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A VAR-MGARCH MODEL FOR THE DEREGULATED ITALIAN ELECTRICITY MARKET

Tesi di Dottorato di: Matteo Della Noce
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Introduction

The objective of this dissertation is to analyse the Italian electricity market (*IPEX*), which became operative in April 2004. Electricity price time series have many similarities with other financial prices (bonds, stocks and other commodities) but, in general, their behaviour is, more complex and more uncertain to interpret because of the features typical of the electricity. Before the opening of the Italian exchange, prices of electricity were decided by the government or by a public operator, while they are currently determined by private agents who operate in the market. In the past, electricity prices showed very low volatility, since the main goal of the public operator was to maintain stable electricity prices, avoiding peaks and jumps and tariffs were set to improve public welfare. Now that prices are market-determined, they are much more volatile. In addition, volatility in the electricity market is generally higher than in other financial markets, mostly due to physical characteristics of electricity, for example the inability of storage.

After liberalization, every agent has been interested in analysing data in order to create models to forecast energy quantities, prices and volatility. In fact, even if the electricity market is a very particular case, it can be compared to any financial market in which operators try to obtain profits and thus the activity of forecasting plays a crucial role. These predictions are then used for typical financial activities, such as risk management and option pricing, but especially to manage orders of electricity to be bought and sold.

The ability to interpret the market is a powerful instrument for market traders, in particular generating companies, who can obtain profits by selling or buying energy in conjunction with peaks or particular conditions. Moreover, authorities are still working towards further deregulation, which makes the market more uncertain. In addition to the financial aspect, which is important for exchange operators, forecasting is also very essential for consumers, producers and firms, since an accurate forecast allows them to plan their activity in the best possible way. The analysis of the electricity market is also useful for anti-trust authorities who can study the level of competition, market power or integration among markets, by comparing prices and volatility in different regions.

The analysis of volatility is strictly related to Engle's research work. In his seminal paper published in 1982, he introduced, for the first time, the idea that the residual variance could be non-constant and he tried to model it through a new approach. In particular, he underlined the role played by conditional variance in time series and introduced the *Autoregressive Conditional Heteroskedasticity (ARCH)* specification. He suggested explaining volatility by considering it to be a function of the previous error terms. His work was then followed by many others, the most important contribution of which was given by Bollerslev (1986), who extend the previous *ARCH* specification by including lagged values of the volatility as well, thereby obtaining the so called *Generalised ARCH* (*GARCH*). Further specifications, allowing for the possibility of asymmetric effects on volatility from positive and negative shocks, have also been developed.

Recently, the univariate *GARCH* model has been extended to the multivariate case, with the recognition that *MGARCH* models are potentially useful developments regarding the parameterization of conditional cross-moments.

MGARCH models have been used extensively in modelling financial time series, see for example Dunne (1999) and Tse and Tsui (2002), but a detailed *MGARCH* study applied to electricity markets has not been undertaken. Since this approach captures the effect on current volatility of both own innovation and lagged volatility shocks within a given market and cross innovation and volatility spillovers from interconnected markets, it allows a greater understanding of volatility and volatility persistence in these interconnected markets. Thus, our goal is to investigate these relationships within the Italian regional electricity markets. This will permit a more thorough understanding of both pricing behaviour within each region and the outcome of efforts to promote and sustain a nationally integrated market.

We examine the transmission of spot electricity prices and price volatility among the 7 Italian regional electricity markets in which Italy was divided [1], namely *Nord*, *Centronord*, *Sardegna*, *Centrosud*, *Sud*, *Calabria* and *Sicilia*. As a consequence, a multivariate generalised autoregressive conditional heteroskedasticity (*MGARCH*) model is used to identify the source and the magnitude of both innovations and spillovers.

In fact, in the Italian electricity market (*IPEX*), the power is transmitted between regions to meet energy demands that are higher than local generators can provide or, when the price of electricity in an adjoining region is low enough, to displace the local supply. However, the scheduling of generators, to meet demand across the interconnected systems, is constrained by the physical transfer capacity of the interconnectors. The

[1] Since 1 January 2009, *Calabria* were joined to *Sud* and thus the areas were reduced to 6.

limitations of transfer capability, within the centrally coordinated and regulated market, are one of its defining features. During periods of peak demand, the interconnectors become congested and Italy separates into its regions, promoting price differences across markets, exacerbating reliability problems and the market power of regional utilities.

While the appropriate regulatory and commercial mechanisms do exist for the creation of an efficient national market and these are expected to have an impact on the price of electricity in each region, the complete integration of the regional electricity markets has not yet been realised. At the same time, the manner in which volatility shocks, in the regional electricity markets, are transmitted across time arouses interest in modelling the dynamics of the price volatility process. This calls for the application of models that take into account the time-varying variances of time series data, such as *ARCH*, *GARCH* and *MGARCH*.

Market integration has been increasingly recognized as a source of welfare gains by economists as well as policy makers. In the *Lisbon Agenda* in March 2002, the European Union countries identified interconnection of network utilities – both within and across its member countries – as a necessary condition to improve the overall welfare.

Implementation of market integration in network industries requires physical infrastructure interconnection across different markets. In our work, we want to discuss the gains resulting from interconnection, in the context of the Italian electricity spot market.

In an electricity market, a grid congestion could potentially lead to two types of inefficiencies:

- allocative, since efficient generators cannot serve geographically distant customers due to insufficient transmission capacity.
- competitive, since these bottlenecks also create local monopolies. The demand for electricity is close to inelastic, thus the presence of local monopolies implies market prices and quantities significantly different from the first-best (price equals marginal cost). In addition, storage of electricity for the future is not possible and, as a consequence, location, capacity and grid utilization become crucial elements while analysing any policy decisions in the electricity market.

The Italian electricity market is a good example to analyse the consequences of market integration. In fact, the market is divided into several zones with the amount of electricity that can flow across regions being limited, due to insufficient capacity. Generators, with different levels of efficiency and capacity, are located in every zone. While no arbitrage guarantees that the market clearing price is the same across all zones during low demand periods, market prices differ across zones during peak demand periods.

To eliminate price dispersion, investments in inter-zonal transmission capacity are required. Reducing price dispersion is necessary to:

- provide a necessary step towards checking the economic viability of improving the transmission facility;
- if viable, to provide a necessary tool to design an appropriate mechanism to achieve complete market integration.

Increasing interconnections in an electricity market has been a relevant point for several electricity markets. For example, in the *Electricity Act* of 2003, the Indian government recognized the need to improve transmission capacity to solve the rural electricity problems. In particular, increasing transmission capacity is more relevant where electricity generation is deregulated. In 2006 the *FERC* [2] commissioned a study to determine whether or not competition in the American wholesale electricity market resulted in prices close to perfectly competitive levels and, if not, what the possible remedies could be. One of the policy recommendations was to improve transmission capacity, since

"Building appropriate transmission capacity may encourage entry of new generation or more efficient use of existing generation." [3]

Improved interconnections ease market participation, thereby reducing the possibility of market power being concentrated within few firms, which is one of the main reasons for market failure. In any case, before undertaking any policy measure, it is necessary to analyse the trade-off between the welfare improvement from augmenting interconnections and the cost related to such interconnections.

The present dissertation is organised as follows. The first chapter reviews the literature about the volatility in the electricity markets and its characteristics in general. The second chapter presents a description of the electricity market in Italy and a brief depiction of the other relevant European markets, the data

[2] Federal Electricity Regulatory Commission, the American agency that coordinates interstate electricity transmission.

[3] Page 4, Staff Report Docket No. AD 05–17–000: http://www.ferc.gov/legal/staff-reports.asp

source, how the data are recorded and the manner in which we construct the time series which are later analysed. In the third section we present the descriptive statistics and highlight the characteristics of the series. We then describe the modelling approach, the criteria employed to evaluate forecasts and the results. In the fourth chapter, we present the models employed to carry out the multivariate analysis and the results obtained. In the last section, the conclusions and possible suggestions for further research are presented.