Modelling EU Electricity Market Competition Using the Residual Supply Index—Recent Research from London Economics-Global Energy Decision/Ventyx and the DG Competition

Gregory Swinand, Derek Scully, Stuart Ffoulkes and Brian Kessler*

London Economics and Global Energy Decisions

1 Introduction

The EU Commission DG Competition conducted a comprehensive inquiry into the state of competition in the EU's electricity markets from 2005 to 2007. As part of that inquiry, the EC commissioned London Economics, in association with Global Energy Decisions, to undertake a detailed study of six of the EU's major electricity markets. The study covered Belgium, France, Germany, the Netherlands, Spain, and the UK.[1]

This paper gives a broad overview of the study and some of its key results, as well as pointing to some directions for future research.[2] The paper also presents new analysis on the economic foundations of the RSI as a market structure variable, and also describes how similar analysis could be used for *ex ante* competition analysis in the sector.

---

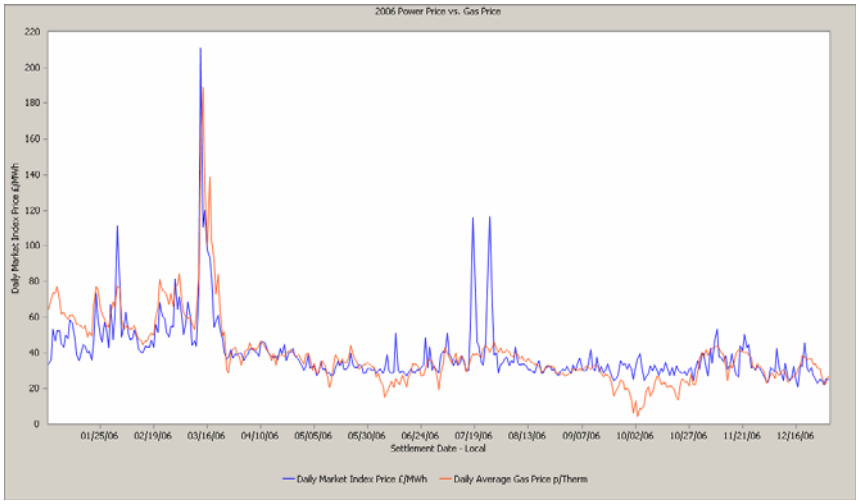
* The authors are, respectively, Divisional Director and Senior Consultant with LE, and Principal Consultants, GED. The authors wish to thank colleagues at LE and GED including Pat McCloughan, Patrice Muller, and Paula Ramada, David Hoffman, as well DG Competition staff members Philippe Chauve and Martin Godfried. Any opinions, omissions, or errors are solely the responsibility of the authors.

[1] These countries were chosen due to the number of complaints DG Competition received. Chauve and Godfried (2007).

[2] The complete study is available at www.londecon.co.uk or http://ec.europa.eu/competition/sectors/energy/inquiry/index.html

The study is based upon the structure-conduct-performance paradigm; that is to say, that market structure is hypothesized to be a significant determinant of market performance. Studying the competition in liberalised markets, however, presents particular challenges. Electricity markets are extremely dynamic. Market structure, as well as market outcome measures, such as price relative to marginal cost, changes hourly.

Figure 1: UK Gas and Electricity Prices



Source: GED

Other factors, such as volatile fuel prices (not always correlated as shown above compared to UK Balancing Prices), high fixed costs, and the non-storability of electricity, make the study of competition in electricity markets even more challenging. This confluence of factors means that electricity markets may behave competitively (á la Bertrand competition[3]), even when the market is 'concentrated' by

[3] Bertrand, J., 1883. "Théorie Richesse: revue de *Théorie mathématique de la richesse sociale* par Leon Walras et *Recherches sur les principles mathématique de la théorie de richesses* par Augustin Cournot", Journal de Savants 67, pp. 499-508.

traditional standards; conversely, the market may facilitate non-competitive outcomes, even when the market is reasonably unconcentrated (á la Cournot[4]). Critically, a firm's level of generation capacity in the market relative to residual demand, or the 'pivotalness' has been hypothesized to be a major driver of market performance.[5] An empirical measure of pivotalness is the Residual Supply Index (RSI).[6]

The case for the RSI can be motivated graphically. The figure below is a simplified version of an electricity market in the short run with a just two demand levels, D and D'. The market consists of just two players each with 500MW capacity, each with very similar marginal generation costs, and no demand price responsiveness. The HHI in the market would be 5000, which indicates a very highly concentrated structure.[7] However, it can be argued that D represents a situation where intense price competition is likely, as either player can satisfy >100% of demand. If a player bids a price slightly above the marginal cost of the other, the opponent can capture the entire market and still earn a positive profit. Once demand shifts to D', the situation is very different. Now, since demand is not price responsive, a player can bid a very high price and still be assured of achieving a positive output and a positive profit. It is argued that since the game is repeated hourly, there is potential learning, dynamic strategies with punishments, etc.

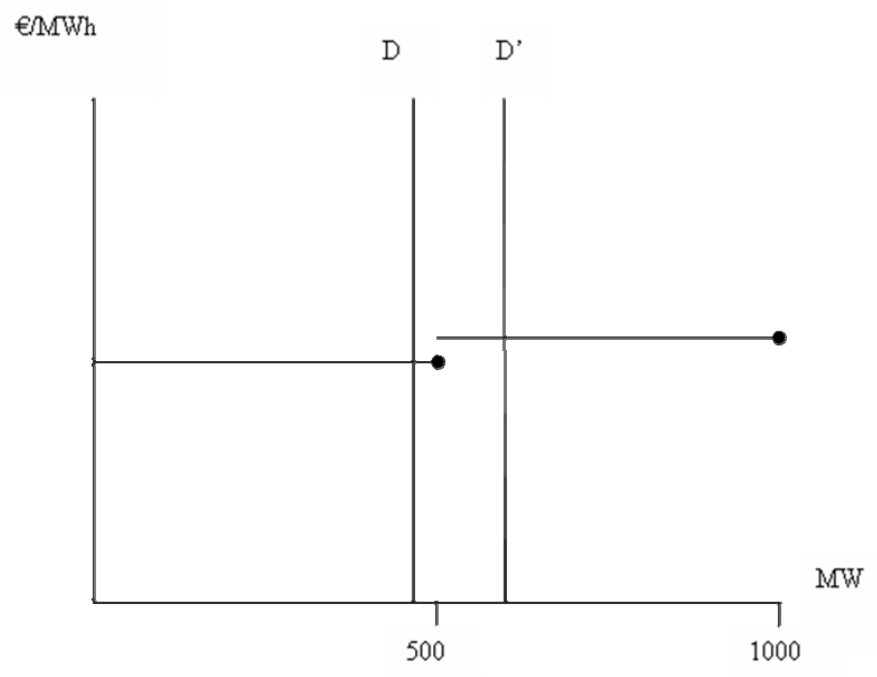
[4] Cournot, A., 1838. Recherches sur les principles mathématique de la théorie de richesses.

[5] See Stoft (2002) and Sheffrin (2001, 2002).

[6] The RSI was originally proposed by Sheffrin (2001, 2002).

[7] Based on capacity. *A priori* the HHI is ambiguous based on generation because it isn't obvious who would generate, but for demand level D would be bounded by 5000 (they share the market) and 10,000 (the lower cost player captures all the market).

Figure 2: Ambiguous Nature of Concentration in Electricity



Source: LE

2 Data and methodology

The data used for the purpose of this study was collected by DG Comp as part of the European Commission's Sector Inquiry into Energy Markets in Europe. The final database is one of unprecedented quantity and quality including data on plant characteristics, maintenance and outage schedules, hourly generation data[8], and plant and system level constraints including long-term contracts and system reserve requirements, over the period 2003-2005.[9] Data was also collected at the system level from the TSOs for the same period.[10] Utilising the information on plant characteristics and load, and flowing the calculation of the available installed capacity of each unit on an hourly basis, GED's Prosym™ market simulation dispatch model was used to model an optimal system dispatch and returning an hourly system marginal cost.

The competition assessment in relation to each country was undertaken using structural, market based, and outcome measures of competition, as well as regression analysis. The traditional structural measures of concentration ratios and Herfindahl-Hirschman Indices (HHI) were computed based on both hourly available installed capacity and hourly generation. Noting the limited ability of these traditional measures to assess competition in electricity markets, electricity market specific measures, namely the Pivotal Supplier Index (PSI) and the Residual Supplier Index (RSI) were calculated for the largest firms in the respective countries. To assess competition in the market outcomes, price-cost margins and mark-ups were calculated using hourly traded spot market prices from the principle power exchanges in each country and the estimated system marginal

[8] The average hourly generation profile of all units greater than 25MW was provided by the companies and for units less than 25MW, they were aggregated on an hourly basis (by company and technology).

[9] For the purpose of this study, the database contains data on six EU member States; Belgium, France, Germany, Great Britain, the Netherlands, and Spain.

[10] For the purpose of the project and system despatch simulation, the hourly load on the system was taken to be the sum of reported generation in that hour, of the units contained in the study.

cost provided from the optimal dispatch modelling undertaken by GED.

One of the main goals of the study was to empirically examine whether market structure was significantly impacting market performance. Our measure of market performance was the hourly price cost margin (PCM). Economic theory[11] and practice[12] suggest that the price on short-term competitive electricity markets is set by the short run marginal cost of the last unit required to meet demand. Thus, when price is observed above marginal cost[13], this can be an indicator of a market that is less than perfectly competitive.

There are of course needs to model the ability of the firm to recoup fixed costs in some hours. In general, this is done via inframarginal units with low running costs which run when the market price is above their production cost.

One of the most interesting results of the LE-GED-DG Comp study was to use regression analysis to study the relationship between market structure and market outcomes. This method is superior to merely observing relationships between price and marginal cost, as it has the ability to model random error and market structure in a variety of ways.

The market structure variable used was the residual supply index (RSI). The RSI is the ratio of total available capacity less the capacity of the largest firm all divided by the market demand. Justification for this model has been given by Sheffrin (2002), as based on supply function relationships.

We suggest that the following relationship is a very straightforward yet compelling justification of the RSI variable as an explanatory variable for price cost margins. Consider that the largest firm

[11] See Stoft (2002), Borenstein & Bushnell (1999) and Borenstein, Bushnell & Knittel (1999).

[12] This was confirmed from questionnaires of the inquiry. (Chauve & Godfried, 2007)

[13] The marginal cost may include a scarcity rent element.

maximises the following profit function, where the firm faces residual demand according to the efficient rationing rule (Tirole, 1987).[14]

(1) $$\pi_1 = [D(p_1) - \bar{q}]p_1 - [D(p_1) - \bar{q}]c_1$$

(2) $$D_1 = \begin{cases} [D(p_1) - \bar{q}] & \text{if} \quad D(p_1) \rangle \bar{q} \\ 0 & \text{otherwise} \end{cases}$$

The firm 1 faces a residual demand function where other firms with total capacity *q-bar* fill demand first, or as if firm 1 will always have to be dispatched in case 1, and zero otherwise (the RSI is the measure of how much this is true).

The RSI for firm 1 can be written as:

(3) $$RSI_1 = \frac{\bar{q}}{D(p)}$$

By taking the first order conditions, letting $p_1 = p$, and with some rearranging:

(4) $$\frac{p - c}{p} = \frac{[D(p) - \bar{q}]}{D(p)} \left[\frac{-\partial D}{\partial p} \frac{p}{D} \right]^{-1}$$

Or;

(5) $$\frac{p - c}{p} = \frac{1}{\varepsilon} - \frac{1}{\varepsilon} RSI_1$$

[14] $D(\bullet)$ is total demand, *q*-bar is the total available capacity of all other firms, p is price.

Thus the margins or Lerner Index (LI) can be seen to be a simple linear function of the RSI, and the estimated parameters are related to the inverse demand elasticity. While the short-run demand elasticity in power generation markets may be low, this parameter might be interpreted as the elasticity of the residual demand firm 1 faces.

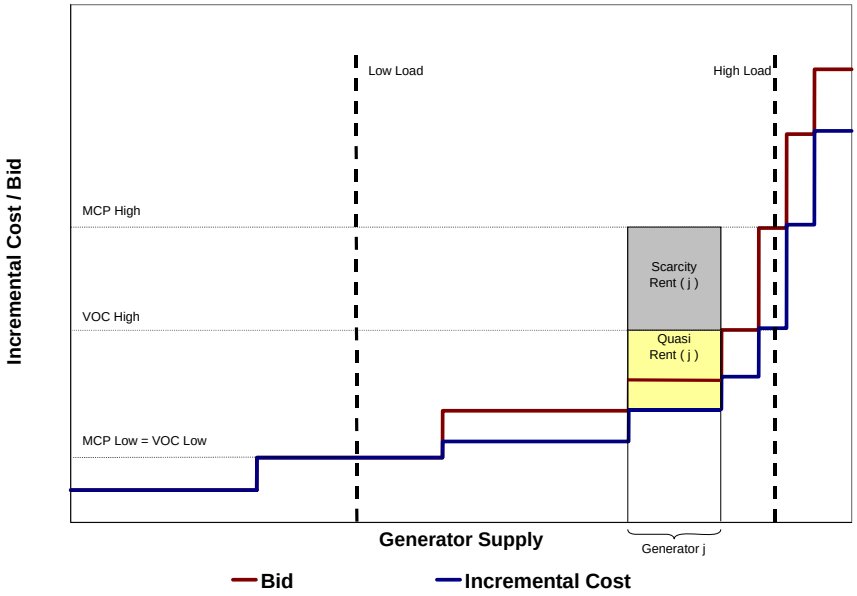
An interesting and testable implication of the RSI equation above is that the estimate slope parameter should be equal to the intercept parameter (in absolute terms). Empirical evidence (presented later) suggests that this relationship tends to hold.

One of the important and novel elements of the study's methodology was to include a control for a potential scarcity rent. In general, scarcity rents arise when the supply curve is less continuous. They also allow peaking units to potentially recover their capital costs. Finally, price may be above the marginal cost of the last unit dispatched, but not above the marginal cost of the last unit *not dispatched*.[15] The existence of a price in this range involves no dead-weight loss, and is not considered indicative of a non-competitive market.[16]

[15] This point has been highlighted previously by researchers, including Borenstein. The point arises from the likely existence of a significant 'gap' in marginal cost between the marginal cost of the last unit despatched and the last unit *not despatched*. Competitive bidding (and no welfare distortion) will occur even if P>MC of the most expensive unit running, but P=MC-ε of the next most expensive unit on the system (where ε is an infinitesimally small number).

[16] See Stoft (2002), Borenstein & Bushnell (1999) and Borenstein, Bushnell & Knittel (1999).

Figure 3: Supply Curve Example



Source: GED

To control for scarcity, a variable measure of scarcity was included as an explanatory variable in the regressions. The scarcity variable represents, on an hourly basis, the excess available capacity on the system as a percentage of the load.

3 Results

It is useful to consider first broad results on the price-cost mark-ups. These results are presented below. The results show a number of things. First, variable costs increased steadily during the sample period in all markets, as fuel prices were rising. Interestingly, the cost of carbon seems to have been passed on to the power price in all cases, but to a varying degree.[17] For example, the cost of carbon in Germany was €13.86/MWh, while it was only €9.52/MWh in the Netherlands. Finally, the mark-ups in all markets were positive and rose between 2004 and 2005, with the exception of the NL.

[17] Whether the cost of carbon *should be passed on* is another question. In general, we believe it should be, taking the goals of EU ETS at face value. In other words, the objective was to create the proper "price" of carbon, and the fact that allowances were allocated for free should not be relevant as there is an opportunity cost to using them (as long as allowances are scarce).

Table 1: Contribution to Power Price (€/MWh)			
Country	**2003**	**2004**	**2005**
BE Belgium			
Sys Modelled MC	€29.75	€31.70	€50.40
Carbon	€0.00	€0.00	€10.11
DE Germany			
Sys Modelled MC	€19.46	€24.27	€28.17
Carbon	€0.00	€0.00	€13.86
Mark-Up	€11.42	€5.36	€6.39
Total	€30.88	€29.63	€48.42
EEX Price	€30.88	€29.63	€48.42
ES Spain			
Sys Modelled MC	€23.95	€27.51	€33.65
Carbon	€0.00	€0.00	€10.12
Mark-Up	€6.29	€1.39	€12.20
Total	€30.24	€28.89	€55.97
OMEL Price	€30.24	€28.89	€55.97
NL Netherlands			
Sys Modelled MC	€36.26	€34.64	€50.50
Carbon	€0.00	€0.00	€9.52
Mark-Up	€11.99	-€0.63	-€3.09
Total	€48.24	€34.01	€56.93
APX Price	€48.24	€34.01	€56.93
GB Great Britain			
Sys Modelled MC	-	€33.33	€39.06
Carbon	-	€0.00	€10.00
Mark-Up	-	€1.25	€6.35
Total	-	€34.58	€55.41
UKPX Price	-	€34.58	€55.41
Note: all values in this table are load weighted average values. *Source: LE-GED DG Comp Study*			

While the results of the broad mark-up analysis presented above are interesting, there are many factors which might explain mark-ups

including random error. What is of interest from a policy perspective is how market structure may be influencing mark-ups. For this reason, regression models relating margins and market structure were developed and studied.[18]

Although a great deal of results in relation to market structure, much of it focusing on the traditional variables such as the CR(n) and the HHI - we do not focus on these results here.[19] Instead we focus on the results of the regression analysis relating margins and the electricity specific market structure variable (RSI) that are reported.[20] The results of the regression modelling showed that the RSI variable was a significant determinant of mark-ups in most markets.

The table below presents the estimated coefficients from the most parsimonious regression models estimated. In this case, the regression model simply related the hourly price-cost mark-up to the hourly RSI value calculated in relation to each of the companies in each of the countries. For all of the companies presented, the estimated coefficient on the RSI variable was of the expected sign and, were in all cases highly statistically significant.

[18] Note in relation to this table; hourly price data from the UKPX is only available from July 2004 onwards. Therefore, there is no result for 2003 under this approach and the result for 2004 should be viewed in the light of the data availability issue; and, our opinion was that the BPI, in Belgium was not a relevant comparator with which to calculate margins as it is not an hourly exchange traded price. It further was found not to be related to scarcity, and its quantity and price are set by the largest operator in the market. The price is not likely to reflect market conditions. However, Belgium is included in this case because we felt it was worthwhile to document the estimated impacts of carbon.

[19] Much of this effort was done to show the lack of sensitivity of market structure to various methods of allocating interconnection capacity, definitions of available capacity, etc.

[20] Following Stoft (2002), the traditional measures of market structure (CR(n) and HHI) were not considered to be best suited to this analysis, *"In spite of its popularity (HHI), it provides almost no guidance (in) predicting market power when used in a power market"*. The previous discussion in this paper in support of the RSI (Figure 2) further supports this statement, as do the authors' own observations of historical and empirical data.

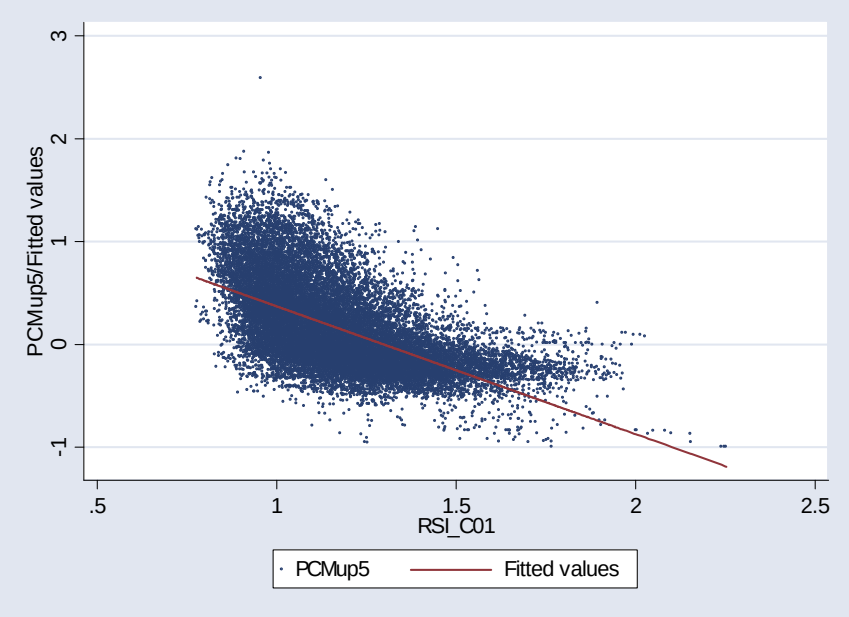
Table 2: Regression results relating margins (PCMU) to market structure (RSI) for largest generators

Company-Country	Variable Name	Coefficient	Std. Err.	t	R-squared
0577-S-ES	RSI	-1.242	0.010	-120.0	35.6%
0875-S-ES	RSI	-1.385	0.012	-118.5	35.1%
0453-S-GB	RSI	-0.90	0.015	-58.8	20.8%
1340-S-GB	RSI	-0.87	0.015	-58.4	20.6%
1477-S-GB	RSI	-0.87	0.015	-56.4	19.5%
0436-S-DE	RSI	-2.36	0.034	-69.1	15.4%
0569-S-DE	RSI	-2.00	0.030	-66.7	14.5%
1338-S-DE	RSI	-2.43	0.042	-57.5	11.2%
1681-S-DE	RSI	-1.92	0.029	-67.0	14.6%
0511-S-NL	RSI	-1.22	0.021	-57.2	11.1%
0712-S-NL	RSI	-1.22	0.021	-57.2	11.1%

Source: LE-GED DG Comp Study

The below picture is the simple linear regression with fitted values for one of the Spainish companies. The simple linear regression can be considered the estimate of the impact of RSI on PCM "not all else equal". As previously noted, the simple regression results showed significant t-values on the RSI variable for all the selected companies in each of the markets studied. This picture provides strong justification for the suitability of the parsimonious model estimated.

Figure 4: Spain Simple Regression



Source: LE-GED DG Comp Study

The picture above also motivates more detailed regression models with additional explanatory variables. For example, the shape of the scatter suggests that a peak and off-peak effect might be present. Results showed significant and improved fits with peak dummies for the slope and intercept terms. There is also the impact of scarcity, seen as a benign (i.e., not market power related) rationale that our measures of price-cost markup might be negatively correlated with the RSI.[21] While a number of different models were estimated, summary results from the preferred model can be found in the table below.

[21] In other words, the margins might rise as RSI falls (capacity get tighter) merely as an efficient reflection of scarcity and the size of jumps on the supply curve as demand rises. By including a scarcity variable, we rule this out. In other words, the correlations between the PCM and the RSI are not correlated with scarcity

Table 3: Multivariate Regression Analysis

(Dependent variable; price cost mark-up)

Explanatory variable name	DE	ES	GB	NL
RSI_C01	-0.42	-2.11*	-3.21*	-2.26*
RSI_C02	2.21*	-2.28*	-2.27*	-2.35*
RSI_C01_C02	-0.02	1.72*	1.54*	2.25*
Scar	-2.16*	-0.73*	-0.32**	-1.87*
C0_gas	0.00*	0.00*	0.00*	0.00*
C0_coal	0.00***	0.00*	0.00*	0.00*
d2004	-0.25*	-0.27*	-0.09*	-0.18*
d2005	-0.37*	-0.08*	-	-0.25*
dpeak	0.22*	0.08*	-0.02**	0.04*
dsummer	0.11*	0.01***	0.11*	0.02***
dwinter	-0.12*	-0.08*	-0.22*	-0.20*
dwkday	-0.03*	-0.07*	-0.19*	-0.21*
_cons	-0.65	3.58*	5.14*	3.70*
R-squared	*26.2%*	*51.2%*	*29.8%*	*16.4%*

*Note: *=significant at 1% level; **= significant at 5% level; ***= significant at 10% level*
Source: LE-GED DG Comp Study

Returning to the testable hypothesis posited previously in this paper in relation to the derived relationship between the Lerner Index (LI) and the RSI, the following table presents the estimated coefficients from the regression analysis of the hourly LI values on the RSI. Following on from the algebraic relationship it was posited, *ex-ante*, that one would expect to find empirically that the slope parameter of the estimated regression equation will equal the estimated coefficient on the constant (in absolute terms). The results of the regression

alone, when the scarcity variable is included.

equations, presented overleaf, do indeed bear out this relationship with the estimated slope and constant coefficients being broadly equal for all of the companies in each of the countries (far right column shows the absolute differences). While the magnitude of these coefficients is interestingly close in almost every case, it is also useful to carry out the appropriate statistical test (difference between two t-stats). The results of this are also presented in the table. Interestingly, although Great Britain's coefficients are quite close in absolute magnitude, statistically they are the most different. Also interesting is that an apparent country pattern emerges, with GB being consistently statistically different, DE being different if 3 out of 4 cases, and NL and ES being statistically the same in each of their cases. Further research is needed to determine if this pattern is meaningful.

Table 4: Regression results relating margins (LI) to market structure (RSI) for largest generators					
Company - Country	**Variable Name**	**Coefficient**	**Std.Err.**	**Difference t**	**Absolute value difference**
0577-S-ES	RSI	-3.53	0.502	0.64	0.50
	Constant	4.04	0.599		
0875-S-ES	RSI	-3.54	0.564	0.40	0.34
	Constant	3.89	0.646		
0242-S-GB	RSI	-0.69	0.010	15.65	0.27
	Constant	0.96	0.014		
0453-S-GB	RSI	-0.72	0.010	14.47	0.26
	Constant	0.97	0.015		
1340-S-GB	RSI	-0.69	0.010	15.30	0.26
	Constant	0.95	0.014		
1477-S-GB	RSI	-0.68	0.010	12.50	0.22
	Constant	0.90	0.014		
0436-S-DE	RSI	-3.13	0.099	2.86	0.43
	Constant	3.56	0.113		
0569-S-DE	RSI	-2.73	0.086	5.65	0.80
	Constant	3.53	0.112		
1338-S-DE	RSI	-3.56	0.120	0.45	0.08
	Constant	3.64	0.123		
1681-S-DE	RSI	-2.58	0.082	5.88	0.80
	Constant	3.38	0.108		
0511-S-NL	RSI	-37.04	3.306	0.75	4.09
	Constant	41.14	4.366		
0712-S-NL	RSI	-46.38	3.717	0.31	1.78
	Constant	48.17	4.490		
Source: LE-GED DG Comp Study					

4 Uses of the RSI Model for ex ante analysis

An important element of any modelling exercise is whether it is potentially useful for *ex ante* analysis. Policy makers must make decisions about mergers; firms must make decisions about investments, all with a prospective element. We argue that the RSI approach to market structure can and should be used for such analysis, but that the limitations of the method should be noted.

Using the LE methodology for *ex ante* analysis would first involve `replicating the main steps used in the DG Comp study. The first step of the analysis should be to collect the necessary data: market prices, unit cost (delivered fuel price, efficiency), demand, capacity and availability. The second step is to simulate the market and estimate the hourly marginal cost. Thirdly, the RSI should be calculated for each hour, for the players in question (these might be the two largest generators, or perhaps the two generators that intend to merge). Finally, the regression models should be estimated. As an example, consider:

(6) $$PCM = \alpha + \beta_1 RSI\_01 + \beta_2 RSI\_02 + \gamma RSI\_01\_02 + \chi X + e$$

Where PCM is the price cost mark-up, RSI_01 is the RSI of the largest firm, **X** is a matrix of explanatory variables other than the RSIs, and χ is a vector of coefficient estimates.

The next phase of the *ex ante* analysis involves estimating a change in the RSI for the largest player, given say that the largest firm acquires a certain amount of generation capacity, and using the estimated equations to predict the marginal impact on margins. The new RSI can be estimated either hourly, or for a certain set of representative days. A useful analysis in terms of the *ex ante* merger analysis would be to compare and contrast first the new RSI with the previous RSI in terms of the screening thresholds proposed by Sheffrin.[22] Then,

[22] Sheffrin (2002) proposed the following screening rules.

depending on what regression model was the preferred model, the derivative of the preferred model's estimated equation with respect to the largest firm's RSI (call it RSI_01) should be calculated from the estimated equation. An example is given below. (In this case, we have included an interaction term between the largest and second largest firms' RSIs):

(7) $$\frac{\partial PCM}{\partial RSI\_01} = \beta_1 + \gamma RSI\_02$$

Including the values for the right hand side variable changes can then be used to give a prediction. Which, using the results from Spain above (and evaluating at a point RSI_02=1.0), would give:

(8) $$\Delta PCM = \left[-2.11 + 1.72(1.0)\right]\Delta RSI\_01 = -0.39\Delta RSI\_01$$

It is then up to the policy maker to determine whether the predicted impact of the change in RSI on the predicted margin is acceptable. The prediction might be evaluated at a range of RSIs, based on thresholds of the data generated by expected frequency during the year. The predicted change in margin can be compared to norms such as the well known SSNIP test, or other such norms. (The model will predict a change in margin, but if the absolute price change is desired, then this can be backed out using the marginal cost estimates.)

We argue that this type of analysis is likely to be superior to a number of other possible analyses for *ex ante* merger analysis in electricity generation. For example, analysis that merely relies on basic market structure variables, such as the HHI, will likely miss the dynamic interactions of supply and demand intrinsic to electricity generation markets, and also will either over estimate (if spare capacity is high) or underestimate (if capacity is tight) the impact of market structure on market power. Analysis that relies purely on market simulation will not be capable of comparing the simulation with the realities of the market, and differentiating random error and modelling error from

market structure's impact on market power will difficult to model. Analysis that relies on theoretical models, such as the supply function equilibrium approach has limits in terms of the number of firms, the assumptions about the cost function (most analyses assume a quadratic and continuous cost function), as well as model validation.[23]

While we argue that this type of analysis is likely to be superior to more traditional competition tools, it is important to recognise the limitations of the above analysis. The analysis is based on estimations done *ex post*, but the predictions are made *ex ante* about the impacts on the market given a potential change in structure, all else equal. There is always the caveat that the future may not bear a resemblance to the past. We would therefore argue that a number of different analyses might be used in concert, as a means of cross-checking model-based error.

However, we would argue that the above RSI-type analysis represents a *conservative* assumption in terms of estimating the impact of market structure on market power. The estimated coefficients are from the prior un-merged situation. We would argue that it is more likely that the impact of RSI on margins would go up after a merger involving the largest firms, rather than down. In addition, in any such analysis, there will be a need to make assumptions and simplifications with certain levels of detail. The challenge of the researcher is to make balanced assumptions that are less likely to necessarily bias the results. Such challenges are often a matter of judgment.

[23] See Green & Newberry (1992).

5 Conclusions

This paper has reviewed the major findings of the LE-GED-DG Comp study into the structure and functioning of six major EU electricity generation markets. The article reviewed the major findings of the study and focused on the novel elements, the relationships between RSI and PCM. The results of the study suggest that market structure does indeed impact market performance, and that the degree of residual supply in the market is a significant driver of market price cost margins. This suggests that electricity prices have not been as keen as they might have been.

The paper also demonstrated a straight-forward theoretical interpretation of the RSI as a market structure variable based on the effective demand elasticity facing a firm that fulfils residual demand. An implication of the theory, that the constant and RSI-slope coefficients from the simple regressions of the LI on RSI should be the same, appears to be supported by the results.

The paper then discussed how the RSI methodology could be used to undertake *ex ante* analysis of electricity market competition. The proposal is to use regression modelling results to model the dynamic realities of the local electricity market. Then, a new RSI variable can be estimated for the proposed merged entity. The regression results can then be used to predict the impact on margins, and prices (given a predicted marginal cost).

The room and indeed need for additional research is significant. It would be useful to advance the simple theoretical model to include a potentially richer set of parameters and also to relate that to the multivariate regression models. A more generalised theory of residual supply might emerge. Additional market studies using a similar methodology would also be interesting to further explore the empirical generality of the results here. It would also be interesting to see if the RSI and a similar framework might be adopted to explain margins in other commodities, such as natural gas (an additional accounting would have to be made for storage, but storage is limited as is the rate of delivery from storage). In the meantime, however, the evidence continues to support the use of the RSI as a key market structure variable in power generation market analysis.

6 References

Bertrand, J., 1883. “Théorie Richesse: revue de Théorie mathématique de la richesse sociale par Leon Walras et Recherches sur les principles mathématique de la théorie de richesses par Augustin Cournot”, *Journal de Savants*, 67, pp. 499-508.

Borenstein, S., and J. Bushnell, 1999. "An empirical analysis of market power in a deregulated California electricity market", *Journal of Industrial Economics*, 47(3).

Borenstein, S., J. Bushnell and C. Knittel, 1999. "Market power in electricity markets: Beyond concentration measures", *The Energy Journal*, 20(4).

Chauve, P., and M. Godfried, 2007. "Modelling competitive electricity markets: are consumers paying for a lack of competition", DG Competition, *Competition Policy Newsletter*, 2007(2).

Cournot, A., 1838. Recherches sur les principles mathématique de la théorie de richesses.

Green, R., and D. M. Newberry, 1992. "Competition in the British electricity spot market", *Journal of Political Economy*, 100(5), pp. 929-53.

LE-GED DG Comp Study., 2007. “Structure and Performance of Six European Wholesale Electricity Markets in 2003, 2004 and 2005”, http://ec.europa.eu/comm/competition/sectors/energy/inquiry/index.html#study

Sheffrin, A., 2001. "Critical actions necessary for effective market monitoring", Draft Comments, Dept. of Market Analysis, California ISO, *FERC RTO Workshop*, October 19, 2001.

Sheffrin, A., 2002. "Predicting market power using the residual supply index", Presented to *FERC Market Monitoring Workshop*, December 3-4 2002.

Stoft, S., 2002. "Power system economics: Designing markets for electricity", *IEEE Press*.

Tirole, J., 1988, “The Theory of Industrial Organization,” Cambridge, MA: MIT Press.