Market coupling between electricity markets: theory and empirical evidence for the Italian-Slovenian interconnection.

Lucia Parisio and Matteo Pelagatti

DEMS - University of Milan-Bicocca

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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.

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1 Introduction

The creation of a unique European electricity market is considered a fundamental step towards the achievement of competitiveness, security of supply and sustainability which represent the main EU energy policy objectives[1]. The integration of independent and often separated national markets can be obtained if two intermediate steps are accomplished: i) increasing the amount of interconnecting lines that flow electricity cross-border and ii) implementing technical rules and allocation methods that use efficiently the available and future interconnection capacity.

Regulation 1228/2003/EC introduced some fundamental guidelines for the management of cross-borders flows. First it stated the principle that cross-border capacity should be allocated in a transparent and non-discriminative way by means of market-based rules that convey the efficient set of signals and incentives to market participants and Transmission System Operators (TSO).

[1]EU Directives 96/92/EC, 2003/54/EC and 2009/72/EC.

Second, transport capacity which is not used must be reallocated to the market according to the same principles outlined above. To insure a full usage of the capacity the netting of flows is encouraged. Third, the access price for the interconnecting lines should be harmonized and paid to TSOs on the basis of scarcity signals (demand supply imbalances) more than on distance between the points of injection and withdrawal.

The new principles introduced by the above mentioned Regulation changed substantially the approach toward energy trade among EU countries. While in the past cross-border trade was considered an instrument to preserve safety of national systems in case of sudden faults, in the era of merit order allocations it becomes an instrument to promote effective competition at the EU wide level.

In the last decade, the EU Commission has worked for the creation of a common legislative framework to ease the establishment of the Internal Electricity market. The "Third Energy Package" issued in 2009 further enhanced the cooperation among national regulators and TSOs and encouraged the establishment of permanent working groups with the aim of promoting harmonization.

The EU rules however did not indicate a specific market mechanism to allocate cross-border capacity and this left room for the flourishing of different regional initiatives implemented by national TSOs and regulators with varying degrees of coordination. Therefore, progress towards electricity markets integration seems to follow a bottom-up direction connecting areas and countries who share similar concerns about energy exchanges. These regional groupings of regulators and TSOs are seen as platforms for the experimentation and development of new and efficient exchange procedures. At the same time, this bottom-up policy perspective has been complemented by a common EU policy towards the co-financing and construction of large energy infrastructure[2] according to the EU "Priority interconnection plan" of 2006. The mixing of regional initiatives with an EU wide coordination plan should at the end promote the creation of one or more optimal energy exchange areas.

2 Interconnection methods

Market methods available for allocating interconnection capacity can be classified according to the different degrees of cooperation among national TSOs and/or power exchanges. One first method employed, which is based on a low degree of coordination among TSOs, is the explicit auction mechanism. Segments of capacity in the opposite directions are allocated in a multi-unit auction. We find examples of explicit auctions conducted by national TSOs, jointly or independently in the two different directions, with or without reserve price. Explicit auctions have been criticized[3] for not being efficient, particularly in the presence of meshed networks (networks normally operated with a number of parallel flow paths). More generally, explicit auctions are suitable for the case in which operators have signed physical contracts for energy in a foreign country and

[2] These provisions are contained into Regulation n.347/2013 of the European Parliament

[3] See [1] and [2]. [3] evaluate various approaches to congestion management in the EU.

consequently need the capacity to transport energy in the country of delivery. The management of explicit auctions is successful when there exists some form of coordinated action and exchange of information between TSOs. National ad hoc cross-border agreements supported the implementation of coordinated explicit auctions. On October, 1st 2008 a new common market platform, CASC-CWE, has been created by the five countries of the Central-West EU region. On November, 10th, 2010, the TSOs of Central-South countries and Switzerland officially joined CASC-CWE S.A. which becomes CASC.EU S.A. Since April, 1st 2011 CASC.EU operates the explicit auctions on behalf of national TSOs on the shared borders of a large region of the EU. To this end, TSOs committed to a close cooperation to ensure reliable operation, optimal management and the best technical evolution of the transmission system. The products auctioned on CASC-EU platform are physical transmission rights for different time duration: year, month, day and infra-day. Auction rules are common for all borders and products. Transmission rights are allocated on the basis of a merit order and paid under a uniform price rule. Pro-quota rationing is applied for identical bids received at the margin. Different products are allocated in separated auctions and resale is possible only for a subset of them. The nomination is managed by local TSOs and yearly and monthly allocations can be re-auctioned in the auction for daily capacity. Daily and infra-daily capacities are subjected to the use-it-or-loose-it principle. Finally, the coordinated explicit auction mechanism requires a joint cross-border congestion management by TSOs and therefore the creation of a single point of operation, where the same IT-tools and harmonized rules are used.

A second market-based method is known as the implicit auction mechanism, also referred to as market splitting, which is the allocation procedure that has been used by North European countries since 1993. In implicit auctions, the available capacity is allocated simultaneously with the physical energy in the domestic markets[4]. The electricity bought is charged at the equilibrium price prevailing in the local market, whereas the use of cross-border capacity is remunerated by the difference between the two prices realized in each interconnected market. TSOs retain this price difference as compensation for the intermediation activity after netting, i.e. once the opposite flows are taken into account and compensated for.

There are three models of implicit auctioning implemented in the EU area. In the so-called Nordic model of market splitting (involving Sweden, Finland, Denmark and Norway) there is one single power exchange acting on behalf of TSOs. The market splits itself in different pricing zones when transmission constraints arise[5]. Netherlands, Belgium and France introduced a coupling of their national exchanges based on a common pricing algorithm governing the clearing of prices among the three regional markets. Finally Germany and

[4] [4] analyze the allocation properties of the implicit auction mechanism and the associated welfare.

[5] Cooperation between a group of northern Eu members begun in 1963 with the creation of Nordel organization. Since then, a long tradition of energy exchange, particularly between Swden and Norway, was eased by the presence of a relatively high capacity interconnector.

Denmark experienced a volume coupling model in which quantities demanded and offered in the two markets are linked whereas prices are determined locally. Evidence from Nordic markets contrasts with that obtained for other European experiences. [5] finds that wholesale markets of continental countries are not well integrated, whereas [6] use a robust multivariate long-run dynamic analysis that reveals the presence of four highly integrated central European markets (France, Germany, the Netherlands and Austria).

The implicit auction in the form of "market coupling" soon emerged as the most recommended method for managing cross-border congestion. Market coupling is based on the assumption that an administered day-ahead market exists in each region (i.e. at each node of the simplified transmission model). Subject to the ability of the transmission model to support the associated flows, market coupling enables the regional markets to trade with each other if it is economically efficient to do so. A number of processes are necessary to support the day-ahead markets, for example by supplying data and providing financial settlement services and, moreover, some measures of short-term energy balancing are also required. The key advantage of market coupling is flow-netting for energy flows scheduled in the opposite directions. Since flows in opposite direction cancel, the line can be used up to full capacity. Therefore under market coupling imperfect arbitrage, which is a quite common attribute of explicit auctions, can be easily avoided and this results in an efficient use of the infrastructure.

On a policy perspective, the approach followed by the EU is know as Price Coupling of Regions (PCR) with the objective of building a common pricing mechanism to coordinate power exchanges acting in a decentralized network[6]. This approach is less demanding with respect to a fully centralized one, i.e. based on a unique pan-European electricity market, and allows to maintain some degree of regulatory independence in local exchanges.

In this paper we analyze one experiment of market coupling between Italian and Slovenian day-ahead markets. In the next section we will describe how market coupling has been implemented and then we empirically analyze 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.

3 The Coupling between Italy and Slovenia

Since January 1st, 2011 the electricity day-ahead markets of Italy (GME) and Slovenia (BSP) allocate the cross-border transmission capacity by means of an *implicit auction* mechanism. The *market coupling* implemented is a decentralized mechanism jointly managed by the two operators who share a common matching algorithm. Post-coupling activities like settlements, nomination and determination of the congestion rents are solved locally.

[6] [1] observes that PCR is the easiest way to achieve a better integration especially for those countries, like Italy, which are characterized by peculiar features in the wholesale market organization.

The Italian-Slovenian implicit auction mechanism is scheduled as follows:

1. the market participants submit their offers to the two day-ahead markets,
2. the two grid operators (Terna and Eles) communicate the available transmission capacity (ATC) for each hour of the next day,
3. the two markets share their information about the anonymous offers involving the use of the ATC,
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.

The new mechanism complements explicit auctions for the allocation of transfer rights on interconnection lines joining the two countries. Explicit auctions, which require a separate allocation of transmission rights and physical energy, are still managed by CASC-EU for yearly and montly products. Daily cross-border capacity is allocated simultaneously with electricity when the coupled interconnected markets clear. Under the implicit auction mechanism imperfect arbitrage cannot occur as energy always flows towards the high price country. Moreover flows-netting implies that power flows scheduled in the opposite directions cancel out leaving the inter-connector to be efficiently used.

The implementation of market coupling requires a preliminary harmonization activity between the power exchanges involved. In particular, coupled markets should share the same timetable for bidding and computing activities and have compatible bid formats.

The IT-SL market coupling experiment has been considered very important for its peculiar characteristics: on the Italian side, we have a quite large and liquid market characterized by the presence of generating units having high variable costs, whereas on the Slovenian side we have a comparatively smaller market (registering regular transactions since June 2010) with very limited capacity and a different fuel mix. In particular, the total installed capacity in Italy[7] amounts at 106 GW whereas Slovenian capacity is equal to 3 GW only. Italian production is mainly based on fossils fuels (71%) with a portion of 28% based on renewable and hydro, whereas Slovenian[8] production comes from nuclear (24%), fossils fuels (45%) and hydro (30%).

The integration of a large market with a small one poses a number of interesting questions to be investigated. A first question is related to how the two markets interact in forming the clearing prices. Perfect integration requires a unique equilibrium price whereas partial integration entails some form of common dynamic of the two price series. A second question is related to the effect of interconnection on the bidding strategies followed by non-atomistic players in

[7]Details about the Italian electricity industry are presented in [7].
[8]See [8] for details about the recent evolution of the Slovenian electricity industry.

one or both markets. In this paper we pursue the first line of research while we leave the second to future work. In particular it will be interesting to analyse how the coupling experience has influenced the supply schedules of bidders on the importing side and the effect on marginal technologies.

The IT-SL market coupling is considered a very positive experience. A first reason of success is recognized to be the attraction of higher volumes than those prevailing before coupling. The average capacity initially available on the It-SL border was equal to 465 MW. At the beginning of the coupling experience only 35 MW were allocated in the foreign BSP zone integrated in the Italian market, whereas the other portion of capacity was still allocated through daily explicit auctions. After one year of implementation of the new mechanism and due to the expiring of previously signed import contracts, the allocated capacity grew substantially to 165 MW and then to 526 MW in the Spring 2012, i.e. to 97% of total available capacity[9].

Figure 1 illustrates the evolution of the figures about market coupling. The above result is a clear signal of the approval granted by market participants to this new allocation mechanism. Another indirect proof of the success of IT-SL coupling is the increase in the liquidity registered on the Slovenian exchange which grew from 0.2 TWh in 2010 to 1.5 TWh in 2011 and to 4,4 TWh in 2012. This success is partly explained by the massive use of the use-it-or-sell-it clause by participants: market agents may resell to the TSO the import capacity bought in advance (yearly and monthly allocations) and then buy it back on the Slovenian exchange by placing sale offers.

A second evidence of success of the new coupling mechanism is the improved efficiency in the use of the interconnection infrastructure: the system is able to allocate at all hours the transit capacity in the direction consistent with the price spread. Moreover the full usage is guaranteed every time there is a positive differential[10]. Congestion rents are thus fully exploited.

A third reason of success is recognized in the ability of the coupling mechanism to promote a progressive convergence of prices between the two wholesale markets. While full convergence has not been achieved yet, still we notice a narrow price gap as the volume allocated through market coupling has increased. In the next Section we analyse the effect of coupling on clearing prices on the two day-ahead-markets.

4 The data

The Slovenian electricity market manager (BSP) 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

[9] The share of capacity allocated through the market coupling mechanism was stable at 95 % in 2012.

[10] In 2011 the flows resulting from market coupling were 100% efficient.

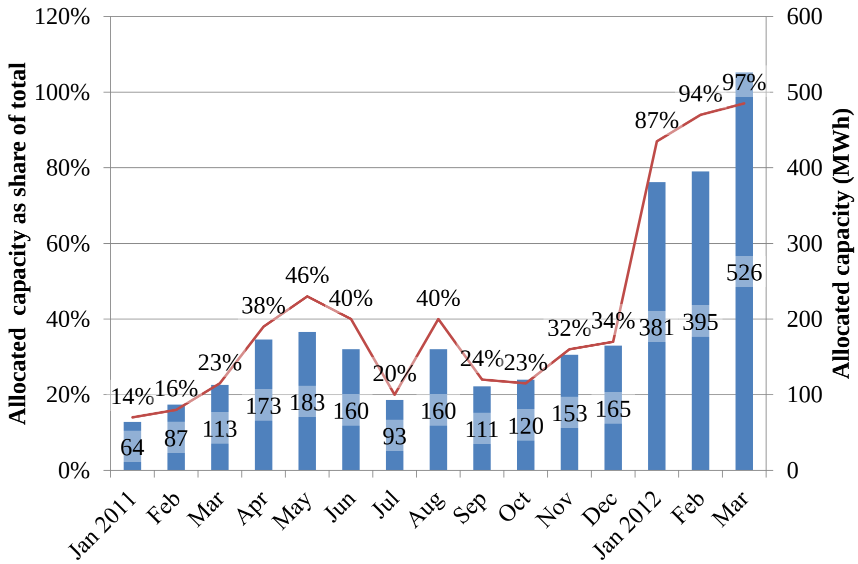

Figure 1: Interconnection capacity IT-SL allocated by market coupling

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 clearing prices of the day-ahead market run by BSP and clearing prices determined in the North Zone of the day-ahead market run by GME. We look for some form of convergence of the two series emerging after the activation of the market coupling mechanism. While Italian prices are available on a regular basis since April 2004, data on equilibrium prices for Slovenia are irregular until June 2010. The Italian series is therefore longer than its Slovenian counterpart. In fact, the Slovenian market operator Borzen was established on 28 March 2001 but the exchange soon happened to be very illiquid. In 2005 for example, only 0,3% of the electricity consumed was traded on Borzen[11]. The 99.7% of the consumed electricity was exchanged through bilateral contracts lasting from one to five years. It was only with the expiring of these long term contracts that the power exchange started to be more liquid (11% in 2011).

By observing the plot of the daily MWh of electricity exchanged in the BSP in Figure 2, 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

[11]Activities connected with energy exchange were under the responsibility of Borzen until November 2008, when responsibility was passed to the newly established company BSP Regional Energy Exchange, which was founded by Borzen and Eurex, the international derivatives exchange.

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		

quantity level also the volatility had an important increase.

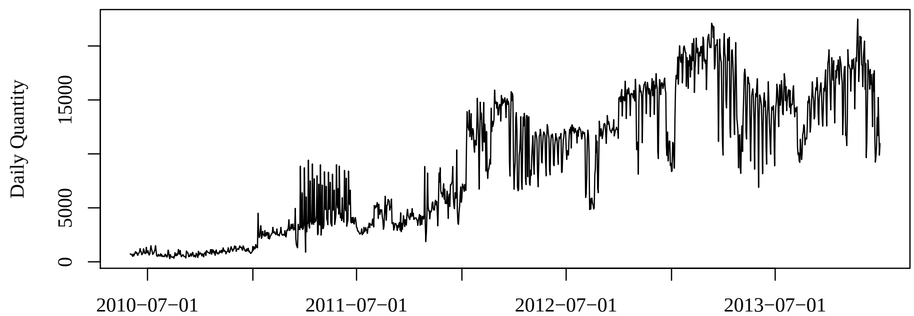

Figure 2: Daily quantities exchange on the BSP day ahead market.

Interestingly, the daily average price prevailing in the BSP day-ahead market appeared to be not influenced by the increase in the exchanged quantity (cf. Fig. 3). By observing Table 1 we see an increase of the average Slovenian prices

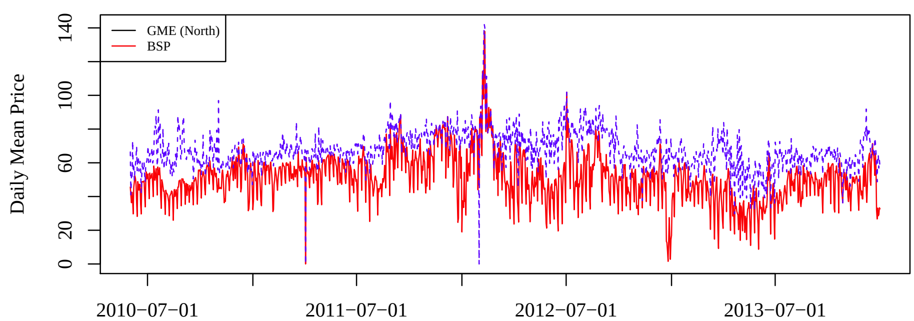

Figure 3: Daily mean prices on the Slovenian and Italian day ahead markets.

taking place only in 2011, whereas this increase has been 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 registered in 2010.

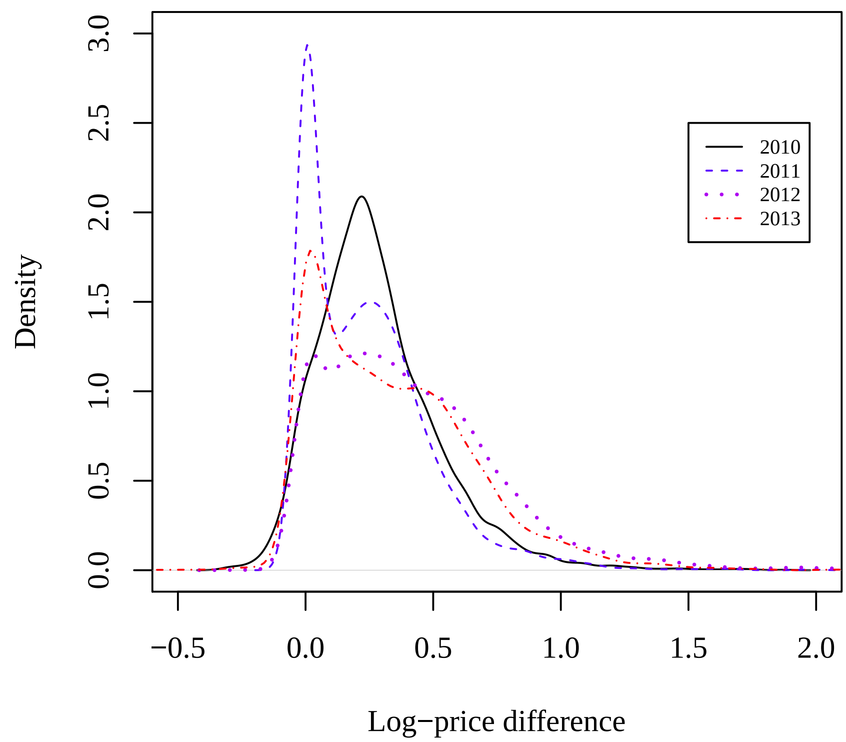

Figure 4: Densities of the difference between GME log-prices and BSP log-prices since June.

If we concentrate on the distribution of the difference of the logarithms of the two price series depicted in Figure 4, we see that the shapes of the estimated densities change even more radically than their means: as expected, since January 2011 there 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.

5 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 for stationarity, unit roots and cointegration using the outlier-robust tests that we developed in [6] and [9]. In fact, by observing the price time series (Fig. 3), we notice a number of extreme values that make any normality-based procedure unreliable.

In particular, we exploit the results in [9], where it is proved that by applying the well known KPSS test [10] 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	GME	Diff
Hourly data			
KPSS	16.422	12.24	10.846
Rank KPSS	18.711	14.846	12.936
Daily averages			
KPSS	2.534	2.084	2.038
Rank KPSS	3.021	2.284	3.138
Weekly averages			
KPSS	0.859	0.644	1.0015
Rank KPSS	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 [11] 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 vector different from $[1, -1]$, which the KPSS test rejected, again stealing from the terminology of [11], we could speak of *weak integration*.

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 [12] based on a k-dimensional vector error correction model (VECM) with Student's t innovations with 5 degrees of freedom (df):

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

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

For estimating the non-normal (VECM) we implement an EM algorithm based on iteratively re-weighted least squares adapted from [13], and for the computation of the finite sample p-values we used the bootstrap strategy of [14]: for $r = 0, 1, \ldots, k-1$,

1. estimate the unrestricted model (rank $= k$) under Student's t innovations, and compute the relative residuals $\hat{\varepsilon}_{p+2}, \ldots, \hat{\varepsilon}_T$;

2. estimate the reduced rank (rank $= r$) model under Student's t innovations;

3. using equation (1), generate bootstrap samples $\{\boldsymbol{y}_{p+1}^{(i)}, \ldots, \boldsymbol{y}_T^{(i)}\}$, for $i = 1, \ldots, N$ and N large enough, using the first p observations $\boldsymbol{y}_1, \ldots, \boldsymbol{y}_p$ as initial values, the parameters of the restricted model estimated at step 2., and shocks re-sampled from $\hat{\varepsilon}_{p+2}, \ldots, \hat{\varepsilon}_T$ 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

Series	Stat	p-value
BSP	0.623	0.499
GME	0.326	0.591

Cointegration test

H_0: rank $\leq$	PLR	p-value
0	27.565	0.004
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 $\log(BSP), \log(GME)$.

6 Conclusions

We analysed the clearing prices formed in the Italian and Slovenian electricity exchanges before and after the mechanism of market coupling was implemented and we observed that, although some form of price equilibrium has been reached as the cointegration relation between the two log-price time series proves, the two markets are still far away from being two strongly integrated markets.

North Italian prices are much higher than 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 it has a rather limited impact. The values of the cointegration vector show that Slovenian prices tend to amplify the volatility of the common component, and this fact is probably due to the two regimes of Slovenian prices: aligned to the higher Italian prices (16.5% of the times in 2013), lower then Italian prices (82.4% of the times in 2013).

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 [6] and [9], 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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