Pitfalls in Empirical Spatial Market Delineation: Impact of false estimation on Market Power in European Power Markets

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Abstract

The assessment of market power crucially depends on the correct definition of the relevant market with regard to its product, geographical, and time dimension. We focus on a perfectly homogenous good, electricity, where the law of one price should apply in the relevant geographic market. Spatial market delineation has gained in importance as a result of the European Commissions effort to create a joint market within the European Union and there are various price based test methods, but each of them faces several drawbacks. In European electricity wholesale markets most regulatory and competition authorities delineate markets by their national boundaries. This paper contributes to the empirical spatial delineation literature in two ways. We demonstrate the pitfalls of three different empirical tests and their consequences to the quantitative assessment of market power and introduce a new strategy to uniquely identify the relevant power market. The focus lies on the pivotal role of the German electricity market and we test for pairwise market integration with eight of its neighbor countries. We apply price correlations, price-difference stationarity tests, and Vector Error Correction Models to test for market integration. In our Vector Error Correction analysis we use national holidays as a unique identification strategy to test for integration. We find that standard tests indicate a large increase in the degree of market integration, whereas our new approach only finds one strong link between Austria and Germany, so the hypothesis of national boundaries cannot be upheld anymore.

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1 Introduction

In competition economics the assessment of market power or the welfare effects of mergers is often based on quantitative, usually static, models. The correct denfinition of the relevant market in its product, time and geographic dimension is the first important step to conduct a suitable economic analysis. In case of product differentiation, economists estimate price elasticities and often try to empirically apply the SSNIP (small but significant and nontransitory increase in price)-test. 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 generally able to capture the degree of market integration for every product. This paper contributes to the literature in two ways. We show the effects of neglecting important information, e.g. seasonalities and input prices, in three price based tests and their consequences on static market share measurement. The problems are exemplified by analyzing the European markets for wholesale electricity. Competition authorities still define wholesale energy markets to be national while industry members regard Europe as almost completely integrated. Motivated by a recent study of Nitsche et al. (2010), we analyze the degree of market integration between Germany's wholesale electricity market and corresponding markets of its neighboring countries. The second contribution of our paper is to introduce an new identification method for the degree of integration between these markets. The remainder of our paper is as follows. In the next section we provide a brief overview of the theoretical background and present empirical literature on market integration of wholesale electricity markets. In section three, we give a short introduction to the European power markets and the particular importance of a correct definition of the geographic dimension of the market. Section four describes the steps of our empirical analysis and motivates the application of our new identififcation strategy. We describe our data set in section five. The results and implications for quantitative assessment of market shares are discussed in section six. We conclude and give some suggestions for future research in section seven.

2 Theory and Related Literature

The main idea of the price tests goes back to Jevons (1888: 40 p.), 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. So for two perfectly substitutable products, i and j, at a given point of time, t, the law of one price leads to:

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

Jevons notes, that prices may deviate at some point in time for a very short period, but, on average, prices will be balanced. This effect is captured by ϵ, which is i.i.d. N(0;δ). Since we will later analyze wholesale prices for electricity, the concept has to be extended. If transportation costs are nonzero, the equation extends to

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

where $t(x)$ indicates transportation costs, depending on factor price 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 are zero. If the capacity limit has been reached, prices may theoretically fluctuate between close to zero and infinity. Although, in reality, prices often do not go very high.

$$t = \left\{ \begin{array}{ll} 0 & if\ x < x_{max} \\ \mu\ to\ \infty & if\ x = x_{max} \end{array} \right\}. \tag{3}$$

In theory, we would therefore assume that wholesale electricity prices should always be equal, whenever interconnection capacities between two neighboring countries are not fully constrained. Overcapacities of country A should flow over to country B, whenever prices are higher, hence decreasing the price level there. 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, a lack of including common drivers such as seasonalities and input prices, may force overestimation of the degree of integration. The relationship between fuel and energy prices has also been investigated and will be incorporated in our analysis. 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 in 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 relationship between the respective spot markets. However, they neither take seasonalities nor input prices into consideration, leaving out two significant common drivers to power markets. 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 and energy prices in the US and Europe. An unconditional correlation is put against the mean of a rolling correlation to emphasize the weakness of a simple correlation analysis. From their analysis they conclude that European fuel and energy markets are less integrated in comparison to the US. De Vany and Walls (1999) restrict their analysis to the US and test eleven US wholesale spot prices for cointegration. They take data for the years from 1994 to 1996 and perform pairwise cointegration tests. Each of the off-peak 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 Coordinated Council.[1] The only integration analysis, to our knowledge, that controls for input prices is Mjelde and Bessler (2009) who analyze two power spot markets in the US, PJM (Pennsylvania-New Jersey-Maryland Connection)[2] 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 energy 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 for fully integrated markets. Another but very similar approach to test for market in-

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

[2] 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).

tegration is used by Forni (2004).[3] He uses the log price ratio of two markets and tests these for stationarity. The log price ratio is expected to fluctuate around a certain mean, zero if optimal, and therefore exhibits stationary behavior. He 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 good economic reasons for the persistence of price differences between markets other than (non) integration of the market. 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. Werden and Froeb (1993) argue that neither of the proposed tests is without significant flaws. They argue that price correlations suffer, if not controlled for, from common drivers, such as seasonalities 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 miscalculate 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 a company specific demand applies, for instance, to consumer goods, but not to power markets due to the physical nature of electricity. With regard to price analysis, they 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). In addition, not price equality was important, but, following the SNIPP approach, the threshold of price elasticity, at which consumers start to substitute products. The speed

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

of adjustment, proclaimed by Horrowitz (1981) would be also a flawed approach, because if products are not perfect substitutes, even instantaneous reactions from competitors to a price increase by a hypothetical monopolist would not induce substitution. In addition, 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 hourly basis. Also the nature of power markets necessitates quick adjustments, because supply always has to be equal to demand, which is mostly inflexible. An increase in prices in a certain market will mostly not persist for long and the necessary time for power transportation is not rather short. Finally, common drivers are also one of two main points of critique according to Werden and Froeb (1993: 344 p.), because, if neglected, they can be the sole reason for a cointegration relationship. If not controlled for, such relationships can falsely be interpreted as long-run equilibrium 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 significant sample reduction.

3 European 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. The European Commission aims at creating a single European market for power. Up until today, most of the power markets are being dominated by 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 large 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 and build joint institutions that aim at connecting markets. The first aim is to increase the efficiency of cross-border flows, hence strengthening the already existing link between national transmission operators, before markets are truly integrated. As 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, leads to a uniform price for the complete area. Germany plays a pivotal role in the European transmission system being surrounded by ten neighboring countries and is the largest producer in Europe. This makes spatial market delineation even more important in antitrust and merger cases.[4] 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, very 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. The exact characteristical influence of seasons and business cycles will be crucial to our identification strategy and shall be discussed in the next chapter. Note, however, that the general seasonal effects are generally the same for each of the surveyed European countries, i.e. low demand during summer and high demand during winter.

4 Empirical Strategy

In order to account for the seasonalities and business cycles, we will not only include deterministic variables, but split the dataset up in two. The first data set deals with the so-called peak hours, which relate to the hours where daily demand is highest (mostly 8.00 a.m. To 8.00 p.m.). The respective offpeak hours encompass the time before and after peak hours. This is standard in energy economics and is very important when analyzing the degree of market integration or detecting abusive market behavior. The overall procedure aims at controlling for pairwise market integration relationships, i.e. Germany and each of the respective neighbors. Our analysis is threefold and each of these three steps will be done for each time series, peak and offpeak.

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

In addition, each of the three steps is calculated using raw price data, seasonally adjusted data, and price data, where we controlled for seasonalities and input prices. By this, we want to point out the problems, mentioned by Werden and Froeb (1993), i.e. that a lack of including common price drivers may overestimate the actual relationship. In step one, we analyze price correlations as a first indicator for the presence of market integration. In detail, three different types of correlations are calculated, i.e. unconditional, yearly and, rolling correlation given a 100 day period. We are fully aware of the fact that correlation analysis is limited to the short-run, because we always calculate correlations between realizations of variables from identical time periods. For step two and three, we split the dataset in two subsamples, i.e. two time periods (2004-2006 and 2007-2011), in order to deal with the aforementioned problem of cointegration relationships and to show a potential increase in market integration. The second method directly aims at the law of one price. The differences between prices in Germany and its neighboring countries are checked for stationarity, using the ADF test, and are subsequently analyzed by nonparametric tests, such as percentile analysis and a Kolgomorov-Smirnov-test to check whether there are significant differences between prices. An increase in market integration indicates a higher number of days, where the price difference is zero, or at least very close to it.

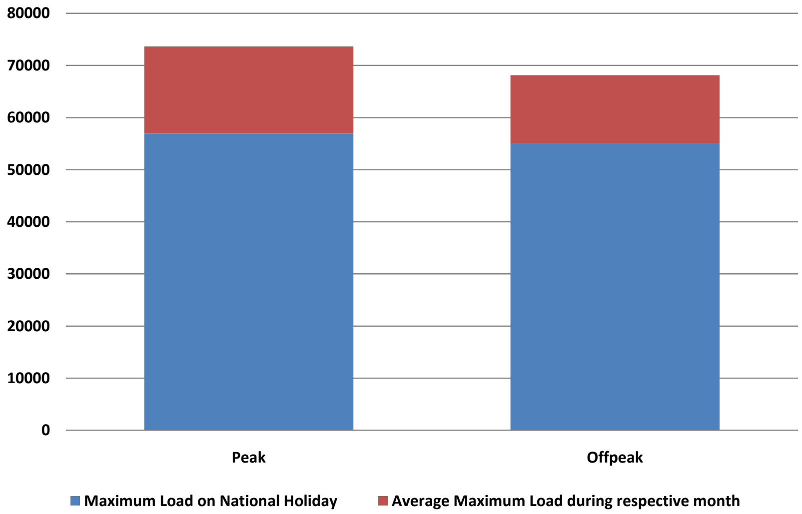
In step three we first check the pair of power prices for cointegration. Keep in mind, that this is, again, done with raw data, detrended data, and prices, that have been adjusted for seasonalities and input prices. In the latter case, the input prices are directly included in the cointegration analysis, as the cointegration relationship between two power prices may consist of their common link to input prices. First, unit-root tests are run for each time series. If the series are nonstationary a Johansen trace tests 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 then estimate either a Vector Error Correction model or a Vector Autoregressive model. The underlying VAR is estimated as follows:

$$\begin{aligned} p_{i,t} = &\sum_{n=1}^{\rho} \beta_n p_{i,t-n} + \sum_{n=1}^{\rho} \gamma_n p_{j,t-n} \\ &+ \sum_{n=1}^{\rho} p_{uranium} + \sum_{n=1}^{\rho} p_{coal} + \sum_{n=1}^{\rho} p_{oil} \\ &+ \sum_{s=1}^{3} \delta_s d_{season} + d_{weekday} + holiday_i + holiday_j + \epsilon \end{aligned} \tag{4}$$

Whatever model is estimated, it will incorporate two dummy variables indicating the national holidays of the respective countries. The motivation behind this unique strategy is as follows: First, the cointegration vector may indeed not indicate the long-run price equilibrium between two price series. If, for example, two or three cointegration relationships are found, the hypothesis of the single long-run equilibrium cannot be upheld. In order to account for possible flaws in the interpretation of the cointegration vector, we use an exogenous demand-side shock to identify the price link between two power markets. Demand for electricity is, as mentioned before, subject to seasonalities and business cycles. The seasonal effect leads to higher demand during winter than in the summer period. Business cycle effects cause weekdays to induce higher demand levels than weekends. The same argument holds for intra-day cycles, i.e. peak and offpeak hours. Therefore, demand during peak hours on a winter's weekday is higher than during a saturday night in summer. This is where our identification strategy sets in. On national holidays when there are no holidays in neighboring countries, e.g. July 14th in France or October 3rd in Germany, business activities, especially those of high energy consuming industries, are very low, especially during peak hours.

Therefore 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 owing over to market B. These national-holiday dummies are included in our analysis and should, regardless of the actual model (VAR or VECM), reflect this relationship.

Figure 1: Impact of Holiday on German Demand



5 Data

We use data from ten European wholesale electricity spot markets (see table below). Prices are day-ahead on an hourly basis in its original format, but where transformed into mean daily peak and off-peak prices. Peak and off-peak refers to the hours traded at the power exchanges.[5] The former covers the most important hours of the day and will be defined from 8:00 a.m to 8:00 p.m. The latter therefore includes all other from 9:00 p.m. to 7:00 a.m. We checked for the change between daylight saving time during summer and winter time by deleting duplicate hours (often the hours from 02:00-03:00 a.m. during a day in march) and including missing hours (often the hours from 02:00-03:00 a.m. during a day in October). Missing hours are replaced by the previous prices. The other variables used especially for the cointegration analysis are deterministic variables, input prices and the aforementioned national bank holidays. 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

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[5] 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.

Table 1: Data Overview

EEX, Germany	2004-2011
EEX, Austria	2004-2011
Belpex, Belgium	2006-2011
APX, Netherlands	2004-2011
PPE, Poland	2004-2011
OTE, Czech Republic	2004-2011
Swissix, Switzerland	2006-2011
Nordpool, Denmark	2004-2011
Nordpool, Sweden	2004-2011
Nordpool, System	2004-2011

twice a weak provided by Platts database (2011), uranium, weekly reported provided by UX Consulting Company (2011), and oil, reported weekdays provided 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 bought every day by power generators. We define national bank holidays as the single day that is labeled as the day where the respective nation was proclaimed, e.g. October 3rd for Germany.

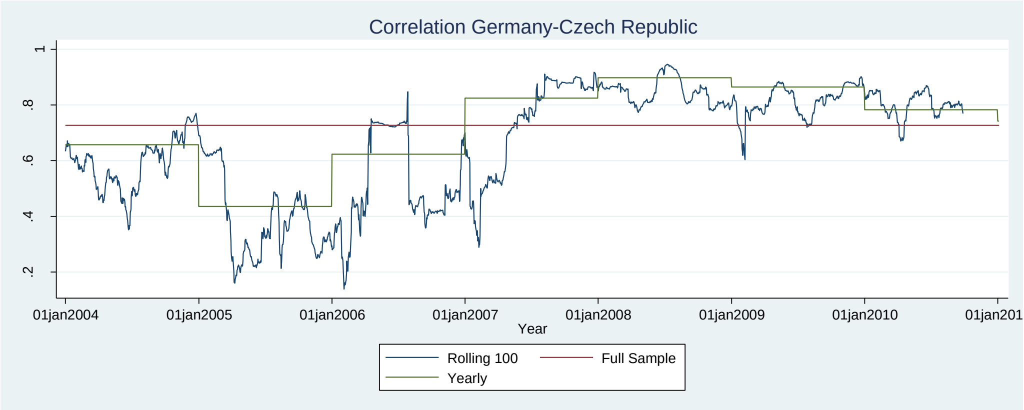
6 Estimation results

There are two clear 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, trends, business cycles, and seasonalities. 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. However, applying our new identifiFcation strategy, only the pair Germany-Austria can be confirmed as fully integrated. The detailed results are presented in the following subsections.

6.1 Correlation Analysis

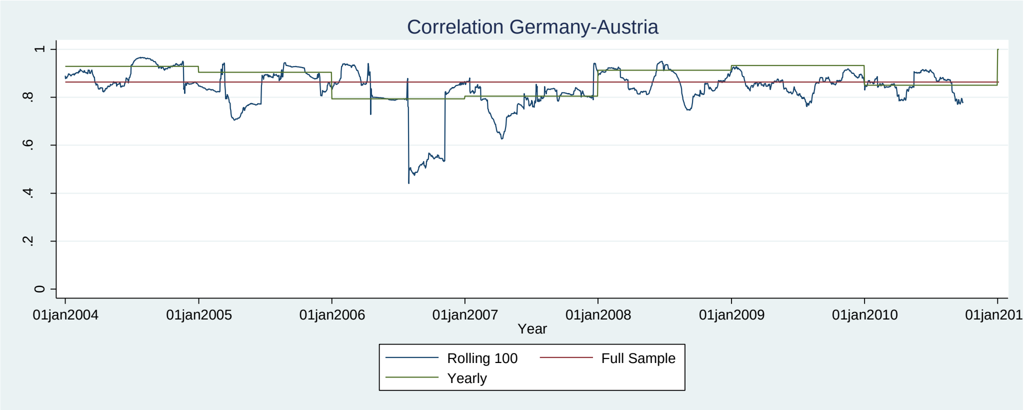
The correlation analysis includes full sample, yearly, and rolling 100 days correlation. In calculating correlations according to these three sample sizes, we want to show the insufficient and misleading results of long sample periods. As can be seen from the figures below, rolling correlations seem to capture the increasing degree of correlations best. Figure 2 clearly shows that full sample correlation clearly overstates the price correlations before 2007 and understates these afterwards. Also, the rolling correlation shows that the integration seems to have taken a large increase in the year 2007. The same cannot be said however for the Nordic countries, where correlation values do not display such a development.

Figure 2: Correlation and Sample Size I



Disregarding the effect of seasonalities and input prices clearly overestimates the degree of correlation as table 2 shows. After controlling for these influences, there are four countries 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 between them. Also, 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 good indicator. Despite the overall result of high price correlation between the

Figure 3: Correlation and Sample Size II



national markets, the degree varies a lot if the correlation sample period and the difference between raw and detrended data are concerned. Furthermore, it is still difficult to define the threshold level at which markets are considered integrated. From our analysis, we take the aforementioned countries of Austria, Netherlands, Belgium and Denmark East as possible candidates, with Austria being the most promising candidate.

Table 2: 100 Days Rolling Correlation with the German EEX

Test	Raw	Detrended	Detrended and fuel controlled
Peak			
Belgium	0.8235	0.7342	0.6623
Netherlands	0.7870	0.6984	0.7072
Switzerland	0.8005	.7094	.0.6043
Austria	0.8805	0.8322	.0.8374
Czech Republic	0.7444	0.6629	0.6637
Poland	0.4988	0.3514	0.2971
Denmark East	0.5471	0.4589	0.4706
Denmark West	0.5564	0.5471	0.5564
Sweden	0.4647	0.3132	0.3226
Nordic System	0.4602	0.3267	0.3343
Offpeak			
Belgium	0.7125	0.6535	0.5980
Netherlands	0.8056	0.7511	0.7547
Switzerland	0.5929	0.5342	0.4704
Austria	0.8073	0.7497	0.7441
Czech Republic	0.6317	0.5597	0.5589
Poland	0.4065	0.3038	0.3032
Denmark East	0.6680	0.6076	0.6091
Denmark West	0.5017	0.4473	0.4470
Sweden	0.4238	0.3677	0.3677
Nordic System	0.3827	0.3456	0.3433

6.2 Price-Differences

First, the data set is split up into two subsamples, ranging from 2004 to 2006 and 2007 to 2011, respectively. We analyze the price differences through descriptive statistics and non-parametric tests and subsequently test the time series for stationarity. The first result is, that detrending the price series and conrolling for input prices does not change the results of the price difference analysis for each pair. This is exemplified by the Netherlands, depicted in figure 5. Most pairs, however, show great changes in the distribution function. So our further presentation of the results will be restricted to the fully detrended and input price controlled price-differences. In general, the distribution of sample 2 is different from sample 1 in that it has become denser around zero and the kurtosis has changed drastically in some cases.

Figure 4: Price Difference Distribution I

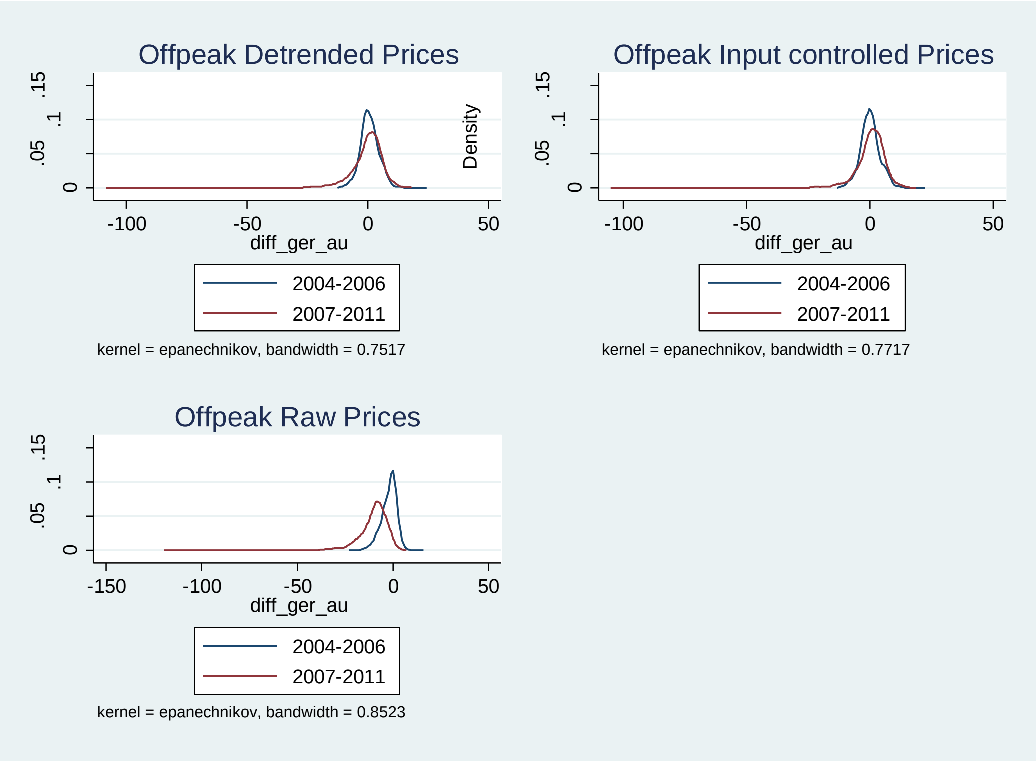
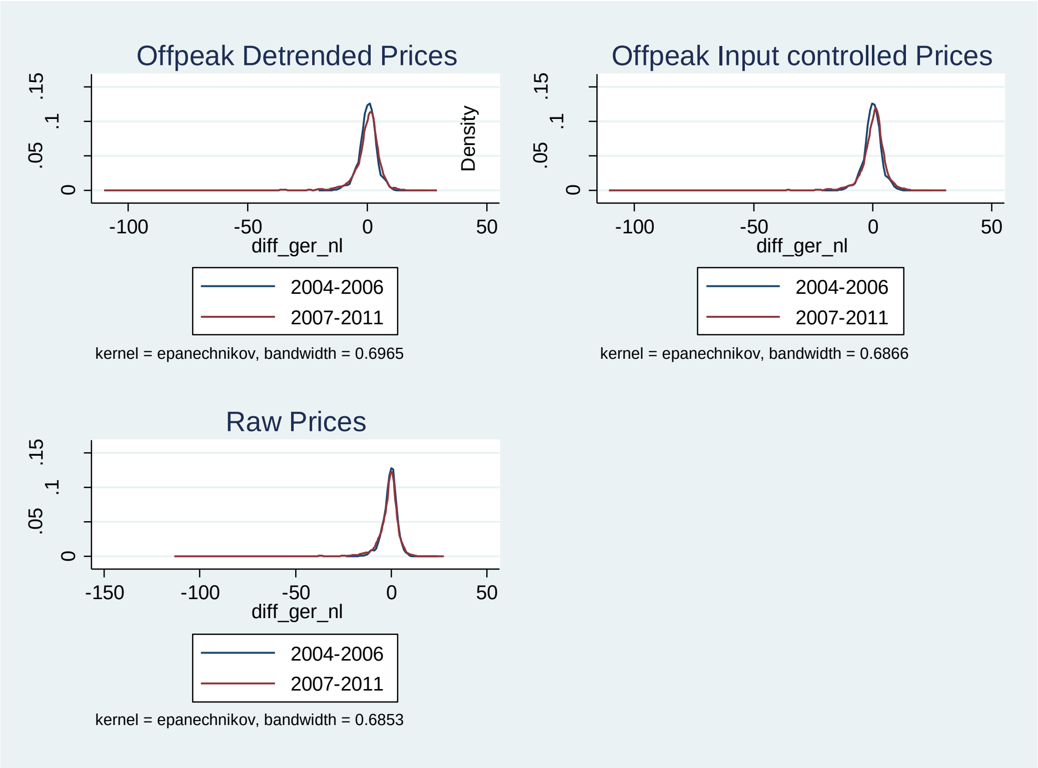


Figure 5: Price Difference and Sample Size II


Offpeak Detrended Prices

Offpeak Input controlled Prices

Raw Prices

kernel = epanechnikov, bandwidth = 0.6965

kernel = epanechnikov, bandwidth = 0.6866

kernel = epanechnikov, bandwidth = 0.6853

The Kolgomorov-Smirnov test clearly indicates that the price difference distribution has changed. Especially the variance of the price series has decreased for most series, except the Nordic countries. Mean values are very close to zero, especially in the case of Austria. While the differences are often close to zero, the value zero has not been realized on many occasions.

Table 3: Distribution of Price Differences

Test	KS-Test	Mean /Variance Sample 1	Mean /Variance Sample 2
Peak			
Belgium	-	-	-1.17/410.56
Netherlands	0.1701*	-0.38/554.01	0.28/216.20
Switzerland	-	-	-1.12/230.69
Austria	0.0485	0.05/199.65	-0.04/79.46
Czech Republic	0.2000*	0.55/445.34	-0.41/90.60
Poland	0.0354	0.98/655.71	-0.73/276.69
Denmark East	0.2084*	-0.37/593.84	0.28/914.53
Denmark West	0.124*	0.04/576	-0.03/206.41
Sweden	0.2206*	-0.68/717.27	0.51/917.24
Nordic System	0.1782*	-0.92/709.57	0.68/346.85
Offpeak			
Belgium	-	-	0.5980/91.41
Netherlands	0.1040*	-0.08/14.38	0.06/41.14
Switzerland	-	-	-0.69/105.41
Austria	0.1535*	0.06/15.69	-0.04/65.24
Czech Republic	0.1338*	0.23/81.01	-0.17/49.35
Poland	0.0585**	0.62/76.56	-0.46/92.41
Denmark East	0.1272*	-0.5/93.56	0.38/150.47
Denmark West	0.0592*	-0.16/46.60	0.12/43.64
Sweden	0.1580*	-1.07/134.50	0.80/177.60
Nordic System	0.1496*	-1.29/139.97	0.96/136.98

Null hypothesis of Equal Distribution is rejected on a 1%, 5%, 10% level.

The stationarity tests indicate that each series of price differences is stationary. This result alone, however, does not yet suffice to support the hypothesis of the law of one price. The mean value can only be tested through the estimation of Autoregressive models. The constant would then be tested for significant difference from zero. Such an analysis is not included in our paper, but it would naturally support the results of this stationarity test. From the non-parametric and descriptive analysis we expect the mean value to be close to zero.

Table 4: Stationarity of Price Differences

Test	ADF-Value Sample 1	ADF-Value Sample 2
Peak		
Belgium	-	-10.50*
Netherlands	-15.506*	-16.555*
Switzerland	-	4.581*
Austria	-13.683*	-10.611*
Czech Republic	-6.562*	-3.822*
Poland	-6.225*	-6.785*
Denmark East	-7.637*	-7.971*
Denmark West	-7.019*	-4.663*
Sweden	-5.693*	-7.590*
Nordic System	-6.103*	-2.680***
Offpeak		
Belgium	-	-8.554*
Netherlands	-16.760*	-15.851*
Switzerland	-	-7.479*
Austria	-5.773*	-9.523
Czech Republic	-9.825*	-15.051*
Poland	-4.274*	-7.922*
Denmark East	-4.102*	-6.758*
Denmark West	-5.132*	-10.056*
Sweden	-3.197**	-5.709*
Nordic System	-3.108**	-4.932*

Null hypothesis of nonstationarity is rejected on a 1%, 5%, 10% level.

6.3 Cointegration

The severe effects of disregarding seasonalities and input prices become very clear when estimating Vector Error Correction Models and testing for cointegration. When testing each series for stationarity (see table 8 in the appendix) the analysis is already flawed, since the price series for the German power exchange is stationary on a 10% level. This holds also true for the Dutch and West Danish power prices. The East Danish and Czech price series is stationary on a 5% and 1% level. In the second sample, German prices are stationary on a 1% level, so a cointegration analysis is not possible. If controlled for input prices and seasonalities, stationarity cannot be confirmed, but the Johansen Trace test finds mostly two cointegration relationships (see appendix). This makes an interpretation of the cointegration relationships difficult. We estimate each VEC model and if the cointegration rank is one, we can examine the cointegration vector. If theory is right, this is the long-run equilibrium between the price pairs and should, if the law of one price holds, mean that $p_i - p_j = 0$. In total only seven cointegration relationships of rank one were found, none of which from the first data sample. Only Austria is included in both peak and offpeak samples and only the cointegration vectors of Poland and Austria are close to one. All other cointegration vectors cannot be interpreted in favor of market integration and will thus not be considered any further.

Table 5: Cointegration Vector

Test	Cointegration Vector
Peak	
Austria 2007-2011	-1.066
Switzerland 2007-2011	-0.5888
Nordpool System 2007-2011	-0.201
Offpeak	
Austria 2007-2011	-0.722
Nordpool System 2007-2011	-0.534
Sweden 2007-2011	-0.111
Poland 2007-2011	-1.099

Using national holiday dummies as identification method, we find that only the pair Germany-Austria can be considered to belong to the same market. Not only does the German holiday influence Austrian power prices, but the same holds true for the Austrian holiday at least for the last sample period. The dummy is also significant for peak hours in Denmark West in the last sample period. However, in none of the other periods significant effects were found. Therefore the interpretation of this market combination has to be more careful at this point.

Table 6: Influence of National Holiday 2004- 2006

Test	German Holiday	Other Holiday
Peak		
Austria 2004-2006	-8.782	-7.943
Austria 2007-2011	-15.812*	-17.161*
Denmark West 2007-2011	-13.911*	-1.359
Offpeak		
Austria 2004-2006	-5.241**	-5.279**
Austria 2007-2011	-5.947**	-1.058

Null hypothesis of indifference from zero is rejected on a 1%, 5%, 10% level.

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 7: Market Shares and Market Definition

Test	German	Germany+Austria	Germany+Austria+Denmark
RWE AG	20.83%	18.49 %	17.04 %
E.ON AG	19.82%	15.45 %	14.24 %
Vattenfall	12.14%	9.8 %	10.63 %

Market Shares calculated on net owned capacity. Source: Platts (2011).

sufficient in power markets. Energy-specic 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.

7 Conclusion

A correct definition of the relevant market is important to market power assessment and merger control. However, spatial market delineation on a price basis has essential drawbacks and can lead to biased results. In this paper we applied three different methods, i.e correlation analysis, tests of price difference stationarity and Vector Error Correction Models, and emphasize the importance of seasonalities and input prices as main drivers of covariation. Moreover, we included bank holidays as a unique identification scheme into our analysis, which changes results significantly. By subdividing the data set into two subsamples, we show that the degree of market integration has increased between 2007-2011. However, we find strong empirical evidence only for the pair of 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 has to be acknowledged by national competition authorities when assessing market power. Further analysis 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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8 Appendix

Table 8: Stationarity of Raw Price Differences

Test	ADF-Value Sample 1	ADF-Value Sample 2
Peak		
Germany	-5.754*	-2.481
Belgium	-	-2.425
Netherlands	-2.536	-2.044
Switzerland	-	-2.542
Austria	-3.524*	- -2.593***
Czech Republic	-5.575*	-2.707***
Poland	-6.225*	-6.785*
Denmark East	-4.867*	-7.971*
Denmark West	-2.546	-6.730*
Sweden	-1.798	-6.529*
Nordic System	-1.676	-1.749
Offpeak		
Germany	-2.786***	-2.144
Belgium	-	–2.588***
Netherlands	-2.581***	-2.204
Switzerland	-	-2.315
Austria	-2.540 *	-2.049
Czech Republic	-5.968*	-2.498
Poland	-6.225*	-6.785*
Denmark East	-3.149**	-3.771*
Denmark West	-2.784***	-2.259
Sweden	-2.239	-2.657***
Nordic System	-2.373	-2.227

Null hypothesis of nonstationarity is rejected on a 1%, 5%, 10% level.

Table 9: Stationarity of detrended and input controlled Prices

Test	ADF-Value Sample 1	ADF-Value Sample 2
Peak		
Belgium	-	-10.50*
Netherlands	-15.506*	-16.555*
Switzerland	-	4.581*
Austria	-13.683*	-10.611*
Czech Republic	-6.562*	-3.822*
Poland	-6.225*	-6.785*
Denmark East	-7.637*	-7.971*
Denmark West	-7.019*	-4.663*
Sweden	-5.693*	-7.590*
Nordic System	-6.103*	-2.680***
Offpeak		
Belgium	-	-8.554*
Netherlands	-16.760*	-15.851*
Switzerland	-	-7.479*
Austria	-5.773*	-9.523
Czech Republic	-9.825*	-15.051*
Poland	-4.274*	-7.922*
Denmark East	-4.102*	-6.758*
Denmark West	-5.132*	-10.056*
Sweden	-3.197**	-5.709*
Nordic System	-3.108**	-4.932*

Null hypothesis of nonstationarity is rejected on a 1%, 5%, 10% level.

Table 10: Cointegration Rank

	Sample LR value/Rank	Sample 2 LR value/Rank
Peak		
Belgium	-	31.28/2
Netherlands	19.94/3	32.64/16
Switzerland	-	55.72/1
Austria	20.14/3	59.69/1
Czech Republic	19.16/3	32.93/2
Poland	19.95/3	35.05/2
Denmark East	19.73/3	27.78/2
Denmark West	19.91/3	28.04/2
Sweden	60.89/1	27.96 /2
Nordic System	57.21/1	51.62/1
Offpeak		
Belgium	-	27.64/2
Netherlands	19.93/3	27.95/2
Switzerland	-	53.89/1
Austria	19.78/3	56.75/1
Czech Republic	18.78/3	33.78/2
Poland	19.70/3	58.95 /1
Denmark East	19.64/3	61.17/1
Denmark West	20.00/3	27.91/2
Sweden	62.92/1	54.98/1
Nordic System	58.41/1	50.57/1