On the Leverage Effect in the Spanish Electricity Spot Market

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Abstract: This article focuses on the study of the leverage effect in the deregulated Spanish wholesale electricity market. For this purpose, we propose a stochastic volatility alternative, a threshold asymmetric autoregressive stochastic volatility (TA-ARSV) model over the well known AGARCH and EGARCH models. The results clearly favour the TA-ARSV specification over the GARCH based models and reject the existence of the perverse inverse leverage effect.

Keywords: Electricity prices, leverage effect, asymmetric response of volatility, GARCH, stochastic volatility, TA-ARSV model.

1 Introduction
The process of liberalisation and deregulation of the electricity market has resulted in a higher complexity of pricing behaviour. In particular, pricing volatility is the feature that best characterises this new ‘competitive’ market. It has been shown that the volatility of prices in the electricity market is substantially higher than that in the financial and other relevant commodity markets. Therefore, understanding the volatility process in the electricity market is critically important to distributors, generators and market regulators. In addition, it strongly influences the pricing of derivative contracts traded on electric power prices that allow market participants to better manage their financial risks.

This feature or stylized fact being important, the existing literature is not conclusive about the existence or not of an asymmetrical response of the volatility of electricity prices (that the effects of positive and negative shocks on the dynamics of volatility are different). What is more, some authors suggest a perverse leverage effects in these markets (a positive shock will increase the volatility more than a negative one).

Since the liberalisation and deregulation of the electricity market, research into electricity pricing and, in particular, into the volatility of electricity prices has become vast and diverse. Restricting ourselves to the recent literature focusing on the asymmetrical response of volatility in wholesale electricity markets, GARCH-type models after filtering outliers are the common instrument used to analyze the asymmetrical pattern of volatility. Without wishing to be exhaustive, after the works of [1]–[5], in the framework of the econometric approach based on discrete time, [6] investigates the intraday price volatility process in four Australian wholesale electricity markets using a range of processes including GARCH, Risk Metrics, normal Asymmetric Power ARCH (APARCH), Student APARCH and skewed Student APARCH. [7] examines the volatility of the wholesale electricity prices for five US markets using TARCH models. [8] studies the changes in Norwegian electricity prices combining an AR-GARCH model with the extreme value theory, [9] also uses GARCH strategies for volatility modelling. [10] uses the EGARCH modelling for the analysis of returns. [11] considers the underlying volatility process in five regional pool markets in the NEM (Australia), and examines the applicability of a range of GARCH specifications including the basic GARCH, TGARCH, EGARCH and PARCH models. [12] proposes what they call the GGk-APARCH (k-factor Gegenbauer with Asymmetry Power GARCH) process to modelling the leverage effect and other stylized facts of electricity prices. [13] compares ARMA-GARCH models and mean-reverting Ornstein-Uhlenbeck models for their respective capability to capture the statistical properties of real electricity spot market time series. [14] analyses the volatility of wholesale electricity markets for five markets in Europe using GARCH(1,1) and EGARCH(1,1) models after filtering the anomalous values.

In this paper, the two most popular GARCH-type models are estimated to compete with the threshold asymmetric autoregressive stochastic volatility (TA-ARSV) model that we propose when it comes to detecting the asymmetrical pattern of volatility. The GARCH models are: (i) the AGARCH model proposed by [15] and (ii) the EGARCH model developed by [16]. The threshold asymmetric autoregressive stochastic volatility (TA-ARSV)
model was proposed by [17] and developed by [18]. We also estimate the ARSV specification, because it is nested in TA-ARSVA and it is used to test the symmetrical response hypothesis.

As far as we know, the TA-ARSV strategy has never been used to describe the volatility pattern of electricity prices. However, it has been successfully used to describe the volatility behaviour of returns of other energy products that include crude oil (OPEC reference basket and London Brent index), unleaded regular oxygenated or reformulated gasoline, natural gas, butane and propane [19].

We focus our attention in the Spanish electricity spot market because most of the existing literature refers to multiple pools in Australia, the U.S. and the Nordic Power Exchange (“NordPool”). However, the Spanish case has not received sufficient attention. We focus on the returns of the spot (in fact a day-ahead) market because the adequate modelling of volatility allows for a more accurate estimation of the margins needed when negotiating contracts in the forward and derivatives markets. The time reference we consider is January 2000 - October, 2010; probably the largest and most recent interval studied in the literature.

The remainder of the paper is organized as follows: After this introduction, section 2 delineates the main features of electricity returns in the Spanish spot market. Section 3 briefly describes the novel TA-ARSV specification that we propose to explain the asymmetrical pattern of volatility. Section 4 reports the empirical results derived from the comparison of TA-ARSV and GARCH strategies. Section 5 concludes the paper.

2 Stylized Facts of the Spanish daily marginal spot energy prices

As in [4] and [14], we deal with the daily marginal prices reported by OMEL (http://www.omel.es/files/flash/ResultadosMercado.swf). The daily series (January 1, 2000, to October 26, 2010) has been obtained by averaging the series of hourly prices and is shown in Fig.1.

Fig.1. Daily series of hourly prices

Figure 1 demonstrates that:

(i) Prices are not stationary, neither in mean nor in variance.
(ii) There is a weekend effect:
(iii) Some extreme spikes occur.

Since prices are non-stationary, we deal with logarithms to correct the dispersion problem. To correct from trend, we used a first-difference (Δ). To overcome the weekend effect, we calculated a seventh-difference (Δ7). These transformed prices (Δ7ΔlogPrice) are what we call returns.

Table 1 and Figure 2 show that electricity returns have null mean (t-statistic is 0.14 and the critical value is 1.96) but non-constant variance. Specifically, some volatility clusters can be detected, which can be indicative of a non-constant conditional variance. Electricity returns are also uncorrelated, although they are not independent because the squared returns are positive and significantly correlated. In addition, some persistence on volatility can be noticed. Marginal distributions of returns are both asymmetrical and leptokurtic (Table 1). This asymmetrical behaviour indicates that the volatility of returns could have an asymmetrical pattern (leverage effect).

Table 1. Electricity Returns (Spanish Spot Market): Basic statistics.

<table>
<thead>
<tr>
<th>Mean</th>
<th>STD</th>
<th>Skewness</th>
<th>Excess Kurtosis</th>
<th>Normality Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0191</td>
<td>8.54</td>
<td>0.140</td>
<td>8.5156</td>
<td>3243.1*</td>
</tr>
</tbody>
</table>

*The null hypothesis is rejected at the significance level 0.05.

Fig. 2. Electricity Returns (Spanish Spot Market): (1/1/2000–26/11/2010).

The above-mentioned features of the volatility of Spanish daily spot returns suggest that it can be modelled. GARCH models are the strategy traditionally used in the existing literature to estimate the volatility of electricity returns, but we propose a new strategy (the TA-ARSV model) which is more powerful than GARCH models when it comes to account for the stylized facts of electricity returns,
especially the volatility pattern - the stylized fact we focus on in this work.

3 Modelling the Volatility of Electricity Returns
We propose a new TA-ARSV strategy to explain the dynamics of the volatility of electricity returns. We also estimate the symmetric ARSV model, because it is nested in the TA-ARSV specification, and we use it to test whether or not the parameters that indicate the asymmetrical response of volatility in the TA-ARSV model are significantly equal. This new strategy is compared with the AGARCH and EGARCH models, which are the most commonly-used strategies in the literature.

The TA-ARSV(1) model we introduce in this paper as an alternative to describe the dynamics of the volatility in the series of electricity returns has the same mean equation as the ARSV(1) model, but the way of specifying the conditional variance is different.

The asymmetrical pattern of volatility rests on establishing a known threshold that changes the value of the parameters in the model. Therefore, obtaining the TA-ARSV model from an ARSV model implies:

a) adding two new parameters, \( \phi_1 \) and \( \phi_2 \), which measure the effect of the positive and negative shocks on volatility, respectively.

b) adding two indicator variables, \( I_{v_t} \) and \( I_{n_t} \), defined as:
\[
I_{v_t} = \begin{cases} 1 & \text{when the price variation is zero or positive} \\ 0 & \text{otherwise} \end{cases}
\]
\[
I_{n_t} = \begin{cases} 1 & \text{when the price variation is negative} \\ 0 & \text{otherwise} \end{cases}
\]

Therefore, the TA-ARSV(1) strategy we propose can be seen as a generalisation of the ARSV(1) model that includes two additional parameters, which allow for an asymmetrical pattern of volatility. Volatility is defined as an exponential function. Thus, the model is not linear. However, for estimation purposes, it can be expressed in a linear form by squaring the mean equation and taking logarithms. Following [20], we express the specification in a space state form to obtain the following linear model:
\[
\begin{pmatrix} h_{t+1} \\ Y_t \end{pmatrix} = \begin{pmatrix} \delta_t + \Phi h_t + u_t \end{pmatrix}
\]
where \( Y_t = \log y_t \)

\[
u_t \sim i.i.d. \ N(0, \Omega_f), \quad \delta_t = \begin{pmatrix} 0 \\ \ln \sigma^2_t \end{pmatrix}
\]

\[
\Phi = \begin{pmatrix} \phi_1 I_{v_t} + \phi_2 I_{n_t} \\ 1 \end{pmatrix}, \quad \Omega_f = \begin{pmatrix} \sigma^2_{\nu} & 0 \\ 0 & \pi^2/2 \end{pmatrix}
\]

The unknown likelihood function of a TA-ARSV(1) model, which is a non-Gaussian model, has been evaluated by using the Monte Carlo method, approximating the non-Gaussian model by importance sampling.

The estimation of the parametric vector requires the following algorithm:

A) An approximated Gaussian model is obtained from an initial vector of parameters of the model. The initial values of the parameters are estimated from the available information for each return.

B) The Gaussian likelihood function for the approximated model is calculated using the Kalman filter.

C) The process is repeated until the desired level of convergence is achieved. At this level, the likelihood function reaches its maximum value.

Finally, the parametric vector that maximises the simulated likelihood function is obtained by using the Broyden–Fletcher–Goldfarb–Shanno (BFGS) method, a well-known method to solve unconstrained nonlinear optimization problems.

The leverage effect is checked by testing the null hypothesis: \( H_0: (ARSV \text{ model}) \) versus the alternative one: \( H_1: \text{TA-ARSV}(1) \text{ model} \). Since the null and the alternative hypotheses refer to two nested models, this strategy allows for the implementation of a likelihood ratio test, the test statistic being \( \lambda = -2(\log L - \log L^0) \), which follows (under the null) a chi-squared distribution with one degree of freedom. If the null hypothesis is not rejected, then there is no evidence of an asymmetrical pattern of volatility. In this case, the ARSV(1) model could be preferred. On the other hand, the rejection of the null hypothesis suggests that the effects of positive and negative shocks on the dynamics of the volatility are different.

The estimation procedure for model ARSV(1) has been conducted in Ox language and it is available at www.feweb.vv.nl/koopman/sv. The estimation of TA-ARSV(1) has been carried out with a new proprietary code using Ox 4.1. language following the steps proposed by [21-23] for ARSV(1) modelling.

4 Case Study: Spanish Spot Electricity Returns
Tables 3 and 4 report, respectively, the results obtained from the estimation of both the
AGARCH(1,1) and EGARCH(1,1) models and both the ARSV and TA-ARSV strategies.

As Table 3 indicates, $\gamma$ is positive and significant in both GARCH models. This indicates that if returns in $t + 1$ are more volatile in the case that in period $t$ the return had been negative than in the case that it had been positive. The proposed strategy, TA-ARSV model, also detects the same asymmetrical pattern of volatility in returns, since $\phi_2$ exceeds $\phi_1$. This result contradicts the finding of [24], confirmed by [14], who advocates for the existence of an inverse leverage effect (i.e. that a negative shock will increase volatility more than a positive one).

However, the TA-ARSV specification is clearly preferred to GARCH-type models because the sum of the $\alpha$, $\beta$ values is 1 in the AGARCH(1,1) model, suggesting a potentially unstable model, and ranking by Akaike Information (AIC) Criterion favours the TA-ARSV strategy over the EGARCH(1,1) specification.

Table 3. Estimates of Asymmetric GARCH(1,1)-Type Models Coefficients

<table>
<thead>
<tr>
<th>AGARCH</th>
<th>EGARCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>-0.0056</td>
<td>-0.0120</td>
</tr>
<tr>
<td>(-1.93)</td>
<td>(-7.891)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>$\beta$</td>
</tr>
<tr>
<td>0.1576</td>
<td>0.9702</td>
</tr>
<tr>
<td>(2.03)</td>
<td>(127.0)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>$\gamma$</td>
</tr>
<tr>
<td>0.04755</td>
<td>-0.4726</td>
</tr>
<tr>
<td>(4.66)</td>
<td>(16.360)</td>
</tr>
<tr>
<td>$\alpha + \beta$</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The values between parentheses indicate the value or the t-statistic.

Table 4. Estimates of ARSV(1) and TA-ARSV(1) Coefficients

<table>
<thead>
<tr>
<th>TA-ARSV Estimates</th>
<th>$\sigma^*$</th>
<th>$\phi_1$</th>
<th>$\phi_2$</th>
<th>$\sigma_\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.049</td>
<td>0.962</td>
<td>0.999</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>(0.08)</td>
<td>(0.41)</td>
<td>(0.34)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ARSV Estimates</th>
<th>$\sigma^*$</th>
<th>$\phi$</th>
<th>$\sigma_\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.042</td>
<td>0.986</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td>(0.08)</td>
<td>(0.25)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Another core finding is that, unlike in other electricity markets, the existence of an inverse leverage in the Spanish electricity market effect can be rejected. That is to say, as in the stock markets and other commodity markets, a positive shock will increase volatility more than a negative one. This finding will be of great help for market participants.

5 Conclusion

The two last decades have witnessed the liberalisation and deregulation of electrical monopolies worldwide. As expected, this process has yielded an increase in the complexity of the behaviour of prices. Since, in the new context, high volatility is the feature that best characterises the electricity markets, understanding the volatility process is critically important to distributors, generators and market regulators. In addition, the volatility of spot prices strongly influences the pricing of derivative contracts traded on electric power prices. Thus, understanding the behaviour of volatility allows market participants to better manage their financial risks.

Volatility in electricity markets is even higher than in financial markets and in some markets its asymmetrical pattern is suspected to be the opposite of that of financial returns (the well-known inverse leverage effect). Therefore, modelling the volatility behaviour, checking if its response is symmetrical or not and detecting the presence or not of the perverse leverage effect are still core open questions in this topic, especially in the Spanish market due to the scarcity of studies in the literature.

The usual techniques to deal with the above-mentioned research questions are the well-known GARCH-type models. In this article, we propose a new asymmetric autoregressive stochastic volatility (TA-ARSV) specification to compete with the two more popular GARCH-type models in the literature on this topic (AGARCH and EGARCH).

Results obtained for the Spanish wholesale electricity spot markets indicate that the TA-ARSV model detects the asymmetrical pattern of volatility in returns. This asymmetrical response is also detected by AGARCH (1,1) and EGARCH(1,1) strategies. However, the AGARCH(1,1) model is a potentially unstable model and Akaike Information (AIC), Hannan-Quinn (HQC) and Schwartz Bayesian Criteria favour the TA-ARSV strategy over the EGARCH(1,1) model.

A Likelihood Ratio Test (LR), $\lambda = -2(ln L^0 - ln L)$. Critical value: 3.84 (5%). The values between parentheses indicate the estimated standard deviation.
for risk management in these new ‘competitive’ and deregulated electricity markets.

Acknowledgment:
The authors wish to acknowledge Abdel-El Shaarawi and Fernando Bellido for their interesting comments and suggestions in the preparation of this article. The research for this article would not have been possible without the financial support of The Junta de Comunidades de Castilla-La Mancha (Spain), the European Regional Development Fund and the European Social Fund (POII10-0250-6976).

6 References