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Competition in Germany's Minute Reserve Power Market: An Econometric Analysis*

Justus Haucap†, Ulrich Heimeshoff‡, and Dragan Jovanovic§

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Abstract

The German reserve power market was subject to important regulatory changes in recent years. A new market design was created by synchronization and interconnection of the four control areas. In this paper, we analyze whether or not the reforms led to lower prices for minute reserve power (MRP). In contrast to existing papers, we use a unique panel dataset to account for unobserved heterogeneity between the four German regional markets. Moreover, we control for endogeneity by using weather data as instruments for electricity spot market prices. We find that the reforms were jointly successful in decreasing MRP prices leading to substantial cost savings for the transmission system operators.

JEL-Classification: C33, C36, L59, L94

Keywords: Competition, Frequency Control, Minute Reserve Power, Regulation, Productive Efficiency, Welfare

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1 Introduction

The nature of electricity requires that balance between production and consumption is maintained in the electricity grid at each point in time. Typically, this task is imposed as a responsibility on the transmission system operator (TSO) to ensure system stability by procuring so-called (electricity) reserve power.[1] For this reason, generation units are obliged to reserve some fraction of their capacity which can be used then by TSOs to restore frequency and load in the electricity grid.[2] As imbalances between supply and demand can be caused e.g., by incorrect demand predictions, stochastic fluctuations of electricity generation from renewable energy sources, especially wind and solar energy, and (or) breakdowns of generation units, the provision of ancillary services such as frequency control is a crucial element for ensuring system stability.

In Germany, as well as in all other 33 member states of the European Network of Transmission System Operators for Electricity (ENTSO-E), three different 'qualities' of reserve power are used: 1.) primary control power (PCP), 2.) secondary control power (SCP), and 3.) minute reserve power (MRP) (tertiary control power). Moreover, two types of SCP and MRP have to be distinguished: *incremental* (positive) reserve power and *decremental* (negative) reserve power. While the former is used when the demand for electricity exceeds the supply of electricity, the latter is needed when more electricity is generated than consumed. In Germany, the prices charged for each of the reserve power products are two-part tariffs. The so-called capacity price is paid for the stand-by provision of reserve power, while the operational price is paid in case of delivery. The capacity price reflects the suppliers' opportunity cost of committing not to use the reserved capacity to supply it on electricity wholesale (spot) markets. The focus of our paper is on MRP capacity prices for both incremental and decremental MRP. It should be noted that MRP is only used if both PCP and SCP were insufficient to restore the desired grid frequency of 50 Hz.

[1] The term (electricity) reserve power builds on the fact that certain fractions of generating capacities have to be reserved for frequency control purposes. Alternative expressions are balancing power and frequency control power. However, we use the term (electricity) reserve power throughout the rest of the paper.

[2] According to the European Network of Transmission System Operators for Electricity (ENTSO-E) the power line frequency must be 50 Hz. Whenever there are deviations exceeding certain predefined threshold levels (+/-10 mHz), reserve power is needed to restore the desired value of 50 Hz.

The German market for reserve power has been subject to two important regulatory changes in recent years. The first regulatory change focused on the synchronization and standardization of the four distinct and time-separated control areas (regional markets) in Germany. More precisely, a common web-based tendering platform (www.regelleistung.net) was launched as a result of the Energy Industry Act of 7 July 2006 (see BNetzA, 2006, 2007a, and 2007b). Initially, each of the four TSOs[3] in Germany procured reserve power in its own control area at various times based on bilateral contracts with affiliated generation plants. In 2001 and 2002, respectively, the German Federal Cartel Office replaced these bilateral contracts by procurement auctions, while the four control areas remained distinct and time-separated. By introducing a common web-based tendering platform, the control areas were synchronized and standardized in time and place on 1 December 2006, for MRP, and one year later, on 1 December 2007, for PCP and SCP.[4] According to the German Federal Network Agency (Bundesnetzagentur, BNetzA), the aim of these reforms was to foster competition and to increase efficiency by eliminating strategic behavior and facilitating market entry (see BNetzA, 2006).

The second regulatory change comprised the period from December 2008 and July 2010. The four TSOs were obliged to gradually interconnect and to cooperate their operations in order to realize synergies (see BNetzA, 2010). Whereas market synchronization and standardization aimed at increasing market efficiency by promoting competition and reducing the possibilities of strategic behavior, the second regulatory change solely tackled the inefficient use of reserve capacities. It has been designed to reap benefits from interconnection without directly affecting the competitive process. The reform concerned only SCP and MRP. For illustration purposes, consider the following example: Suppose that one control area exhibits excess electricity supply, while another control area has excess demand for electricity. Further assume that the resulting frequency deviations are independent and equal in volume. Based on the ‘old’ regulatory framework, one TSO would have to procure decremental MRP, while the other needed to purchase incremental MRP, to eliminate the resulting frequency deviations. With interconnection and cooperation, there is no need to procure any kind of MRP, since the excess production of one

[3]The four German TSOs are ENBW Transportnetze, Amprion, TenneT TSO, and 50Hertz Transmission.

[4]It should be noted that MRP is procured daily, while a monthly auction is used for PCP and SCP. Since June 27, 2011, both PCP and SCP are procured based on a weekly auction.

control area completely offsets the excess consumption of the other. Hence, such compensating deviations can be managed internally through joint TSO balancing without involving MRP suppliers, and thus the MRP market. One implication is that a generation unit, which has been formerly prequalified for only one regional market, is now automatically able to offer SCP and MRP in all four control areas. In other words, there is one merit order including all four control areas which results in one market price rather than four market prices.

The academic literature on competition in electricity reserve markets is rather scarce. Most papers studying the efficiency of the MRP market in Germany analyze the market design from a theoretical perspective. While some papers focus on the possibility of strategic and collusive behavior given the procurement auction design (see e.g., Müller and Rammerstorfer, 2008), others either study optimal decision rules for network operators and reserve capacity suppliers (see Swider, 2006, and Swider and Weber, 2007) or analyze productive efficiencies (Swider and Ellersdorfer, 2005).

The second strand of literature empirically evaluates the effects of the structural reforms, solely focusing on the synchronization of the MRP markets. Growitsch et al. (2007) analyze the reform's effect on both incremental and decremental MRP prices. They use time series analyses testing for a structural break when the common web-based tendering platform for MRP was launched. In addition to the incremental and decremental MRP price time series, they use data on electricity spot market prices, and find that the launch of the common web-based tendering platform had no significant effect on incremental and decremental MRP prices, i.e., no evidence for structural breaks. Growitsch and Weber (2008) analyze the spread between incremental MRP prices and electricity spot market prices. They apply a mean reversion model to test whether the degree of market integration between the MRP market and the spot market has increased due to the new market design. They show that the MRP market has become more efficient, although the price spread has increased over time. Finally, Riedel and Weigt (2007) provide a correlation analysis where they study the interdependence between the four German regional markets and their relationship to the electricity spot market.

We extend these papers in four directions. First, we have created a unique dataset for the period from 1 January 2006 to 30 September 2010 to apply panel data models accounting for unobserved heterogeneity between the four German control areas. Second, we estimate causal effects by performing instrumental variable techniques. In doing so, we control for endogeneity of the wholesale electricity (day-ahead) spot market price using German weather data as instruments. Third, we also consider the synchronization of the PCP markets and SCP markets as well as the interconnection of the four TSOs, and ask whether they had an impact on MRP prices. However, our main focus is on the launch of the common web-based tendering platform for MRP because it is natural to expect a direct effect on MRP prices. We perform Chow tests to check whether or not each of the reforms led to a significant change of MRP prices. It is straightforward that a reform is classified as successful only if it leads to a significant structural change and if its effect on MRP prices is negative. Finally, we quantify the reforms' joint success in the MRP market by comparing the actual MRP prices with the counterfactual scenario, i.e., estimated MRP prices presuming no reforms.

We find that market synchronization and standardization significantly decreased both incremental MRP prices and decremental MRP prices, while the second regulatory change apparently had no further impact on prices. More precisely, TSO interconnection and cooperation partially also led to an increase of MRP prices or did not significantly affect MRP prices at all. Hence, the effect is ambiguous. Nevertheless, the reforms' joint effect on MRP prices is negative which has led to considerable savings in each of the four regional markets.

The remainder of the paper is structured as follows. Section 2 provides a brief overview of the regulatory changes. Section 3 contains the main part of our paper: we present the data and perform an econometric analysis to evaluate the reforms' effects on MRP prices. Finally, the reforms' success is quantified. Section 4 concludes the paper.

2 Regulatory Changes in the German Electricity Reserve Power Markets

The synchronization and standardization of the electricity reserve power markets in Germany started on 1 December 2006, when a common web-based tendering platform was launched for MRP. The timing of auctions, the prequalification procedure,[5] and the selection of reserve

[5]Prequalification means the procedure of evaluating whether or not a generation unit meets the required criteria to be approved to offer electricity reserve power. It has been changed by reducing the minimum quantity to be supplied, allowing joint capacity offerings, and using specified publication obligations in order to facilitate

power providers in merit orders were specified and standardized. Whereas the auctions were time-separated and imposed different prequalification requirements for generation units before 1 December 2006, the new market design harmonized and synchronized the procurement auctions, while each TSO continued to procure MRP for its own control area. Hence, the four distinct regional markets remained. Moreover, the new market design prescribed that the procurement auction had to close before the electricity (day-ahead) spot market at the European Energy Exchange (EEX) opened.

The procurement auction after 1 December 2006 can be basically characterized as a *i)* repeated (daily), *ii)* day-ahead, *iii)* multi-unit (incremental and decremental), *iv)* one-sided (only reserve capacity supplier make offers), *v)* multi-part (capacity price and operating price), and *vi)* pay-as-bid auction (see e.g., Müller and Rammerstorfer, 2008).[6] The market synchronization was completed on 1 December 2007, when joint web-based tendering platforms were also launched for PCP and SCP. In contrast to MRP, the procurement auction was initially held monthly, and the prequalification procedures were more restrictive due to the inherently higher technical requirements of PCP and SCP.[7]

The four TSOs started to interconnect and to cooperate already before the German Federal Network Agency made it mandatory as of 16 March 2010. Initially, two alternative concepts were discussed to reduce the inefficient use of reserve power capacity in the SCP market.[8] On the one hand, one central and overriding TSO was proposed to control the frequency in all four control areas. This alternative was favoured by Amprion which is the TSO owned by the integrated German electricity company RWE. However, the three remaining TSOs (ENBW Transportnetze, TenneT TSO, and 50Hertz Transmission) supported the second alternative which consisted of a cooperation and interconnection of all four TSOs in order to realize synergies. ENBW Transportnetze, TenneT TSO, and 50Hertz Transmission already started to cooperate and to interconnect their operations before 16 March 2010. In doing so, they preempted the Federal

market entry. For a more detailed discussion see BNetzA (2006).

[6]Note that the procurement auction for PCP cannot be classified as a multi-unit auction, since incremental and decremental reserve power are not distinguished in primary control.

[7]Note that the procurement auctions for PCP and SCP are held weekly since 27 June 2011. Our dataset does not include this change in market design.

[8]A more detailed discussion can be found in e.g., BNetzA (2010).

Network Agency's decision, and, thereby, made the installation of one central TSO more difficult. As a result, the second alternative was put in place by the Federal Network Agency, and Amprion was forced to join the existing TSO network in 2010 (see BNetzA, 2010).

The process of cooperation and interconnection, which initially concerned the SCP market, was realized gradually, comprising four modules. In a first step, the TSOs had to eliminate the use of opposed SCP and to ensure that they determine the required reserve capacity by jointly balancing all four control areas (modules 1 and 2, M1 and M2). In a second step, the TSOs had to start to procure SCP jointly and to use one merit order for all control areas (modules 3 and 4, M3 and M4). Finally, Amprion was required to join the existing TSO-network at the latest on 31 May 2010. However, Amprion already joined in April 2010. On 1 July 2010, the reform was extended to the MRP market, and the TSOs began to cooperate and interconnect their operations while procuring MRP.

The following table summarizes and illustrates the sequence of reforms encompassed by the regulatory changes in the German electricity reserve power markets.

Table 1: Sequence of reforms in the German electricity reserve market

Synchronization		**Interconnection and Cooperation**					
1/12/2006	1/12/2007	17/12/2008	1/5/2009	1/7/2009	1/10/2009	15/4/2010	1/7/2010
MRP	PCP+SCP	Module 1	Module 2	Module 3	Module 4	Amprion	MRP
reform 1	reforms 2+3	reform 4	reform 5	reform 6	reform 7	reform 8	reform 9

In the next section, we ask whether or not each of the regulatory reforms led to increased competition in the MRP market. We measure a strengthening of competition by reductions in both incremental MRP prices and decremental MRP prices. Our focus is especially on the introduction of the new market design for MRP on 1 December 2006. Moreover, we test if the four control areas have become more integrated due to the reforms. Finally, we quantify the reforms' joint success in reducing MRP prices by comparing the actual prices after the first reform on 1 December 2006 with those prices which would have been realized without the reforms.

3 Econometric Analysis

3.1 Data

We have created a unique panel dataset on both daily incremental MRP prices and daily decremental MRP capacity prices in Germany for the period from 1 January 2006 to 30 September 2010. Throughout the rest of our analysis, we refer to MRP capacity prices when using the term MRP prices. Incremental and decremental MRP prices are separately used as dependent variables to check whether or not the reforms led to increased competition, reflected by lower prices in the four control areas. We have calculated the MRP prices for each control area as weighted mean values, where capacities (in megawatt, MW) were used as weights. The data on MRP prices and MRP capacities were collected from the common web-based tendering platform for electricity reserve power (www.regelleistung.net). Figure 1 illustrates the incremental MRP prices in each control area from 1 January 2006 to 30 September 2010.

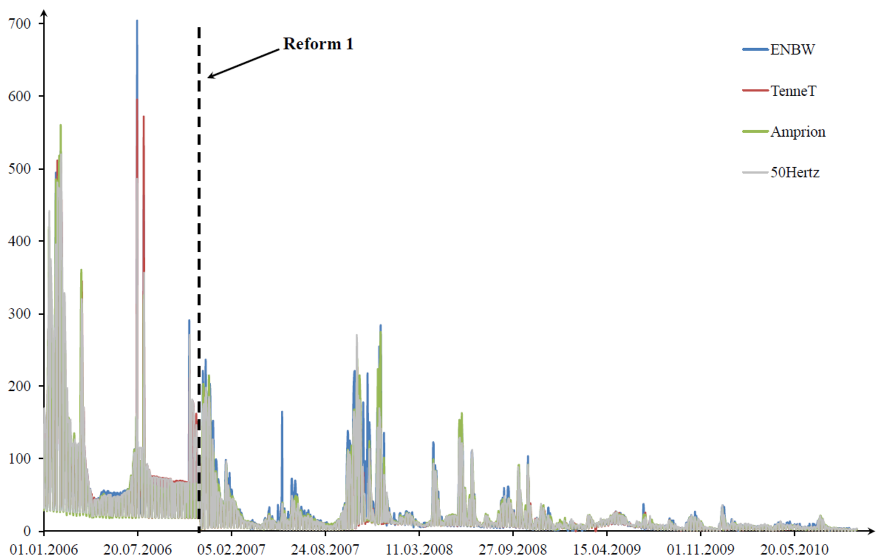

Figure 1: Average incremental MRP prices per control area

It can be seen that, on average, incremental MRP prices have fallen in each control area after the first reform on 1 December 2006. The same appears to be true for the price volatility. Table 2, in which we present some descriptive statistics on incremental MRP prices in each control area before and after reform 1 was implemented, further supports this view. Notice that "Period 1" indicates the period from 1 January 2006 to 30 November 2006, i.e., before reform 1 was implemented, whereas “Period 2” ranges from 1 December 2006 to 30 September 2010.

Table 2: Descriptive statistics of incremental MRP prices

	Period 1					**Period 2**				
	obs	mean	std	min	max	obs	mean	std	min	max
Amprion	334	83.13	93.82	18.49	551.11	1400	19.92	32.10	0.83	272.37
ENBW	334	90.62	100.52	19	703.76	1400	20.23	34.82	0.46	284.28
TenneT	334	90.88	99.15	18.47	594.86	1400	17.15	27.35	0	225.31
50Hertz	334	95.62	101.42	18.82	519.97	1400	18.29	29.18	0.84	270.14

However, further graphical inspection does not reveal any obvious effects of the remaining reforms.

A very similar picture is offered when we shift our focus to decremental MRP prices which are presented in Figure 2.

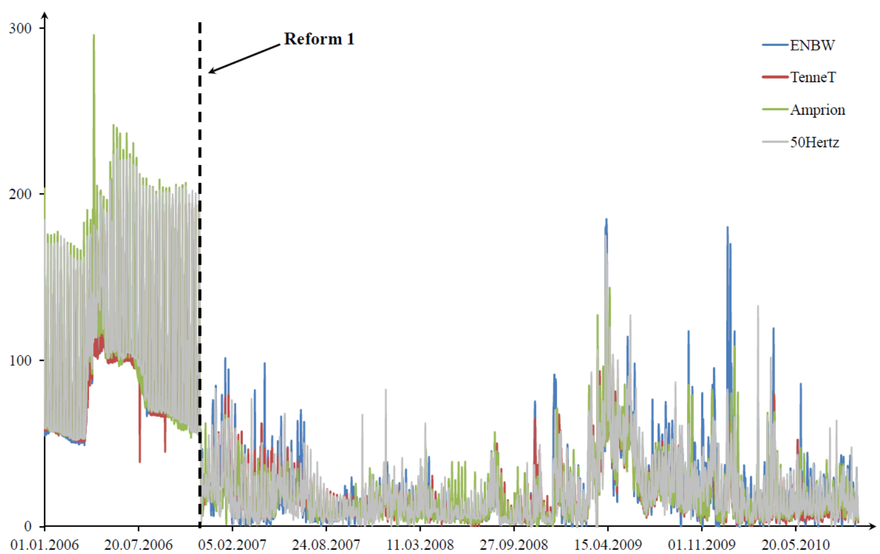

Figure 2: Average decremental MRP prices per control area

Whereas graphical inspection supports the view that the first reform on 1 December 2006 had a negative effect on decremental MRP prices, it is less clear whether or not the remaining reforms had an effect. This is further confirmed by the following table.

Table 3: Descriptive statistics of decremental MRP prices

	Period 1					**Period 2**				
	obs	mean	std	min	max	obs	mean	std	min	max
Amprion	334	100.07	50.45	52.40	292.33	1400	18.33	18.02	0	145.09
ENBW	334	94.38	41.98	49.29	206.04	1400	21.57	22.67	0	185.05
TenneT	334	92.62	41.39	38.79	204.23	1400	17.50	17.03	0	128.76
50Hertz	334	99.90	47.72	52.06	226.82	1400	19.99	20.28	0	173.99

Our main explanatory variable is the electricity (day-ahead) spot market price for base load on the European Energy Exchange (EEX).[9] Alternatively, we could have used data on over-the-counter (OTC) spot market prices. However, due to high correlation between EEX spot market prices and OTC prices, we had to choose one of the variables.[10] Other explanatory variables are the Western Texas Intermediate (WTI) oil price, the brown coal price and the natural gas price.[11] In addition, we control for seasonal variations, as they lead to differences in electricity consumption, by incorporating dummy variables into our regressions. More specifically, we consider both weekly seasonal variations and yearly seasonal variations. The former reflect variations between weekdays and weekends, while the latter represent variations between summertime, wintertime and the rest of the year.

Two instruments are used to account for endogeneity of the EEX spot price. The first instrument is a time series of the maximum daily wind strength (mws) in northern Germany. Since the largest part of wind power is produced in the north of Germany and wind power is the most important renewable resource, we expect the EEX spot price to be negatively affected by the maximum daily wind strength.[12] A necessary prerequisite is that mws must be a good proxy for daily produced wind power which reduces the demand for electricity traded on the

[9] Descreptive statistics are provided in Appendix .

[10] It can be shown that our results hold when the OTC spot price is used as an explanatory variable instead of the EEX spot price. The results can be requested form the authors.

[11] Whereas the WTI oil price was collected from the website of the U.S. Department of Energy (energy.gov), the brown coal price and the natural gas price were available on Platts.

[12] In 2011, the share of wind power in gross total electricity production amounts to 8%, whereas the share of all renewables is 20% (see e.g., BDEW, 2011).

EEX.[13]

The second instrument contains rain data on the daily amount of precipitation for control area-representative German cities (Berlin, Cologne/Bonn, Nuremberg, and Stuttgart). The reasoning is as follows: It can be expected that the demand for electricity depends on weather, and, thus probably varies with the amount of precipitation. If this is true, then the wholesale market price will be inevitably affected by demand variations caused by changes in weather conditions.

3.2 Interrelationship between the Control Areas

We construct a Vector Autoregressive Model (VAR) to investigate whether or not the interrelationship between the four control areas has changed due to the reforms. Instead of analyzing each reform individually, we simply consider the reforms' joint effect. Hence, we compare the interrelationship between the control areas before the first reform was put in place on 1 December 2006 with the interrelationship after 1 December 2006. Thereby, we estimate a VAR model of the following form:

$$y_t = A_1 y_{t-1} + ... + A_4 y_{t-4} + t + u_t.$$

In our basic VAR model, $y_t = (y_{1t}, y_{2t}, y_{3t}, y_{4t})'$ represents a vector of four observable endogenous variables, i.e., the observed prices on the four control areas, where t is a deterministic linear time trend. The term u_t is a standard unobservable white noise process with zero mean, and A_i is a parameter matrix (see Hamilton, 1994: 257-258). The VAR-system is estimated by feasible generalized least squares. Based on our estimations, we perform Granger-causality tests to check whether the price series of the regional operators influence each other as a measure of interrelationship. Granger-causality exists if a variable helps to improve forecasting another variable (see Lütkepohl, 2005: 41-43). Hence, Granger-noncausality can be expressed as

$$y_{1,t+h|\Omega_t} = y_{1,t+h|\Omega_t \setminus \{y_{2,s}|s \leq t\}}.$$

The series of the variable y_{2t} is not Granger-causal to y_{1t} if removing past information of y_{2t} from the information set has no effects on the optimal forecast of y_{1t}. Instead, Granger-causality

[13] If this condition is met, then it could be argued that mws should be included as an explanatory variable. As will be shown later, based on the Sargan-Hansen test, our analysis reveals that the instruments are correctly excluded, and thus constitute valid instruments.

exists if the equation holds for at least one step, h (see Lütkepohl, 2004: 144). To avoid spurious regressions, we first have to check whether the subscriber series of the competitors are stationary. Before estimating VAR models, it is very important to analyze the time series properties of the series used in the analysis, because regressions of non-stationary time series on each other usually suffer serious spurious regressions problems. Accounting for these problems, one usually applies unit root tests. In our case, it is important to test on unit roots and structural breaks jointly because it is reasonable that changes in regulatory environments cause structural breaks in our data. To obtain statistically robust results, we apply unit root tests which additionally take into account structural breaks in the time series. We use the one break version of a unit root test developed by Clemente, Montanes, and Reyes (1998). The procedure to apply this test for two structural breaks starts with the estimation of the following regression:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + v_t.$$

In this regression, $DU_{mt} = 1$ for $t > T_{bm}$, and 0 otherwise, for $m = 1, 2$. T_{b1} and T_{b2} are the breakpoints. The residuals obtained from this regression, v_t, are the dependent variables in the next equation to be estimated. In order to make the distribution of the test statistic tractable, the residuals have to be regressed on their lagged values, a number of lagged differences, and a set of dummy variables:[14]

$$v_t = \sum \varpi_{1i} DT_{b1,t-i} + \sum \varpi_{2i} DT_{b2,t-i} + \alpha v_{t-i} + \sum \theta_i \Delta v_{t-i} + e_t,$$

where $DT_{bm,t} = 1$ if $t = T_{bm} + 1$, and 0 otherwise, for $m = 1, 2$. In a next step, the regression is estimated over feasible pairs of T_{b1} and T_{b2} to find the minimal t-ratio for the hypothesis $\alpha = 1$ which means the strongest rejection of the null hypothesis of the unit root. As the minimal value of the t-ratio does not follow the standard Dickey-Fuller distribution, it is compared with the critical values calculated by Perron and Vogelsang (1992). The following table shows the results of the unit root tests.

[14] See Baum (2005) for a more detailed dicussion.

Table 4: Clemente, Montanes, and Reyes Unit Root Test for incremental MRP prices

Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-131.510	-0.145	169.004
t-statistic	-17.401	-5.545	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-140.501	-0.139	174.999
t-statistic	-21.522	-5.893	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-138.443	-0.139	160.687
t-statistic	-23.331	-5.591	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-154.820	-0.139	188.510
t-statistic	-24.462	-5.806	
p-value	0.0000	-3.560	

The results of our tests are twofold: Firstly, the tests support our hypothesis that there is a structural break on 1 December 2006, when the new regulatory regime was implemented. Secondly, the four price series are non-stationary. The results have two consequences. The first consequence is estimating the VAR models in first differences to avoid spurious regression problems. The second consequence is estimating our models for the time periods before and after the structural break separately to investigate differences caused by the new market design.

The following tables repeat the analysis for decremental MRP prices.

Table 5: Clemente, Montanes, and Reyes Unit Root Test for incremental MRP prices

Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-74.905	-0.097	94.586
t-statistic	-39.938	-3.793	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-82.182	-0.094	100.370
t-statistic	-41.208	-3.571	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-74.459	-0.097	92.758
t-statistic	-43.254	-3.403	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-81.138	-0.101	100.197
t-statistic	-240.852	-3.985	
p-value	0.0000	-3.560	

VAR models are quite sensible with respect to the lag length of the relevant time series. We base our lag length selection on three familiar information criteria. The standard information criteria Akaike, Hannan-Quinn, and Schwarz-Bayes all suggest an optimal lag length of four for the VAR model.

Table 6: Lag length selection

Lag	AIC	HQIC	SBIC
Unimplemented multicol			
4	36.578	36.891	37.363
Unimplemented multicol			
4	31.847	31.984	32.206
Unimplemented multicol			
4	32.934	33.247	33.719
Unimplemented multicol			
4	30.086	30.223	30.445

The following tables provide information on the results of our Granger causality tests between the price series for both incremental and decremental MRP as measures of the interrelationships between the four control areas.

Table 7: Granger-causality tests for incremental MRP prices before structural break

Lags	H_0	Granger-Causality
4	enbw → amprion	0.248 (0.619)
4	enbw → tennet	0.273 (0.602)
4	enbw → 50hertz	0.796 (0.372)
4	amprion → enbw	1.106 (0.293)
4	amprion → tennet	0.785 (0.376)
4	amprion → 50hertz	1.118 (0.290)
4	tennet → enbw	0.662 (0.416)
4	tennet → amprion	0.197 (0.657)
4	tennet → 50hertz	1.978 (0.160)
4	50hertz → enbw	0.356 (0.551)
4	50hertz → amprion	0.030 (0.863)
4	50hertz → tennet	0.547 (0.459)

For incremental MRP, Table 7 clearly shows that there is no interrelationship between the four regions before the change in market design on 1 December 2006. The result changes significantly after the launch of the common web-based tendering platform for MRP, as it can be immediately seen in Table 8.

Table 8: Granger-causality tests for incremental MRP prices after structural break

Lags	H_0	Granger-Causality
4	enbw → amprion	45.268 (0.000)*
4	enbw → tennet	56.443 (0.000)*
4	enbw → 50hertz	32.428 (0.000)*
4	amprion → enbw	48.289 (0.000)*
4	amprion → tennet	49.213 (0.000)*
4	amprion → 50hertz	39.942 (0.000)*
4	tennet → enbw	39.325 (0.000)*
4	tennet → amprion	15.960 (0.000)*
4	tennet → 50hertz	42.690 (0.000)*
4	50hertz → enbw	33.547 (0.000)*
4	50hertz → amprion	22.228 (0.000)*
4	50hertz → tennet	52.675 (0.000)*

After the structural break there is a statistically significant relationship between all incremental MRP price series of the four control areas. The implication is that including prices from other regions in the information set of an individual MRP price series provides better forecasts of future prices than just using past values of the own price series. As a result, the change in market design clearly has effects on the interrelationship of the four regional markets for incremental MRP. Finally, we extend our analysis on the series of decremental MRP prices in Germany.

Table 9: Granger-causality tests for decremental MRP prices before structural break

Lags	H_0	Granger-Causality
4	enbw → amprion	0.920 (0.337)
4	enbw → tennet	0.319 (0.572)
4	enbw → 50hertz	0.882 (0.348)
4	amprion → enbw	0.017 (0.898)
4	amprion → tennet	0.429 (0.513)
4	amprion → 50hertz	1.069 (0.301)
4	tennet → enbw	0.015 (0.903)
4	tennet → amprion	1.018 (0.313)
4	tennet → 50hertz	1.060 (0.303)
4	50hertz → enbw	0.054 (0.816)
4	50hertz → amprion	0.541 (0.462)
4	50hertz → tennet	0.372 (0.542)

Our analysis of Granger-causality between decremental MRP prices before the reform on 1 December 2006 yields the same results as before when incremental MRP prices were concerned. Before the structural break, there is no interrelationship between the four decremental MRP prices. Examining the interrelationship between decremental MRP prices after the structural break leads to the following results presented in Table 10.

Table 10: Granger-causality tests for decremental MRP prices after structural break

Lags	H_0	Granger-Causality
4	enbw → amprion	0.248 (0.618)
4	enbw → tennet	4.117 (0.042)*
4	enbw → 50hertz	1.318 (0.251)
4	amprion → enbw	0.514 (0.473)
4	amprion → tennet	0.478 (0.490)
4	amprion → 50hertz	1.837 (0.175)
4	tennet → enbw	0.811 (0.368)
4	tennet → amprion	0.573 (0.449)
4	tennet → 50hertz	4.497 (0.034)*
4	50hertz → enbw	2.423 (0.120)
4	50hertz → amprion	1.300 (0.254)
4	50hertz → tennet	1.447 (0.229)

The set of Granger-causality tests for decremental MRP prices after the structural reform provides mixed results. In contrast to our results for incremental MRP prices, we do not find evidence for interrelationships between the series. Our tests only detect Granger-causality between ENBW and TenneT as well as 50Hertz and TenneT. We conclude that changes of interrelationships between the four regional markets for decremental MRP are less strong compared with incremental MRP.

VAR models, estimated in first differences, clearly measure short run relationships. Therefore, we have additionally tested for cointegration between the four regional markets because there might be a long run interrelationship. However, we reject all hypotheses of cointegration relationships between the four control areas.

3.3 Determinants of MRP Prices

3.3.1 Empirical Strategy

In the following, we take advantage of the panel structure of our data. The main benefit of such a strategy is that it allows us to account for unobserved heterogeneity between the four control areas in Germany by including fixed effects in our panel regression. In order to analyze whether or not the structural reforms have fostered competition in the MRP markets, we begin by estimating separate regressions for incremental and decremental MRP prices for the periods before and after each reform. Thereby, we examine each of the nine reforms in isolation, while accounting for the remaining reforms via shift-dummy variables.[15] Our main focus is on the effects of the implementation of the common web-based tendering platform for MRP on 1 December 2006. The reason is that it is natural, by regulatory design, to suppose that this reform should have had a direct impact on the performance of the MRP markets. Nevertheless, we ask whether or not the other reforms had an impact on both incremental and decremental MRP prices, too. In addition to the separate regressions for each reform, we perform pooled regressions where we use the Chow test to investigate whether or not structural breaks occurred due to the reforms.

Taking the panel structure of our data into account, we can derive an adequate specification as

$$y_{it} = \alpha_{it} + \sum \beta_k x_{it,k} + \epsilon_{it}, \tag{1}$$

where y_{it} represents the incremental MRP prices and decremental MRP prices, respectively,and $x_{it,k}$ are explanatory variables. The error term is given by ϵ_{it} and the α's and the β's are parameters to be estimated. Assuming that α_{it} is fixed over time, but differs with cross-section units, the equation in (1) can be estimated using fixed effects controlling for unobserved heterogeneity. Alternatively, one could assume that α_{it} can be composed into a common constant, α, and a unit specific random variable, v_i, so that $\alpha_{it} = \alpha + v_i$ holds. In this case, the equation in (1) would be estimated with the random effects model. However, we apply fixed effects (FE) because it seems to be a natural choice. Since unobserved heterogeneity between regions is usually constant over time, FE regressions present the more accurate approach. Moreover, we use instrumental variable techniques to account for possible endogeneity problems of the EEX electricity spot market price. It is reasonable to believe that there could be some feedback from the MRP market to the electricity wholesale market on the EEX. Intuitively, the reason is that, at least to some extent, the market for MRP and the electricity wholesale spot market are substitutes for at least some

[15]Note that reforms 2 and 3, reflecting the launch of common web-based tendering platforms for SCP and PCP, cannot be separately analyzed. The reason is that both reforms were simultaneously implemented on December 1, 2007. Thus, we test for eight rather than for nine structural breaks.

generators; they can (partially) choose where to use their capacities. Hence, generators will base their decision on the expected price gap between the MRP price and the EEX spot price. To avoid endogenous regressors, we instrument the EEX spot prices by using data on the daily maximum wind strength in northern Germany and the daily amount of precipitation in control area-specific German cities. The idea of such an approach is that there is no direct effect on MRP prices, but that there are effects on EEX spot prices. The first stage results of our FE two stage least squares regressions can be found in Appendix B.

The remaining explanatory variables comprise the WTI oil price, and dummy variables accounting for the seasonality of MRP prices which arises from differences in electricity consumption between summertime and wintertime as well as weekdays and weekends. Other potential exogenous variables, such as the natural gas price, the brown coal price, and the feed-in from wind energy, were not incorporated into our analysis due to problems of multicollinearity.[16]

3.3.2 Econometric Results

In this section, we present the results of our panel regressions. The Chow test, whose main purpose is to compare the residual sum of squares of the pooled regression and the separate regressions, is used to determine whether or not the reforms had a statistically significant effect on MRP prices. To avoid spurious regressions problems, we conduct unit root tests for all variables.[17] Whereas both incremental and decremental MRP prices as well as the control area specific daily amount of precipitation are stationary, the WTI oil price, the EEX spot price, and the daily maximum wind strength in northern Germany are integrated of order one to eliminate non-stationarity. We start our analysis by focussing on the launch of the common

[16]The correlation between the WTI oil price and the natural gas price is .78. An obvious first explanation is the fact that, in Germany, the natural gas price is linked to the oil price by contractual arrangements (Ölpreisbindung). The WTI oil price and the brown coal price are also highly correlated (.76). The same is true for the relationship between the feed-in from wind energy and our instruments. Due to serious concerns with regards to multicollinearity issues, these variables have been left out.

[17]While both the Phillips-Perron test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test are used for the time series data (EEX spot price, WTI oil price, and mws), the Im-Pesaran-Shin unit root test is performed for the panel data (incremental and decremental MRP prices, (control area specific) daily amount of precipitation). Note that the Im-Pesaran-Shin test is a specifically tailored unit root test for panel data. For a more detailed discussion see Im et al. (2003). The results can be found in Appendix A.

web-based tendering platform on December 1, 2006. The remaining reforms are considered via regulatory shift-dummies.[18] First, we estimate the two separate panel regressions of incremental and decremental MRP prices for the time before and after the change in market design. The following table presents our results.

Table 11: Separated panel regressions of incremental MRP prices (reform 1)

	Period 1		**Period 2**	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-1.29**	.5173	-.08	.1386
WTI oil	-2.77	3.7126	1.25***	.3804
dummy weekend	-109.89***	10.8148	-19.81***	1.6870
dummy summer	3.71	4.5535	-4.73***	.7951
dummy winter	143.72***	9.9697	8.98***	1.1913
dummy scp+pcp			-7.91***	1.3494
dummy M1			-19.18***	1.0292
dummy M2			10.21***	1.0053
dummy M3			-4.76***	.6655
dummy M4			-7.53***	.9172
dummy amprion			5.20***	.8057
dummy mrp2			0.01	.6672
Obs.	1332		5600	
R^2	.3710		.2258	
Residual sum of squares	8164675.77		4161996.74	
Weak identification test	25.681		88.075	
Sargan-Hansen p-value	.1684		.2354	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Note that the remaining regulatory dummies do not appear in the model for period 1, since the reforms, presented by these dummies, were implemented after 1 December 2006. We use

[18] A list of all variables used in the panel regressions can be found in Appendix B.

two tests to evaluate our instrumental variables. The weak identification test supports the choice of our instruments, since it indicates small biases in both periods (less than 10 per cent). In addition, we report the Sargan-Hansen test on overidentification of all instruments. The reported p-values do not allow a rejection of the null hypothesis so that our instruments can be classified as valid instruments.

The same procedure is performed with regards to decremental MRP prices. The two separate regressions are shown in Table 12.

Table 12: Separated panel regressions of decremental MRP prices (reform 1)

	Period 1		**Period 2**	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.22	.2161	.33***	.0902
WTI oil	.83	1.1043	.23	.1721
dummy weekend	65.08***	4.3103	15.11***	1.1808
dummy summer	10.69***	2.2489	-2.06***	..4602
dummy winter	-23.99***	2.0156	-3.08***	.6718
dummy scp+pcp			-6.05***	.4662
dummy M1			24.32***	1.455
dummy M2			14.33***	1-9131
dummy M3			-23.11***	1.3430
dummy M4			-4.52***	1.0208
dummy amprion			-8.16***	.9588
dummy mrp2			.7814	.7212
Obs.	1332		5600	
R^2	.4253		.2798	
Residual sum of squares	1574236.11		1551248.72	
Weak identification test	25.681		88.075	
Sargan-Hansen p-value	.8712		.0211	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

The EEX spot price has a significant impact on incremental MRP prices before the reform, but an insignificant effect after the reform. This result is reversed when decremental MRP prices are investigated. The WTI oil price has a statistically significant effect only on incremental MRP prices after the reform. Moreover, we find that the seasonal dummies exert a significant effect on both prices in both periods. The only exception is the summer season with respect to incremental MRP prices.

Finally, we perform the Chow test to identify whether or not the reform created a structural break on 1 December 2006. Therefore, we run pooled regressions for both types of MRP prices which are used together with the separate regressions to calculate the Chow test statistics. The results are presented in the following table.

Table 13: Pooled regression and Chow test (reform 1)

	inc MRP		**dec MRP**	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.31	.2324	.18	.1476
WTI oil	.41	.6184	.12	.2621
dummy weekend	-36.27***	3.1620	22.97***	2.1021
dummy summer	-4.89***	1.2618	1.73	1.1721
dummy winter	29.13***	2.3387	-10.26***	.9089
dummy scp+pcp	-37.13***	1.7134	-43.46***	0.9764
dummy M1	-24..69***	1.4987	27.21***	1.4268
dummy M2	-21.74***	1.9931	8.52***	1.9789
dummy M3	-5.07***	1.1771	-23.74***	1.4014
dummy M4	-16.84***	1.7554	1.29	1.2139
dummy amprion	14.47***	1.6790	-12.95***	1.0891
dummy mrp2	.02	1.5994	-.28	.8905
Obs.	6932		6932	
R^2	.2594		.2818	
Residual sum of squares	17691582.32		8125882.28	
Weak identification test	110.687		110.687	
Chow test statistic	**214.63**		**779.61**	
Sargan-Hansen p-value	.0018		.0128	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Based on the Chow test statistics, we find strong evidence for a structural break for both incremental and decremental MRP prices. In other words, the launch of the common web-based tendering platform for MRP had a statistically significant effect on MRP prices. Thus, we have to extend our set of exogenous variables by a dummy variable which accounts for the new market design introduced on 1 December 2006 and perform another pooled panel regression. The results are shown in Table 14.

Table 14: Pooled regression with regulatory dummy (reform 1)

	inc MRP		**dec MRP**	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.30	.2125	.20**	.0999
WTI oil	.69	.5864	.25	.1918
dummy weekend	-36.00***	2.8978	23.32***	1.3949
dummy summer	-5.17***	1.1658	1.35*	.6976
dummy winter	31.80***	2.1987	-6.73***	.7375
dummy mrp1	**-60.01*****	**2.7187**	**-79.17*****	**1.1646**
dummy scp+pcp	-8.68***	1.3610	-5.91***	.5110
dummy M1	-25.50***	1.5121	26.13***	1.4392
dummy M2	23.30***	1.9312	10.58***	1.9454
dummy M3	-4.96***	1.1660	-23.60***	1.3838
dummy M4	-18.28***	1.6790	-.61	1.0489
dummy amprion	15.84***	1.5482	-11.15***	1.0197
dummy mrp2	.07	1.1237	-.16	.8498
Obs.	6932		6932	
R^2	.3647		.6653	
Weak identification test	110.639		110.639	
Sargan-Hansen p-value	.1786		.1582	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

The launch of the new market design is reflected by the dummy variable *dummy mrp1*. The coefficients are significant and negative for both MRP prices indicating that the reform was successful in decreasing both MRP prices. We conclude that the launch of the common web-based tendering platform for MRP has indeed increased competition leading to a significant decrease of both incremental and decremental MRP prices. Finally, the choice of our instruments is supported by both the weak identification test and the Sargan-Hansen test on overidentification.

The same methodology is applied to investigate the remaining reforms' individual success. The results of our separate and pooled panel regressions can be found in Appendix B. Below the

Chow test statistics and the coefficients of each reform's dummy variable are reported. Tables 15 and 16 present our results.

Table 15: Each reform's effect on incremental MRP prices (Chow test)

	Synchronization		Interconnection and Cooperation					
	1/12/2006	1/12/2007	17/12/2008	1/5/2009	1/7/2009	1/10/2009	15/4/2010	1/7/2010
Reform	1	2+3	4	5	6	7	8	9
Chow stat.	214.63	79.05	45.46	18.69	17.07	18.61	6.13	1.63
coefficient	-60.01***	-8.68***	-25.50***	23.30***	-4.96***	-18.28***	15.84***	.07

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 16: Each reform's effect on decremental MRP prices (Chow test)

	Synchronization		Inteconnection and Cooperation					
	1/12/2006	1/12/2007	17/12/2008	1/5/2009	1/7/2009	1/10/2009	15/4/2010	1/7/2010
Reform	1	2+3	4	5	6	7	8	9
Chow stat.	779.61	37.07	55.25	8.22	16.89	5.17	6.00	1.16
coefficient	-79.17***	-5.91***	26.13***	10.58***	-23.60***	-.61	-11.15***	-.16

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

The first three reforms, which introduced a new market design for MRP, SCP and PCP on 1 December 2006 and 1 December 2007, respectively, were all successful in reducing MRP prices. This result is reflected by the existence of structural breaks and negative coefficients. However, note that the first reform had a stronger impact on both MRP prices than reforms 2 and 3. This finding is straightforward, since these reforms did not directly affect the markets for MRP.

When we analyze the effects of the second set of regulatory changes (reforms 4 to 9), we obtain mixed results. While there is empirical evidence that interconnection and cooperation of the four TSOs in the SCP market largely created structural changes, the effects on MRP prices were not throughout negative. For instance, reform 5 (module 2), i.e., the joint balancing of SCP, rather increased than decreased both incremental MRP prices and decremental MRP prices.

Finally, it may be surprising that interconnection and cooperation of the TSOs in the MRP market had no significant effect on MRP prices. However, it must be noted that our data encompasses only three months after reform 9 was put in place. Hence, one needs to be cautious when interpreting such a result because a different picture could be revealed if the data were extended in terms of time.

3.4 The Reforms' Joint Success

In a last step, we quantify the reforms' joint success by comparing the actual MRP prices, which were realized between 1 December 2006 and 30 September 2010 with the hypothetical prices which would have been realized without any reforms. Such a comparison necessitates an adequate construction of the counterfactual. To accomplish this goal, we use our basic FE model in (1) where we set an upper bound for the time variable to ensure that the FE model is restricted to the time before the first reform was put in place. Thus, we estimate incremental MRP prices and decremental MRP prices, respectively, using the following specification

$$y_{i\bar{t}} = \alpha_i + \sum \beta_k x_{i\bar{t},k} + \epsilon_{i\bar{t}}, \tag{2}$$

where $\bar{t} \in [1, 334]$ covers the period from 1 January 2006 to 30 November 2006. The estimated coefficients are then used to predict the hypothetical (counterfactual) MRP prices from 1 December 2006 to 30 September 2010. In addition, we use daily MRP quantities in order to quantify the exact savings each TSO realized due to the reforms. The following table shows our results.

Table 17: The reforms' joint success in the MRP markets (in million euros)

	Incremental MRP				Decremental MRP			
	ENBW	Tennet	Amprion	50Hertz	ENBW	Tennet	Amprion	50Hertz
Hypoth. costs	280.4	831.5	828.3	529.5	148.1	668.8	602	347.5
Actual costs	81.9	159.6	171.2	108.9	42	127.9	119.8	76.7
Savings	198.5	671.9	657.1	420.6	106.1	540.9	482.2	270.8

Since MRP prices constitute costs of maintaining the frequency level in the electricity grid, and thus, ensuring system stability, they are considered in the regulated grid usage fees charged by the TSO. Hence, MRP price reductions represent cost savings.[19] It can be immediately seen that the reforms jointly led to substantial savings in the markets for both incremental MRP and decremental MRP (1948.09m euros and 1399.97m euros, respectively).

4 Conclusion

In this paper, we have evaluated the recent reforms in Germany's electricity reserve power markets with respect to their effects on incremental and decremental MRP prices. The reforms consisted of synchronization and standardization on the one hand, and TSO interconnection and cooperation on the other hand. The regulator aimed at fostering competition, increasing efficiency, and realizing synergies in the electricity reserve power markets.

In a first step, we have applied time series techniques to investigate whether the reforms changed the interrelationships between the MRP price series of the four German control areas. We find strong evidence for interrelationships between all incremental MRP prices after the first structural reform was implemented. However, decremental MRP prices have apparently not been affected. The regulatory changes had rather no effect on the relationship between decremental MRP prices suggesting that the control areas remained partly distinct.

In a second step, we have used a unique panel dataset, accounting for unobserved heterogeneity and endogeneity, to check whether or not the reforms were successful in decreasing both incremental and decremental MRP prices. It is demonstrated that the launch of common web-based tendering platforms for PCP, SCP, and MRP has been successful in decreasing MRP prices, while this is not the case for the second set of regulatory changes. We rather find mixed effects revealing that either some reforms had an adverse impact on MRP price, i.e., MRP prices were increased or did not cause any significant structural changes at all. However, we show that the reforms were jointly successful in decreasing MRP prices leading to savings of roughly 1950m EURO and 1400m EURO for incremental MRP and decremental MRP, respectively. Moreover, the first reform on 1 December 2006 may have also had a positive impact on wholesale market competition on the EEX. Since the wholesale (day-ahead) spot markets and the MRP markets are, at least partly, substitutes for generators, it is reasonable to suppose that synchronization

[19] Alternatively, these cost savings can be termed productive efficiency gains, although they were not entirely created by common means such as scale economies, process innovation, etc.

and standardization reduced the suppliers' possibility of strategic pricing.

Appendix A

In Appendix A, we present our results of the stationarity tests and unit root tests. We test all relevant explanatory variables (WTI oil price, EEX spot price), both instruments (mws, inst_rain), and the dependent variables (incremental and decremental MRP prices). While the KPSS test and the Phillips-Perron test are performed with regards to single time series, the Im-Pesaran-Shin unit root test is performed for the panel data. The latter tests the null hypothesis that at least one cross section contains a unit root. Our results are presented in the following tables.

Table 18: KPSS test statistics (critical values: 10%: .119; 5% : .146; 2.5%: .176; 1% : .216)

Lag order	EEX spot	WTI oil	mws
0	5.97	9.69	.695
1	3.49	4.85	.44
2	2.57	3.24	.349
3	2.09	2.43	.301
4	1.78	1.95	.27
5	1.56	1.63	.247
6	1.38	1.4	.23
7	1.22	1.22	.216
8	1.1	1.09	.206
9	1.01	.981	.197
10	.93	.892	.19
11	.868	.819	.184
12	.815	.757	.179

Table 19: Phillips-Perron test

			critical values		
		test statistic	1%	5%	10%
EEX spot	Z(rho)	-494.797	-20.70	-14.10	-11.30
	Z(t)	-17.009	-3.43	-2.86	-2.57
WTI oil	Z(rho)	-6.075	-20.70	-14.10	-11.30
	Z(t)	-1.739	-3.43	-2.86	-2.57
mws	Z(rho)	-762.177	-20.70	-14.10	-11.30
	Z(t)	-21.850	-3.43	-2.86	-2.57

Table 20: Im-Pesaran-Shin unit root test for panel data

				critical values		
		test statistic	p-value	1%	5%	10%
inc MRP	t-bar	-15.6098		-2.40	-2.15	-2.01
	t-tilde-bar	-14.6164				
	Z-t-tilde-bar	-31.1422	.00			
dec MRP	t-bar	-16.2766		-2.40	-2.15	-2.01
	t-tilde-bar	-15.1603				
	Z-t-tilde-bar	-32.4367	.00			
inst_rain	t-bar	-34.1073		-2.40	-2.15	-2.01
	t-tilde-bar	-26.3799				
	Z-t-tilde-bar	-59.1424	.00			

Appendix B

List of variables used in the panel regressions.

Table21: List of variables

Variable	Label; Type
incremental MRP price	inc MRP; dependent
decremental MRP price	dec MRP; dependent
EEX (day-ahead) spot price	EEX spot; explanatory
WTI oil price	WTI oil; explanatory
seasonal dummy weekend	dummy weekend; explanatory
seasonal dummy summer	dummy summer, explanatory
seasonal dummy winter	dummy winter; explanatory
reform 1	dummy mrp1; explanatory
reforms 2+3	dummy scp+pcp; explanatory
reform 4 (module 1)	dummy M1; explanatory
reform 5 (module 2)	dummy M2; explanatory
reform 6 (module 3)	dummy M3; explanatory
reform 7 (module 4)	dummy M4; explanatory
reform 8 (amprion joins TSO network)	dummy amprion; explanatory
reform 9	dummy mrp2; explanatory
daily maximum wind strength (mws)	mws; instrument
daily amount of precipitation	inst_rain; instrument

Descriptive statistics of the electricity (day-ahead) spot market price for base load on the European Energy Exchange (EEX).

Table 22: Descriptive statistics of incremental MRP prices

	Period 1					**Period 2**				
	obs	mean	std	min	max	obs	mean	std	min	max
EEX spot	334	51.82	25.14	15.57	301.54	1400	46.32	19.35	−35.57	158.97

First stage results of the two stage least squares panel regressions.

Table 23: First stage regression

EEX spot	coeff.	std. err.
constant	-.06	.1857
mws	-.64***	.0478
inst_rain	.04	.0409
R^2	.0281	
F-test	88.77	
Obs.	6932	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

In the following, we present our results of the separated and pooled panel regressions of the remaining eight reforms. Note that reforms 2 and 3 cannot be analyzed individually because they were both realized on December 1, 2007.

Reforms 2 and 3. Launch of common web-based tendering platforms for PCP and SCP on December 1, 2007.

Table 24: Separate panel regressions of incremental MRP prices (reforms 2+3)

	Period 1		**Period 2**	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.63	.3938	-.03	.1006
WTI oil	-1.59	2.4768	1.15***	.3094
dummy weekend	-70.89***	5.9794	-12.54***	1.2538
dummy summer	-6.06**	2.2822	1.60*	.8526
dummy winter	73.81***	4.6210	2.17**	1.0257
dummy mrp1	-62.89***	2.6590		
dummy M1			-15.76***	1.0028
dummy M2			3.26***	.9479
dummy M3			-5.85***	.5393
dummy M4			-.13	.8806
dummy amprion			-.41	.7225
dummy mrp2			-1.78***	.4718
Obs.	2792		4140	
R^2	.3659		.2330	
Residual sum of squares	11660001.94		1469097.882	
Weak identification test	50.142		61.517	
Sargan-Hansen p-value				

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 25: Separate panel regressions of decremental MRP prices (reforms 2+3)

	Period 1		**Period 2**	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.01	.1635	.41***	.1124
WTI oil	.77	.6381	.24	.1823
dummy weekend	35.48***	2.5688	15.82***	1.5054
dummy summer	6.42***	1.2935	-2.81***	.5319
dummy winter	-2.73**	1.2892	-9.06***	.8375
dummy mrp1	-79.41***	1.1114		
dummy M1			25.77***	1.4318
dummy M2			11.38***	1.9128
dummy M3			-22.97***	1.3443
dummy M4			-2.26**	1.0657
dummy amprion			-10.63***	.9908
dummy mrp2			.97	.7279
Obs.	2792		4140	
R^2	.6934		31.97	
Residual sum of squares	2284341.64		1261832.913	
Weak identification test	50.142		61.517	
Sargan-Hansen p-value	1.455		0.940	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 26: Pooled regression and Chow test (reforms 2+3)

	inc MRP		**dec MRP**	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.30	.2131	.20**	.1002
WTI oil	.78	.5851	.31	.1941
dummy weekend	-36.03***	2.9046	23.30***	1.3978
dummy summer	-5.15***	1.1565	1.36*	.6985
dummy winter	31.61***	2.2072	-6.86***	.7405
dummy mrp1	-64.53***	2.6159	-82.18***	1.1248
dummy M1	-29.69***	1.4693	23.28***	1.4340
dummy M2	23.18***	1.9301	10.49***	1.9448
dummy M3	-4.94***	1.1668	-23.59***	1.3834
dummy M4	-18.19***	1.6758	-.55	1.0500
dummy amprion	15.75***	1.5481	-11.21***	1.0207
dummy mrp2	.06	1.1240	-.16	.8498
Obs.	6932		6932	
R^2	.3623		.6630	
Residual sum of squares	15233645.33		3812728.036	
Weak identification test	110.621		110.621	
Chow test statistic	79.05		37.07	
Sargan-Hansen p-value	1.268		2.867	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Reform 4. Module 1 of the gradual TSO interconnection and cooperation in the SCP market.

Table 27: Separate panel regressions of incremental MRP prices (reform 4)

	Period 1		**Period 2**	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.47*	.3010	-.03	.0338
WTI oil	.87	.8769	-.05	.0845
dummy weekend	-55.62***	4.8107	-5.60***	.3309
dummy summer	-1.88	1.6373	-.64***	.2236
dummy winter	47.34***	3.0998	-2.27***	.2466
dummy mrp1	-61.03***	2.6664		
dummy scp+pcp	-9.08***	1.4650		
dummy M2			1.99***	.4499
dummy M3			-5.59***	.4011
dummy M4			.4786	.3047
dummy amprion			-1.69***	.2340
dummy mrp2			-1.14***	.2452
Obs.	4320		2612	
R^2	.3347		.3978	
Residual sum of squares	14080010.38		45833.995	
Weak identification test	58.893		92.734	
Sargan-Hansen p-value	.0410		.1088	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 28: Separate panel regressions of decremental MRP prices (reform 4)

	Period 1		**Period 2**	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.003	.1242	.62***	.1650
WTI oil	.12	.2290	.28	.3408
dummy weekend	24.96***	2.0063	19.47***	1.7750
dummy summer	4.82***	.9212	-2.93***	.7388
dummy winter	.44	.8548	-18.51***	1.4367
dummy mrp1	-79.56***	1.1370		
dummy scp+pcp	-6.09***	.5070		
dummy M2			6.14***	2.1052
dummy M3			-22.93***	1.3718
dummy M4			2.06	1.2942
dummy amprion			-14.95***	1.1904
dummy mrp2			1.04	.7603
Obs.	4320		2612	
R^2	.7258		.3059	
Residual sum of squares	2608343.575		1034197.083	
Weak identification test	58.893		92.734	
Sargan-Hansen p-value	.1936		.4249	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 29: Pooled regression and Chow test (reform 4)

	inc MRP		**dec MRP**	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.30	.2137	.20**	.1019
WTI oil	.52	.6008	.42*	.2075
dummy weekend	-35.98***	2.9093	23.30***	1.4253
dummy summer	-3.52***	1.1691	-.35	.7229
dummy winter	29.80***	2.1605	-4.68***	.7206
dummy mrp1	-59.82***	2.7286	-79.37***	1.1688
dummy scp+pcp	-15.03***	2.7286	.59	.6391
dummy M2	3.28**	1.4039	31.10***	1.3607
dummy M3	-5.29***	1.1660	-23.26***	1.3624
dummy M4	-16.24***	1.6328	-2.71***	1.0437
dummy amprion	14.26***	1.5109	-9.53***	1.0107
dummy mrp2	-.41	1.1131	.32	.8489
Obs.	6932		6932	
R^2	.3541		.6420	
Residual sum of squares	15428142.02		4050659.052	
Weak identification test	110.587		110.587	
Chow test statistic	45.46		55.25	
Sargan-Hansen p-value	.2162		.2461	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Reform 5. Module 2 of the gradual TSO interconnection and cooperation in the SCP market.

Table 30: Separate panel regressions of incremental MRP prices (reform 5)

	Period 1		**Period 2**	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.52*	.2774	-.04	.0401
WTI oil	.50	.7684	.14	.1097
dummy weekend	-51.23***	4.3000	-5.64***	.3749
dummy summer	-4.58***	1.6206	-.63***	.2232
dummy winter	38.72***	2.6567	.29	.3264
dummy mrp1	-60.47***	2.6918		
dummy scp+pcp	-8.87***	1.4172		
dummy M1	-27.35***	1.8033		
dummy M3			-5.55***	.4013
dummy M4			-.71**	.3086
dummy amprion			-.49**	.2389
dummy mrp2			-1.14***	.2440
Obs.	4860		2072	
R^2	.3294		.3787	
Residual sum of squares	14670335.1		36161.32659	
Weak identification test	71.072		59.844	
Sargan-Hansen p-value	.0472		.1599	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 31: Separate panel regressions of decremental MRP prices (reform 5)

	Period 1		**Period 2**	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.17	.1199	.41**	.1730
WTI oil	.17	.2321	.51	.3369
dummy weekend	25.64***	1.8989	18.64***	1.7542
dummy summer	2.92***	.9269	-2.89***	.7289
dummy winter	-6.53***	.8599	-5.48***	1.5046
dummy mrp1	-79.15***	1.1482		
dummy scp+pcp	-5.91***	.5292		
dummy M1	26.47***	1.4673		
dummy M3			-22.87***	1.3440
dummy M4			-3.99***	1.2617
dummy amprion			-8.93***	1.1628
dummy mrp2			1.03	.7598
Obs.	4860		2072	
R^2	.6822		.3792	
Residual sum of squares	3211062.67		530979.0064	
Weak identification test	118.652		59.844	
Sargan-Hansen p-value	.2633		.1728	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 32: Pooled regression and Chow test (reform 5)

	inc MRP		**dec MRP**	
	coeff	std. err.	coeff.	std. err.
EEX spot	-.30	.2132	.20**	.1005
WTI oil	.75	.5876	.27	.1942
dummy weekend	-35.99***	2.9088	23.33***	1.4019
dummy summer	-3.91***	1.1379	1.92***	.6958
dummy winter	30.27***	2.1251	-7.43***	.7094
dummy mrp1	-59.87***	2.7242	-79.11**	1.1638
dummy scp+pcp	-8.61***	1.3550	-5.88***	.5173
dummy M1	-18.00***	1.1956	29.54***	1.0723
dummy M3	9.87***	1.4534	-16.87***	1.2096
dummy M4	-16.73***	1.6026	.09	1.0387
dummy amprion	14.65***	1.4922	-11.69***	1.0134
dummy mrp2	-.29	1.1139	-.32	.8517
Obs.	6932		6932	
R^2	.3610		.6638	
Residual sum of squares	15263948.05		3804389.781	
Weak identification test	110.613		110.613	
Chow test statistic	18.69		8.22	
Sargan-Hansen p-value	.2893		.0973	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Reform 6. Module 3 of the gradual TSO interconnection and cooperation in the SCP market.

Table 33: Separate panel regressions of incremental MRP prices (reform 6)

	Period 1		**Period 2**	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.44*	.2684	-.02	.0381
WTI oil	-58	.7472	.11	.1094
dummy weekend	-47.95***	4.0388	-5.45***	.3718
dummy summer	-5.01***	1.4943	1.43***	.1987
dummy winter	38.60***	2.6521	.29	.3259
dummy mrp1	-60.47***	2.6878		
dummy scp+pcp	-8.88***	1.4056		
dummy M1	-27.39***	1.7694		
dummy M2	27.17***	2.3728		
dummy M4			-.68**	.2764
dummy amprion			-1.30***	.2499
dummy mrp2			-1.73***	.2441
Obs.	5104		1828	
R^2	.3378		.3037	
Residual sum of squares	14643256.98		27862.11986	
Weak identification test	74.936		55.682	
Sargan-Hansen p-value	.1003		.4825	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 34: Separate panel regressions of decremental MRP prices (reform 6)

	Period 1		**Period 2**	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.13	.1184	.50***	.1736
WTI oil	.26	.2300	.09	.3127
dummy weekend	24.47***	1.8092	19.92***	1.8792
dummy summer	1.44*	.8772	.88	.6673
dummy winter	-6.95***	.8516	-5.45***	1.5201
dummy mrp1	-79.16***	1.1482		
dummy scp+pcp	-5.90***	.5219		
dummy M1	26.20***	1.4586		
dummy M2	10.42***	1.9783		
dummy M4			-1.40	1.2597
dummy amprion			-10.43***	1.1703
dummy mrp2			-.04	.7538
Obs.	5104		1828	
R^2	.6783		.2004	
Residual sum of squares	3290992.991		451933.4222	
Weak identification test	74.936		55.682	
Sargan-Hansen p-value	.3771		.0376	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 35: Pooled regression and Chow test (reform 6)

	inc MRP		**dec MRP**	
	coeff	std. err.	coeff.	std. err.
EEX spot	-.30	.2125	.20**	.1011
WTI oil	.71	.5860	.34*	.1956
dummy weekend	-35.98***	2.8985	23.41***	1.4125
dummy summer	-5.30***	1.1609	.75	.7115
dummy winter	31.78***	2.1986	-6.87***	.7366
dummy mrp1	-60.01***	2.7186	-79.18***	1.1656
dummy scp+pcp	-8.68***	1.3610	-5.90***	.5115
dummy M1	-25.53***	1.5116	26.02***	1.4385
dummy M2	20.38***	1.8549	-3.34**	1.6992
dummy M4	-20.32***	1.5756	-10.32***	1.1817
dummy amprion	15.87***	1.5476	-10.97***	1.0201
dummy mrp2	.10*	1.1239	.01	.8501
Obs.	6932		6932	
R^2	.3646		.6579	
Residual sum of squares	15178941.18		3871125.102	
Weak identification test	110.650		110.650	
Chow test statistic	17.07		16.89	
Sargan-Hansen p-value	.2039		.0391	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Reform 7. Module 4 of the gradual TSO interconnection and cooperation in the SCP market.

Table 36: Separate panel regressions of incremental MRP prices (reform 7)

	Period 1		**Period 2**	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.37	.2541	.01	.0433
WTI oil	.62	.6959	.16	.1270
dummy weekend	-44.44***	3.7134	-5.03***	.4307
dummy summer	-4.18***	1.3598	.43*	.2351
dummy winter	38.84***	2.6531	.30	.3256
dummy mrp1	-60.47***	2.6896		
dummy scp+pcp	-8.89***	1.3960		
dummy M1	-27.22***	1.7394		
dummy M2	26.82***	2.2999		
dummy M3	-5.24***	1.4563		
dummy amprion			-.91***	.2444
dummy mrp2			-1.44***	.2356
Obs.	5472		1460	
R^2	.3488		.2862	
Residual sum of squares	14681311.1		22522.75589	
Weak identification test	82.792		41.969	
Sargan-Hansen p-value	.0977		.2107	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 37: Separate panel regressions of decremental MRP prices (reform 7)

	Period 1		**Period 2**	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.14	.1128	.51**	.2014
WTI oil	.30	.2175	-.14	.3716
dummy weekend	24.51***	1.6709	18.69***	2.2552
dummy summer	1.53*	.8057	-.18	.7541
dummy winter	-6.92***	.8448	-5.43***	1.5246
dummy mrp1	-79.16***	1.1498		
dummy scp+pcp	-5.90***	.5215		
dummy M1	26.21***	1.4577		
dummy M2	10.38***	1.9771		
dummy M3	-23.60***	1.4004		
dummy amprion			-10.04***	1.1839
dummy mrp2			.25	.7430
Obs.	5472		1460	
R^2	.6779		0.1334	
Residual sum of squares	3338951.604		408832.7497	
Weak identification test	82.792		41.969	
Sargan-Hansen p-value	.4783		.0034	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 38: Pooled regression and Chow test (reform 7)

	inc MRP		**dec MRP**	
	coeff	std. err.	coeff.	std. err.
EEX spot	-.30	.2128	.20**	.0999
WTI oil	.63	.5865	.24	.1917
dummy weekend	-36.10***	2.9035	23.32***	1.3954
dummy summer	-2.99***	1.0809	1.42**	.6614
dummy winter	30.62***	2.1405	-6.77***	.7261
dummy mrp1	-59.87***	2.7244	-79.16***	1.1647
dummy scp+pcp	-8.62***	1.3556	-5.91***	.5113
dummy M1	-24.65***	1.4659	26.16***	1.4337
dummy M2	21.59***	1.8509	10.52***	1.9348
dummy M3	-16.43***	1.2825	-23.99***	1.3746
dummy amprion	9.24***	1.1609	-11.37***	.8147
dummy mrp2	-.56	1.1065	-.18	.8475
Obs.	6932		6932	
R^2	.3612		.6653	
Residual sum of squares	15258684.48		3787078.516	
Weak identification test	110.523		110.523	
Chow test statistic	18.61		5.17	
Sargan-Hansen p-value	.1338		.1611	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Reform 8. Amprion joins the existing TSO network for the provision of SCP.

Table 39: Separate panel regressions of incremental MRP prices (reform 8)

	Period 1		**Period 2**	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.30	.2165	-.08	.1706
WTI oil	.78	.6475	-.06	.1236
dummy weekend	-39.20***	3.0185	-4.48**	1.8628
dummy summer	-6.13***	1.3523	.44**	.2217
dummy winter	31.58***	2.1889		
dummy mrp1	-60.01***	2.7070		
dummy scp+pcp	-8.66***	1.3634		
dummy M1	-25.71***	1.5410		
dummy M2	23.68***	2.0085		
dummy M3	-4.80***	1.2844		
dummy M4	-18.82***	1.7901		
dummy mrp2			-1.44***	.2220
Obs.	6256		676	
R^2	.3550		.2352	
Residual sum of squares	15036328.52		6701.349721	
Weak identification test	109.583		4.690	
Sargan-Hansen p-value	.1536		.6436	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 40: Separate panel regressions of decremental MRP prices (reform 8)

	Period 1		**Period 2**	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.20**	.1009	.81*	.4710
WTI oil	.27	.2098	-.40	.4121
dummy weekend	24.63***	1.4568	17.60***	5.2118
dummy summer	1.60**	.8010		
dummy winter	-6.67***	.7432		
dummy mrp1	-79.17***	1.1587		
dummy scp+pcp	-5.91***	.5193		
dummy M1	26.18***	1.4469		
dummy M2	10.47***	1.9592		
dummy M3	-23.63***	1.3983		
dummy M4	-.48	1.0749		
dummy mrp2			.25	.7490
Obs.	6256		676	
R^2	.6614		.0974	
Residual sum of squares	3706563.372		61309.88859	
Weak identification test	109.583		4.690	
Sargan-Hansen p-value	.2536		.1491	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

Table 41: Pooled regression and Chow test (reform 8)

	inc MRP		dec MRP	
	coeff	std. err.	coeff.	std. err.
EEX spot	-.30	.2127	.20**	.1004
WTI oil	.65	.5862	.28	.1925
dummy weekend	-36.02***	2.8998	23.34***	1.4009
dummy summer	-4.29***	1.1422	.73	.6932
dummy winter	30.63***	2.1310	-5.91***	.7231
dummy mrp1	-59.90***	2.7218	-79.24***	1.1660
dummy scp+pcp	-8.64***	1.3566	-5.94***	.5041
dummy M1	-24.97***	1.4758	25.76***	1.4432
dummy M2	22.23***	1.8731	11.33***	1.9388
dummy M3	-5.12***	1.1655	-23.48***	1.3757
dummy M4	-12.93***	1.3293	-4.38***	.8726
dummy mrp2	10.55***	1.3442	-7.54***	.8848
Obs.	6932		6932	
R^2	.3624		.6629	
Residual sum of squares	15230160.9		3813722.428	
Weak identification test	110.649		110.649	
Chow test statistic	6.13		6.00	
Sargan-Hansen p-value	.1344		.1067	

*,**,*** statistically significant on the 10%, 5%, and 1% level, respectively. Standard errors are heteroskedasticity robust.

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