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Veit Böckers and Ulrich Heimeshoff, April 2012*

Abstract

This paper analyzes the convergence process of Central-West European wholesale electricity markets from 2004 to the beginning of 2011. Jevon's law of price indifference is scrutinized using price correlation, parametric and nonparametric tests of price-differences and cointegration analysis. As a unique identifaction strategy national bank holidays are used as exogenous system shocks to trace the degree of market integration before the advent of the so-called market coupling of European power markets. In order to avoid overestimation of the degree of market integration, we specifically control for seasonal effects and common input factors. While the overall degree of integration between Germany and its neighbours has increased in the course of time, results suggest that only Austria and Germany already constitute a joint price area and that market coupling increases the convergence of markets at least between its participants.

JEL Codes: *C32, L1, L40, L94, Q40*
Keywords: *Market Structure, Spatial Market Delineation, Time Series Econometrics, Energy Data, Electricity, Europe*

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1 Introduction

In competition economics the assessments of market power or welfare effects of mergers are often based on quantitative, usually static, models. The correct definition of the relevant market in its product, timely and geographic dimension is the first important step towards the execution of a suitable economic analysis. In case of product differentiation, economists estimate price elasticities and often apply tests such as SSNIP (small but significant and nontransitory increase in prices) on an empirical basis. If products are completely homogenous and time and transportation costs do not play a substantial role, the law of one price (Jevons, 1888) is supposed to hold in the relevant geographic market. Therefore, many empirical tests based on prices have been developed in order to verify the law for various products and trading relationships between countries. However, as Werden and Froeb (1993) have shown, the tests inherit certain flaws and none is completely unbiased and fully capable to capture the degree of market integration for every product.

Spatial market delineation has grown especially difficult for the European wholesale electricity markets as transmission capacities have been upgraded. The European Commission aims at creating a joint market for wholsale electricity, thus strengthening the concept of an unified Europe. In order to do so, markets are intended to be gradually integrated. However, European competition authorities still spatially delineate most power markets by their national borders. The process of market integration, however, is dynamic in Europe and markets are being coupled (Scandinavia since liberalization; Germany, France and the Benelux states recently in November 2010) in order to further increase the contemporary degree of integration.

Motivated by a recent study of Nitsche et al. (2010) who used price based tests such as correlation and cointegration relationships to identify joint power price areas, we analyze the degree of market integration between Germany's wholesale electricity market and corresponding markets of its neighboring countries. We therefore estimate pairwise correlation and cointegration relationships as well as price-differences on a paramteric (time series stationarity) and nonparametric basis (change of price distributions). These tests can be applied to power markets because the product, power, is homogenous as cross-price elasticities with other substitutes do not exist. However, as Werden and Froeb (1993) have shown, these tests still suffer from the neglect of common influences, which may be the main driver of market co-movement.

This paper contributes to the energy economics literature in two ways. First, we analyze the degree of integration between European power markets, focussing on Germany as the main pivotal point in Western-Central Europe. In order to scrutinize the degree of integration before the coupling of power markets, we use national holidays as exogenous system shocks. Second, we show the effects of neglecting important information, e.g. seasonal effects and input prices, on three price based tests. Subsequently we illustrate the consequences of an ill-defined power market for static share based indicators for market power. The remainder of our paper is as follows. In the next section we provide a brief overview of the theoretical background of the price tests, present three empirical methods and provide a short literature review on market integration of wholesale electricity markets. In section three, we give a short introduction to the European power markets. Section four describes the data set, adjustments made to the price tests and the motivation for using national holidays as identification strategy. The results and implications for a quantitative assessment of market shares are discussed in section five. We conclude and give some suggestions for future research in section six.

2 Price based Tests and Spatial Market Delineation

In their seminal paper from 1985, Stigler and Sherwin stated that the main reason to delineate markets is not "to determine whether the market is competitive or monopolistic" (p.558), but to estimate market power or detect cartels. Observable market data usually consists of prices, equilibrium prices to be more exact, and is often readily available. While price and cross-price elasticities as well as demand elasticity is regarded as more precise in terms of market definition (see Woerden and Froeb, 1993), price tests, mostly based on time series econometrics, can be helpful tools to define the relevant market.

2.1 Jevon's Law and the Extent of Markets

The main idea of using price tests goes back to Jevons (1888: p. 40) who, as one of the first economists, introduced the law of indifference, or more commonly known as the law of one price. This law describes the fact, that in one single market with a perfect homogenous product, and absent transportation costs, there cannot be two different prices for the same good. Hence, for two perfectly substitutable products, i and j, at a given point in time, t, the law of one price is formalized as:

$$p_{i,t} = p_{j,t} + \epsilon_t \tag{1}$$

Jevons notes, that prices may deviate in the short-run, but on average prices will be balanced. This effect is captured by ϵ, which is i.i.d. N(0;σ^2). Since we will later analyze wholesale prices for electricity, the concept is extended. If transportation costs are nonzero, the equation extends to

$$p_{i,t} = \delta(x_t) + p_{j,t} + \epsilon_t, \tag{2}$$

where $\delta(x_t)$ indicates transportation costs, depending on factor x. For our purpose, x indicates interconnection capacity of the transmission lines between two countries. If offered quantities for import or export of electricity do not exceed the maximum transmission capacity, transportation costs should equal zero[1]. If the capacity limit has been exceeded, price differences may theoretically fluctuate between infinitisimal small values and infinity.

$$\delta(x) = \left\{ \begin{array}{ll} 0 & if\ x \leq x_{max} \\ \mu\ to\ \infty & if\ x > x_{max} \end{array} \right\}. \tag{3}$$

In theory, we therefore assume that under competition wholesale electricity prices are equal, whenever interconnection capacities between two neighboring countries are not fully constrained or capacity in both countries is under maximum utilization. Overcapacities of country A should flow over to country B, whenever prices in the latter area are higher, thereby decreasing the price level. So econometricians use two aspects of the law of one price in order to estimate the degree of market integration. First, an existing (constant) price equilibrium as the one described above necessitates prices

[1]The costs for the interconnection can either be implicit, where there price difference indicates the costs or explicit, which means that the transmission capacities can be auctioned for a specific price.

to move together, i.e. their covariance is non-zero. Second, if prices move perfectly together and deviations from the equilibrium are random, then the time series of price differences should fluctuate around a constant value.

2.2 Price based Tests

In case of a (perfectly) homogenous good which fulfills the conditions of Jevon's Law, prices should reflect this through a price equilibrium of price areas that belong to the same relevant geographic market. However, Werden and Froeb (1993) show that neither of the most common tests is without significant flaws. Therefore, adjustments have to be made, if these price tests are used.

2.2.1 Correlation Analysis

The idea of this test is simple as it states that (almost) perfectly equal prices, p_i and p_j, move together, therefore causing a very high correlation. If the law of one price holds true, then the degree of correlation is expected to be very close to one, deviating from this value only due to random shocks.

$$\rho_T(p_i, p_j) = \frac{\sum_{t=1}^{T} (p_{i,t} - \hat{p_i})(p_{j,t} - \hat{p_j})}{\hat{\sigma_{p_i}} \hat{\sigma_{p_j}}} \tag{4}$$

Woerden and Froeb (1993) argue that price correlations suffer, if not controlled for, from common drivers such as seasonal effects and input prices in the sense that these common drivers induce a correlation that may otherwise not have occurred. Another problem is that correlation may still over- or underestimate the true relationship between two markets if one market is subject to competition and the other to anticompetitive behavior, e.g. collusion (see Werden and Froeb, 1993: 333pp.). The problem of the variation caused by company specific demand applies, for instance, to consumer goods, but not to power markets due to the physical nature of electricity. Here, an individuals demand is, at least in most power markets, not the result of a buyers demand for power from a specific company, instead power markets are often organized as a (centralized) power spot market where all buyers and sellers bid into a sealed bid first price auction. Werden and Froeb further argue that products which are supposed to be very close substitutes have to be normalized, e.g. transformed into comparable price levels, in order to have any relevance at all (Werden and Froeb, 1993: 339). This does not apply here, as the substitutes are not close, but perfect substitutes.[2]

Furthermore, not only can common shocks lead to biased results, but the choice of the sample period can be crucial in terms of over- or underestimating dynamic developments. Instead of calculating the correlation for the full sample, a rolling correlation embracing z observations inside a sample of T observations can reveal the dynamics of market integration. In extreme, a former non-existing correlation due to physical disconnected countries can switch to full correlation in a given period (however unlikely this may be). A full sample correlation would therefore be misleading.

$$\rho_r(p_i, p_j) = \frac{\frac{1}{z-1}\sum_{t=r}^{r+z}(p_{1,t} - \hat{p_i})(p_{2,t} - \hat{p_j})}{\hat{\sigma_{p_i}}\hat{\sigma_{p_j}}} \tag{5}$$

Another point of criticism made by Sherwin and Stigler (1985) concerns the actual correlation value. They argue that there is no general criterion to determine the critical correlation value which separates joint from distinct markets. In addition, the transitivity of price correlation values is questionable when three or more price areas are being analyzed.

2.2.2 Distribution and Stationarity of Price Differences

This approach concentrates on absolute price differences rather than covariation of prices. One way is to analyze the distribution of price differences non-parametrically. In theory, Jevon's law holds, if the mean is zero, the variance very small, no skewness can be observed and the curtosis should show an excess (around the value zero). This necessitates a comparison of distributions of different time periods, as a comparison with a normal distribution does not imply the comparison with a standard non-integrated market.

In the second approach, also applied by Forni (2004)[3], the price difference time series is tested for stationarity, e.g. using the Augemented Dickey-Fuller test (ADF test). Let Δ be the price difference and l the number of lags in-

[2] Electricity may become a heterogenous product if the generation process is differentiated in its ecological dimension.

[3] The general idea was already applied by Shrives (1978), Horowitz (1981) and discussed by Baffes (1991).

cluded according to information criteria with $l = 1, 2..k$ and $t = 1, ...T$.

$$\Delta_t = p_{1,t} - p_{2,t} \tag{6}$$

$$\Delta_t = \alpha + \sum_{l=1}^{k} \beta_l \Delta_{t-l} + \epsilon_t \tag{7}$$

A stationary time series is a mean-reverting process, fluctuating around zero if optimal. Forni applies this method to regional milk markets in Italy and finds that the integration hypothesis is often not rejected for direct neighbors. The advantage of this approach is that only one test is needed, whereas cointegration analysis is based on the aforementioned stationarity tests. However, Hosken and Taylor (2004) and Genesove (2004) argue that this analysis can be misleading or biased, e.g. through small-sample bias of the stationarity tests or false results for markets with differentiated products. The test therefore overlooks the possibility of other sound economic reasons for the persistence of price differences between markets other than a low degree of market integration. In addition, if prices are integrated of a higher order than one, the test fails to detect the possible existence of integration. Hosken and Taylor (2004) exemplify this by showing the problems caused by the application of the tests on the wholesale gasoline market in the U.S. We still use this test, since we have no small-sample bias and (perfectly) homogenous products. Furthermore, we want to show that the outcome of the tests may be contradictory to the previous findings, hence emphasizing the necessity to run a full set of empirical tests and not rely on a single method.

Furthermore, a price difference may indeed exist, although there are no cross boarder capacity constraints. However, the threshold of "accepted" price differences is likely to be very low since even small differences of, say, 5 €/MWh can result in large generator revenues if persistent for a longer period.

The speed of adjustment, proclaimed by Horowitz (1981), would be also a flawed approach, because if products are no perfect substitutes, even instantaneous reactions from competitors to a price increase by a hypothetical monopolist would not induce substitution. Furthermore, the observed time periods are crucial to the speed of adjustment, since quarterly data may deliver quick adaption while estimations based on daily data for the very same product may result in slow adjustments. However, this can be neglected for power markets, as the data is readily available even on an hourly basis. Also the nature of power markets necessitates quick adjustments, because supply always has to equal demand, with the latter being rather inflexible. An increase in prices in a certain market will thus not persist for long and the necessary time for power transportation is rather short.

2.2.3 Cointegration analysis

The idea behind this time series approach is that the long-run equilibrium $p_i - p_j = c$, can be estimated through a vector error correction model. So while the prices may deviate in the short-run, they move together in the long-run, ideally reflecting perfect co-movement. This common effect is captured through the decomposition of a vector autoregressive model into its long-run component and the short-run deviations. Technically, there exists a linear comibination of nonstationary time series, here prices, which result in a stationary process, i.e. the new formed time series always returns to its mean value. An intuitive example is given by Murray (1994) who describes the relationship between a drunk person and her dog. Both move in the sense of a random walk process, which is nonstationary, but have a common direction, home.

First, unit-root tests are run for each time series and should be integrated of order one, i.e. they both have a unit root. If the series are nonstationary, a Johansen trace test (Johansen, 1994; 1995) for each nonstationary country pair is done in order to examine a possible cointegration relationship. Depending on whether a cointegration relationship cannot be rejected by the Johansen trace test, we either estimate vector error correction model or a vector autoregressive model . For instance, assume that two prices are nonstationary and can be described by an underlying VAR (2) process. Then this VAR can be transformed into the VECM. Let p_t be a vector of prices, $\Delta_t = p_t - p_{t-1}$ and ϵ_t be a vector of residuals:

$$\Delta_t = \alpha \ \beta p_{t-1} + \gamma \Delta_{t-1} + \epsilon_t \tag{8}$$

Then α indicates the speed of adjustment, i.e. how quickly the prices return to the long-run-equilibrium, and β indicates the coefficients of this long-run equilibrium.[4] The coefficient β therefore indicates, whether the price series belong to same market or not.
Again, Woerden and Froeb find significant flaws in applying the cointegration

[4]Note that one of the beta coefficients is set to one and the other coefficient indicates the relative relationship to one.

analysis. Common drivers are one of two main points of critique (Woerden and Froeb, 1993: 344p.), because if neglected they can be the sole reason for a cointegration relationship. Thus, such relationships can falsely be interpreted as long-run equilibriua between two price areas. Werden and Froeb also argue that the long-run character of the cointegration vector can for instance extend to years and thus price deviations which last for months will not be considered as suspicious. The latter point poses indeed a significant problem in terms of the sample period. A rolling VECM could solve the problem, but this would come at the cost of a significant sample reduction.

2.3 Related Literature

There exists extensive empirical literature on the integration of markets, especially on the wholesale electricity sector. Most studies focus on either of the three empirical testing methods: price correlation, price differences, and cointegration analysis. These three methods will also be used in our study. However, neglecting common drivers such as seasonal effects and input prices may lead to an overestimation of the degree of integration. This is due to the interdependent relationship between fuel and energy prices which has also been investigated by researchers. Therefore, our literature review includes results from price based integration tests as well as the analysis of the relationship between primary fuel prices and wholesale power prices.

Nitsche et al. (2010) apply the cointegration method in order to analyze the degree of integration between European wholesale markets. They focus on the central role of Germany within the European electricity sector and find that the degree of integration has increased. Support for this finding comes from their correlation analysis, which captures the short-run relationships between the respective spot markets. However, they take neither seasonal effects nor input prices into consideration, leaving out two significant common drivers in power markets. A trend variable was only included into the vector error correction model after visual inspection of the time series.

De Vany and Walls (1999) also test market integration using cointegration analysis. They restrict their analysis to the US and test eleven US wholesale spot prices for cointegration. Pairwise cointegration tests are applied on a data basis ranging from 1994 to 1996. Each of the offpeak and 87% of the peak price pairs are found to be cointegrated, leading to the result of largely integrated wholesale markets in the region of the Western System Coordi-

nated Council.[5]
Bencivenga and Sargenti (2010) use rolling correlations to examine short-run reactivity in order to support their findings from the cointegration analysis. They examine the relationship between fuel prices and and wholesale power prices in the US and Europe. However, only one power spot price was chosen for each region. An unconditional correlation is put against the mean of a rolling correlation to emphasize the weakness of a simple full sample correlation analysis. From their empirical results they conclude that European fuel and energy prices are less integrated in comparison to the ones in the US. While the connection between input and power prices is supported by their findings, they do not survey the degree of market integration of power spot markets for the respective region.

The only integration analysis, to our knowledge, that controls for both the fuel-power relationship and degree of power market integration is Mjelde and Bessler (2009) who analyze two power spot markets in the US, PJM (Pennsylvania-New Jersey-Maryland Connection)[6] and Mid-Columbia (Mid-C), from 2001 to 2008. The input prices considered are coal, uranium, and gas. They specically test the causal direction and the short- and long-run relationships using Vector Error Correction models. Their findings suggest that not only is there a dynamic relationship between fuel and power spot prices, but also a possible cointegration relationship between the two energy prices cannot be rejected. Specific tests of the cointegration vector indicate that the degree of integration is not as high as theory would suggest in case of fully integrated markets.

[5]For further literature on cointegration analysis as a device to delineate energy markets and a survey of the fuel-power relationship see Mohammadi (2009) Neumann, Siliverstovs and von Hirschhausen (2006) and Ravallion (1986).

[6]The PJM area covers the wholesale electricity markets "in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia" (PJM, 2011).

3 European Wholesale Power Markets

The liberalization phase of the European power markets took place around 1990-2000, with different types of market designs and degrees of privatization.[7] Up until today, most of the power markets are being dominated by a few major generation companies, which are also often vertically integrated. Most national competition and regulatory authorities still regard markets to be defined by their national boundaries. Many mergers have been denied due to the possible detrimental effect on competition and welfare. Often concentration ratios played a crucial role in identifying potential market power, regardless of the flaws of such static quantifications. While the Nordic countries have been integrated almost right from the start of the liberalization phase, it took the rest of Europe longer to follow their lead and build joint institutions that aim at connecting markets.

The European Commission aims at the creation of a single European market for power. Therefore the first aim is to increase the capacity and efficiency of cross-border flows. In a second step, a joint market operator optimizes the joint supply and demand of every member state of the joint venture, which, if there are no constraints, optimally leads to a uniform price for the complete area. [8] So if, say, two markets A and B are coupled, the bids offered by supply and demand of the respective market areas are combined and under the necessity of technical and physical feasibilty (transmission constraints) optimized. As mentioned before, the Scandinavian markets have been connected since liberalization, while the market coupling of France, Belgium, Netherlands and Germany has been realized only recently. In Figure 1 the intended extent of the coupled market areas is depicted. For our analysis of market delineation, we expect this market coupling to significantly influence the correlations, price differences and vector autoregressive models. While this may not necessarily lead to perfect price equality, a significant reduction

[7] See Sioshansi, 2008 and Sioshansi & Pfaffenberger, 2006 for a thorough introduction to the subject.

[8] With the advent of European Market Coupling in 2010 (EMCC 2011), the idea of creating a single market is being pushed forward. In this concept, the Nordic regions and Central Western European countries (France, Belgium, Luxembourg, Netherlands, Germany) are being coupled, so that the energy flow between these countries is being optimized.

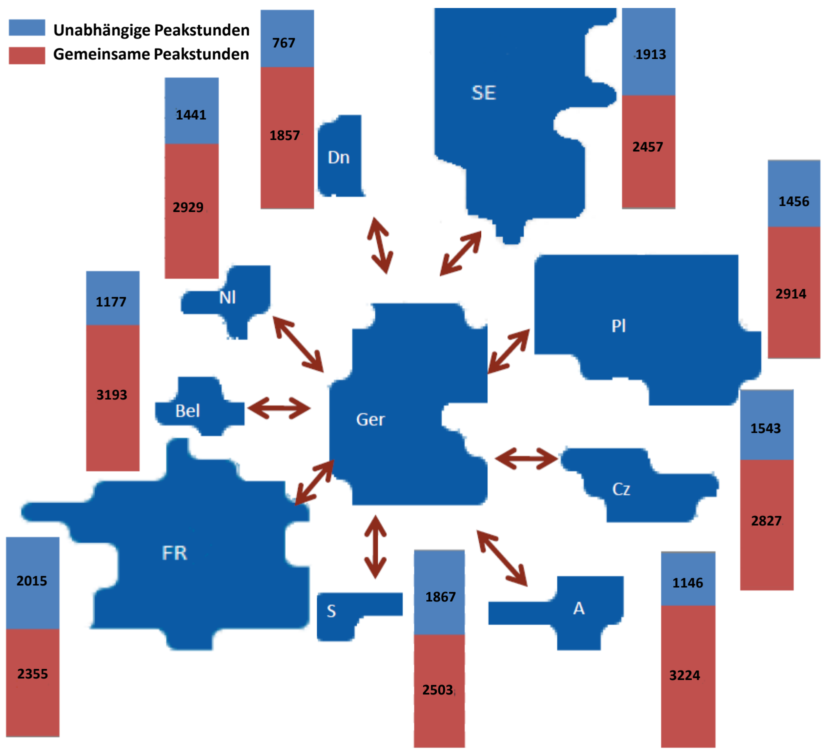
in price differences is expected.

Figure 1: Intended European Market Size after Market Coupling

Source: EMCC, 2011.

Germany plays a pivotal role in the European transmission system being surrounded by ten neighboring countries and being the largest producer in Europe. This makes spatial market delineation even more important in antitrust and merger cases. So whether Germany is regarded as a single market or even a market embracing its ten neighbors is crucial to competition policy and the assessment of market power. Because of the typical characteristics of power markets, such as network dependency, unsubstitutability, low demand elasticity, and physical necessity to always match actual supply and demand, power markets must have generation overcapacities in order to deal with seasonally dependent demand. From a national security of supply perspective, each country has to provide enough generation overcapacities to cover national demand. From a European perspective, the sum of those national generation capacities is inefficient in the sense that other foreign capacities may just as well cover national demand as long as there exist free transmission capacities. The potential of free generation capacities therefore depends on the co-movement of demand of country A with that of country B. If country A exhibits the exact same demand profile, spare capacities, flowing from country A to country B, are small. The other extreme, though not likely, would be two countries which have mirror-inverted load profiles. In this case, capacities could flow from one area to another reducing each nations amount of generation capacity.

Figure 2: Common and Independent High Peak Load Hours between Germany and Neighbor Countries, 2006-2010



High Peak Load refers to the highest ten percent of load. Common load hours are labelled as "Gemeinsame Peakstunden" and independent load hours as "Unabängige Peakstunden". Data on Danish Load only from 2007-2009. Own Calculation. Source: ENTSO-E, 2011.

On the one hand, as can be seen in Figure 2, the highest ten percent of load hours are not exactly the same when Germany is compared to its neighbors. Still, a very large portion of the load profiles appears to be congruent. A nation-specific exogenous shock in demand, as can be whitnessed on national holidays, would therefore increase the potential free capacities thereby theoretically producing competitive pressure on neighboring power market prices.

4 Data and Empirical Strategy

4.1 Data

We use data from ten price series from European wholesale electricity spot markets (see Table 1 below). Prices are hourly and day-ahead, i.e. traded one day ahead of delivery, but subsequently transformed into mean daily peak (the period of hours where daily demand is highest due to industrial production, mostly 8.00 a.m. to 8.00 p.m.) and offpeak prices (from 9.00 p.m. to 7.00 a.m.).[9] We checked for the change between daylight saving time during summer and winter time by deleting duplicate hours (the hours from 02:00-03:00 a.m. during a day in march) and including missing hours (the hours from 02:00-03:00 a.m. during a day in October). Missing price data are replaced by previous observations of these prices. The other variables used especially for the cointegration analysis are deterministic variables, input prices and national bank holidays (which will be explained in more detail in the next section). Deterministic variables cover seasonal effects and business cycles, therefore we include a trend variable, a weekday dummy, and quarterly dummies. Fuel price data encompasses coal, reported twice a week by Platts database (2011), uranium, weekly reported by UX Consulting Company (2011), and oil, reported weekdays by Brent Europe. While using uranium and coal data on a daily basis creates less variation, we believe that this variation is sufficient, as it is unlikely that coal and uranium, in particular, are solely bought on an every day basis by power generators. We define national bank holidays as the single day where the respective nation was proclaimed, e.g. October 3rd for Germany.[10]

[9] We are aware of the fact that the trading hours are not the same in every country, leaving arbitrage opportunities. Also the definition of peak may vary slightly. However, we define peak to embrace the trading hours from 8 a.m. to 8.pm. and offpeak the remaining hours.

[10] It can, of course, be argued that other holidays should be included, too. The most conservative approach was to focus solely on nation-founding days, neglecting potential religious holidays. These religious days are difficult in so far as many countries share a large portion of the Christian holidays. For instance, Germany may have the same dates for holidays as France and Belgium, but not as the Netherlands. Identifying the effect of

Table 1: Data Overview of Daily Averaged Prices

Power Market	Obs.	Mean	SD	Min	Max
Offpeak					
EEX, Germany	2561	33.69	13.07	-91.57	79.95
EEX, Austria	2560	40.67	16.40	10.79	159.78
Belpex, Belgium	1505	37.53	15.36	6.84	188.42
APX, Netherlands	2561	34.92	12.63	5.57	93.62
PPE, Poland	2561	31.78	8.67	0	86.30
OTE, Czech Republic	2561	28.82	13.40	0.03	78.16
Swissix, Switzerland	1485	43.37	16.14	10.26	94.94
Nordpool, Denmark East	2559	36.27	13.65	6.40	231.46
Nordpool, Denmark West	2561	34.52	11.12	-44.46	75.44
Nordpool, Sweden	2561	36.99	14.41	7.36	231.46
Nordpool, System	2560	35.97	12.82	6.01	97.45
Peak					
EEX, Germany	2561	53.87	27.39	7.4	508.74
EEX, Austria	2559	48.71	23.26	8.85	275.85
Belpex, Belgium	1505	59.52	31.85	5.58	519.8
APX Netherlands	2561	59.75	31.54	14.7	485.76
PPE, Poland	2561	40.72	15.77	0	140.33
OTE, Czech Republic	2561	48.71	24.43	0.03	252.63
Swissix, Switzerland	1485	64.59	26.50	17.73	254.3
Nordpool Denmark East	2559	47.75	28.65	9.24	737.71
Nordpool Denmark West	2561	45.08	17.48	6.24	278.37
Nordpool, Sweden	2561	42.98	24.15	7.25	737.71
Nordpool, System	2560	40.26	14.33	10.08	166.41
Input Price					
Coal, Platts	543	85.84	28.93	50.5	218
Uranium, UXC	366	50.03	26.11	14.5	136
Oil, Brent Europe	1782	66.82	21.93	29.02	143.95

4.2 Empirical Strategy

In order to account for the seasonalities and business cycles, we will not only include deterministic variables, but split up the dataset in two parts. The first data set encompasses the so-called peak hours and the second data set the respective offpeak hours. This is standard in energy economics (see e.g. Stoft, 2002) and is very important when analyzing the degree of market integration or detecting abusive market behavior, because during peak hours supply is scarce, causing higher price levels and offering high incentives to exert market power. In addition, if price areas share the same very high peak hours, i.e., when the power system is at stress, the potential of connected markets to dampen high prices is lower. Therefore a distinction between offpeak and peak hours appears necessary.

The overall analysis aims at controlling for pairwise market integration relationships, i.e. Germany and its respective neighbors. By adjusting the data step by step for deterministic influences, we want to point out the problems mentioned by Werden and Froeb (1993), i.e. the neglect of common price drivers may overestimate the actual relationship. For that matter, our three price based integration tests will be computed for each price type, peak and offpeak, and the three degrees of common driver adjustment, i.e. raw, seasonally adjusted as well as input and season controlled.

4.2.1 General Procedure

We now specify our price based tests from the previous section. In the list below, you will find an overview of our procedure for each price test.

1. Split hourly price series into peak and offpeak and calculate daily averages for correlation and cointegration
2. Controlling for common drivers
   - Unadjusted ('Raw')
   - Seasonally adjusted ('Seasonal Adjusted')
   - Seasonally adjusted and Input controlled ('Input Controlled') for Correlation and Cointegration Analysis

the holidays in a pairwise analysis would therefore be biased towards the free potential capacities from other countries.

3. Control for time dynamic process
   - Unadjusted ('Full Sample') for Correlation
   - Rolling 100-days (Correlation) or subsamples 2004-2006 and 2007-2011 (Cointegration)
   - Yearly (Correlation and Price Difference)
4. Analyze the effects of holidays and market coupling

We follow the approach by Sherwin and Stigler (1985) to account for the aforementioned common drivers and regress these on the respective power price series and use the computed residual, ϵ, as adjusted price data. Hence, the two regressions following the raw price analysis are:

$$p_{i,t} = \sum_{s=1}^{3} \alpha_s * d_s + \gamma d_{weekday} + \phi trend + \epsilon_{i,t} \quad (9)$$

$$\begin{aligned} p_{i,t} = & \sum_{s=1}^{3} \alpha_s * d_s + \gamma d_{weekday} + \phi trend \\ & + \beta_{oil}\ p_{oil,t} + \beta_{uranium}\ p_{uranium,t} + \beta_{coal}\ p_{coal,t} + \epsilon_{i,t} \end{aligned} \quad (10)$$

Besides, as mentioned before, three different types of correlations are calculated, i.e. unconditional, yearly and, rolling correlation as in Bencivenga and Sargenti (2010), who used a rolling time window of 100 days. We are fully aware of the fact that correlation analysis is limited to the short-run, because we calculate correlations between realizations of variables from identical and contemporary time periods.

We analyze the price differences by means of descriptive statistics and non-parametric tests and subsequently test the time series for stationarity. It can be argued that price differences need not be detrended, since the main aim of the price difference analysis is to find the (constant) equilbrium, which in theory should be zero if no transaction costs such as transmission capacities exist. As we do not detrend the data in any way, we can use raw hourly price data.

In the third approach, the data is split into two subsamples (2004-2006 and 2007-2011) in order to account for the criticism on the cointegration vector as a long term market equilibrium. However, the data is not adjusted in the sense that we first regress the price series on deterministic and input variables. Instead, power and input prices and the seasonal dummy variables, here monthly effects s, weekdays d and a general linear trend $trend$, are included in a vector autorgressive model. In addition, we include bank holidays and therefore check for an indicator of early market integration. In case we observe serial correlation in the residuals, the vector autoregression will be divided into single equations with Newey-West robust standard errors.

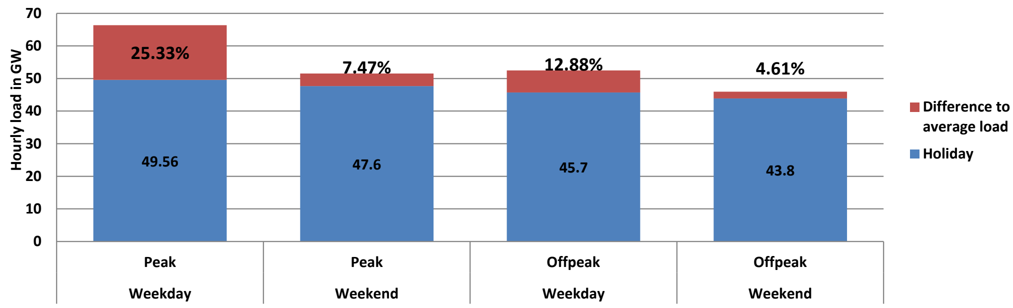
$$
\begin{aligned}
p_{i,t} = & \sum_{n=1}^{\rho} \beta_n p_{i,t-n} + \sum_{n=1}^{\rho} \gamma_n p_{j,t-n} \\
& + \sum_{n=1}^{\rho} \nu p_{uranium,t} + \sum_{n=1}^{\rho} \lambda p_{coal,t} + \sum_{n=1}^{\rho} \zeta p_{oil,t} \\
& + \sum_{s=1}^{3} \delta_s d_{season} + \gamma d_{weekday} + \phi trend + \kappa holiday_i + \mu holiday_j + \epsilon_{i,t}
\end{aligned} \tag{11}
$$

4.2.2 Holiday Impact

The motivation behind this unique strategy is as follows: We use an exogenous demand-side shock to identify the degree of integration between two power markets. Demand for electricity is subject to seasonal fluctuation and business cycles. The seasonal effect leads to high (low) demand during a winter (summer) period. Business cycle effects cause weekdays (weekends) to induce high (low) demand levels. The same argument holds for intra-day cycles, i.e. peak (high demand) and offpeak hours (low demand). Therefore, demand during peak hours on a winter's weekday is higher than during a saturday night in summer. On national holidays when there are no holidays in neighboring countries, e.g. July 14th in France or October 3rd in Germany, business activities, including those of high energy consuming industries, are very low, especially during peak hours.

We expect this nation-specific demand reduction to cause price decreases if markets are integrated. As a consequence, a national holiday in country A should cause prices in market B to drop due to overcapacities of market A bidding into market B. Therefore, national holiday dummies are included in our analysis and should in case of an integrated market reflect this relationship. This is indicated by the potential German capacities set free due to the German national holiday. Theoretically, these could, aside from transmission

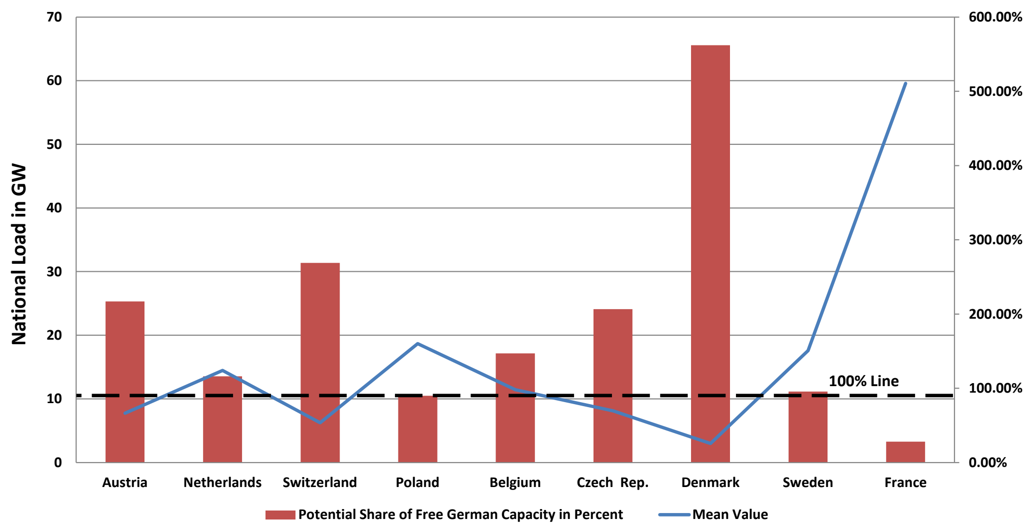
Figure 3: Impact of National Holiday on average hourly load, Germany



Own calculation. Source: ENTSO-E, 2011.

constraints, suffice for a large fraction or even more than the total demand in several neighbouring countries. Note however, that this causal direction is likely to be one-sided in the pairwise analysis (holiday of A influences B but not vice versa). This is due to the fact that the absolute amount of capacity set free on any national holiday in country A, may be only a very small portion of the contemporary load of country B. For example, the potential Austrian capacity set free on its national holiday is only roughly 1.81 GW while the German capacity is around 16.8 GW.

Figure 4: Potential Impact of free German Capacity on European Load due to German National Holiday



Own Calculation. Source: ENTSO-E, 2011.

5 Results

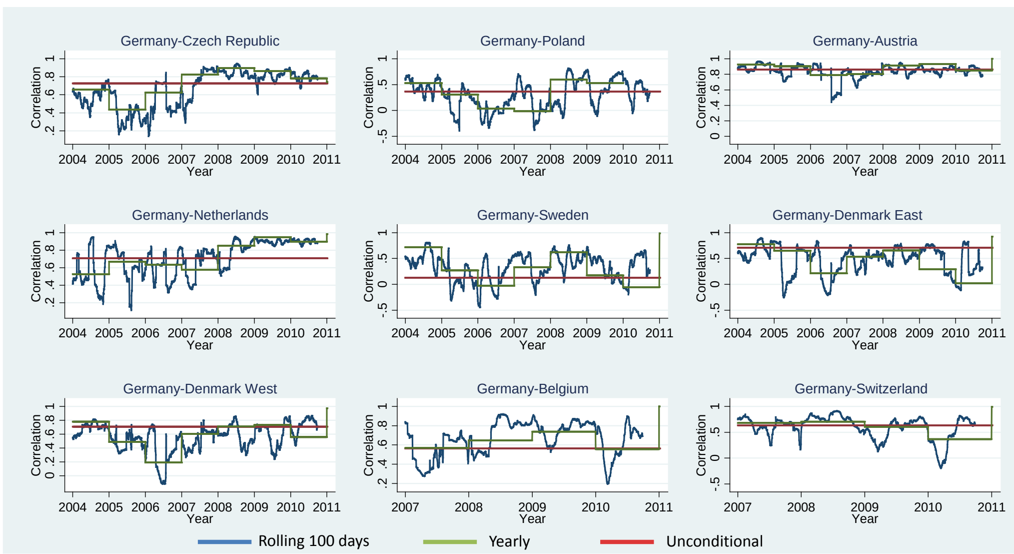
There are three main results from the empirical spatial delineation analysis. First, a thorough analysis of the correlation and cointegration relationship between wholesale electricity prices necessitates the inclusion of input prices and deterministic seasonal effects. If not considered, price tests overestimate the degree of integration. Second, all three tests indicate that in general the degree of market integration has increased over the years. Using holidays as a new identification method, we find that before market coupling Austria and Germany already constituted a joint market. While the data period after market coupling is yet too short at this stage, the results of the hourly price difference analysis strongly suggest, that Belgium and the Netherlands may belong to the same price area as Germany.[11] Detailed results are presented in the following subsections.

[11]We have no power data on France and therefore cannot deduct the same conclusion. However, since France is also part of the market coupling process, we suggest that the results should be the same.

5.1 Correlation Analysis

As can be seen from the Figure below, rolling correlations seem to capture the increasing degree of correlations better than full sample correlations as Figure 5 shows. In addition, the rolling correlation indicate that there seems to have occured a large and persistent increase in correlation from 2007 ownwards. Nordic countries, however, seem to be the exception as the values do not display such a development.

Figure 5: Correlation of Peak Prices and Sample Size



Correlation is based on input controlled price series.

Disregarding the effect of seasonalities and input factors clearly overestimates the degree of correlation as Table 2 shows. The two-sample mean test supports the hypothesis that raw correlations are significantly different from those of the detrended and input controlled correlations, but the latter two are only significantly different from one another in six out of twenty cases. After controlling for these influences, there are four markets that still stand out: Austria, Netherlands, Belgium and Denmark East. The relatively large degree of correlation between Germany and Austria is expected, because it is officially claimed that there is no congestion between the two markets and hence arbitrage between these two markets should lead to a high correlation.

Morover, the correlation degree neither varies much between peak and off-peak prices nor between raw and detrended data, so the interaction can be regarded as a good indicator.

Table 2: Mean Value of 100 Days Rolling Correlation with the German EEX

Test	Raw		Seasonal adjusted		Input controlled	
	Peak	Offpeak	Peak	Offpeak	Peak	Offpeak
Belgium	$0.82^{A,B}$	$0.71^{A,B}$	0.73^{C}	0.65^{C}	0.66	0.59
Netherlands	$0.78^{A,B}$	$0.80^{A,B}$	0.69	0.75	0.70	0.75
Switzerland	$0.80^{A,B}$	$0.59^{A,B}$	0.70^{C}	0.53^{C}	0.60	0.47
Austria	$0.88^{A,B}$	$0.80^{A,B}$	0.83^{C}	0.74	0.83	0.74
Czech Republic	$0.74^{A,B}$	$0.63^{A,B}$	0.66	0.55	0.66	0.55
Poland	$0.49^{A,B}$	$0.40^{A,B}$	0.35^{C}	0.30	0.29	0.30
Denmark East	$0.54^{A,B}$	$0.66^{A,B}$	0.45	0.60	0.47	0.60
Denmark West	$0.55^{A,B}$	$0.50^{A,B}$	0.54	0.44	0.55	0.44
Sweden	$0.46^{A,B}$	$0.42^{A,B}$	0.31	0.36	0.32	0.36
Nordic System	$0.46^{A,B}$	$0.38^{A,B}$	0.32	0.34	0.33	0.34

A: Two sample mean test between raw and seasonal adjusted correlation rejects two-sided null hypothesis on 5% level. B: Two sample mean test between raw and input controlled correlation rejects two-sided null hypothesis on 5% level. C: Two sample mean test between seasonal adjusted and input controlled correlation rejects two-sided null hypothesis on 5% level. Own Calculation.

Despite the overall result of high price correlation between the national markets, the degree varies a lot if the correlation sample period and the difference between raw and detrended data are considered. Furthermore, it is still difficult to define the threshold level at which markets are considered to be integrated. Given our analysis, we take the aforementioned power markets of Austria, Netherlands, Belgium and Czech Republic as likely candidates, with Austria being the most promising, for an integrated market area. A critical point in this approach is the definition of the threshold for the correlation value that marks a price area to be integrated with another. Here we focussed on a threshold of 0.66 on each of the input controlled price series, but since there exists no official critical value, one may arguably set these thresholds lower or higher.

We now turn to the (potential) effect of market coupling. While the observable time period is quite short in comparison to the former analysis, the effect of market coupling should still be large. In Table 3 the results of the correlation between power spot prices before and after market coupling, respectively, are presented. The expected effect of market coupling, a (large) increase in correlation, is not that clear cut in the correlation analysis. Suprisingly, Austria and the Netherlands show a decrease in correlation. This, however, seems to be on a small scale and the overall correlation is still very large. So according to these results and a defined threshold of 0.66, there are five candidates which differ with regard to the former correlation analysis. The Netherlands, Austria and Belgium remain while the Western area of Denmark replaces East Denmark and the Czech Republic is also added to the set of candidates.

Table 3: Correlation of Input Controlled Daily Spot Prices before and after Market Coupling in 2010/2011

Germany and...	peak		offpeak	
	Before MC	After MC	Before MC	After MC
Belgium	0.4954***	0.8129***	0.5567***	0.6745***
Netherlands	0.9066***	0.8645***	0.8271***	0.7759***
Switzerland	0.2996***	0.6901***	0.3308***	0.5538***
Austria	0.8671***	0.7616***	0.6960***	0.7343***
Czech Republic	0.7910***	0.8533***	0.7271***	0.8061***
Poland	0.2524***	0.3826***	0.3992***	-0.0445
Denmark East	-0.0160	0.3125**	-0.0420	0.4256***
Denmark West	0.6214***	0.7434*	0.6228***	0.8137***
Sweden	-0.0678	0.2649*	-0.1073*	0.1348
Nordpool System	-0.0047***	0.3908***	-0.0324	0.1332

Null Hypothesis rejected on *** 1%,** 5%, * 10%.

Also, as was the case before, input controlled correlations mostly decrease in comparison to raw and detrended price correlations (see appendix for the latter two). However, after market coupling the correlations do not vary much with regard to common drivers.

5.2 Price-Differences

If small means and a decrease in the standard deviation are taken as a combined indicator, we can say that the overall impression is an increase in integration between Germany and its Neighbors (see apendix for the years 2004-2007). Especially during offpeak hours, where there is low demand and large supply available, the differences are small. Suprisingly, the price differences between Austria and Germany have become larger. This seems counterintuitive as Austria and Germany have no official transmission capacity constraint, but this may reflect the fact that the two countries have slightly different trading hours. Austria trades a few hours earlier than Germany (EXAA, 2012) hence creating arbitrage opportunities. Why this was and still is the case, is not made clear. So while the difference is nonzero in the mean, the reason is not accountable to disconnected markets. The other pairs show significant reductions in both standard deviation and mean value, e.g. Czech Republic-Germany, Denmark East and Denmark West. In case of the Netherlands, there seems to be an increase in differences in 2011. This is due to very few hours of price difference. Since we have no observations for Switzerland and Belgium earlier than the last two months of 2006, we naturally cannot analyze the price differences in the same way.

While both Danish areas appear to be closely connected, Sweden and the Scandinavian system price seem to have moved away. This may well be due to some very large outliers in 2010 (31 observations smaller than -200, and 11 observations smaller than -500), but this was not the case in 2011. So before market coupling, Germany and its Neighbors seem to have grown more closely together.

Consequently, Table 5 describes the number of equal hourly prices after market coupling and clearly indicates a positive effect between Germany, Belgium and the Netherlands. As is the case with correlation analysis, there is no official price equality threshold. So whether price deviations of, say, 0.05€ are too large is not clear. In relative terms, which percentage of equal price betwee two price areas is necessary to constitute a joint market? What can be taken from this analysis is a clear difference between the linked power exchanges and the other German Neighbors. So Belgium and Netherlands are two clear candidates from this perspective.

While the mean values can be affected by large outliers, the distribution mass of the prices differences is expected to have shifted towards zero over

Table 4: Mean and Standard Deviation of Hourly Price Difference, 2008-2011

Germany and...	2008	2009	2010	2011
Peak				
Belgium	-5.69[19.5701]	-0.19[7.83594]	-2.32[8.4919]	-1.93[16.1466]
Netherlands	-5.06[18.6674]	0.04[6.9357]	-1.15[4.6296]	-3.37[5.5385]
Switzerland	-9.16[16.2126]	-10.09[15.2548]	-6.79[10.2063]	-4.20[6.2827]
Austria	10.21[31.1746]	8.26[19.2305]	8.19[15.5422]	10.34[16.64]
Czech Republic	-0.17[13.6531]	0.34[8.6897]	-0.37[6.4093]	-0.51[10.5958]
Poland	11.48[24.6098]	3.15[11.4951]	-1.90[9.2611]	-3.33[15.2755]
Denmark East	14.68[21.0400]	1.79[32.1951]	-13.44[66.6114]	-18.877[11.6924]
Denmark West	15.50[20.7792]	6.92[13.3599]	-0.26[5.9117]	-9.14[8.44374]
Sweden	23.99[22.4674]	6.71[32.6092]	-11.26[53.6519]	-32.67[12.4450]
Nordic System	31.41[22.6589]	9.66[14.2151]	-5.39[15.9942]	-31.83[15.5397]
Offpeak				
Belgium	-3.87[15.2552]	-0.877[4.1902]	-1.21[8.3280]	-9.60[24.7978]
Netherlands	-3.38[11.0218]	-0.72[13.7538]	-0.56[5.5414]	-6.66[13.1842]
Switzerland	-7.96[14.5413]	-7.84[18.3332]	-5.98[10.2327]	-11.39[11.0117]
Austria	-12.98[25.9547]	-10.10[21.1471]	-10.36[14.4706]	-27.95[24.1402]
Czech Republic	2.97[11.7517]	1.87[14.6740]	2.15[7.9641]	7.56[15.6806]
Poland	7.62[14.8589]	-4.68[16.7072]	-5.54[11.6628]	-3.68[17.6335]
Denmark East	2.53[14.5693]	-4.35[16.6203]	-11.28[27.9356]	-2.05[12.6283]
Denmark West	2.03[12.4486]	-2.06[14.6317]	-4.06[7.400599]	0.11[9.0640]
Sweden	3.58[15.9976]	-3.91[16.9888]	-13.60[28.3001]	-47.38[15.6993]
Nordic System	8.76[17.7496]	-3.05[17.0364]	-12.33[14.1224]	-44.13[17.8146]

Standard Error in paranthesis.

Table 5: Number of equal hourly prices before and after Market Coupling

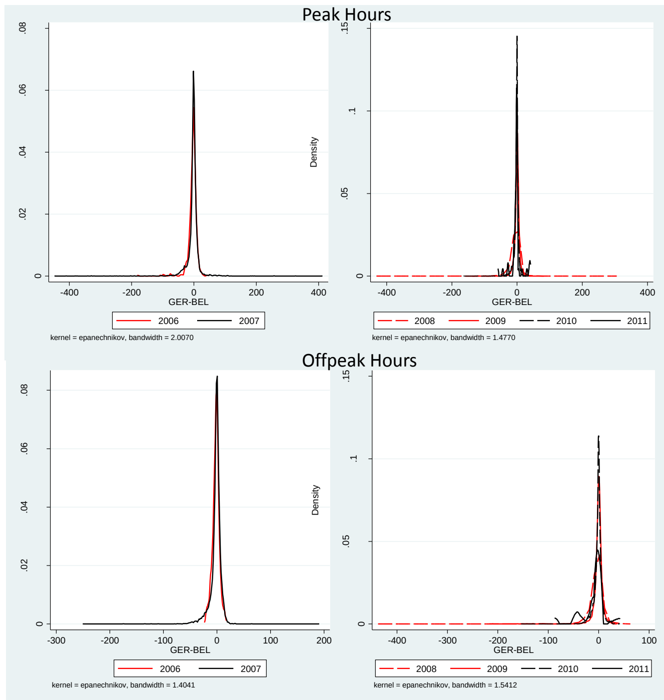
Germany and...	2004-Oct.2010		After MC		in % after MC*	
	Peak	Offpeak	Peak	Offpeak	Peak	Offpeak
Belgium	36	23	428	312	58.79%	50.65%
Netherlands	94	101	543	518	74.59%	84.09%
Switzerland	17	10	0	1	0%	0.16%
Austria	16	12	0	0	0%	0%
Czech Republic	9	11	1	1	0.14%	0.16%
Poland	1	0	0	0	0%	0%
Denmark East	501	318	18	13	2.47%	2.11%
Denmark West	646	468	77	46	10.58%	7.47%
Sweden	426	284	16	4	2.2%	0.65%
Nordic System	158	99	10	1	1.37%	0.16%

Percentage indicates the relation to total number of hours during that period.* Period ranges from November 2010 to January 4th 2011. Source: Own calculation.

the course of time if markets have really grown closer. The density functions confirm the impression that there is a dynamic process of market integration (see apendix for graphs). Interestingly, most spikes in price differences, defined as higher than 500 €/MWh in absolute value, occured in 2006 and 2007. Apart from these few outliers the mass of price differences has shifted towards zero. Exceptions are Sweden and the Nordic System which exhibit a shift away from zero in 2011. However, as there are only very few observations for that period, this may only be of stochastic and not permanent nature. Price differences with Austria appear to be stable with the exception of 2004, where there was a high mass of values near zero. In graph 7 the effect of market coupling is already depicted, as there is a large excess in the density function at value zero. This holds especially true if compared to the density functions for price differences with the Netherlands and Belgium (see graphs 10 and 11 in the appendix).

Finally, the tests for stationarity of the price difference time series also indicate that there has been some development in the course of time, but it does not deliver such clear results as the tests before. If stationarity is considered as an indicator for a common market, then Switzerland, Sweden, the Nordic System and Denmark East do not belong to the German price area by 2009 or 2010. Only in the case of Austria and Belgium, stationarity

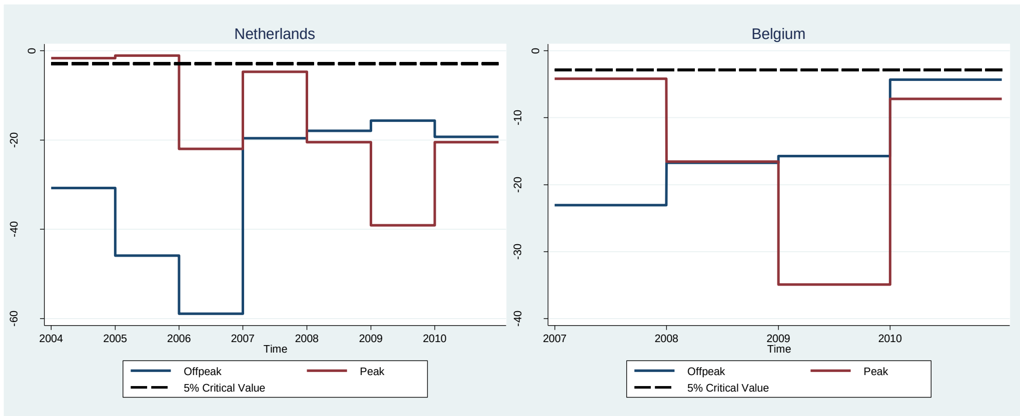
Figure 6: Density Function of Price Differences after Market Coupling



*Own Calculation.

was confirmed for each time period. The Netherlands, Denmark West, the Czech Republic and Poland show a change from a nonstationary process towards stationarity. A critical point however, is the selection of lags, which is necessary in order to compute the dickey fuller test for these univariate time series. We relied on the information criteria tests by Schwarz-Bayes, but other information criteria tests, however, suggested much longer lag lengths. We also tested for these lag lengths, but only a very small number of test results changed from stationarity to nonstationarity, so the results from the stationarity analysis are robust.

Figure 7: Dickey Fuller Test for Stationarity of Price Differences I



Critical Values from Dickey-Fuller test, Own Calculation.

As a final result from the stationarity analysis, the Dutch and Belgian price area as well as Denmark West appear to show strong reactivity to the German price area. Even Austria can be considered as a candidate since the price differences exhibhit a stable density function centered around a near-zero value throughout the years. Especially after the start of the market coupling process at the end of 2010, a common market is strongly indicated between Germany, the Netherlands and Belgium.

5.3 Cointegration

First, the German price series has to be tested for nonstationarity because otherwise there is no sensible cointegration analysis between the price series. Detrending the price series changes the results of the stationarity tests which are essential to the further cointegration analysis. Two out of four stationarity test results change when switching from raw to detrended price data. This switch is necessary, because otherwise the common stochastic trend, which goes along with cointegration, may be due to seasonal effects.

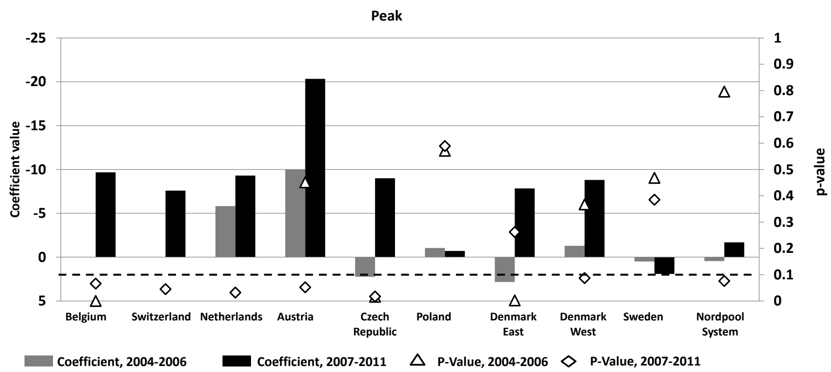
Therefore, the results are restricted to detrended data and from the tests we infer that only offpeak data is nonstationary, see Tables 10 and 11 in the appendix. Consequently, tests for cointegration are only applied to offpeak time series. Only a single cointegration relationship is found on a 5% level for detrended data. The next step is to test which effect the inclusion of input prices has. In order to integrate these into the analysis, the input data are also detrended, but using monthly dummy variables as the data is not daily. Stationarity tests indicate that coal and brent are statiorary in the second sample, rendering a cointegration analysis meaningless. In the first sample the input prices are all nonstationary, but the cointegration analysis exhibits no coherent results, as there is no single cointegration equation.

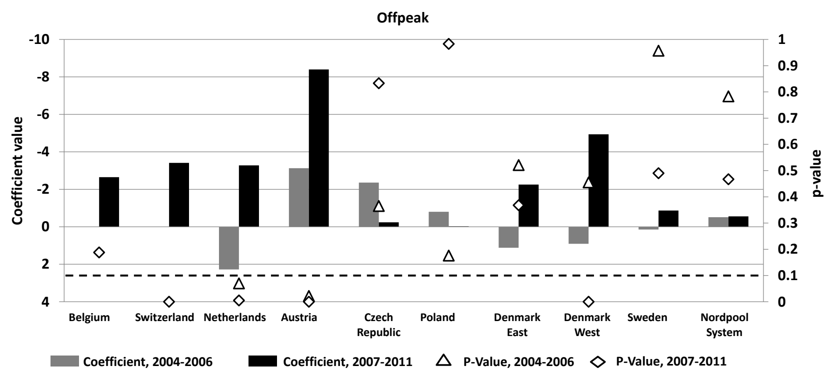
To sum up the basic analysis of stationarity and cointegration tests, we cannot study the degree of market integration based on cointegration tests as this is mainly driven by common drivers such as seasonal effects or even input prices. The underlying vector autoregressive model will thus be transformed into first differences in the further analysis.[12] Each regression produced autocorrelated residuals, so the models were reestimated with Newey-West standard errors. In order to still assess the degree of market integration before market coupling, we rely on the exogenous shock of national holidays in the differenced VAR model and see whether this has significant effects on Neighboring markets. An impact of holidays is, of course, limited to cross-border network capacities. Still, this is a good measure, as the connectivity of two price areas depends on the potential degree of arbitrage exploitation, which is largest during asysmmetric peak hours. Asymmetry here describes the situation where one price area witnesses high (regular) price spikes while another Neighboring price area realizes very low peak prices due to exogenous shocks (national holiday). The effects of the German holiday on German peak and offpeak prices can be analyzed as this coefficient is included in every single pairwise model.

In Figure 8 and 9 the impact of the German holiday on European power spot prices is depicted and vice versa. The results are based on the aforementioned Newey-West estimations including input prices and seasonal effects. Even if only detrended power price series are included in the model, the results remain very similar.

[12]As there are 100 regression output tables, these are not presented in the paper. For each price pair and sample period this includes offpeak vs peak hours, detrended VARs as well as Newey-West robust detrended time series and input price controlled regressions with and without Newey-West standard errors. Of course, the output tables can be easily made available by the authors to interested readers.

Figure 8: Impact of German Holiday on other Peak Spot Prices



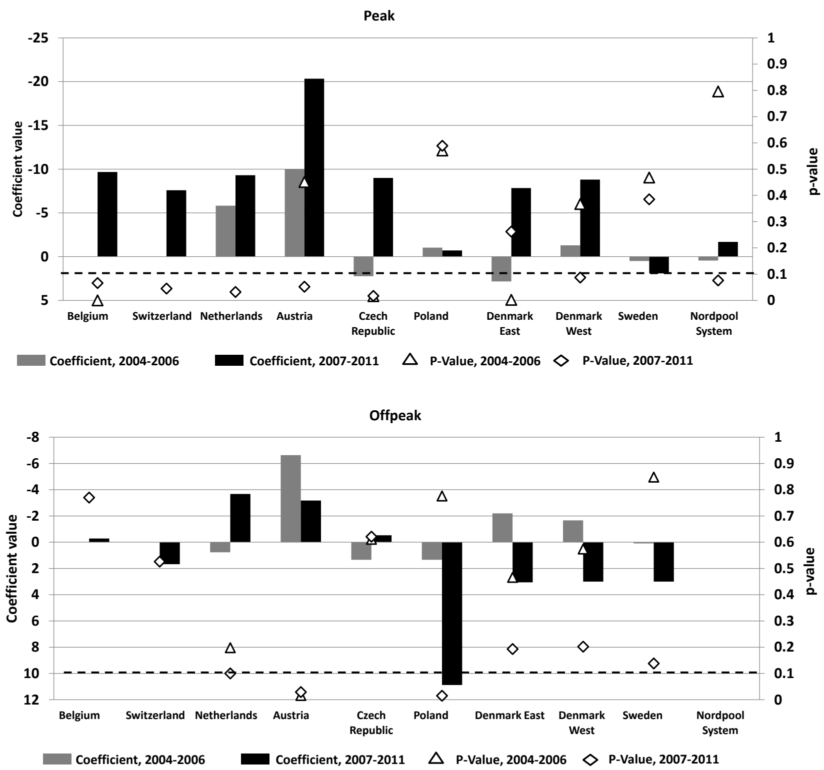


Estimation results with Newey-West robust errors.

The impact of other holidays on the German power price has changed in that it is more often statistically significant in the second sample than before. In the second sample national holidays of Belgium, Netherlands, and Austria have a significant negative effect on the German peak price, with Austria and Netherlands causing the largest price reduction. In offpeak hours the only significant effect is found for the Austrian national holiday.[13] In the first sample, only the Austrian holiday is found to have a significant effect on German power price; which only holds for offpeak prices to be precise.
The German holiday on the other hand, has large and stable significant effects on German peak prices, with coefficients ranging from -14.18 to -17.51,

[13]The Swiss holiday (offpeak) and the Polish holiday (peak) even exhibit positive coefficients, which appears counter-intuitive.

Figure 9: Impact of Other Holiday on German Spot Price



Estimation results with Newey-West robust errors.

but insignificant effects on offpeak prices in the second sample(see Table 23 in the appendix). The impact of the German national holiday on the other power prices shows that only Austria has been significantly and negatively affected. Again, a development between the first and second sample can be observed, as the Dutch, Belgian, Swiss, Czech and West-Danish prices are influenced during peak times. The same holds true for offpeak prices with the exception of Belgium.

A market coupling effect could not be found, if incorporated in the model as a shift dummy. As the number of observations after market coupling is relatively small in comparison to the ex-ante period, we propose to re-examine the potential effect of market coupling on a daily basis, when at least more than one year of data is available.

In summary, we find that Austria, despite its constant difference caused by different trading hours, is strongly connected to the German price area throughout the first and second sample. The second result is, that the common price area is very likely to expand to the Belgium, Netherlands and probably France due to the advent of market coupling between the areas. However, the connection to France has to be analyzed.

The implications for competition policy can easily be seen, when market shares in terms of installed capacity are being compared under the different market delineation regimes. Germany's three largest power generation companies make up roughly 50% of net owned generation. If Austria and Denmark were added subsequently to the relevant market, their share would fall to ca. 43 % and 41%, respectively. Especially the concentration rate for the two largest firms would significantly drop down to 33.94% and 31.28%. Only taking market shares of installed capacity into account is of course not

Table 6: Market Shares and Size

Market Size	E.ON AG	RWE AG	VATTENFALL
Germany	14.17%	17.77 %	10.56 %
GER+AT	12.71%	15.96 %	9.33 %
GER+AT+BEL+NL	11.61%	14.88 %	9.29 %
GER+AT+BEL+NL+DK	11.01%	13.98 %	9.68 %

Market Shares calculated on net owned installed capacity. Source: Platts (2011) with update from third quarter.

sufficient in power markets. Energy-specific market power indicators such as the PSI (pivotal supplier index) and RSI (residual supplier index) draw a clearer picture of potential market power. Still, this market share overview shall only clarify that the geographic extent of the relevant power market has to be revised by national competition authorities, especially in Germany. The concentration ratio for the three largest generators, from a German perspective, drops from 42.5% down to 34.67%, which is roughly eight percentage points. The largest competitor in case of a combination of Germany, Austria, Belgium and the Netherlands is GDF-SUEZ with 8.34%, which is the largest producer in Belgium and the Netherlands with market shares of 67% and

22%, respectively.
The subject of common price areas as a measure of the geographical extent of power markets becomes more important, if the common peak demand hours are analyzed. If peak demand is the same throughout the connected power systems and national authorities regard an autarc power supply as a primary objective, then price differences may occur despite sufficient cross-border capacities. In other words, if each national power generator sticks to his own national area, this could have the same effects as agreements on exclusive territories.

As the change to more ecological power generation, which is mostly wind, solar and water, proceeds, the effects caused by these generation technologies, such as replacement of conventional capacities, should spread through the whole connected system. For instance, Germany has set its target concerning the share of renewable resources in power generation to 30% until 2020. Capacities that have not yet been deconstructed will either retire or bid into the neighboring power exchanges, causing an oversupply in these areas. This should be revised after the completion of the market coupling process.

6 Conclusion

A correct definition of the relevant market is crucial for the assessment of market power and appraisal of mergers. In this paper we analyzed the convergence of European power markets between Jan 2004 and Jan 2011 using three different methods, i.e correlation analysis, parametric and nonparametric tests of price difference and cointegration analysis. Aside from the results of the tests, we find that a neglect of seasonal effects and input prices can lead to biased results as these are main drivers of covariation. Moreover, we used bank holidays as a unique strategy to identify potentially connected price areas. The introduction of market coupling seems to have lead to a large increase in market integration at least among the participating price areas. However, the strongest empirical evidence for a joint price area is found for Austria and Germany. While the simple statement that wholesale electricity markets in Europe are fully integrated cannot be confirmed by our analysis, competition authorities still have to revise the geographic extent of the market. This can cause a huge impact on the assessment of market power and mergers as our analysis indicates. Further research could focus on the long-run effect of market coupling and on the potential integration of European energy markets could be done by detailed simulation studies of the effects of shocks in some countries on energy markets in neighboring countries.

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7 Appendix

Table 7: Correlation of Raw Daily Spot Prices before and after Market Coupling in 2010/2011

Germany and...	Before MC 2010		After MC	
	Peak	Offpeak	Peak	Offpeak
Belgium	0.8632***	0.7570***	0.8655***	0.6751***
Netherlands	0.9364***	0.8651***	0.9226***	0.7898***
Switzerland	0.6466***	0.5411***	0.8365***	0.5773***
Austria	0.8827***	0.7975***	0.8574***	0.7989***
Czech Republic	0.8816***	0.8095***	0.8999***	0.8256***
Poland	0.7036***	0.4619***	0.6663***	-0.0614
Denmark East	0.1000**	0.1597***	0.5046***	0.4894***
Denmark West	0.9088***	0.7258***	0.8435***	0.8573***
Sweden	0.0834	0.0980*	0.5292***	0.2955**
Nordpool System	0.2346***	0.1872***	0.6515***	0.2964**

Null Hypothesis rejected on *** 1%,** 5%, * 10%.

Table 8: Correlation of Detrended Daily Spot Prices before and after Market Coupling in 2010/2011

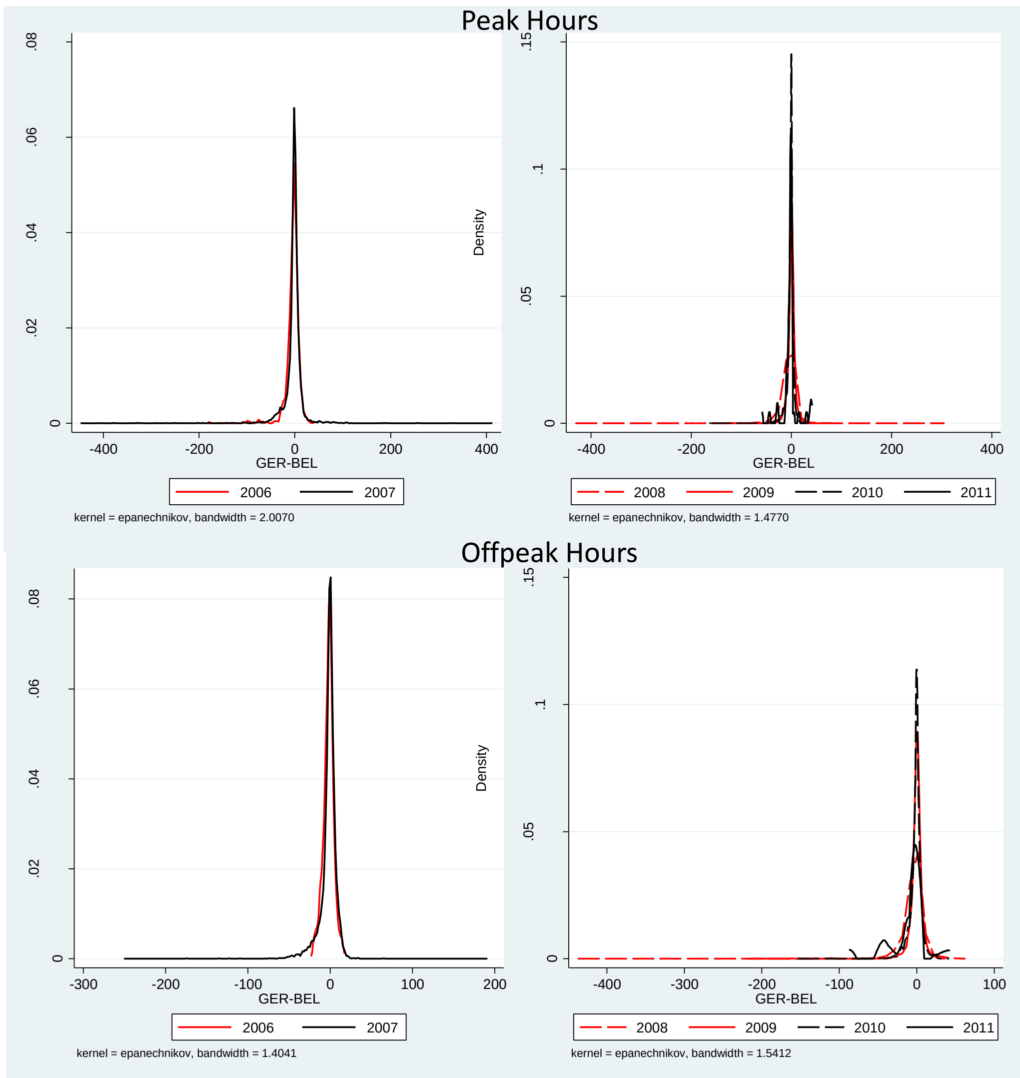
	Before MC 2010		After MC	
Germany and...	Peak	Offpeak	Peak	Offpeak
Belgium	0.7040***	0.6893***	0.8157***	0.6875***
Netherlands	0.8732***	0.8189***	0.8705***	0.7725***
Switzerland	0.5820***	0.4584***	0.7551***	0.5999***
Austria	0.8254***	0.6798***	0.7525***	0.7409***
Czech Republic	0.7910***	0.7221***	0.8533***	0.8098***
Poland	0.5186***	0.4312***	0.4118***	-0.0804
Denmark East	0.0057	-0.0144	0.3758***	0.4546***
Denmark West	0.6257***	0.6405***	0.7751***	0.8165***
Sweden	-0.0197	0.0723	0.3668***	0.2549**
Nordpool System	0.0801***	0.0107	0.5207***	0.2626**

Null Hypothesis rejected on *** 1%,** 5%, * 10%.

Table 9: Mean and Standard Deviation of Hourly Price Difference, 2004-2007

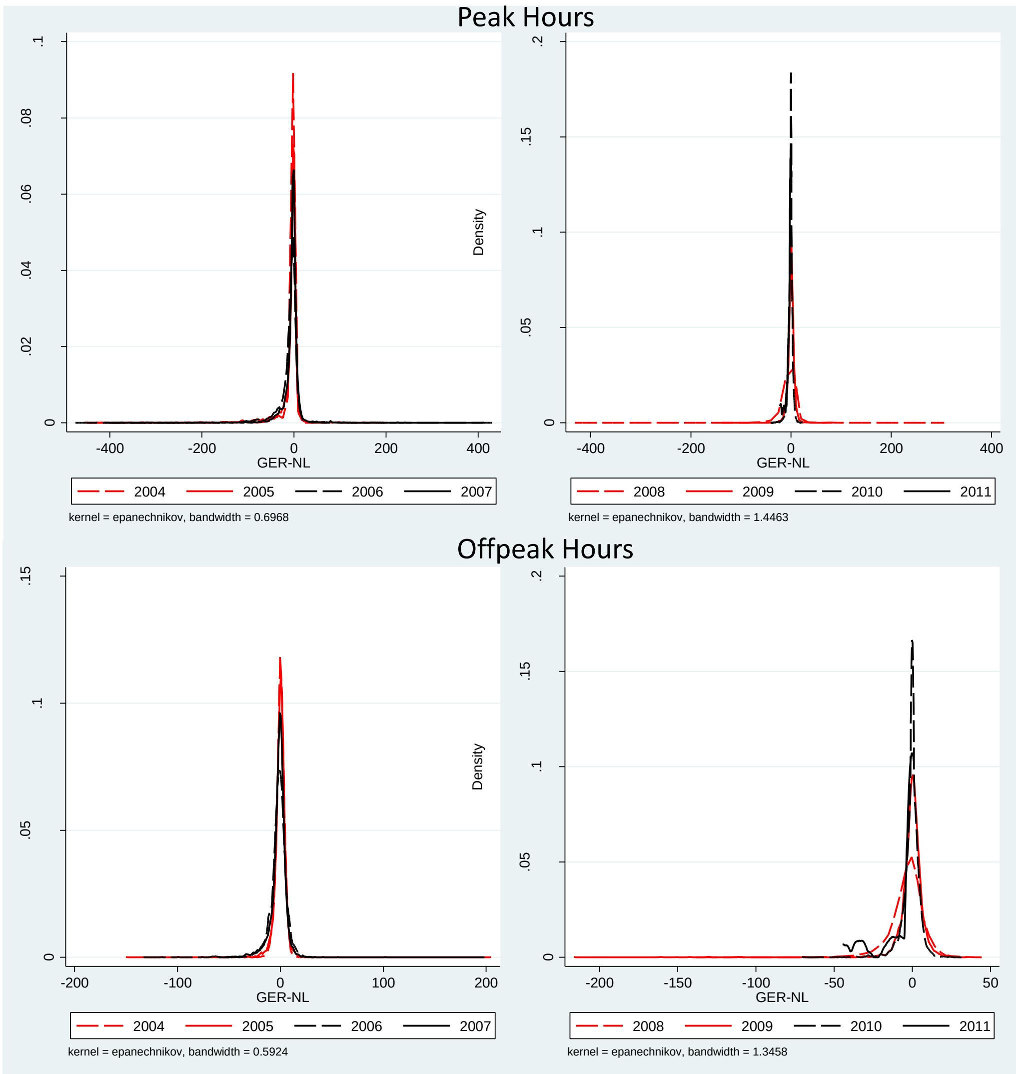
Germany and...	2004	2005	2006	2007
Peak				
Belgium				-5.31[58.1947]
Netherlands	-5.61[24.4238]	-11.60[44.8518]	-11.91[59.583]	-5.89[36.7065]
Switzerland				-7.56[25.5738]
Austria	-0.26[5.4143]	0.71[24.0402]	3.55[58.5344]	5.41[30.7644]
Czech Republic	6.14[12.2690]	17.53[27.7125]	12.39[55.8202]	0.35[20.8521]
Poland	8.09[8.8654]	25.71[30.5639]	31.43[62.4159]	14.31[33.9257]
Denmark East	3.81[8.8576]	17.45[33.6492]	9.23[61.8415]	9.74[28.1262]
Denmark West	2.90[7.9740]	13.07[27.7361]	13.78[61.5199]	9.82[27.2474]
Sweden	4.41[8.7042]	24.48[29.7935]	12.73[62.974]	15.63[31.9365]
Nordic System	4.00[8.9597]	25.24[30.1212]	12.60[62.9454]	18.30[31.8383]
Offpeak				
Belgium				-2.10[11.8304]
Netherlands	-0.02[4.5071]	-0.27[7.4129]	-1.87[8.7382]	-1.61[7.9943]
Switzerland				8.52[14.4344]
Austria	-0.10[4.9970]	-1.89[12.9048]	-4.57[17.2075]	-8.73[30.3028]
Czech Republic	6.69[10.8881]	11.44[13.3730]	7.28[13.6091]	1.66[8.3394]
Poland	-0.35[7.3403]	8.73[12.6009]	8.40[15.2447]	-0.70[12.3662]
Denmark East	-4.12[7.6518]	5.93[10.7721]	-5.99[15.0580]	-0.66[10.1361]
Denmark West	-4.04[7.7454]	3.63[10.0124]	-1.88[12.1191]	0.58[9.1699]
Sweden	-4.24[7.6379]	6.43[11.8505]	-9.22[17.8599]	1.61[11.81]
Nordic System	-5.60[7.7610]	6.57[12.1412]	-10.11[17.5774]	0.31[12.7217]

Figure 10: Density Function of Price Differences I, Ger-Bel



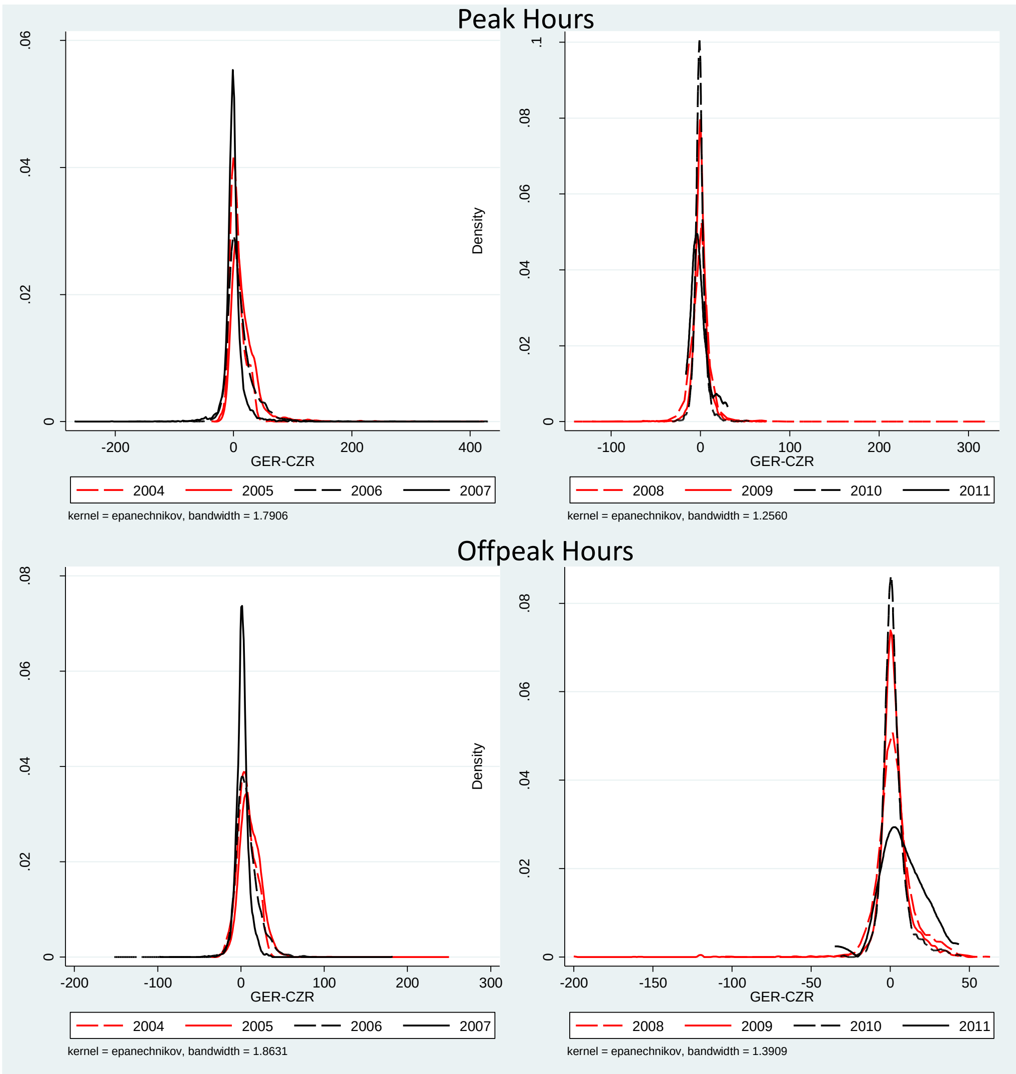
*12 Outliers from 2007 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 11: Density Function of Price Differences II, Ger-Nl



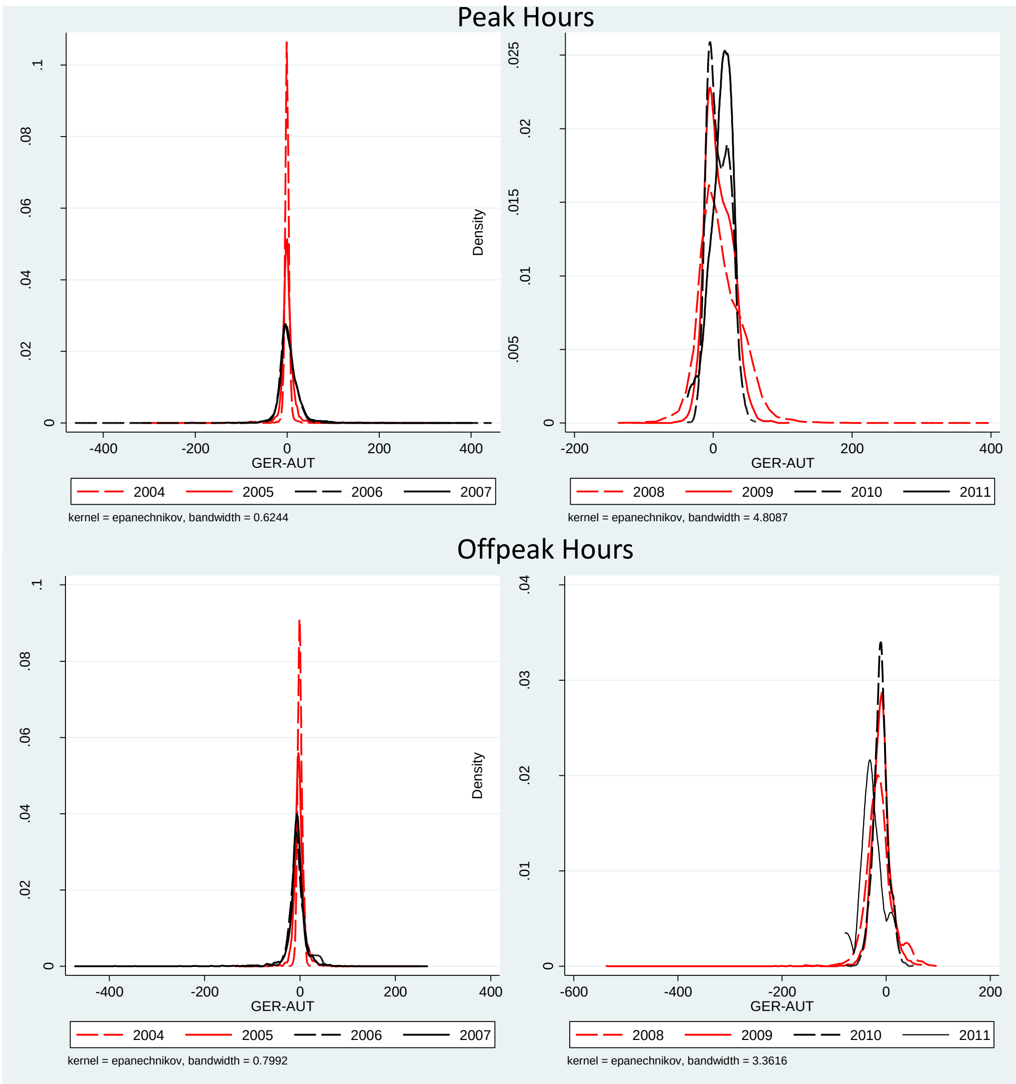
*24 Outliers from 2006 and 2007 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 12: Density Function of Price Differences III, Ger-Czr



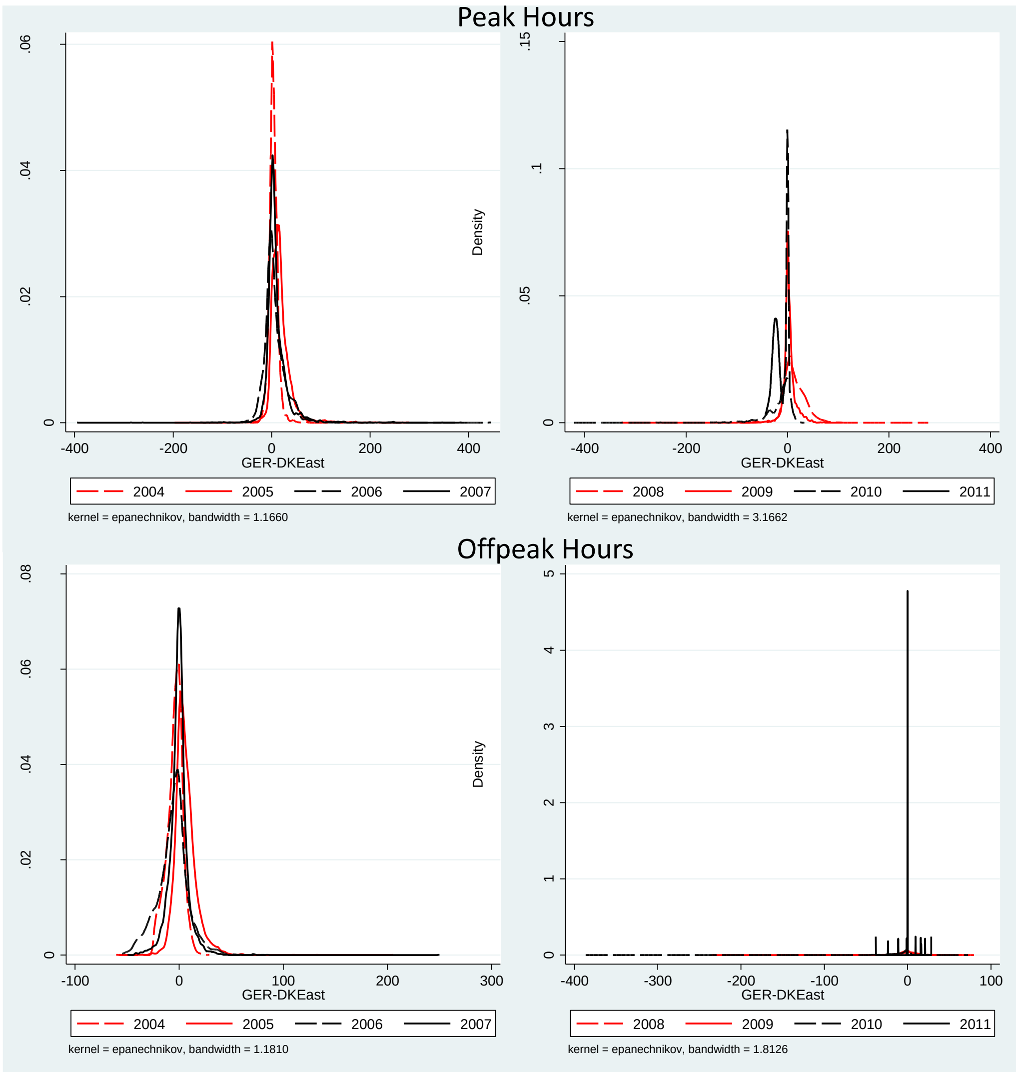
*7 Outliers from 2006 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 13: Density Function of Price Differences IV, Ger-Aut



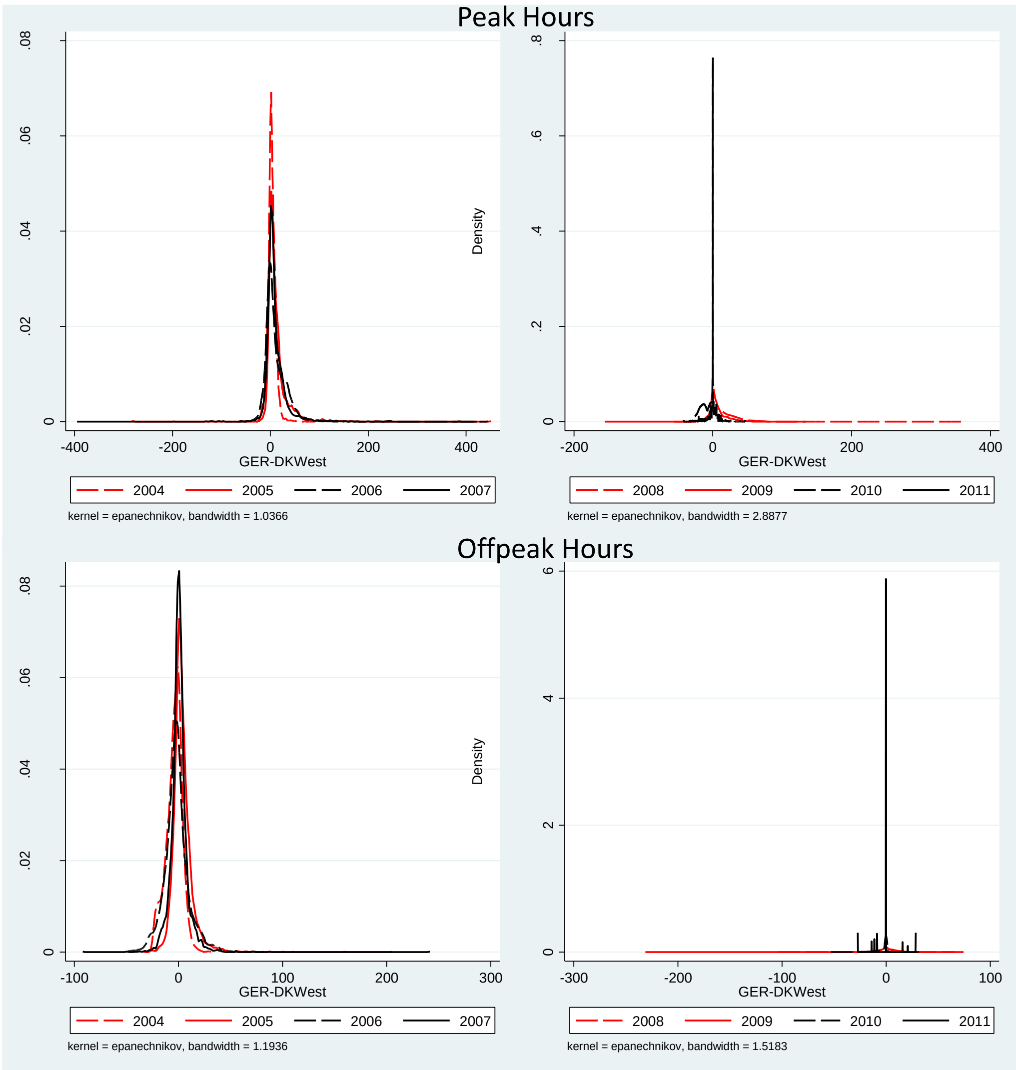
*24 Outliers from 2006 and 2007 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 14: Density Function of Price Differences V, Ger-Denmark East



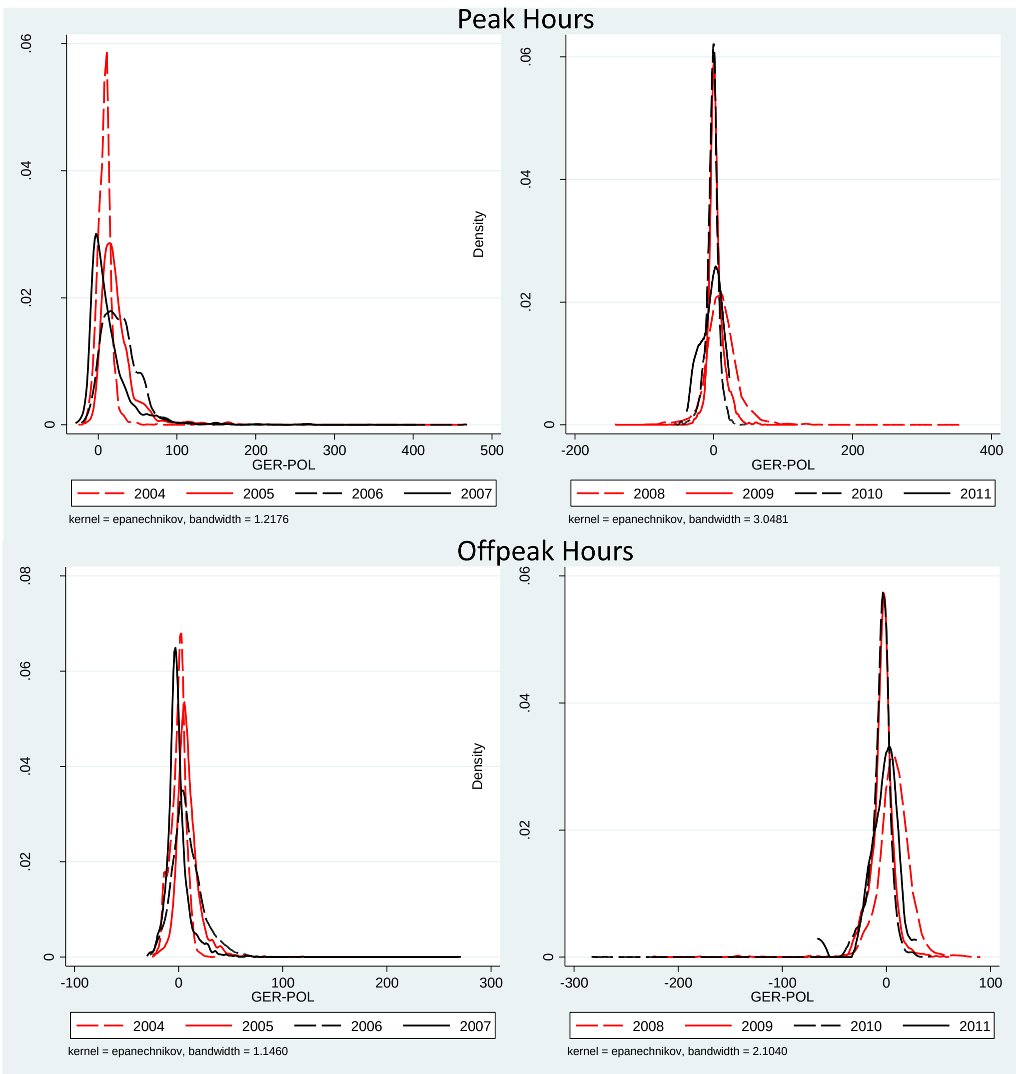
*76 Outliers from 2006 and 2010 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 15: Density Function of Price Differences VI, Ger-Denmark West



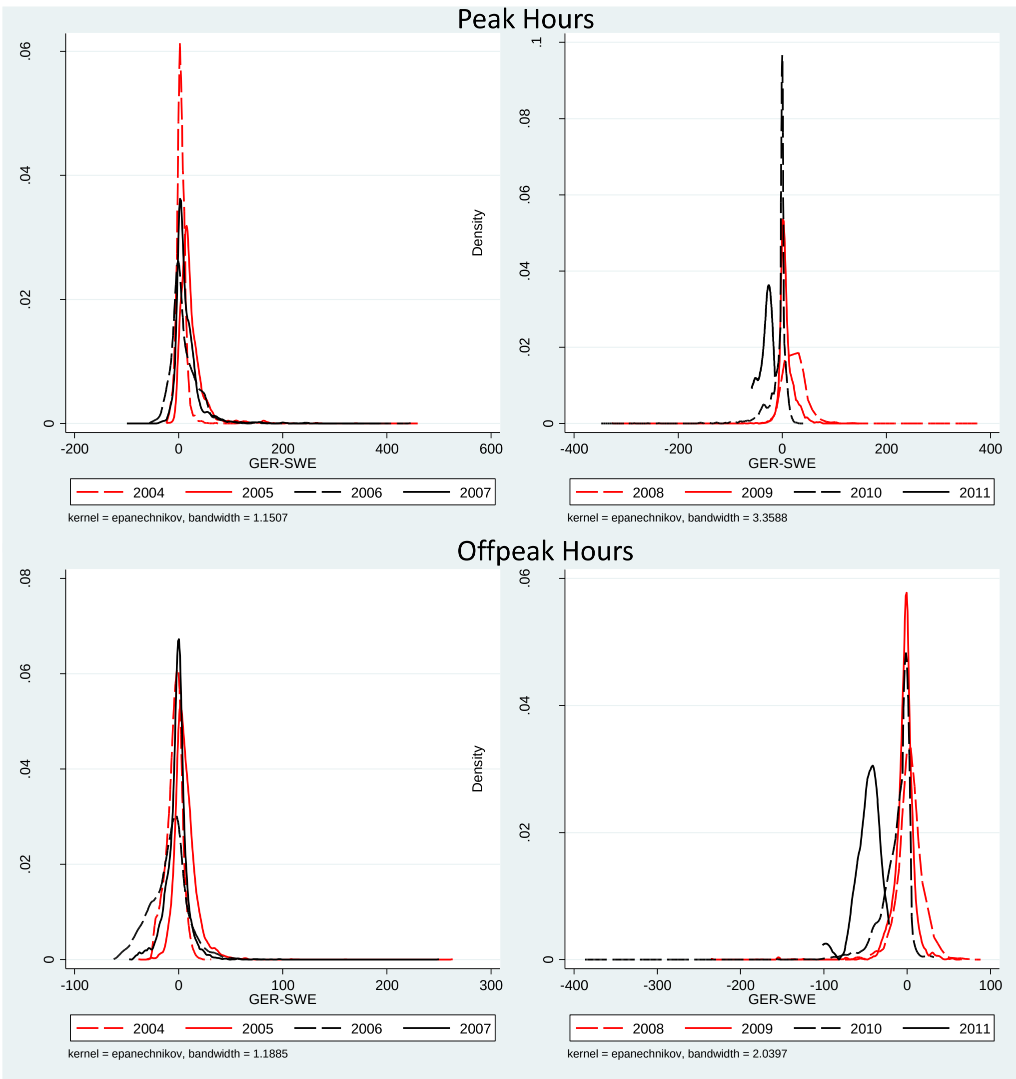
*10 Outliers from 2006 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 16: Density Function of Price Differences VII, Ger-Pol



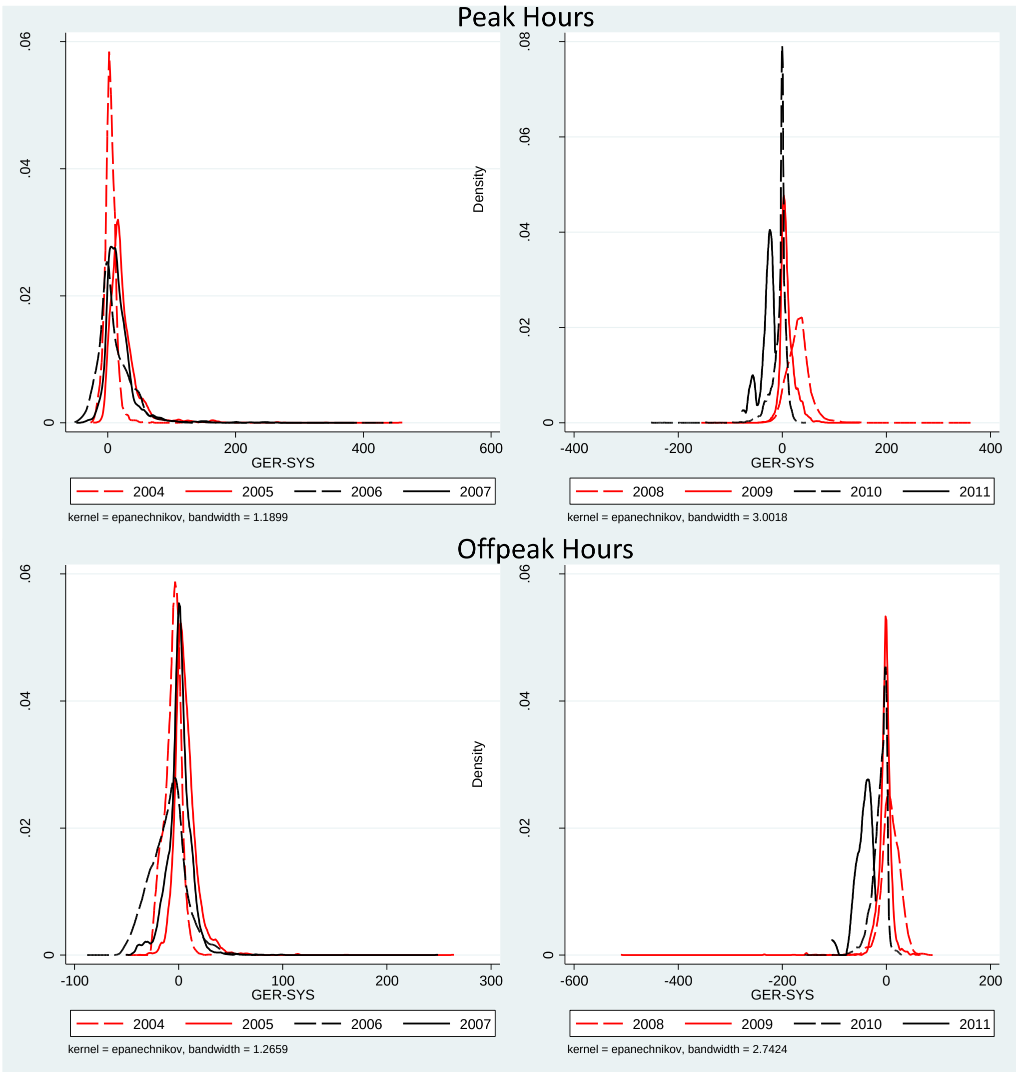
*13 Outliers from 2006 and 2007 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 17: Density Function of Price Differences VIII, Ger-Swe



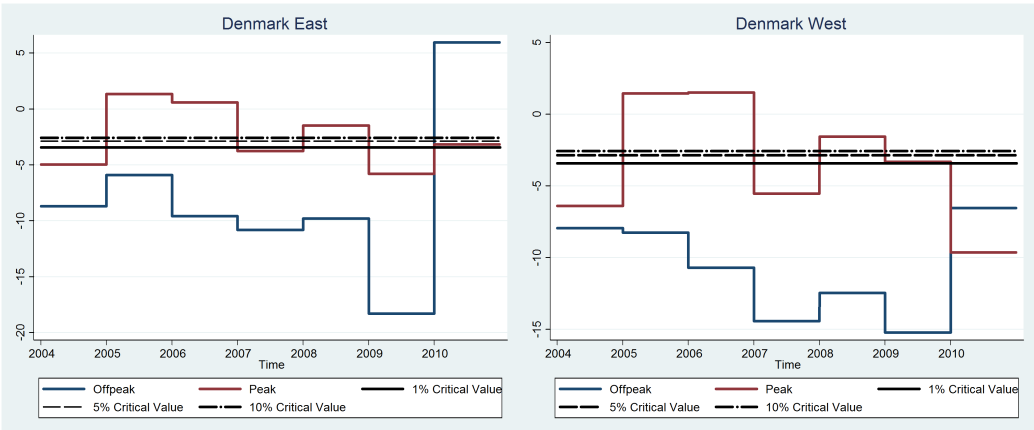
*26 Outliers from 2006, 2007 and 2010 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 18: Density Function of Price Differences IX, Ger-Nordic System



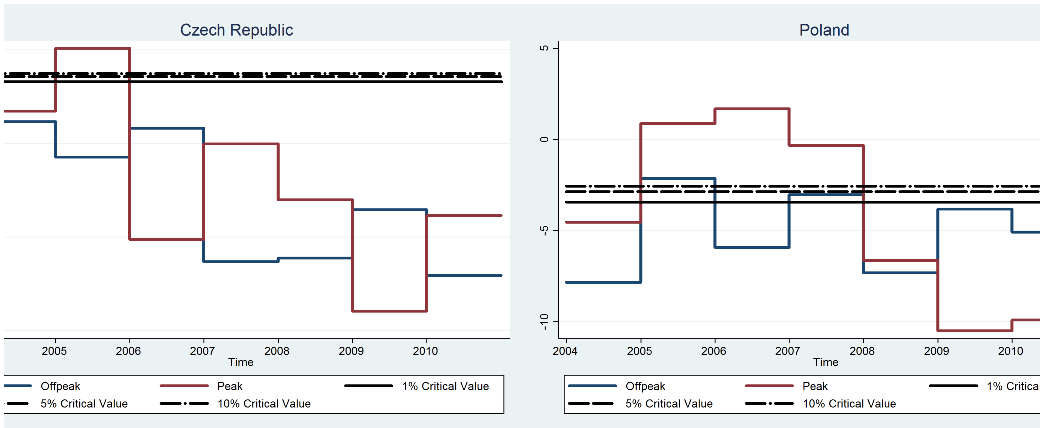
*36 Outliers from 2006, 2007 and 2010 with absolute values of larger than 500 were left out of this graph in order to zoom into the mass of the density.

Figure 19: Dickey Fuller Test for Stationarity of Price Differences II



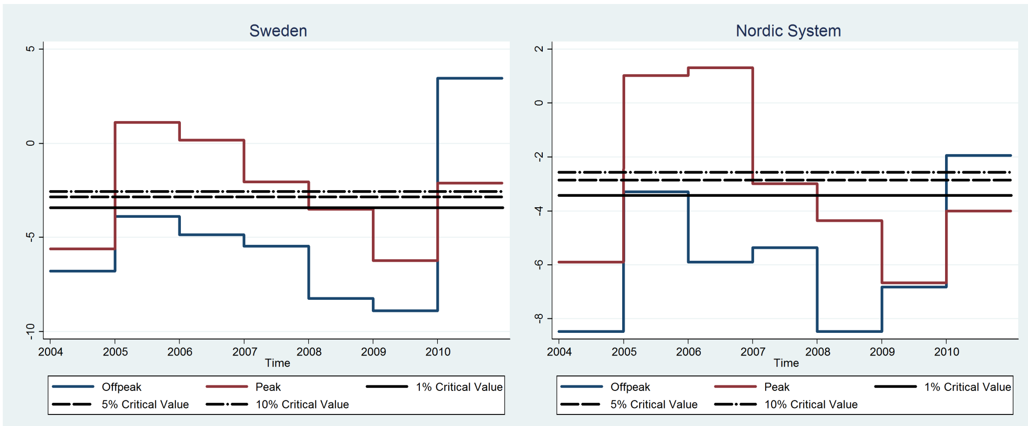
Critical Values from Dickey-Fuller test, Own Calculation.

Figure 20: Dickey Fuller Test for Stationarity of Price Differences III



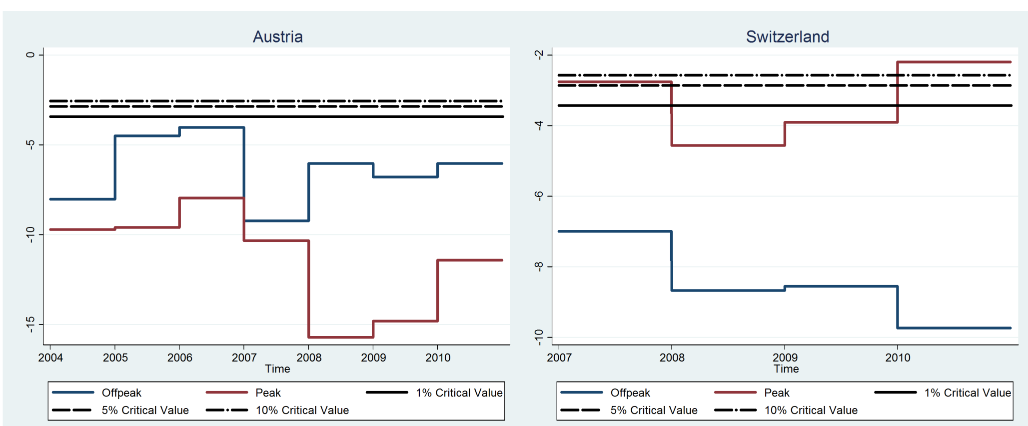
Critical Values from Dickey-Fuller test, Own Calculation.

Figure 21: Dickey Fuller Test for Stationarity of Price Differences IV



Critical Values from Dickey-Fuller test, Own Calculation.

Figure 22: Stationarity of Price Differences V



Dickey Fuller Test for Critical Values from Dickey-Fuller test, Own Calculation.

Table 10: Stationarity of German and Input Price Series

Test	ADF-Value Sample 1	ADF-Value Sample 2
Uranium, detrended	0.872	-2.847
Coal, detrended	-2.547	-3.051
Brent, detrended	-1.355	-4.534
Peak		
Germany, raw	-5.754***	-2.481
Germany, detrended	-5.371***	-3.135**
Offpeak		
German, raw	-2.786*	-2.144
Germany, detrended	-2.273	-2.181
5% critical value	-2.860	
10% critical value	-2.570	

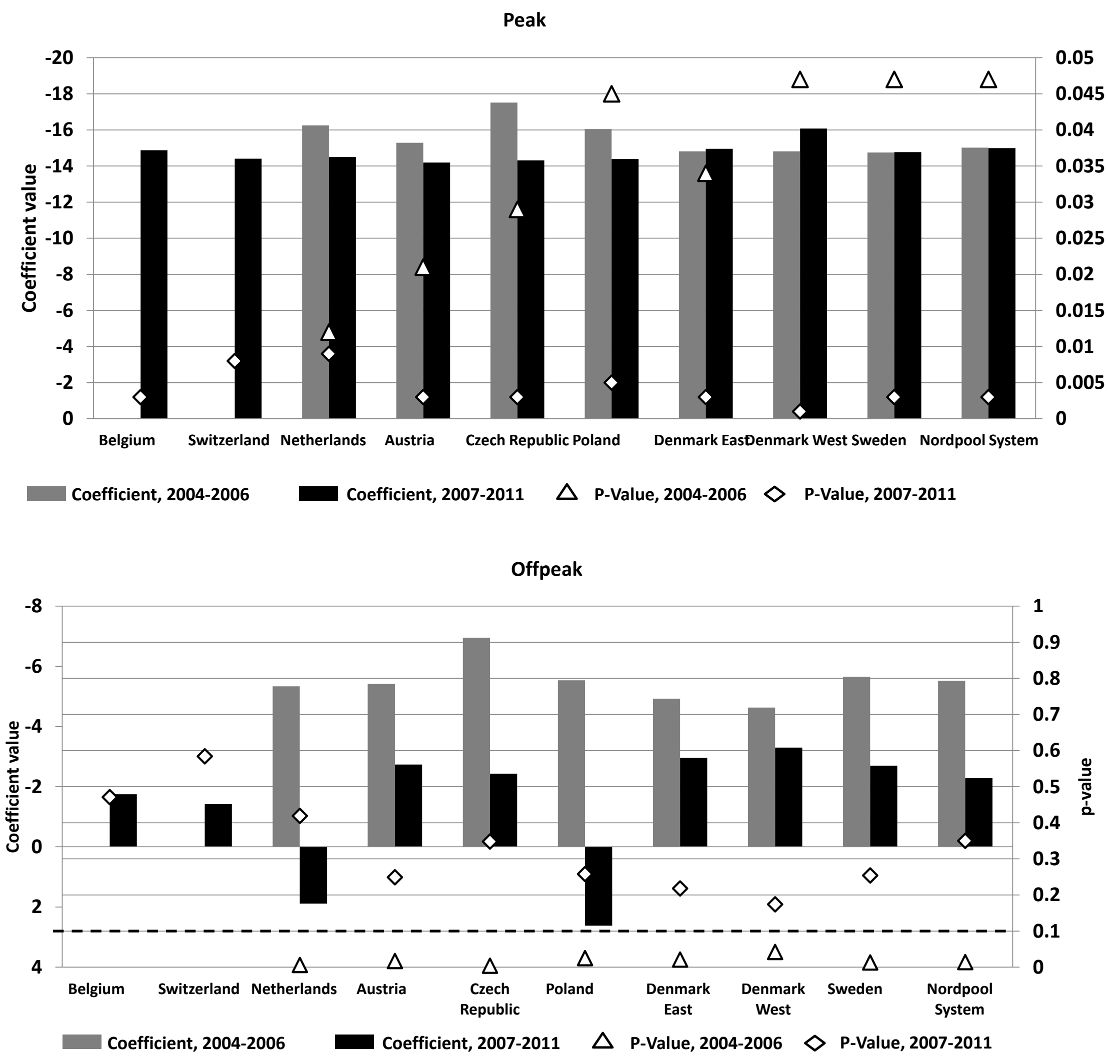
Null hypothesis of nonstationarity is rejected on a *** 1%, ** 5%, * 10% level. We followed the results from the SBIC test for the lag lenth of the process

Table 11: Stationarity of other European Detrended Price Series

Test	ADF-Value Sample 1		ADF-Value Sample 2	
	Peak	Offpeak	Peak	Offpeak
Belgium	-	-	-5.328***	-2.926**
Netherlands	-2.738*	-2.413	-4.839***	-2.723*
Switzerland	-	-	-3.346**	-2.909**
Austria	-4.735***	-2.024	-2.937**	-2.392
Czech Republic	-5.477***	-5.478*	-3.374*	-2.385
Poland	-2.301	-2.553	-2.191	-1.741
Denmark East	-3.920***	-2.849*	-6.579***	-3.889***
Denmark West	-2.628*	-2.940**	-2.364***	-2.625*
Sweden	-2.121	-2.761*	-6.116***	-2.024
Nordic System	-2.028	-1.791	-2.282	-1.987

Null hypothesis of nonstationarity is rejected on a *** 1%, ** 5%, * 10% level. We followed the results from the SBIC test for the lag lenth of the process

Figure 23: Impact of German Holiday on German Spot Price



Estimation results with Newey-West robust errors.

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