: what does the data tell us? Energy Economics. 31, 38-47.

Appendix A: Effect of market coupling and netting on the utilization of the import capacity

We estimate the impact of market coupling on the utilization of the cross-border infrastructure through the occurrence of inefficient cross-border flows before and after market coupling. If the import capacity is efficiently utilized, there would be no differences in prices on both sides of the border unless the capacity would be fully (physically) utilized. We measure the efficiency of the utilization (*e*) as follows:

$$e_t = \frac{I_t}{IC_t + E_t}, if \Delta P_t > 0, \qquad \text{(A.1)}$$

where ΔP is the difference between the domestic price of electricity and the price in the neighbouring country, *I* import, *IC* available import capacity, *E* export and *t* the index for hours. If $\Delta P > 0$, import is profitable, export in the opposite direction is not. With complete cross-border price arbitrage, exports should be zero while the import capacity should be fully utilized, reflected by an *e* of 1. If, however, import is below the import capacity and/or export is positive when ΔP is positive, the cross-border capacity is inefficiently used, and the *e* is below 1. Note that the efficiency of the import capacity is only calculated for those hours when the domestic price exceeds the price in the neighboring country.

Fig. A.1 presents the hourly values of *e* for the Dutch-German border, both before and after the introduction of market coupling. It clearly shows that before the introduction of market coupling, in many hours the import capacity was not efficiently used: the APX price exceeded the EEX price without a full utilization of the import capacity.

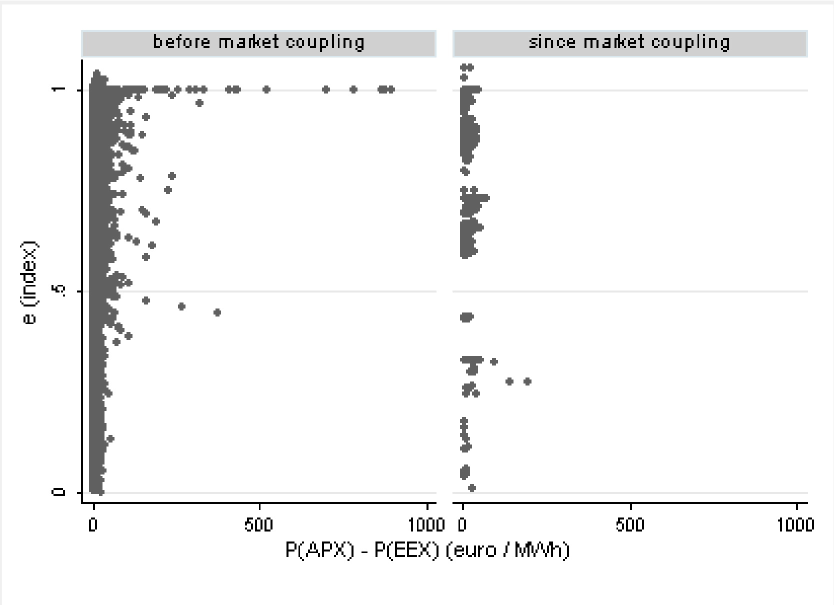

Fig. A.1. Efficiency of the utilization of Dutch-German import capacity, 2006-2011, all hours when P(APX) > P(EEX).

We use the average values of *e* in both periods (i.e. before and after the introduction of market coupling) in order to estimate the impact of market coupling on the efficiency of the utilization of the import capacity. For each period, this average value (*E*) is determined as

$$E = \frac{\sum_{t=1}^{T} e_t}{T}, \tag{A.2}$$

where T is the number of hours with a positive price difference per period. Since border-specific data on import flows is not available for 2006, we are not able to conduct this analysis for the impact of the introduction of market coupling on the Dutch-Belgian border as here this measure was already introduced in 2006. Therefore we estimate E for the Dutch-German border. Here, we find that the average E was 0.63 before the introduction of market coupling and 0.82 afterwards. For each average it holds that the corresponding standard error is smaller than 0.01, implying that the two averages differ strongly from each other. We apply these values as estimates of the efficiency of the utilization of the import capacity with both Germany and Belgium during all hours in the respective periods.

The impact of netting on the available import capacity is estimated through the available day-ahead transport capacity. Netting means that this capacity increases by the net amount of bidirectional long-term (i.e. monthly and yearly) contracts. According to TenneT (2012c), "the available transfer capacity for one day in one direction will be the difference between the net transfer capacity (NTC) in this direction and the difference between the long term (yearly and monthly) total nominated value in this direction and the long term (yearly and monthly) total nominated value in the other direction."

Because data on the nominated long-term capacity is not published, we use data on the available short-term capacity. For the Dutch-Belgian border the data is available since November 2006, but for the Dutch-German border only since November 2009. As netting has been introduced in November 2008 on both borders, we use the data on the Dutch-Belgian border from TenneT (2012c). It appears that before the introduction of netting, the available day-ahead capacity was on average 79% of the total import capacity. Afterwards, the day-ahead capacity was on average 102% compared to the total import capacity. For each average it holds that the corresponding standard error is smaller than 1%, implying that the two averages differ strongly from each other. We apply these values as estimates of the impact of netting on the available import capacity with both Germany and Belgium during all hours in the respective periods.

The available import capacity (*IC**) after taking into account market coupling and netting can now be calculated as follows:

$$IC^* = E\,.\,\alpha\,.\,IC + \beta\,.\,IC\,, \qquad \text{(A.3)}$$

where α is the ratio of day-ahead capacity and total import capacity, and β is the share of long-term capacity in total import capacity. The value of β is equal to 1 minus the share of day-ahead capacity before the introduction of netting.

The size of the available import capacity in the counterfactual of no market coupling and netting is determined by using the pre-market-coupling values of *E* (i.e. 0.63) and α (i.e. 0.79), respectively.

Appendix B: Descriptive statistics of the market RSI in the different variants

Table B.1

Market RSI per variant per year, 2006-2011, annual average (super peak hours).

Year	RSI(A)	RSI(B)	RSI(C)	RSI(D)	RSI(E)	RSI(F)	RSI(G)	RSI(H)	RSI(I)
2006	0.93	0.93	0.93	0.93	0.93	0.94	0.94	0.93	0.94
2007	1.00	0.98	1.00	0.98	1.00	1.02	0.96	0.96	1.03
2008	1.11	1.08	1.07	1.04	1.11	1.13	1.13	0.97	0.93
2009	1.26	1.20	1.20	1.14	1.26	1.29	1.29	1.05	0.98
2010	1.28	1.21	1.22	1.16	1.28	1.36	1.37	1.08	1.06
2011	1.55	1.44	1.40	1.29	1.57	1.58	1.60	1.20	1.03

Table B.2

Number of hours the market RSI is below the threshold value of 1.1, per variant per year, 2006-2011 (super peak hours).

Year (# hours)	RSI(A)	RSI(B)	RSI(C)	RSI(D)	RSI(E)	RSI(F)	RSI(G)	RSI(H)	RSI(I)
2006 (2259)	2112	2118	2112	2118	2112	2119	2119	2112	2126
2007 (2205)	1904	2001	1904	2001	1904	1683	1683	2084	2015
2008 (2313)	1090	1312	1421	1636	1090	1075	1075	1889	2022
2009 (2304)	336	543	544	878	332	217	197	1566	1934
2010 (2322)	165	553	430	975	149	95	48	1604	1563
2011 (2304)	9	93	136	386	9	13	4	662	1572

List of research reports

12001-HRM&OB: Veltrop, D.B., C.L.M. Hermes, T.J.B.M. Postma and J. de Haan, A Tale of Two Factions: Exploring the Relationship between Factional Faultlines and Conflict Management in Pension Fund Boards

12002-EEF: Angelini, V. and J.O. Mierau, Social and Economic Aspects of Childhood Health: Evidence from Western-Europe

12003-Other: Valkenhoef, G.H.M. van, T. Tervonen, E.O. de Brock and H. Hillege, Clinical trials information in drug development and regulation: existing systems and standards

12004-EEF: Toolsema, L.A. and M.A. Allers, Welfare financing: Grant allocation and efficiency

12005-EEF: Boonman, T.M., J.P.A.M. Jacobs and G.H. Kuper, The Global Financial Crisis and currency crises in Latin America

12006-EEF: Kuper, G.H. and E. Sterken, Participation and Performance at the London 2012 Olympics

12007-Other: Zhao, J., G.H.M. van Valkenhoef, E.O. de Brock and H. Hillege, ADDIS: an automated way to do network meta-analysis

12008-GEM: Hoorn, A.A.J. van, Individualism and the cultural roots of management practices

12009-EEF: Dungey, M., J.P.A.M. Jacobs, J. Tian and S. van Norden, On trend-cycle decomposition and data revision

12010-EEF: Jong-A-Pin, R., J-E. Sturm and J. de Haan, Using real-time data to test for political budget cycles

12011-EEF: Samarina, A., Monetary targeting and financial system characteristics: An empirical analysis

12012-EEF: Alessie, R., V. Angelini and P. van Santen, Pension wealth and household savings in Europe: Evidence from SHARELIFE

13001-EEF: Kuper, G.H. and M. Mulder, Cross-border infrastructure constraints, regulatory measures and economic integration of the Dutch – German gas market

13002-EEF: Klein Goldewijk, G.M. and J.P.A.M. Jacobs, The relation between stature and long bone length in the Roman Empire

13003-EEF: Mulder, M. and L. Schoonbeek, Decomposing changes in competition in the Dutch electricity market through the Residual Supply Index www.rug.nl/feb