CONTAGION IN ELECTRICITY MARKETS: DOES IT EXIST?

C. A. BOLLINO* – D. CIFERRI* - P. POLINORI*[(a)]

**Department of Economics, Finance and Statistics - University of Perugia (I)*

Via Pascoli 20, 06123, Perugia

Tel +39-075-585.5002 Fax +39-075-585.5299

[(a)]Corresponding author

E-mail: bollino@unipg.it, davideciferri@hotmail.com, polpa@unipg.it

Key words: Contagion; Interdependence; Identification, IPX.

1. Introduction

This paper investigates the existence of contagion effects in Italian electricity markets. The concept of contagion has been developed for high frequency financial markets, see the World Bank definition (Word Bank, 2000). In literature there are several reviews about the meaning of contagion (World Bank 2000, Edwards, 2000, Pericoli and Sbracia, 2003). The main result is that there is no consensus on what contagion is (Pericoli and Sbracia, 2003, p. 573). In their survey Pericoli and Sbracia (2003, pp. 573-575) provide five definitions that respectively focus on five key words: probability, volatility, coordination, co-movement and shift.

Following Pick (2005) and Pesaran and Pick (2007) the paper presents a canonical, econometric model of contagion and investigates the conditions under which contagion can be distinguished from mere interdependence. The theoretical and empirical distinction between contagion and interdependence is based upon precise identification conditions, discussed in the paper.

We observe that in the empirical literature there has never been a contagion analysis of electricity markets. This is somehow surprising, since the very high frequency nature of the data, which is hourly market equilibrium data in most organized electricity markets around the world.

Moreover, market structure analysis has widely shown (Wolak, 2003 and Bollino and Polinori, 2006) the existence of substantial departure from competitive equilibrium. In other words, due to market congestions, there are several hours in the day, (typically daily peak hours) characterized by oligopolistic equilibria, while there are others periods (typically nightly off-peak hours) characterized by higher degree of competition.

These characteristics can be summarized in the following stylized fact, to be empirically investigated: in the hourly electric market there exist multiple equilibria solutions. Sudden jumps in one market can be influenced by analogous behavior in another market. This is the canonical situation which is identified as contagion in financial literature.

Thus, in this paper we propose to analyze the contagion effect among different electric markets.

The empirical analysis is based on different regional markets in the Italian Power Exchange (IPEX). This is a novel result in economic literature. The previous literature has focused much on the typical characteristics of electricity prices such as high volatility and very large, or extreme, price changes but, so far, it has ignored the question whether contagion exists among different electricity markets.

The Monsoonal effects, the Tequila effect, the Asian flu, the Russian cold or the Brazilian fever are the most important types of financial crisis cited in this literature. More precisely, some researchers have focused the differences between contagion and interdependence. Pesaran and Pick (2007, p. 1247) identify three possible theories. In the first one, *Monsoonal effects*, financial crises appear to be contagious because underlying macroeconomic variables are correlated; in the second, *spill-over effects*, a crisis affects another country through external links such as trade channels, and finally in the *theory of pure contagion* there exist multiple equilibria and market solution jumps from a 'good' to a 'bad' equilibrium. In this paper we focus only on *pure contagion* relationship in the IPX at the Italian regional level.

2. The empirical framework

The analysis and identification of contagion requires that each individual market equations contains market specific regressors, consequently we have to involve market specific variables in structural equations in order to correctly specify the model. Pesaran and Pick (2007, p. 1266) show that ignoring endogeneity and interdependence can introduce a substantial upward bias in estimation of contagion coefficient. In general, problems of endogeneity requires usage of instrumental variables (IV) estimation and, in agreement with Pick (2005), we obtain consistency by including regional market specific fundamentals. Our canonical model is as follows:

$$y_{it} = \alpha_{0i} + \alpha_i' x_{it} + \beta_i C_{it} + u_{it} \qquad (1)$$

where i indicates markets, t indicates periods, y_{it} is a daily (24h) change in electricity price index, x_{it} is a vector of predetermined variables, α_{0i} is a scalar parameter, α_i is a vector of parameters.

Contagion is addressed by including a dummy variable (Contagion Index), C_{it}, in the model. Following the methodology of Favero – Giavazzi (2002) we consider positive as well as negative extreme movements in the y_{it}. Consequently the model becomes:

$$y_{it} = \alpha_{0i} + \alpha_i' x_{it} + \beta_i C_{it}^{+} + \beta_i C_{it}^{-} + u_{it} \tag{2}$$

where the contagion index is:

$$C_{it}^{+[-]} = I\left(\sum_{j=1, J \neq i}^{N} I(+[-]y_{jt} - c_j) \right) \tag{3}$$

with: I(.) is indicator function that takes value 1 if the price in each market is bigger than the crisis threshold c_j. . The crisis threshold is endogenously estimated allowing them to vary between markets, The thresholds were estimated by minimizing the squared errors from 2SLS estimations using all instruments, as in Pick (2007). The starting point for the gird search of the thresholds was chosen such that for each market between 5% and 10% of observations are crisis observations. For each market, we then compute all possible combinations of crises occurred in the other markets using the two crisis thresholds (5% and 10%)[1]. Alternatively, the thresholds could be estimated using either one of the instrumental selection methods or a different estimator.

Model 2 is estimated for each market, using the generalized instrumental variable estimation (GIVE) procedure with the lagged dependent variables of the markets *j = 1, 2, . (-i)…, N* used as instruments for C^{+}_{it} and C^{-}_{it}.[2] Model 2 also includes additional variables aimed at capturing structural characteristics as market size, market concentration and market congestion. We discuss such variables in section 3.

3. Data description

The hourly data for the electricity spot prices of the seven markets in the Italian Power Exchange-IPEX (Northern, C-South, C-North, Southern, Calabria, Sicily and Sardinia) are from GME[3]. All

---

[1] This procedure leads to 2^6 permutations of the standard model, where 2 is the number of the possible grid points (5% and 10%) and 6 is the number of the n-1 markets which can potentially affect the price behaviour of the market *i.* The choice of the two thresholds (5% and 10%) allows us to be less conservative in including the potential crisis observations in our contagion index with respect to other analysis in which these values are more restrictive.

[2] All other market data are available under request.

[3] The GME is the national agency with the mission of organising and managing transactions in the Electricity Market.

prices are expressed as €/MWh. The hourly daily returns are calculated as the difference of (the logs of) spot prices registered in the same hour between two consecutive days.

We de-seasonalize the spot price returns using the method proposed by Gallant, Rossi and Tauchen (1992). The first step is to regress each variable on a series of adjustment variables as follows:

$$y = d'\lambda + u \tag{4}$$

The adjustment variables we use are as regressor in (4) are: 23 hourly dummies, 30 daily dummies and 11 monthly dummies. Then, to remove the heteroscedasticity in our variables, the residuals are used in the regression:

$$\log(u^2) = d'\theta + v \tag{5}$$

Finally, The adjusted or deseasonalized variables are then calculated as follows:

$$y_{adj} = \bar{y} + \hat{\sigma}_y \frac{\hat{u}}{\exp(d'\theta/2)} \tag{6}$$

where $\bar{y}$ is the unadjusted sample mean of the variables and $\hat{\sigma}_y$ is the unadjusted sample standard deviation. The adjusted series have the same sample mean and variance as the unadjusted series, but the effect of seasonality on the mean and variance is removed. In table 1 we report the descriptive statistics for the seven Italian electricity markets.

[TABLE 1]

4. Results

We have estimated equation (2) and (3) separately for each market for the period April 1, 2004 to November 3, 2009 for a total 49680 hourly observations. In equation (2) the RHS (variable y_{it}) is the daily price change while the specific market variables (x_{it}) contain all the structural determinants (hours, weekdays, months, seasons, years, peak and off-peak hours and so on). In equation 3 the contagion effect on market j is a function of the extreme value indicator for all other markets.

The results are shown in table 2 and 3, where we report the main evidence obtained using 2SLS and GMM estimates, respectively. The top panel of both tables provides OLS results which do not take into account the potential presence of endogeneity between the different contagion indexes.

The testable hypothesis is that contagion exists if the C^+ and C^- coefficents are statistically significant and that contagion can be identify separately from interdependence, thanks to the specific market variables (x_{it}).

[TABLE 2]

The contagion coefficents in the OLS are always significant and with the expected signs for all regional electricity markets. However, as observed also in Pick (2005), parameter estimates of contagion effects using IV (both 2SLS and GMM) are smaller of those of OLS and the significance is also somewhat reduced. As argued by Pesaran and Pick (2007), these evidence are in support of the idea that the results obtained ignoring the endogeneity between contagion variables lead to oversetimate the effects of these indexes on the price behaviours. Nevertheless, contagion seems to be separately identified form interdipendece when IV techquines are used in order to reduce this problem. Regarding 2SLS estimates, it is possible to note that for two markets (C-North and Southern) the coefficents associate with C^+ and C^- are significance at least at 5% level. The sign of the coefficents, as we expected, is positive for C^+ and negative for C^-. Thus, in these markets th espot price returns react to an extra-movements registred in the other markets with a change in the same direction of the distrurbances. This regularity is robust to the change of the order of powers of instruments included in the regression in order to to take into account the presence of nolinerities in the parameters. For Calabria, Sicilia, C-South Italy and Sardinia this evidence is weaker. In fact, we have always significant coefficents with the expected sign only for C^- indexes. Only in the case of the last two markets when we increase the order of the instruments' powers, we find significant coefficents for C^+ associated with the correct sign. For all these markets (with the exception on Northern) in most of the cases we detect an asymmetric effects between contagion effects. In particular, the adjustment intensities observed when there are downward extra-movements in the other markets (that is the estimated coefficients of C^-) is greater than those obtained in response of a spot price increase in the other markets. We interpret this last results as potential different collusive behavoiur among operators. Thus, it is possible to argue that the sudden equilibrium change occurs faster when dynamic patterns are spiking suddenly downward and not upward as results of break down in the collusion which leads to a new competitive framework with lower spot price levels. Finally, different evidence are shown for the Northern, probably the most efficient in the Italian IPEX. Regarding 2SLS estimates, we find that the coefficients associate with C^-.are often not statistically significant at usual levels of confidence. On the other hands, we detect negative and significant coefficients for the contagion index C^+. We associate this result to the market separation due congestion which occurs when physical constraints are binding. For all the models the Cragg-Donald statistics reported in both tables show that the null hypothesis of weak instruments can be rejected and then that the specification of the instruments is valid (Stock and Yogo, 2005).

[TABLE 3]

The GMM estimates shown in table 3 seem to give robustness to the results obtained with 2SLS regressions

5. Conclusions

The most important conclusions of this paper are that contagion can be identified separately from interdependence and that effects are asymmetric. In IPX there occurs contagion effects which can be identified with statistically significant coefficients. Moreover, we find that, most likely, price crisis occur when dynamic patterns are spiking suddenly downward and not upward. This is consistent with theoretical prediction, that sudden equilibrium change occurs when a collusive behavior breaks down, resulting in a competitive behavior. Finally, this indicates that interdependence occurs when price dynamic patterns are moving upward.

References

Bollino, C.A., Polinori, P. 2008. Measuring market power in wholesale electricity Italian market: April-December 2004., SSRN Working Papers. http://papers.ssrn.com/sol3/papers.cfm?abstract _id=1129202. [Download 19-11-2008]

Edwards, S., 2000. Contagion. The World Economy 23, 7, 873-900.

Favero, C.A., Giavazzi, F. 2002. Is the international propagation of financial shocks non-linear? Evidence from the ERM. Journal of International Economics 57, 231–246.

Gallant, R.A., Rossi, P.E., Tauchen G., 1982. Stock Prices and Volume, The Review of Financial Studies. 5, 2, 199-242.

Pericoli, M., Sbracia, M., 2003. A Primer on Financial Conagion. Journal of Economic Surveys 17, 571-608.

Pesaran, M.H., Pick, A. 2007. Econometric issues in the analysis of contagion. Journal of Economic Dynamics & Control, 31, 1245-1277.

Pick, A. 2005. Estimating contagion via instrumental variables, Working Papers, http://www.riskturk.com/ec2/submitted/cec_ec2.pdf [Download 14-01-2008]

Stock, J.H., Yogo, M., 2005. Asymptotic Distributions of Instrumental Variables Statistics with Many Weak Instruments, in D. W. K. Andrews and J. H. Stock (eds.) Festschrift in Honor of Thomas Rothenberg. Cambridge, U.K.: Cambridge University Press.

Word Bank, 2000. Contagion of Financial Crises. http://www1.worldbank.org/economicpolicy/ managing%20volatility/contagion/index.html. [Download 30-01-2009]

Wolak, F.A., 2003. Measuring Unilateral Market Power in Wholesale Electricity Markets: the California Market, 1988-2000. American Economic Review 93, 2, 425-430.

Table1
Descriptive statistics of seven italian market (IPEX)

Variable	Obs	Mean	Std. Dev.	Min	Max	Skeweness	Kurtosis
a) Daily first differences of spot prices (euro/Mwh)							
Northern	49656	-0.002	20.365	-322.827	524.665	0.005	37.326
C-North	49656	-0.002	21.072	-383.263	590.038	0.302	45.896
C-South	49656	-0.002	20.951	-401.054	542.711	0.258	42.974
Southern	49656	-0.002	20.760	-419.682	499.672	0.179	41.644
Calabria	41640	0.010	25.087	-581.005	641.231	1.447	89.532
Sicily	49656	0.026	31.547	-758.899	719.067	0.326	69.216
Sardinia	49656	-0.005	29.613	-526.263	530.183	0.121	40.519
b) Quantities (MWh)							
Northern	49680	19933.380	4659.405	9372.550	30743.920	0.224	1.848
C-North	49680	4056.027	884.576	2080.000	6299.100	0.213	1.841
C-South	49680	4018.038	1095.334	1762.030	8083.740	1.007	4.047
Southern	49680	4448.492	977.878	1667.390	7470.590	-0.226	2.707
Calabria	41664	399.763	95.975	140.000	671.980	0.092	2.367
Sicily	49680	2170.372	406.412	1229.580	3489.610	0.064	2.257
Sardinia	49680	1421.683	146.926	1002.720	2000.090	0.162	2.853
c) Herfindahl index							
Northern	43080	1440.719	410.400	0.000	9431.690	6.731	82.852
C-North	43080	3811.746	650.591	439.950	5935.610	-1.328	7.582
C-South	43080	3277.974	933.042	0.000	7528.250	0.344	5.411
Southern	43080	2372.724	1403.891	0.000	7220.000	-0.140	2.750
Calabria	35064	5454.115	1910.483	133.100	10000.000	0.685	3.907
Sicily	43080	3000.040	888.919	0.000	7323.430	0.275	3.902
Sardinia	43080	3239.882	623.280	0.000	6994.760	-1.626	10.883
d) Number of markets							
IPEX	49680	2.611	1.065	1	7	0.284	2.496

Source. GME (Italy).

Table 2

2SLS estimation results		Northern	C-South	C-North	Southern	Calabria	Sicily	Sardinia
OLS	C^+	14.012***	16.752***	17.746***	21.790***	17.562***	13.031***	13.383***
	St. Err.	(0.405)	(0.230)	(0.231)	(0.233)	(0.277)	(0.383)	(0.416)
	C^-	-13.402***	-18.071***	-17.205***	-17.264***	-17.549***	-12.682***	-12.431***
	St. Err.	(0.218)	(0.237)	(0.224)	(0.264)	(0.273)	(0.377)	(0.578)
	R-sq	0.550	0.542	0.546	0.557	0.517	0.457	(0.404)
IV 2SLS (m=1)	C^+	4.282	-5.298***	0.266	5.451**	-4.871*	-3.068	-9.548***
	St. Err.	(3.331)	(2.274)	(2.212)	(2.146)	(2.544)	(3.730)	(3.630)
	C^-	7.677***	-12.295***	-7.162***	-4.107**	-9.542**	-7.855**	-17.907**
	St. Err.	(2.830)	(2.267)	(1.950)	(1.703)	(2.319)	(3.608)	(3.270)
	R-sq	0.421	0.419	0.450	0.461	0.417	0.430	0.349
	U-ident test	164.089	321.787	345.032	485.476	282.269	293.657	302.555
	g	9.131	17.947	19.249	27.139	15.734	16.371	16.869
(m=2)	C^+	-2.113***	2.480***	3.059***	4.063**	0.006	-2.136***	2.984**
	St. Err.	(0.913)	(0.883)	(0.874)	(1.024)	(0.932)	(1.296)	(1.161)
	C^-	2.779***	-3.271***	-3.840***	-4.001**	-5.018**	-7.124**	-6.618***
	St. Err.	(0.791)	(0.837)	(0.781)	(0.824)	(0.850)	(1.198)	(1.063)
	R-sq	0.4262	0.4384	0.4507	0.453	0.4347	0.431	0.385
	U-ident test	3786.302	4043.706	4004.831	3531.457	3320.355	4072.684	4515.574
	g	110.927	118.912	117.702	103.079	96.622	119.815	133.703
(m=3)	C^+	-0.736	3.684***	4.231***	5.084***	1.495*	-0.487	4.839***
	St. Err.	(0.866)	(0.842)	(0.832)	(0.979)	(0.873)	(1.227)	(1.112)
	C^-	2.644***	-2.553***	-3.447***	-3.507***	-4.339***	-6.335***	-6.064***
	St. Err.	(0.765)	(0.816)	(0.760)	(0.804)	(0.804)	(1.165)	(1.028)
	R-sq	0.436	0.4408	0.4549	0.455	0.440	0.434	0.3873
	U-ident test	4155.026	4479.554	4411.051	3803.399	3846.674	4544.96	5077.532
	g	81.547	88.333	86.895	74.266	75.158	89.708	101.001
(m=4)	C^+	-1.596**	2.341***	3.233***	3.770***	1.232	-1.231	4.624***
	St. Err.	(0.786)	(0.780)	(0.775)	(0.910)	(0.784)	(1.122)	(1.023)
	C^-	1.804	-3.063***	-3.603***	-4.188***	-4.358***	-6.833***	-5.647***
	St. Err.	(0.704)	(0.762)	(0.709)	(0.758)	(0.737)	(1.063)	(0.945)
	R-sq	0.436	0.436	0.4503	0.452	0.439	0.433	0.387
	U-ident test	5229.711	4792.944	4752.218	4046.009	5487.591	6312.041	6855.96
	g	78.155	71.172	70.525	59.431	82.318	95.837	104.931
(m=5)	C^+	-1.569**	1.857***	2.930***	2.888***	0.442	-0.725	4.248***
	St. Err.	(0.762)	(0.763)	(0.753)	(0.897)	(0.764)	(1.096)	(1.005)
	C^-	0.592	-4.350***	-5.244***	-5.015***	-5.653***	-6.747***	-6.340***
	St. Err.	(0.685)	(0.745)	(0.690)	(0.747)	(0.711)	(1.034)	(0.927)
	R-sq	0.444	0.441	0.458	0.451	0.440	0.434	0.388
	U-ident test	5413.903	4896.376	4892.114	4118.351	5797.816	6811.092	7215.381
	g	64.867	58.224	58.17	48.421	69.858	83.298	88.769
(m=6)	C^+	-1.104	2.575***	3.511***	4.244***	1.528**	0.037	5.025***
	St. Err.	(0.729)	(0.732)	(0.728)	(0.861)	(0.732)	(1.052)	(0.972)
	C^-	0.4633	-4.674***	-5.069***	-5.461***	-5.246***	-6.425***	-5.867***
	St. Err.	(0.659)	(0.718)	(0.668)	(0.717)	(0.685.)	(0.994)	(0.897)
	R-sq	0.448	0.447	0.460	0.461	0.445	0.436	0.388
	U-ident test	5536.83	4953.395	4946.294	4229.198	5993.146	7248.718	7621.493
	g	55.354	49.101	49.025	41.482	60.318	74.314	78.567

Table 3

GMM estimation results		Northern	C-South	C-North	Southern	Calabria	Sicily	Sardinia
OLS	***C^+***	14.012***	16.752***	17.746***	21.790***	17.562***	13.031***	13.383***
	St. Err.	(0.405)	(0.230)	(0.231)	(0.233)	(0.277)	(0.383)	(0.416)
	C^-	-13.402***	-18.071***	-17.205***	-17.264***	-17.549***	-12.682***	-12.431***
	St. Err.	(0.218)	(0.237)	(0.224)	(0.264)	(0.273)	(0.377)	(0.578)
	R-sq	0.550	0.542	0.546	0.557	0.517	0.457	(0.404)
IV GMM	***C^+***	6.791	-1.234	3.154	7.847***	0.864	-5.292	-4.039
(m=1)	***St. Err.***	(4.900)	(3.152)	(3.207)	(2.878)	(3.547)	(4.766)	(4.577)
	C^-	7.084*	-9.813***	-5.032**	-3.944*	-7.424**	-6.358	-13.823**
	St. Err.	(3.878)	(3.012)	(2.727)	(2.354)	(2.971)	(4.514)	(4.314)
	R-sq	0.436	0.444	0.457	0.4705	0.4494	0.4194	0.3696
	U-ident test	164.089	321.787	345.032	485.476	282.269	293.657	302.555
	g	9.131	17.947	19.249	27.139	15.734	16.371	16.869
(m=2)	***C^+***	0.675	2.867*	3.475**	4.388***	1.532	-1.433	1.760
	St. Err.	(1.436)	(1.474)	(1.477)	(1.584)	(1.596)	(2.495)	(2.025)
	C^-	1.987*	-5.221***	-3.510***	-5.180***	-6.536***	-2.495	-6.506***
	St. Err.	(1.147)	(1.279)	(1.224)	(1.267)	(1.450)	(1.955)	(1.620)
	R-sq	0.448	0.450	0.451	0.460	0.450	0.423	0.380
	U-ident test	3786.302	4043.706	4004.831	3531.457	3320.355	4072.684	4515.574
	g	110.927	118.912	117.702	103.079	96.622	119.815	133.703
(m=3)	***C^+***	1.055	2.599*	3.515**	4.216***	2.750*	-0.720	3.222*
	St. Err.	(1.357)	(1.347)	(1.396)	(1.496)	(1.514)	(2.215)	(1.876)
	C^-	1.755*	-4.298***	-3.548***	-4.546***	-4.758***	-1.943	-3.754**
	St. Err.	(1.062)	(1.179)	(1.140)	(1.175)	(1.305)	(1.172)	(1.521)
	R-sq	0.452	0.4443	0.451	0.4558	0.4485	0.4224	0.3769
	U-ident test	4155.026	4479.554	4411.051	3803.399	3846.674	4544.96	5077.532
	g	81.547	88.333	86.895	74.266	75.158	89.708	101.001
(m=4)	***C^+***	0.262	1.456	2.889**	4.263***	2.639**	-0.188	2.959*
	St. Err.	(1.364)	(1.270)	(1.322)	(1.429)	(1.348)	(2.007)	(1.659)
	C^-	1.874*	-3.173***	-2.953***	-3.458***	-3.485***	-2.504	-4.431***
	St. Err.	(0.971)	(1.090)	(1.049)	(1.095)	(1.232)	(1.581)	(1.419)
	R-sq	0.447	0.4314	0.444	0.4503	0.4415	0.425	0.3775
	U-ident test	5229.711	4792.944	4752.218	4046.009	5487.591	6312.041	6855.96
	g	78.155	71.172	70.525	59.431	82.318	95.837	104.931
(m=5)	***C^+***	0.219	1.235	2.296*	3.763***	1.307	-0.272	2.269
	St. Err.	(1.125)	(1.106)	(1.192)	(1.306)	(1.198)	(1.888)	(1.513)
	C^-	2.005*	-2.536**	-2.318**	-2.852***	-3.555***	-2.915**	-3.551***
	St. Err.	(0.865)	(1.004)	(0.955)	(1.027)	(1.108)	(1.459)	(1.307)
	R-sq	0.445	0.4262	0.437	0.4439	0.4347	0.425	0.3738
	U-ident test	5413.903	4896.376	4892.114	4118.351	5797.816	6811.092	7215.381
	g	64.867	58.224	58.17	48.421	69.858	83.298	88.769
(m=6)	***C^+***	0.066	0.952	2.058*	4.168***	1.367	-0.973	2.679*
	St. Err.	(1.002)	(1.041)	(1.137)	(1.291)	(1.014)	(1.732)	(1.444)
	C^-	1.214*	-3.311***	-2.614**	-3.751***	-3.738***	-3.664***	-3.852***
	St. Err.	(0.701)	(0.928)	(0.873)	(0.942)	(0.972)	(1.272)	(1.188)
	R-sq	0.450	0.429	0.437	0.4513	0.4359	0.4247	0.3756
	U-ident test	5543.01	4953.395	4946.294	4229.198	5993.146	7248.718	7621.493
	g	55.421	49.101	49.025	41.482	60.318	74.314	78.567