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

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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 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, Q4

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

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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 (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. We propose to assess the relative strength of several influences on competition in this 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 a firm is measured by the ratio of the aggregate supply capacity remaining in the market after subtracting the capacity of that firm, relative to total demand. If the RSI of a firm is below 1, that firm is needed to meet demand, which makes it a 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, we are able to determine how the different events affected the RSI in the Dutch electricity market over the period 2006-2011. The data refer to production levels, capacities and marginal costs of all centralized production units (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. The market-integration events consist of physical extensions of cross-border capacity, market coupling and netting. The firm-level events consist of mergers and acquisitions as well as 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 market power might play 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 five 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 residual demand, which partly resulted from the growth in decentralized production.

The paper is structured as follows. Section 2 describes the European electricity market. Section 3 presents the theoretical approach, while Section 4 describes the events which have taken place in the Dutch electricity market. Section 5 presents the results, while Section 6 concludes.

2. Electricity markets

Electricity markets have a number of specific characteristics determining how competition can evolve (Tamaschke et al., 2005). The product is homogeneous which in the short and medium term can hardly be substituted by other products. As electricity cannot (cheaply) be stored, the product market consists of a range of consecutive (hourly) markets in which supply has to equal demand. The restricted capacity of connections with neighbouring networks limits competitive pressure from abroad.

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. The latter 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 the rather short-term 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 the possibility to withhold capacity in order to exercise market power and, hence, increase its profits (Green, 2011).

Until the mid-1990s, electricity markets in most European countries were 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. In addition, the European Commission pursued integration of national markets into (regional) European markets in order to increase the size of the relevant geographic markets. A number of regulatory measures have been taken to realize this (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 (Leveque and Monturus, 2008).

In the beginning, most of the deals were domestic, but later on cross-border deals became dominant. The concentration tendencies on firm level may have reduced the intensity of competition in the electricity market (Möst and Genoese, 2009).

More recently, electricity markets show a significant growth in decentralized generation capacity, in particular renewable generation capacity. Wind-powered generation has grown strongly in many countries, in particular in Germany, where it has almost doubled to about 25 GW nowadays, but to a lesser extent also in the Netherlands (EWEA, 2012). This increase in renewable generation capacity reduces the residual demand for the conventional power plants.

3. Measuring market power

3.1 Residual Supply Index

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 at (super peak) hour t with n capacity constrained electricity firms. Let $mc_i(t)$ be the marginal costs of firm i, where $mc_1(t) \leq mc_2(t) \leq \ldots \leq mc_n(t)$. The system-marginal firm ($i = s$) denotes the firm with the highest marginal costs ($mc_s(t)$) that is used to meet demand. The standard measure for market power of firm i at hour t is the Lerner index $L_i(t) = (p(t) - mc_i(t))/p(t)$, 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 system-marginal firm is determined by the point of intersection of the market demand and the 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 $mc_s(t)$ is positive. This does not reflect some allocative inefficiency, but rather that such a firm can produce more cheaply 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 at hour t can be written as $L_i(t) = s_i(t) / \varepsilon(t)$, where s_i is the market share of firm i and ε the (absolute value of the) price elasticity. 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.

The generally used measure for pivotality is the Residual Supply Index (RSI), which was introduced by Sheffrin (2002). The RSI[4] of firm $i = 1, \ldots, n$ at hour t is:

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

[4] The RSI is dimensionless as capacity is measured in MW, while demand is measured in MWh/h.

$$RSI_i(t) = \frac{X_i(t)}{D(t)}, \quad (1)$$

where $X_i(t) = \sum_{j=1}^{n} C_j(t) + IC(t) - C_i(t) - FC_i(t)$ and $D(t) = TP(t) + I(t) - E(t)$. Here C_j is domestic (flexible) generation capacity of firm j, IC (total) available import capacity[5], FC_i access to foreign generation capacity through import by firm i, D total domestic demand, TP total domestic production, I import and E export. The $RSI_i(t)$ measures for each hour the aggregate supply capacity remaining in the market after subtracting firm i's capacity relative to total domestic demand. Note that export is subtracted from total domestic production in order to obtain domestic demand, which can only be satisfied by either domestic generation capacity or import capacity.

As the RSI is a continuous variable, its size indicates the degree of pivotality. If the RSI_i is below 1, firm i is needed to meet demand, which makes it a pivotal player and enables it to exercise market power. 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). 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 only measures

[5] The total available import capacity depends on the import transfer capacity and the way this capacity is utilized. The transfer capacity equals the technical capacity minus the so-called transmission reliability margin and the already allocated capacity (TenneT, 2012a).

flexible capacity, i.e. capacity that can be used strategically to exercise market power. Moreover, the RSI includes the capacity of foreign firms to supply to the market, acknowledging that the relevant geographic market can exceed the domestic market (Arnedillo, 2011).

Newbery (2009) demonstrates theoretically that for a number of situations the Lerner index of a firm can be related to its RSI. For example, in the case of an asymmetric Cournot oligopoly, where firms have different capacities and/or different cost functions, demand is linear and contractual commitments are determined endogenously, the Lerner index of each firm is linearly and negatively related to its RSI. Here, both the intercept and coefficient associated with the firm's RSI are a decreasing function of the price elasticity of demand.

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

3.2 Decomposition method

Consider the market at hours t = 0, 1, …, T, and let t = t_0 = 0 be the initial hour. We want to investigate the change in the market RSI between hour t_0 and hour t (for each t = 1, …, T). In particular, in order to determine the contribution of specific events on this change, we calculate the market RSI for different counterfactuals. In each counterfactual we suppose that specific changes did not occur. First, consider the counterfactual in which X_s remains at the initial level of hour t_0, while D is allowed to move to its level of hour t. The difference between the actual market RSI in hour t and the market RSI in hour t under this counterfactual is

$$BX_s(t) = \frac{X_s(t)}{D(t)} - \frac{X_s(t_0)}{D(t)},\ for\ t = 1, \dots, T. \tag{2}$$

We call this difference (BX_s) the basic effect of the change in X_s. Next, consider the counterfactual where D stays at the level of hour t_0, while X_s is allowed to move to its level in hour t. In this case, we suppose that the past changes in D have not taken place. The basic effect (BDs) of the change in D reads

$$BD_s(t) = \frac{X_s(t)}{D(t)} - \frac{X_s(t)}{D(t_0)},\ for\ t = 1, \dots, T. \tag{3}$$

Using this, we obtain the following decomposition of the change in the market RSI between hours t_0 and t :

$$RSI_s(t) - RSI_s(t_0) = BX_s(t) + BD_s(t) - COR_s(t),\ for\ t = 1, \dots, T \tag{4}$$

where

$$COR_s(t) = BX_s(t) - PX_s(t),\ for\ t = 1, \dots, T \tag{5}$$

and

$$PX_s(t) = \frac{X_s(t)}{D(t_0)} - \frac{X_s(t_0)}{D(t_0)}, \quad for\ t = 1, \dots, T. \tag{6}$$

Hence, the difference between the market RSI in hours t_0 and t can be decomposed as the summation of the basic effects (2) and (3) minus a correction term COR_s. The presence of COR_s reflects that, contrary to what has been assumed in (2) and (3), X_s and D in fact change simultaneously. Notice that COR_s is equal to the difference between the basic effect of the change in X_s (BX_s) and the partial effect of the change of X_s (PX_s) which is the effect of X_s when D would remain on the initial level of t_0.

Using this decomposition method, we analyze the effect of different events in the Dutch electricity market on the market RSI for each super peak hour in the period 2006-2011. In our analysis t_0 is the first super peak hour of 2006, while T is the last super peak hour of 2011. Before presenting the results, we describe the main events in this market.

4. Events in the Dutch electricity market

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.

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 (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). Market coupling refers to day-ahead markets only. For monthly and yearly contracts, the capacity is still auctioned explicitly. In the near future, market coupling will be introduced for 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 traded quantities are calculated first, while afterward prices are calculated.

The direct result of market coupling is that the transfer 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 cross-border capacity. We estimate the impact of market coupling on the available import capacity through the occurrence of inefficient cross-border flows before and after market coupling (see Appendix).

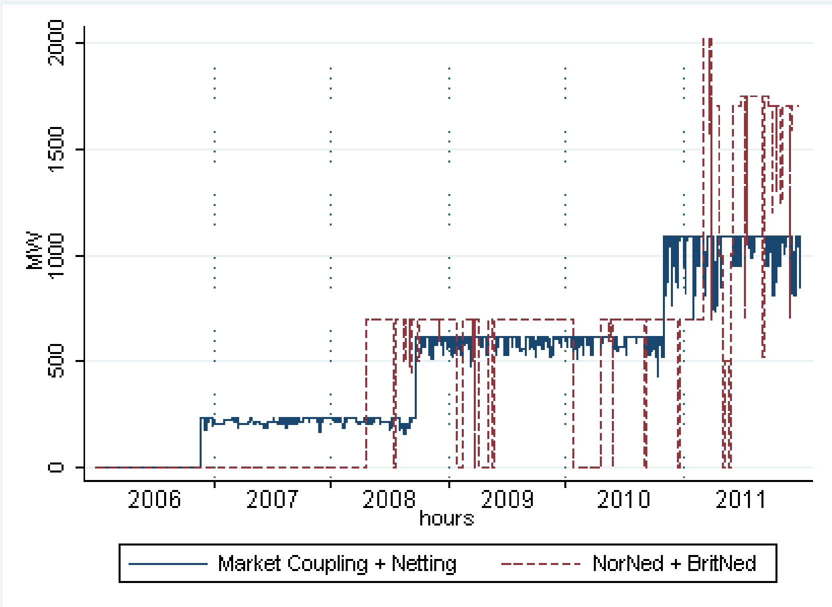

Fig. 1. Effect of NorNed and BritNed, and market coupling and netting, on the available import capacity (MW) in the Dutch electricity market, 2006-2011 (super peak hours; source: TenneT; own calculations).

Another measure which increases the interconnection capacity is netting. With netting, the Transmission System Operator (TSO) nets out bidirectional long-term contracts. This measure effectively increases the transfer capacity available on the day-ahead market by the net size of the bidirectional long-term export contracts (see Appendix). 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.

Fig. 1 depicts the effect of the above measures on the available import capacity on top of the existing capacity of about 2500 MW for each super hour in 2006-2011. It appears that the physical extensions through NorNed (May 2008) and BritNed (March 2011) have significantly increased the available import capacity. This holds also for the virtual extensions through the introduction of market coupling on the Dutch-Belgian border (November 2006) and Dutch-German border (November 2010) and netting

(November 2008). In 2011 the available efficiently used import capacity is more than twice as large as in 2006.

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. The major six firms have different portfolios. Some firms have a relatively large number of plants, while others only have one or two plants. Fig. 2 depicts how the generation capacity of the major electricity companies evolved over 2006-2011. It shows that 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. 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 entered the Dutch market.

Fig. 2. Generation capacity (GW) per firm in the Dutch electricity market, 2006-2011 (source: NMa).

The impact of cross-border mergers and acquisitions on the market RSI depends on the availability of import capacity (Gilbert et al., 2002). 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. 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 upper bound.

4.3 Changes in residual demand

Finally, changes in residual demand (which is total demand minus the supply from decentralized generation units) directly affect the market RSI. The higher the residual demand, the more the centralized units are needed which is reflected by a lower RSI.

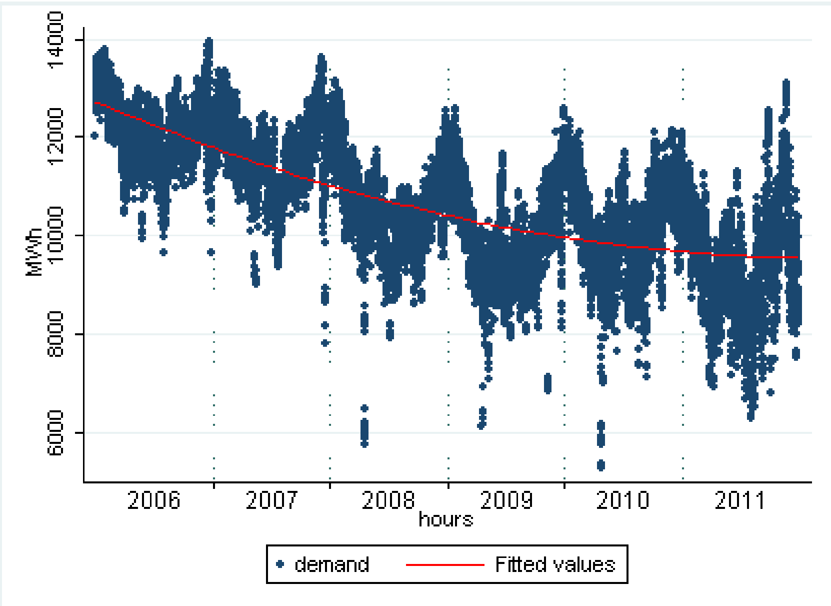

Fig. 3. Residual demand for electricity (MW/h) in the Dutch electricity market, 2006-2011 (super peak hours; source: NMa/TenneT; own calculations).

The relevant demand is 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. 3), which can be partly attributed to the general economic downturn after the outbreak of the financial crisis (TenneT, 2012b). 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.

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 hold one or more components of the market RSI constant at the level of the first super peak hour of 2006, i.e. hour t_0, while the other components attain the value of $t > t_0$, where t denotes a subsequent super peak hour in the period 2006-2011 (Table 2). In variant A all components in the RSI have the value of hour t, 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 remain at the level of t_0. These counterfactuals are defined such that we can analyze the effects of all the different events distinguished above.

The counterfactual of no market coupling and no netting is determined by not correcting the import capacity for the impact of these regulatory measures (see Appendix). The counterfactual of no NorNed line and no BritNed line is defined as the 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 each hourly value in 2007 by x%.

Table 2

Definitions of variants: which events are (not) included: + (-) means (not) included.

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

For each variant, we calculate the market RSI for each super peak hour over the period 2006-2011. The focus of our analysis is on the differences in the market RSI between variant A and the other variants which indicate the effects of the respective events. We present the results for all super peak hours during the whole period in a number of figures. In addition, we calculate the annual average effect for the last year of the analysis (i.e. 2011) as one might expect that the last year will show the eventual effects. We start presenting the annual average market RSI for each variant.

5.2 Findings

Table 3 gives the annual average market RSI in each of the variants.

Table 3

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

We see that in variant A, which includes all events, the annual average market RSI rises from 0.93 in 2006 to 1.55 in 2011, indicating a significant increase in competition. If we exclude all events (variant I), the RSI remains close to 1 implying that these events largely explain the increase in competition.[6]

From Fig. 4 and Table 4, we see that the market-integration events on average increased the market RSI in 2011 by 0.26. We also see that the impact of the connections

[6] Note that variant (I) shows some fluctuations in the RSI. These fluctuations follow from the fact that we have defined the counterfactuals of changes in the generation portfolios as well as in demand by the average annual values compared to 2006 instead of the value in the first (super peak) hour in that year.

with the Nordic power market (NorNed line) and the UK market (BritNed line) is about equal to the combined impact of market coupling and netting.

The firm-level events had a relatively small impact on the market RSI (Fig. 5 and Table 4). On average, they 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. 6 and Table 4). 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. 7. Without these events the market RSI would be 1.03 in 2011, while it actually was 1.55 (Table 3), 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. 8. 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 substantially 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.

Table 4

Difference of the means of the market RSI between variants, 2011 (super peak hours).

Comparison of RSI	Comparison refers to effect of:	Difference of the means	Standard error
Market-integration events			
RSI (A) - RSI (B)	Market coupling and netting	0.11 ***	0.0069
RSI (A) - RSI (C)	NorNed and BritNed	0.15 ***	0.0066
RSI (A) - RSI (D)	Market coupling, netting, NorNed and BritNed	0.26 ***	0.0065
Firm-level events			
RSI (A) - RSI (E)	Mergers and acquisitions	-0.02 **	0.0071
RSI (A) - RSI (F)	Changes in generation portfolio	-0.03 ***	0.0069
RSI (A) - RSI (G)	Mergers and acquisitions and changes in generation portfolio	-0.05 ***	0.0069
Demand events			
RSI (A) - RSI (H)	Changes in average annual level of demand	0.35 ***	0.0063
All events			
RSI (A) – RSI (I)	All events	0.52 ***	0.0058

Note: The sum of the effects 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 COR_s in equation (5)). The T-test is applied to test the null hypothesis that the means of the market RSI in the respective variants are equal to each other. As the null hypothesis of equal variances is rejected (using the F-test, at 5%), the T-test is done assuming unpaired series with unequal variances. In each case, the relevant T-statistic can be calculated by the ratio of the difference of the means in column three divided by the standard error in column four. ** and *** indicate that the null hypothesis of equal means is rejected at 5% and 1% significance, respectively.

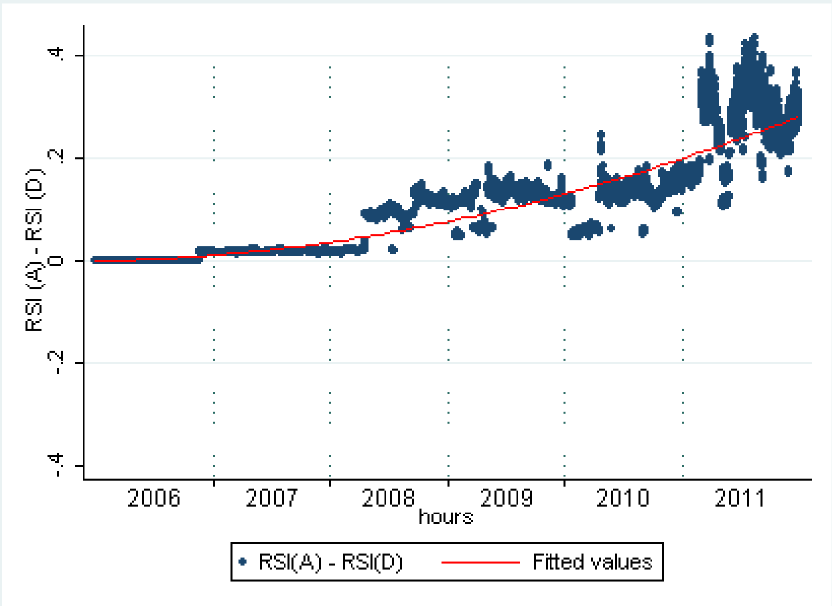

Fig. 4. Effect of market-integration events on the market RSI in the Dutch electricity market, 2006-2011 (super peak hours).

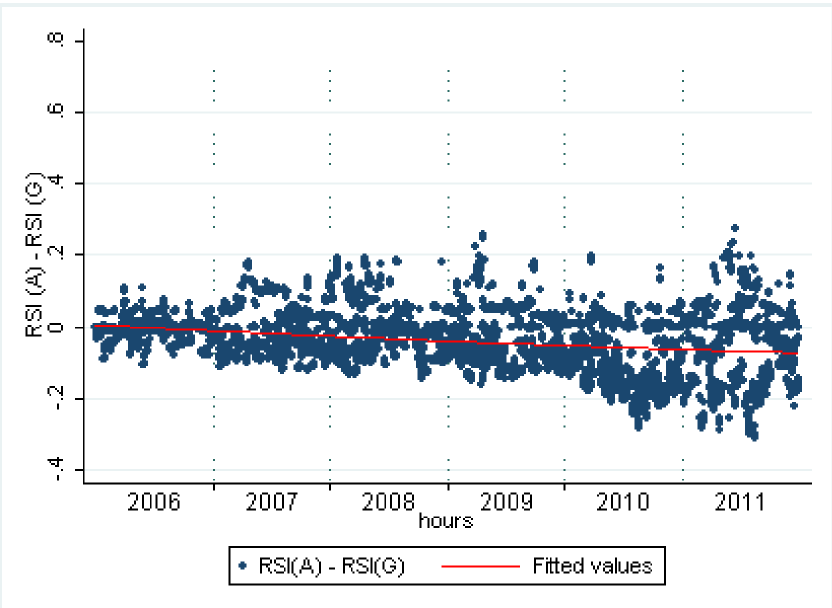

Fig. 5. Effect of firm-level events on the market RSI in the Dutch electricity market, 2006-2011 (super peak hours).

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

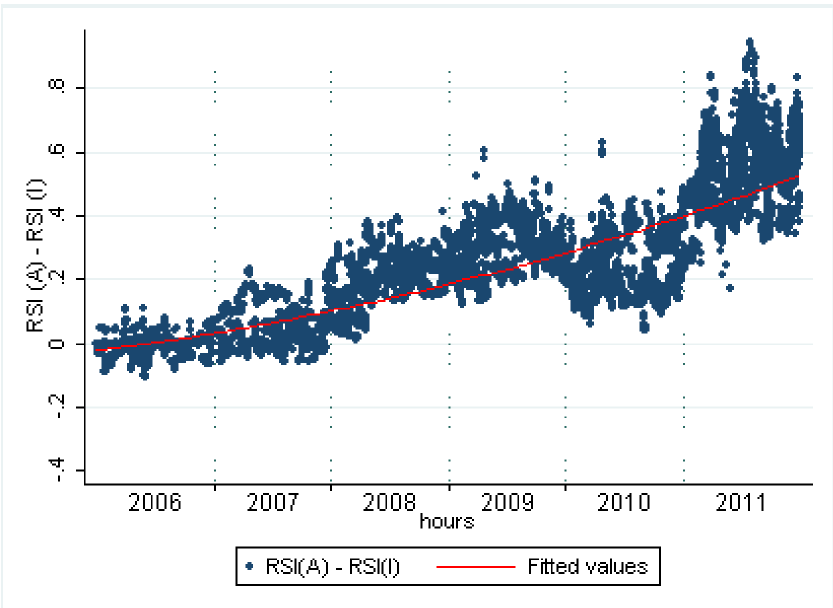

Fig. 7. Overall effect of all events on the market RSI in the Dutch electricity market, 2006-2011 (super peak hours).

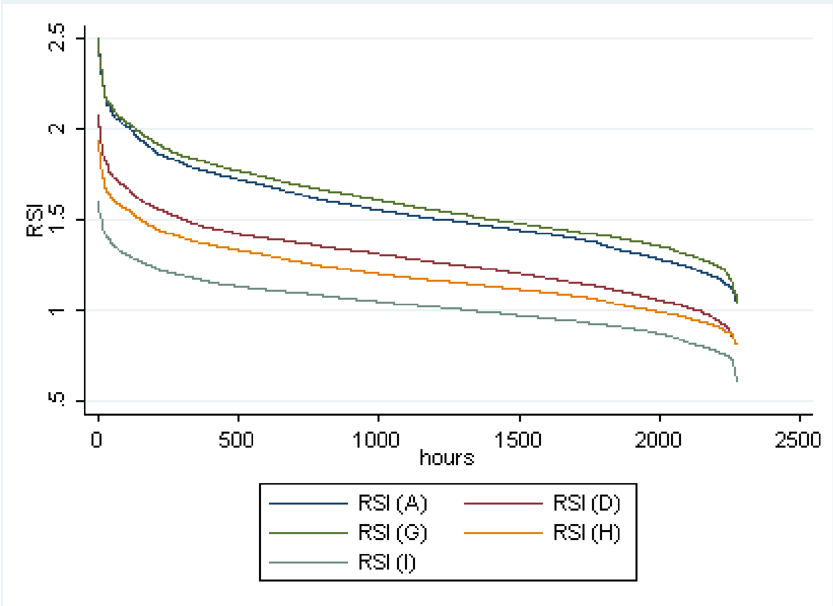

Fig. 8. Duration curves of the market RSI in the Dutch electricity market in five variants, 2011 (super peak hours).

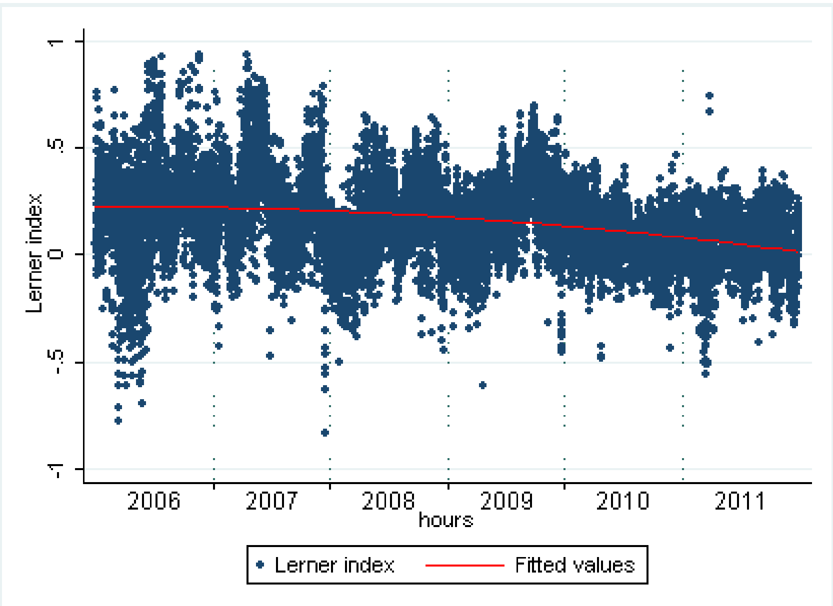

Fig. 9. Lerner index of the system-marginal firm in the Dutch electricity market, 2006-2011 (super peak hours).

Because of the relationship between the market RSI and 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. 9. 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 and discussion

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 (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.

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.

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

For the Dutch-Belgian border and the Dutch-German border, we estimate the impact of market coupling and netting on the available import capacity. The impact of market coupling on the cross-border infrastructure is estimated through the occurrence of inefficient cross-border flows before and after market coupling. If the (import) transfer 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 (*ef*) of the transfer capacity per border (*b*) at hour *t* as follows:

$$ef_b(t) = \frac{I_b(t)}{IC_b^*(t) + E_b(t)}, if\ \Delta P_b(t) > 0, \quad \text{(A.1)}$$

where ΔP_b is the difference between the domestic price of electricity and the price in the neighbouring country, I_b is import, IC_b^* transfer capacity and E_b export at border *b*. If $\Delta P_b > 0$, import is profitable, export in the opposite direction is not. With complete cross-border price arbitrage, exports should be zero while the transfer capacity should be fully utilized, reflected by an ef_b of 1. If import is below the transfer capacity and/or export is positive when ΔP_b is positive, the cross-border capacity is inefficiently used, and ef_b is below 1. The efficiency of the transfer capacity is only calculated for those hours when the domestic price exceeds the price in the neighboring country.

We use the average values of the ef_b in both periods (i.e. across the hours before and after the introduction of market coupling, respectively) in order to estimate the impact of market coupling on the efficiency of the utilization of the transfer capacity.

Since border-specific data on import flows are 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 the average values of the ef_b for the Dutch-German border. Here we find that the average value was 0.63 before the introduction of market coupling and 0.82 afterwards. The difference between these two averages is statistically significant at 1%. We apply these averages as estimates of the efficiency of the utilization of the transfer capacity with both Germany and Belgium during all hours in the respective periods. For each of these borders we define $EF_b(t)$, with $EF_b(t) = 0.63$ for all hours before market coupling was introduced on border *b*, while $EF_b(t) = 0.82$ for all hours afterwards.

The impact of netting on the available transfer 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 here before the introduction of netting, the available day-ahead capacity was on average 79% of the transfer capacity and afterwards 102%. The difference between the two averages is statistically significant at 1%. We apply these values as estimates of the impact of netting during all hours in the respective periods on both the Dutch-Belgian border and Dutch-German border. Hence, for each of these borders we define the share of the available day-ahead capacity in the transfer capacity, $\alpha_b(t)$, and set $\alpha_b(t) = 0.79$ for all hours before netting was introduced at border *b*, while $\alpha_b(t) = 1.02$ for all hours afterwards.

As a result the total available import capacity to the Dutch market (*IC*) after taking into account market coupling and netting is as follows:

$$IC(t) = \sum_b [\alpha_b(t) \cdot EF_b(t) \cdot IC_b^*(t) + \beta \cdot IC_b^*(t)] \qquad \text{(A.2)}$$

where β is the share of long-term capacity in the transfer capacity. The value of β is equal to 1 minus the share of day-ahead capacity before the introduction of netting, as in that period the size of the day-ahead capacity is directly related to the size of the long-term capacity (unaffected by netting). Hence, $\beta = 1 - 0.79 = 0.21$ during all hours in both periods. The size of the total available import capacity in the counterfactual of no market coupling and netting is determined by using $EF_b(t) = 0.63$ and $\alpha_b(t) = 0.79$ for *all* hours *t*. Finally, for expositional brevity we have not included the import capacities of the NorNed line and BritNed line in (A.2). Yet, of course, they are part of *IC(t)*.