

First results on the Italian-Slovenian electricity market coupling

Primi risultati per il market coupling tra Italia e Slovenia sul mercato elettrico del giorno prima

Lucia Parisio and Matteo Pelagatti

Abstract Since January 1st, 2011 the electricity exchanges of Italy and Slovenia are working under a mechanism of *market coupling* for their respective day-ahead markets. Similar mechanisms are being implemented in many European countries to foster the integration of electricity markets that eventually will merge into one large European power market. This short paper is one of the first works in which, by analysing market results, we try to assess the degree of integration of the Italian and Slovenian electricity markets due to the market coupling policy.

Abstract *Dal primo gennaio 2011 le borse elettriche di Italia e Slovenia sono legate da un meccanismo di market coupling per i rispettivi mercati del giorno prima. Meccanismi simili stanno sorgendo in tutta Europa finalizzati alla creazione di un unico grande mercato europeo dell'elettricità. Questo breve paper è uno dei primi lavori in cui vengono analizzati i dati dei risultati dei due mercati per stabilire il grado di integrazione dovuto all'implementazione del market coupling.*

Key words: Market coupling, electricity market, robust stationarity test, robust cointegration test.

1 Introduction

Since January 1st, 2011 the electricity exchanges of Italy (GME) and Slovenia (BSP) are working under a mechanism of *market coupling* for their respective day-ahead markets. The Italian-Slovenian implementation of the market coupling consists in an implicit auction mechanism, in which

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1. the market operators submit their offers to the two day-ahead markets,
2. the two grid operators (Terna and Eles) communicate the available transmission capacity for each hour of the next day,
3. the two markets share their information about the anonymous offers involving the interconnection,
4. the two exchanges compute the equilibrium prices and quantities,
5. if the capacity constraints are respected only one common price is formed, otherwise the two markets are split and a stream of energy compatible with the constraint is guaranteed to the country with higher equilibrium price.

In this short paper we analyse the dynamics of the two price time series in order to determine to what extent the market coupling mechanism has been successfully in achieving the integration of the two electricity markets expected by the European regulators.

2 The data

BSP, the Slovenian electricity market manager, granted us access to its database, which consists of three types of files: i) price curves tables that contain the anonymous bids and offers for every auction since 2011-01-01, ii) market result tables that list equilibrium prices and quantities for every auction since 2010-06-01 and iii) market coupling tables which contain the equilibrium prices in the BSP and in the North Zone of the GME, the offered capacities of Terna and Eles for the lines interconnecting the two countries and the allocated quantities on those lines since 2011-01-01.

In this work we only consider the prices of the BSP and the North Zone of the GME, looking for some form of convergence after the activation of the market coupling mechanism. The only limitation we have with the data is the availability of Slovenian hourly prices starting from June 2010. In fact, while Italian prices are available on a regular basis since April 2004, the equilibrium prices for Slovenia before June 2010 are irregular and sparse over time.

By observing the plot of the daily MWh of electricity exchanged in the BSP in Figure 1, it is striking how these quantities have radically increased from 2010-06-01 to 2013-12-31, with an upward jump at the beginning of 2011. Beside the quantity level also the volatility had an important increase.

Interestingly, the daily average price prevailing in the BSP day-ahead market did not follow the increase in quantity (cf. Fig. 2). By observing Table 1 we see an increase of the average Slovenian prices only in 2011, but this increase is absorbed in the next two years. The Italian mean prices are always higher with a peak of 23 Euro difference in 2012. However, the figures in 2013 are very close to those in 2010.

If we concentrate on the distribution of the difference of the logarithms of the two price series depicted in Figure 3, we see that the shapes of the estimated densities change even more radically than their means: as expected, since January 2011 there

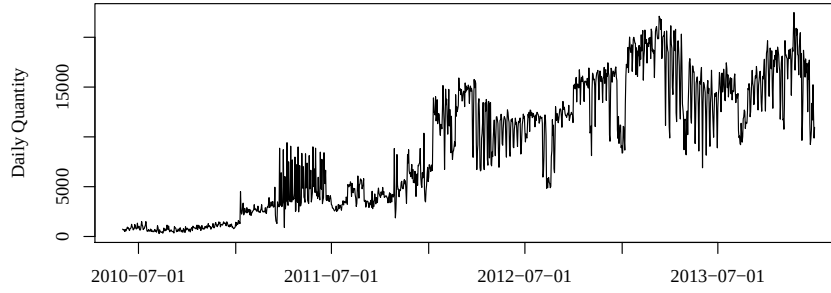


Fig. 1 Daily quantities exchange on the BSP day ahead market.

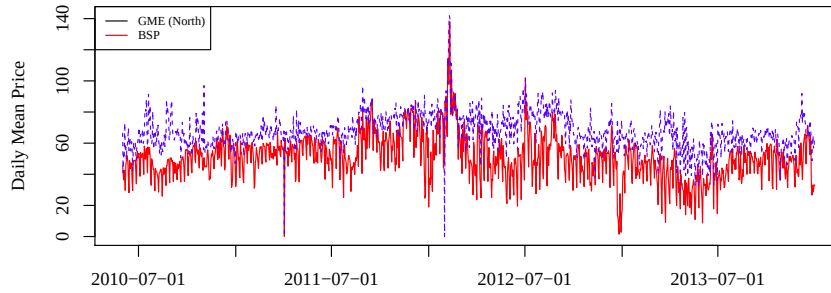


Fig. 2 Daily mean prices on the Slovenian and Italian day ahead markets.

Table 1 Descriptive statistics for GME and BSP prices.

	2010 (from June)			2011 (from June)			2012 (from June)			2013 (from June)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
GME	63.7	10.0	189.0	73.3	15.0	165.1	72.5	16.8	155.0	62.2	0.0	150.4
BSP	48.2	4.8	117.0	59.6	1.0	165.0	49.4	0.0	150.0	45.8	0.0	123.1
GME – BSP	15.5	-13.2	139.5	13.7	-4.98	84.4	23.1	-8.37	108.5	16.4	-35.1	125.1
GME > BSP (%)	91.1			73.1			88.6			82.4		
GME = BSP (%)	0.0			26.8			11.4			16.5		
GME < BSP (%)	8.9			0.1			0.0			1.1		

is a positive probability that the two prices are equal but, at the same time, in 2012 and 2013 the right tails are much thicker. By testing the equality of the medians over the four years using the Kruskal-Wallis test, we reject the null (equal medians) with a virtually zero p -value. Thus, we expect some form of nonstationarity in the log-price difference time series.

3 Dynamic analysis

The results of the preceding section let us expect different forms of nonstationarity in the prices and possibly in the difference of their logarithms. Here, we want to test

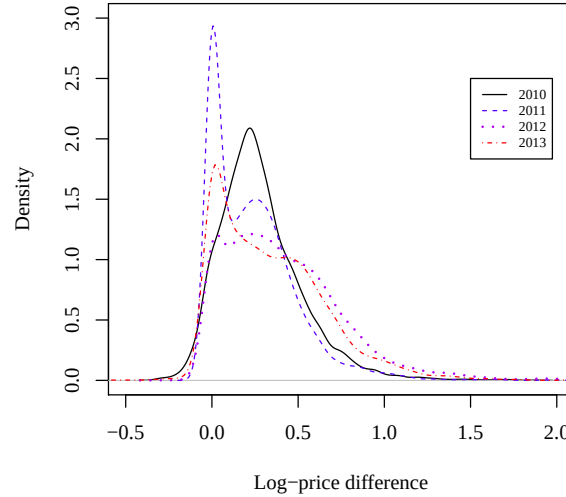


Fig. 3 Densities of the difference between GME log-prices and BSP log-prices since June.

for stationarity, unit roots and cointegration using the outlier-robust tests that we developed in Bosco et al (2010) and Pelagatti and Sen (2013). In fact, by observing the price time series (Fig. 2), we notice a number of extreme values that make any normality-based procedure unreliable.

In particular, we exploit the results in Pelagatti and Sen (2013), where it is proved that by applying the well known KPSS test (Kwiatkowski et al, 1992) to the ranks of the observations we obtain a test statistic which is much more robust to the presence of extreme values but enjoys the same asymptotic distribution as the original KPSS statistic. The Rank KPSS test (and also the KPSS) rejects the null of stationarity at any considered price frequency (hourly, daily, weekly).

Table 2 Stationarity tests for Slovenian and Italian prices on hourly observations, daily and weekly averages (the 5% critical value is 0.463).

	BSP h	GME h	Diff h	BSP d	GME d	Diff d	BSP w	GME w	Diff w
KPSS	16.422	12.240	10.846	2.534	2.084	2.038	0.859	0.644	1.0015
Rank KPSS	18.711	14.846	12.936	3.021	2.284	3.138	1.064	0.722	1.0799

Using the same test, we can assess if the ratio of the prices is stationary. The result of applying the KPSS tests to the logarithm of the price ratio is also reported in Table 2 as “Diff”: the null is rejected and therefore, using the terminology of De Vany and Walls (1999) we can conclude that the market coupling mechanism has not realised the *strong integration* of the two markets.

Although the ratio of prices does not appear stationary, there could be some other form of equilibrium between the prices formed in the two markets. Thus, if we found cointegration between the two log-price time series, albeit with a cointegrating vec-

tor different from $[1, -1]$, which the KPSS test rejected, again stealing from the terminology of De Vany and Walls (1999), we could speak of *weak integration*, as opposed to *perfect integration* which is achieved when the mean log-price difference is zero and the cointegration vector is $[1, -1]$, or *strong integration* when only the latter condition holds.

Since the finite sample distribution of the Johansen test can be rather different from the asymptotic one when heavy tails are present, we use a robust version of it proposed by Lucas (1997) based on a k -dimensional vector error correction model (VECM) with Student's t innovations with 5 degrees of freedom (df):

$$\Delta \mathbf{y}_t = \boldsymbol{\delta} + \boldsymbol{\Pi} \mathbf{y}_{t-1} + \boldsymbol{\Gamma}_1 \Delta \mathbf{y}_{t-1} + \dots + \boldsymbol{\Gamma}_p \Delta \mathbf{y}_{t-p} + \boldsymbol{\varepsilon}_t, \quad (1)$$

with $\boldsymbol{\varepsilon}_t$ multivariate (elliptical) Student's t with 5 df and covariance matrix $\boldsymbol{\Sigma}$.

For estimating the non-normal (VECM) we implemented an EM algorithm based on iteratively re-weighted least squares adapted from Lange et al (1989), and for the computation of the finite sample p -values we used the bootstrap strategy of Swensen (2006): for $r = 0, 1, \dots, k-1$,

1. estimate the unrestricted model (rank = k) under Student's t innovations, and compute the relative residuals $\hat{\varepsilon}_{p+2}, \dots, \hat{\varepsilon}_T$;
2. estimate the reduced rank (rank = r) model under Student's t innovations;
3. using equation (1), generate bootstrap samples $\{\mathbf{y}_{p+1}^{(i)}, \dots, \mathbf{y}_T^{(i)}\}$, for $i = 1, \dots, N$ and N large enough, using the first p observations $\mathbf{y}_1, \dots, \mathbf{y}_p$ as initial values, the parameters of the restricted model estimated at step 2., and shocks re-sampled from $\hat{\varepsilon}_{p+2}, \dots, \hat{\varepsilon}_T$ of step 1;
4. compute the pseudo-likelihood ratio (PLR) statistic for testing hypotheses $H_0 : \text{rank}(\boldsymbol{\Pi}) \leq r$ vs. $H_1 : \text{rank}(\boldsymbol{\Pi}) = k$ for each bootstrap sample of step 3.

For each r , the bootstrap p -value for the PLR test is given by the relative frequency of bootstrapped PLR statistic replications, which are greater than the PLR statistic for the original sample. Of course, this test can be used also for testing for a unit root, if only one series is provided.

We apply this testing strategy only to the log of weekly mean prices for two reasons: i) the periodicities due to within-day and within-week seasonal components are averaged out, ii) since we can think of our price time series as having a stochastic low-frequency trend buried into extremely volatile and leptokurtic noise, the resulting process has an important moving average (MA) component that VAR/VECM models are not able to deal with, and by taking means over 168 observations a relevant part of the noise is also averaged out making the MA component negligible.

Table 3 Lucas' pseudo likelihood ratio test with bootstrapped p -values applied to the log of Slovenian and Italian prices.

Unit root test			Cointegration test		
Series	Stat	p-value	H ₀ : rank ≤	PLR	p-value
BSP	0.623	0.499	0	27.565	0.004
GME	0.326	0.591	1	0.346	0.572

From Table 3 we can conclude that there is a cointegration relation between the two log-price time series. The estimated cointegration vector is $[1.00, -0.93]$ where the order of the variables is $\log(BSP), \log(GME)$.

4 Conclusions

By analysing the prices formed in the Italian and Slovenian electricity exchanges before and after the mechanism of the market coupling was implemented, we observed that, although some for of price equilibrium has been reached, the two markets are still far away from being two strongly integrated markets.

North Italian prices are much higher then Slovenian prices and the capacity constraints for more then 80% of the times limit the transmission of the whole quantity of electricity demanded on the Italian side. Before the implementation of the market coupling the Italian demand was not fully matched some 90% of the times, and so there is an improvement but its impact is rather limited.

It is surprising how Slovenian producers were able to cope with the drastic increase in the demand on the BSP day-ahead market without significantly affecting the wholesale prices.

From a statistical point of view, in this paper, as in Bosco et al (2010) and Pelagatti and Sen (2013), we have shown how classical normality-based statistical techniques can be adapted to successfully deal with the extreme features of electricity price time series.

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