A DETAILED COMPARISON OF VALUE AT RISK IN INTERNATIONAL STOCK EXCHANGES

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A Detailed Comparison of Value at Risk in International Stock Exchanges*

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Abstract:

This work investigates the performance of different models of Value at Risk (VaR). We include a wider range of methods (Parametric, Historical simulation, Monte Carlo simulation, and Extreme value theory models) and several models to compute the conditional variance (exponential moving averages, GARCH and asymmetric GARCH models) under Normal and Student's t-distribution of returns. We analyse four European indexes (IBEX-35, CAC40, DAX and FTSE100), the American Dow Jones and S&P 500 indexes, the Japanese Nikkei 225 index and the Hong Kong Hang Seng index. We examine two periods: a stable period and a volatile one. To choose the best model, we employ a two-stage selection approach. First, we test the accuracy of different models of VaR. We use the unconditional and conditional coverage test, the Back-Testing criterion and the dynamic quantile test. A model survived if all tests indicated the model is accurate. With regard to the first stage, the best models are Parametric and Extreme value theory methods, when they use asymmetric and non-asymmetric GARCH models under Student's t-distribution of returns. Second, we evaluate the loss function of these models. We use several non-parametric tests to test the superiority of a VaR model in terms of the loss function. The result of the second stage indicates that the best model is a Parametric model with conditional variance estimated by asymmetric GARCH model under Student's t-distribution of returns. Nowadays the Parametric models are not as popular because some authors argue that the most conventional parametric specifications have failed in capturing some rare events. However, this paper shows that these models can obtain successful VaR measures if conditional variance is estimated with a GARCH model to capture the characteristic of the returns. This model is usually an exponential GARCH under Student's t-distribution of returns.

JEL: *G32, G11, C52.*
Keywords: *Value at Risk (VaR), Parametric model, Extreme theory value model, GARCH model, Risk management.*

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1. Introduction

Market risk management is a fundamental duty of financial institutions and regulators. Hence, knowing the most appropriate methodology for risk measurement in each context is of utmost importance, and we contribute to that undertaking with a detailed statistical comparison of the performance of the most popular Value at Risk (VaR) methodologies.

In spite of a wide variety of available methodologies to estimate the VaR of a given portfolio, there is an active stream of literature that keeps proposing new avenues for VaR estimation to try to improve upon the existing ones. However, there are surprisingly few empirical studies that attempt to compare VaR measures.

Recent work includes a wide range of methods: Historical simulation, Monte Carlo simulation, Parametric under non-parametric distribution, and Extreme value theory methods [see Bao et al. (2006), Consigli (2002) and Danielson (2002), among others, who show that in stable periods Parametric models provide satisfactory results that become less satisfactory during high volatility periods]. Additional studies that find evidence in favour of Parametric methods are Sarma et al. (2003), who compare Historical simulation and Parametric methods, and Danielson and Vries (2000) in a similar comparison that also includes Extreme value theory methods. Chong (2004), who uses Parametric methods to estimate VaR under a Normal distribution and under a Student’s t-distribution, finds a better performance under Normality.

Another issue is related to the appropriate modelling of the conditional variance of returns. With the exception of Sarma et al. (2003), the papers mentioned above do not compare volatility models. However, some authors show that there are differences in VaR accuracy depending on the volatility models. Hansen and Lunde (2005) find evidence that GARCH models, which allow for a leverage effect, have a better forecasting performance for future returns. Gonzalez-Riviera et al. (2004) and Ñiguez (2008) find that more sophisticated volatility models are preferred when the aim is VaR forecasting. Unfortunately, both papers consider only Parametric models.

Unlike the above mentioned literature, the aim of this paper is to provide an extensive comparison of a wide array of VaR methodologies. The main differences with the previous literature are: (1) we consider a more exhaustive set of methods: Historical and Monte Carlo simulation, Parametric approach and Extreme value theory method, (2) when conditional variance needs to be modelled, we include several models (one of them is the asymmetric GARCH model under both a Normal and a Student's t-distribution of returns that allows for the leverage effect usually observed in financial returns), (3) we analyse the VaR performance in stable and volatile periods, and (4) we evaluate VaR methods on the basis of two criteria: from the point of view of their forecasting accuracy and also from the point of view of a reasonable loss function that might represent investors' or regulators' concerns.

In the next section we present the VaR models we use in the paper. In the third section, we present the statistical test and the loss function that we use to evaluate the performance of the VaR measures. The fourth section presents the empirical results. The last section includes the main conclusions.

2. Characteristics of VaR Models

Let r_1, r_2, $r_3, \ldots r_n$ be identically distributed independent random variables representing financial returns. Use $F(r)$ to denote the cumulative distribution function, $F(r) = \Pr(r_t < r / \Omega_{t-1})$ conditional on the information set Ω_{t-1} available at time t-1. Assume that $\{r_t\}$ follows the stochastic process

$$r_t = \mu_t + \varepsilon_t = \mu_t + \sigma_t z_t \qquad (1)$$

where $\mu_t = E(\varepsilon_t / \Omega_{t-1})$, $\sigma_t^2 = E(\varepsilon_t^2 / \Omega_{t-1})$ and $\{z_t\} \equiv \varepsilon_t / \sigma_t$ has conditional distribution function $G(z)$, $G(z) = \Pr(z_t < z / \Omega_{t-1})$. The VaR with a given probability $\alpha \in (0,1)$, denoted by $VaR(\alpha)$, is defined as the α quantile of the probability distribution of financial returns[1]:

$$F(VaR(\alpha)) = \Pr(r_t < VaR(\alpha)) = \alpha \qquad (2)$$

This quantile can be estimated in two different ways: (1) inverting the distribution function of financial returns, $F(r)$, and (2) inverting the distribution function of standardized financial returns, $G(z)$. With regard to the latter, it is also necessary to estimate μ_t and σ_t^2.

$$VaR(\alpha) = F^{-1}(\alpha) = \mu_t + \sigma_t G^{-1}(\alpha) \qquad (3)$$

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[1] To avoid possible ambiguities, sometimes VaR is defined as: $VaR(\alpha) = \inf\{v \mid P(r_t \le v) = \alpha\}$.

Hence a VaR model involves the specifications of $F(r)$, or μ_t, σ_t^2 and $G(z)$. Historical simulation, Monte Carlo simulation and unconditional Extreme value theory[2] approaches all focus on estimating $F(r)$. On the other hand, the Parametric and conditional Extreme value theory approaches focus on estimating $G(z)$. We describe the general characteristics of the methods that we compare in this paper.

The ***Parametric method*** assumes that standardized financial returns follow a known distribution function. We have considered two types of distributions: Normal and Student's t- distribution.

If $\{z_t\} \equiv \varepsilon_t / \sigma_t$ follows a standard Normal distribution, $\Phi(z)$; then $VaR(\alpha) = \mu_t + \sigma_t \Phi^{-1}(\alpha)$, where $\Phi^{-1}(\alpha)$ is the quantile α of the standard Normal distribution, and μ_t and σ_t^2 are the conditional mean and variance of financial returns, respectively. In all cases considered, we assume as the model for the mean: $\mu_t = \mu$.[3] To estimate the conditional variance of financial returns, we use (1) the asymmetric GARCH model which captures the characteristic of each return (EGARCH)[4], (2) the Riskmetrics model of J.P. Morgan[5], and (3) the GARCH(1,1) model. These are usually used in other papers as benchmarks.

If we assume that $\{z_t\} \equiv \varepsilon_t / \sigma_t$ follows a Student's t-distribution with v degrees of freedom, ($\mathrm{T}_v(z)$); then $VaR(\alpha) = \mu_t + \sigma_t T_v^{-1}(\alpha)$, where, $T_v^{-1}(\alpha)$ is the α quantile of Student's t-distribution with v degrees of freedom, and μ_t and σ_t^2 are the conditional mean and variance of financial returns. To estimate σ_t^2, we use the asymmetric EGARCH model for each index.

Therefore, with the parametric method we obtain four VaR measures for each index, which we denote: *EWMA* (the exponential weighted moving average model of

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[2] The extreme value theory really focuses on direct modelling of the distribution tails.

[3] This is based on the practical absence of any significant autocorrelation in returns.

[4] Exponential GARCH model (EGARCH) (Nelson, 1991) captures the leverage effect, which is detected in all indexes using the bias and sign tests proposed by Engle and Ng (1993). Although there are other models that capture this effect, Nelson's model is the most popular in the literature. The EGARCH model is: $\log(\sigma_t^2) = \omega + \sum_j^q \gamma_j \log(\sigma_{t-j}^2) + \sum_i^p \theta_i \left[\left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| - \sqrt{\frac{2}{\Pi}} \right] + \beta_i \left(\frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right)$ where p=q=1 for all indexes, except for S&P where q=1 and p=2.

[5] The Riskmetrics volatility estimate is an exponential moving average $\sigma_t^2 = (1-\lambda) \Sigma_{j=0}^{N-1} \lambda^j (r_{t-j} - \bar{r})$ with a parameter λ =0.94 and a window size of 74 days This size was selected by Riskmetrics as an optimal window size for daily investments.

Riskmetrics), *GARCH(1,1)*, *EGARCH* (assuming a Normal distribution for returns), and *T-EGARCH* (assuming a Student's t distribution).

The ***Historical simulation*** method uses the empirical distribution of financial returns as an approximation for $F(r)$, so that in this method VaR (α) is the α quantile of the empirical distribution: $VaR(\alpha) = \hat{q}(\alpha)$. The empirical distribution of financial returns is simulated by considering different samples with size: N= 1250, 500, 250 and 125 daily observations.

With regard to ***Monte Carlo simulation***, the underlying stochastic process that drives the dynamics of financial returns needs to be specified. To generate the future financial returns, we use autoregressive models ($r_t = \mu + \sum_{i=1}^{p} \phi_i r_{t-i} + \varepsilon_t$) which imply at time *t+1*:

$$r_{t+1} = \mu + \sum_{i=1}^{p} \phi_i r_{t+1-i} + \varepsilon_{t+1} \tag{4}$$

At time *t,* ε_{t+1} is unknown and needs to be forecasted in order to have a forecast for r_{t+1}. To that end, we either assume that ε_{t+1} follows a Normal distribution or else use Bootstrapping techniques.[6]

Extreme value theory approach focuses on the limiting distribution of extreme returns observed over a long time period, which is essentially independent of the distribution of the returns themselves. The two main models for Extreme value theory are: the block maxima models (McNeil, 1998) and the peaks-over-threshold (POT) model. We use the POT model because it is generally considered to be the most useful for practical applications, due to the more efficient use of the data on extreme values. We can distinguish between two types of analysis: the semi-parametric models built around Hill estimator and its relatives (Beirlant et al. 1996, Danielson, Hartman and

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[6] (1) If ε_{t+1} follows a Normal distribution, then $\varepsilon_{t+1} = \sigma\tilde{\varepsilon}$, where σ is the unconditional standard deviation of ε and $\tilde{\varepsilon}$ is an observation of the Normal standard distribution which we have simulated using a statistical program (MATLAB). (2) When we use bootstrapping techniques, we use $H(\varepsilon)$ to denote the distribution function of ε_{t+1}, where $H(\varepsilon)$ follows a Uniform distribution [0,1]. We simulate the Uniform distribution and work out the value of ε_{t+1} by $\varepsilon_{t+1} = \tilde{H}^{-1}(\varepsilon)$. For each simulated ε_{t+1} value, we obtain a simulated value of r_{t+1}. Repeating this 1000 times, we obtain 1000 simulated financial returns. The $VaR(\alpha)$ can then be calculated as $VaR(\alpha) = \hat{q}_{MC}(\alpha)$, where $\hat{q}_{MC}(\alpha)$ is the α quantile of the 1000 simulated financial returns.

Vries 1998), and the fully parametric models based on the generalized Pareto distribution (Embrechts, Resnic & Samorodnitsky 1998). We use the latter approach.

Among the random variables representing financial returns (r_1, r_2, r_3,... r_n), we choose a low threshold u and look at all values (*y)* exceeding u: $y_1, y_2, y_3 .....y_{N_u}$, where $y_i = r_i - u$ and N_u are the number of sample data over u. The distribution of excess losses over the threshold u is defined as:

$$F_u(y) = P(r - u < y / r > u)$$

$$F_u(y) = \frac{F(y+u) - F(u)}{1 - F(u)} \qquad (5)$$

Assuming that, for a certain u, the distribution of excess losses above the threshold is a Generalized Pareto Distribution, $G_{k,\xi}(y) = 1 - \left[1 + \frac{k}{\xi} y\right]^{-\frac{1}{k}}$, the distribution function of returns is given by:

$$F(r) = F(y+u) = \left[1 - F(u)\right] G_{k,\sigma}(y) + F(u) \qquad (6)$$

To construct a tail estimator from (6), the only additional element we need is an estimate of $F(u)$. For this purpose, we take the obvious empirical estimator $(u - N_u)/u$. We then use the historical simulation method. Introducing the historical simulation estimate of $F(u)$ and setting $r = y + u$ in the equation, we arrive at the tail estimator

$$F(r) = 1 - \frac{N_u}{n}\left[1 + \frac{k}{\xi}(r - u)\right]^{-1/k}, r > u \qquad (7)$$

For a given probability α > $F(u)$, the VaR estimate is calculated by inverting the tail estimation formula (7) to get

$$VaR(\alpha) = u + \frac{\xi}{k}\left[\left[\frac{n}{N_u}(1-\alpha)\right]^{-k} - 1\right] \qquad (8)$$

None of the previous Extreme value theory-based methods for quantile estimation yields VaR-estimates which reflect the current volatility background. These are called *unconditional Extreme value theory* methods. Given the conditional heteroscedasticity characteristic of most financial data, McNeil and Frey (2000) proposed a new methodology to estimate VaR which combines the Extreme value theory with volatility models. This is known as *conditional Extreme value theory.*

Let $(r_1, r_2, r_3, ... r_T)$ be a strictly stationary time series representing financial returns. We assume that the dynamics of r is given by

$$r_t = \mu_t + \sigma_t z_t \qquad (9)$$

where the innovations z_t are a strict white noise process with zero mean, variance equal to one and marginal distribution function $F_z(z)$. Assuming that z_t follows a Generalized Pareto Distribution, denoted by $G_{k,\sigma}(z)$, the conditional α quantile of the returns can be estimated as

$$VaR(\alpha) = \mu_t + \sigma_t G_{k,\sigma}{}^{-1}(\alpha) \qquad (10)$$

where μ_t and σ_t^2 are the conditional mean and variance of financial returns, respectively. Just as in parametric methods, $\mu_t = \mu$ and σ_t^2 are estimated using the same volatility models [EWMA, GARCH(1,1) and EGARCH under a (1) Normal distribution and (2) Student's t-distribution]. $G_x{}^{-1}(\alpha)$ is the α quantile of the Generalized Pareto Distribution:

$$G_{k.\sigma}{}^{-1}(\alpha) = u + \frac{\xi}{k}\left[\left[\frac{n}{N_u}(1-\alpha)\right]^{-k} - 1\right] \qquad (11)$$

3. Data

To study these VaR methodologies, we generate out-of-sample VaR forecasts for returns of 8 equity portfolios. We analyse four European indexes: the Spanish IBEX-35, the French CAC40, the German DAX and the British FTSE100. Furthermore, we include the American Dow Jones and S&P 500 indexes, the Japanese Nikkei 225 index and the Hong Kong Hang Seng index. These indexes were obtained from the Web of Yahoo Finance (Spain)[7] for the period from January 2nd, 1994 to April 28th, 2006. Returns are calculated as $r_t = \ln(I_t / I_{t-1})x100$.

We select two samples to generate out-of-sample VaR forecasts for these 8 portfolios' returns. These samples are quite different from each other. The first sample, called *volatile period,* covers the period from 1 January 2001 to 31 December 2002. This period was really volatile in all stock markets because there was a financial crisis. The second sample, called *stable period,* covers the period from 1 May 2004 to 30 April

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[7] http://es.finance.yahoo.com/

2006 and it was a non-volatile period. Both of them have approximately 500 data, leaving 500 trading days for the out-of-sample evaluation. [8]

To compare these VaR models, we work with out-of-sample one-step-ahead forecasts. First we study the volatile period sample. We have a sample from 2 January 1994 to 31 December 2002, and we split it into an in-sample part (from 2 January 1994 to 31 December 2000) and an out-of-sample part (volatile period). Then we use a rolling scheme to obtain 500 one-step-ahead forecasts. Second we study the stable period sample (from 2 January 1994 to 30 April 2006), and we split it into an in-sample part and an out-of-sample part (stable period).

4. Evaluation Framework

We compare the VaR methodologies using a two-stage selection approach. Since a minimum degree of reliability should be required, we remove in a first stage those methods that fail to pass a given number of statistical accuracy tests.[9] The selected VaR models are then compared in a second stage on the basis of linear and squared loss functions. So while we rely on counting statistics in the first stage, we use a quantitative loss function in the second stage.

First, we test ***the accuracy*** of different models of VaR. We use the standard tests: unconditional and conditional coverage test, the Back-Testing criterion and the dynamic quantile test. We consider that a model is good if all tests indicate the model is accurate and then if it survives the first stage.

As usual, we define the exception to compare VaR(α) measures and the actual change in portfolio value on day t+1 (denoted as ΔV_{t+1}). If ΔV_{t+1} < VaR(α), then we have an exception. We define the exception indicator variable as:

$$I_{t+1} = \begin{cases} 1 & if\ \Delta V_{t+1} < VaR(\alpha) \\ 0 & if\ \Delta V_{t+1} \geq VaR(\alpha) \end{cases}$$

Kupiec (1995) shows that if we assume the probability of an exception is constant, then the number of exceptions ($\sum I_{t+1}$) follows a binomial distribution B(N, α), where N is the number of observations. An accurate VaR(α) measure should produce

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[8] The sample size depends on the stock market of each index, but all samples have approximately 500 data.

[9] An open question in VaR methodology is whether a model with more, but small, exceptions might be preferable to another with less exceptions.

an *unconditional coverage* ($\hat{\alpha} = \sum I_{t+1} / N$) equal to α percent. The *unconditional coverage test* has as null hypothesis $\hat{\alpha} = \alpha$, with a likelihood ratio statistic:

$$LR_{UC} = 2\left[\log(\hat{\alpha}^x (1-\hat{\alpha})^{N-x}) - \log(\alpha^x (1-\alpha)^{N-x})\right]$$

which follows an asymptotic $\chi^2(1)$ distribution.

Christoffersen (1998) developed a *conditional coverage test.* This jointly examines if the total number of exceptions is statistically equal to the expected one and the serial independence of I_{t+1}. The likelihood ratio statistic of the conditional coverage test is $LR_{cc}=LR_{uc}+LR_{ind}$, which is asymptotically distributed $\chi^2(2)$, and the LR_{ind} statistic is the likelihood ratio statistic for the hypothesis of serial independence against first-order Markov dependence. [10]

A similar test for the significance of the departure of $\hat{\alpha}$ from α is the *back-testing criterion* statistic:

$$Z = \left(N\hat{\alpha} - N\alpha\right) / \sqrt{N\alpha(1-\alpha)}$$

which follows an asymptotic N(0,1) distribution.

Finally, the *Dynamic Quantile* (DQ) test proposed by Engle and Manganelli (2004) examines if the exception indicator is uncorrelated with any variable that belongs to the information set Ω_{t-1} available when the VaR was calculated. This is a Wald test of the hypothesis that all slopes in the regression model

$$I_t = \beta_0 + \sum_{i=1}^{p} \beta_i I_{t-i} + \sum_{j=1}^{q} \mu_j X_j + \varepsilon_t$$

are zero, where X_j are explanatory variables contained in Ω_{t-1}. In our implementation of the test we use p=5 and X=VaR(α). By doing this, we are testing for whether the probability of an exception depends on the level of the VaR.

In the second stage we evaluate ***the magnitude of the losses experienced*** when an exception occurs by the models that survive the first stage. Lopez (1999) developed a loss function that accommodates the specific concerns of risk managers and proposed to

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[10] The LR_{ind} statistic is $LR_{ind} = 2\left[\log L_A - \log L_0\right]$ and has an asymptotic $\chi^2(1)$ distribution. The likelihood function under the alternative hypothesis is $L_A = \left(1-\pi_{01}\right)^{N_{00}} \pi_{01}^{N_{01}} \left(1-\pi_{11}\right)^{N_{10}} \pi_{11}^{N_{11}}$ where N_{ij} denotes the number of observations in state $_j$ after having been in state $_i$ in the previous period, $\pi_{01} = N_{01} / (N_{00} + N_{01})$ and $\pi_{11} = N_{11} / (N_{10} + N_{11})$. And the likelihood function under the null hypothesis ($\pi_{01} = \pi_{11} = \pi = (N_{11} + N_{01}) / N$) is $L_0 = \left(1-\pi\right)^{N_{00}+N_{01}} \pi^{N_{01}+N_{11}}$.

examine the distance between the observed returns and the forecasted VaR(α) values if an exception occurs. We measure the magnitude of the losses through this loss function:

$$lf_{t+1} = \begin{cases} \left[\Delta V_{t+1} - VaR(\alpha)\right]^2 & if\ \Delta V_{t+1} < VaR(\alpha) \\ 0 & if\ \Delta V_{t+1} \geq VaR(\alpha) \end{cases}$$

where the VaR measure is penalized with the square distance. [11] So one VaR model is preferred over another if it yields a lower mean loss value, defined as the mean of the penalty scores: $\sum_{t=1}^{N} lf_t \big/ N$.

We select the best model among the surviving models. The best model is the one that minimizes the mean of the associated penalty scores. Nevertheless, we use several non-parametric statistics to test the superiority of the best model, that is, if the mean of this model is different from the mean of the other models. First, we use the Friedman test. This test is an alternative to the ANOVA test, when the assumption of Normality or that of equality of variance are not met. The null hypothesis of the Friedman test is that the penalty scores are the same for the alternative models versus the alternative hypothesis that the penalty scores from at least one model's loss function are different from at least another one. The test statistic is a Chi-square with *n*-1 degrees of freedom, where *n* is the number of the model's loss functions. Friedman's test compares all models to each other, and it could lead to rejection if two ill-performing models are significantly different from each other. To clarify that possible situation, we use Wilcoxon's test. It tests whether the distribution of two paired loss functions is the same. This test takes into account the magnitude of the differences between two paired loss functions, as well as their signs. The null hypothesis is that the penalty scores from two models are identical. We use the asymptotic Normal approximation to the Wilcoxon statistic (correcting for both continuity and ties).

5. Empirical Results

5.1. First Stage: Comparing the Accuracy of VaR Models

Tables 1 to 4 show the forecast accuracy of the alternative VaR methods: Parametric, Monte Carlo simulation, Extreme Value Theory and Historical simulation, respectively. For each VaR model we show two panels: for the volatile period (high volatility sample) and the stable period (low volatility sample). We analyse the accuracy

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[11] The ranking of the models is the same under a linear loss function as under a quadratic loss function and are not presented here. They are available on request.

of daily VaR estimates at 5% and 1% confidence levels. For each VaR method we show the percentage of exceptions and five statistics: the Unconditional coverage test, the Back-testing criterion, the Serial independence test, the Conditional coverage test and the Dynamic Quantile test. A shaded cell indicates a VaR estimate for which all tests suggest an accurate VaR estimate.

The results for the Parametric models (Table 1) indicate that, in the volatile period, this model achieves the highest accuracy when we use the asymmetric volatility method, and the innovations are supposed to follow a Normal or a Student's t distribution (EGARCH and T-EGARCH, respectively). During the stable period, the results point to a high accuracy regardless of the volatility model used and the assumption about the probability distribution.

On the contrary, the tests indicate that Monte Carlo simulation VaR techniques are inaccurate in both periods, regardless of whether we assume a Normal distribution or we employ Bootstrapping techniques (Table 2). Therefore, at this stage we can drop the Monte Carlo simulation VaR technique as inaccurate.

Tables 3 and 4 show, respectively, the test statistics for models based on unconditional and conditional Extreme value theory. For the unconditional Extreme value Theory, VaR estimates are inaccurate in both samples (Table 3). VaR estimates get much better when we use the conditional Extreme value theory (Table 4). In the volatile period, the most accurate cases are observed in the conditional Extreme value theory when we use the asymmetric volatility model either under Normal or Student's t distribution assumptions for the returns (EGARCH and T-EGARCH). Both of them achieve high accuracy in 11 cases, which include all indexes, except the Dow Jones. Just as in the case of the Parametric model, the conditional Extreme value theory approach is always accurate over the stable period. As a result, the most accurate methods are conditional Extreme value theory with the asymmetric volatility model regardless of whether we assume a Normal or Student's t distribution (EGARCH and T-EGARCH) in both periods.

Historical simulation methods (Table 5) are inaccurate regardless of the size of the windows. And this result is robust to the period under consideration, although when we use the shortest window in a stable period the test indicates some accuracy.

Finally, we conclude from this first stage that the most accurate methods in accordance with the tests are Parametric-EGARCH, Parametric-T-EGARCH, EVT-EGARCH and EVT-T-EGARCH. Therefore, these four methods survive because all tests indicate high accuracy of these models in more cases than the other models. It is important to note that the method used to measure the volatility is relevant in terms of accuracy. This result is in line with other papers such as González-Rivera et al. (2004), Hansen and Lunde (2004) and Ñiguez (2008), which find that the Riskmetrics EWMA model and GARCH(1,1) are clearly inferior. Moreover, these results show that, in general, all methods are more accurate in the stable period, as we had expected.

5.2. Second Stage: Evaluating Loss Functions for VaR Models

First, we analyze the loss functions of the four models which survived the first stage of our analysis (EVT-EGARCH, EVT-T-EGARCH, Parametric-EGARCH and Parametric-T-EGARCH). The left panel of Table 6 reports the average of the penalty scores from loss functions in the volatile period. These values indicate that Parametric-T-EGARCH produces lower losses than the other models, except Nikkei's VaR(1%) where EVT-T-EGARCH produces lower losses. The left panel of Table 7 reports the same information in the stable period. We detect the same result: the Parametric-T-EGARCH model produces the lowest losses, except FTSE-100's VaR(1%) where EVT-EGARCH produces lower losses. We also observe that the average of the penalty scores from loss functions of each index is lower in the stable period. This indicates that all models work better in the stable period in terms of losses, just as they do in terms of accuracy. Therefore, this study of the loss function indicates that Parametric-T-EGARCH produces the lowest average losses in both periods.

Second, we test if the losses show a statistically significant difference. On one hand, we use the Friedman test (central panel of Tables 6 and 7) and, on the other, the Wilcoxon test (right panel of Tables 6 and 7). In the volatile period (Table 6), the Friedman test statistic indicates that the null hypothesis that the penalty scores from the model's loss function are identical is rejected, except in Nikkei's VaR(1%) and VaR(5%), Hang Seng's VaR(1%) and DAX's VaR(1%). This result shows that there are differences in the loss functions from these four surviving models, except in the four aforementioned cases. When we test the hypothesis that the distribution of two paired loss functions is the same with the Wilcoxon test, we notice that some paired loss functions are similar. Some of these paired loss functions coincide with the cases where the Friedman test indicates that these functions are similar. It is important to note that the Friedman and Wilcoxon tests indicate that all surviving methods provide similar loss functions for the Nikkei´s VaR(1%), i.e., the case where we detect that the

Parametric-T-EGARCH does not provide the minimum average of the penalty scores, but the penalty scores of this function are similar to the EVT-T-EGARCH.

In the stable period (Table 7), the Wilcoxon test also indicates that the penalty scores from the surviving models' loss function differ from one another in general. In these cases, the Wilcoxon test indicates that pairs of loss functions are similar to each other. It is important to note that the Wilcoxon test shows that the EVT-EGARCH and the Parametric-T-EGARCH models provide similar loss functions for the FTSE-100's VaR(1%).

The final conclusion from our study of loss function is that the Parametric-T-EGARCH model usually provides the loss function with the minimum average value, but when other models provide the minimum value the tests indicate that both loss functions are similar. Therefore, the Parametric T-EGARCH is the model which provides the lowest losses for all indexes and both considered periods. These results provide evidence that GARCH models, combined with asymmetries and heavy-tailed distributions, do help to enhance the performance of GARCH models to forecast VaR. These results are in line with Hansen and Lunde (2005) and Ñiguez (2008).

6. Conclusions

We compare several VaR methodologies: (1) Historical simulation, (2) Monte Carlo simulation, (3) Parametric methods and (4) Extreme Value Theory methods. Parametric and Extreme Value Theory are implemented under alternative specifications for the conditional volatility and the probability distributions of returns. Historical simulation methods are carried out for different windows, while Monte Carlo simulation is performed under Normality as well as by Bootstrapping.

We start by using a variety of accuracy tests available in the literature to select a subset of the best performing models, which are then compared in terms of the values of a quadratic loss function.

Accuracy tests select the Parametric approach and the Extreme Value Theory model, in both cases under an asymmetric specification of conditional volatility. The choice of a Normal or Student's t-distribution for the returns is inconsequential at this level.

A statistical comparison of loss functions indicates that among the selected methods, the Parametric approach under an asymmetric specification for conditional volatility and Student’s t- innovations performs the best in VaR estimation, in stable as well as in volatile periods.

More general implications of our analysis are: i) selecting a proper specification for conditional variance is relevant for VaR estimation [contradicting the conclusions of some other authors], ii) the choice of probability distribution for estimation of the conditional variance model is also important, iii) all VaR methods tend to work better in stable than in volatile market periods, and iv) notwithstanding some criticism of the reliability of the Parametric approach in recent literature, it works at least as well as the Extreme Value Theory approach in VaR estimation.

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Table 1(a). Parametric Method

	S&P		Dow Jones		Nikkei		Hang Seng		IBEX-35		CAC-40		DAX		FTSE-100	
	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%
	Volatile period															
GARCH	**7.6%**	**1.6%**	**10.8%**	**4.6%**	**7.1%**	**1.4%**	**6.3%**	**1.2%**	**6.2%**	**2.0%**	**6.3%**	**1.0%**	**8.9%**	**0.8%**	**8.3%**	**2.0%**
Lruc	2.684	0.668	11.717 *	15.140 *	1.807	0.345	0.718	0.099	0.625	1.708	0.727	0.001	5.789 *	0.103	4.302 *	1.665
BTC	2.668 +	1.348	5.951 +	8.090 +	2.164 +	0.948	1.336	0.494	1.243	2.254 +	1.344	-0.036	4.033 +	-0.47	3.434 +	2.22 +
Lrind	2.264	1.116	4.904 ~	7.905 ~	0.049	--	0.276	--	0.001	0.759	0	--	0.146	--	2.323	--
LRcc	4.949	1.784	16.621 #	23.045 #	1.856	--	0.994	--	0.626	2.468	0.727	--	5.935	--	6.625 #	--
DQT	2.188 ^	1.47	2.625 ^	4.539 ^	1.582	1.84	2.26 ^	0.071	0.957	2.056	0.627	3.333 ^	2.275 ^	5.706 ^	3.396 ^	5.287 ^
EWMA	**4.0%**	**0.6%**	**7.4%**	**2.0%**	**3.1%**	**0.2%**	**3.9%**	**0.4%**	**6.2%**	**1.8%**	**6.9%**	**1.0%**	**8.9%**	**1.0%**	**8.7%**	**2.4%**
Lruc	0.489	0.410	2.309	1.700	1.961	2.028	0.620	0.975	0.625	1.142	1.491	0.001	5.789 *	0	5.296 *	3.039
BTC	-1.026	-0.899	2.462 +	2.247 +	-1.977 +	-1.773	-1.149	-1.320	1.243	1.804	1.954	-0.036	4.033 +	-0.022	3.842 +	3.116 +
Lrind	0.617	--	3.649	2.746	--	--	0.041	--	0.263	0.922	0.038	--	0.118	--	1.883	--
LRcc	1.107	--	5.958	4.446	--	--	0.661	--	0.888	2.064	1.529	--	5.907	--	7.179 #	--
DQT	2.047	0.466	1.722	0.38	0.956	0.026	2.741 ^	0.007	1.633	2.602 ^	1.223	3.373 ^	2.556 ^	3.554 ^	3.282 ^	5.924 ^
EGARCH	**6.0%**	**2.6%**	**9.2%**	**3.2%**	**5.3%**	**0.6%**	**3.7%**	**0.4%**	**5.8%**	**1.8%**	**5.7%**	**1.0%**	**8.3%**	**0%**	**7.1%**	**1%**
Lruc	0.431	3.897 *	6.532 *	6.717 *	0.038	0.378	0.877	0.975	0.286	1.142	0.223	0.001	4.271 *	1.048	1.879	0.076
BTC	1.026	3.596 +	4.309 +	4.944 +	0.300	-0.866	-1.356	-1.320	0.832	1.804	0.733	-0.036	3.42 +	-1.364	2.207 +	0.43
Lrind	0.335	0.398	1.471	4.864 ~	--	--	--	--	0.091	0.922	0.147	--	0.423	--	0.034	--
LRcc	0.766	4.295	8.003 #	11.581 #	--	--	--	--	0.377	2.064	0.37	--	4.694	--	1.912	--
DQT	2.062	2.146	0.828	1.757	0.956	0.165	0.781	0.02	0.987	1.977	0.854	3.225 ^	1.151	0.008	1.047	2.098
T-EGARCH	**4.4%**	**1.2%**	**7.4%**	**2.0%**	**4.7%**	**0.6%**	**1.8%**	**0.4%**	**4.0%**	**0.2%**	**4.7%**	**0.4%**	**5.7%**	**0.2%**	**6.2%**	**0.4%**
Lruc	0.171	0.082	2.309	1.700	0.046	0.378	5.885 *	0.975	0.48	2.083	0.036	1.064	0.243	2.125	0.57	1.043
BTC	-0.616	0.449	2.462 +	2.247 +	-0.321	-0.866	-3.220 +	-1.320	-1.017	-1.795	-0.285	-1.373	0.766	-1.811	1.185	-1.361
Lrind	0	--	3.649	2.746	--	--	--	--	0.021	--	0.008	--	0.18	--	0.267	--
LRcc	0.172	--	5.958	4.446	--	--	--	--	0.502	--	0.044	--	0.424	--	0.837	--
DQT	1.679	1.216	1.722	0.38	0.73	0.142	0.251	0.021	0.442	0.21	0.608	0.108	2.305 ^	0.066	1.277	0.012

Note: We use several models to estimate the indexes' variance: *GARCH* is the GARCH(1,1) model. *EWMA* is the exponential moving averages model used by Riskmetrics. *EGARCH* is the best model for each index. This model is always the Exponential GARCH model as proposed by Nelson (1991), which was estimated assuming that residuals follow a conditional Normal distribution. All indexes are EGARCH(1,1) with one asymmetric term, except S&P which has two asymmetric terms. *TEGARCH* is the best model for each index assuming that the residuals follow a conditional Student's t-distribution. Percentage of VaR exceptions. LRuc is the unconditional coverage test. BTC is the back-testing criterion. LRind is the statistic for the serial independence. LRcc is the conditional coverage test. DQT is the Dynamic Quantile test. *, +, ~, #, ^ denote the rejection of the VaR estimate is accurate. The shaded cells indicate that the null hypothesis that the VaR estimate is accurate is not rejected by any test.

Table 1(b). Parametric Method																
	S&P		Dow Jones		Nikkei		Hang Seng		IBEX-35		CAC-40		DAX		FTSE-100	
	5%	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**
	Stable period															
GARCH	**4.8%**	**1.6%**	**5.0%**	**1.8%**	**3.1%**	**1.2%**	**4.8%**	**1.2%**	**3.4%**	**0.6%**	**3.7%**	**1.4%**	**5.1%**	**1.4%**	**4.2%**	**1.8%**
Lruc	0.022	0.658	0.000	1.121	1.943	0.101	0.010	0.092	1.415	0.434	0.886	0.262	0.002	0.268	0.338	1.107
BTC	-0.225	1.337	-0.020	1.785	-1.969 +	0.499	-0.155	0.474	-1.702	-0.924	-1.365	0.819	0.071	0.83	-0.858	1.773
Lrind	2.192	1.119	0.886	0.928	1.367	1.597	0.242	--	--	--	0.053	1.364	0.041	1.361	0.514	--
LRcc	2.214	1.777	0.886	2.049	3.310	1.698	0.252	--	--	--	0.939	1.626	0.043	1.63	0.852	--
DQT	2.78 ^	1.694	1.159	1.332	1.717	3.288 ^	0.377	0.248	0.856	0.052	0.694	1.575	0.88	2.731 ^	1.228	1.124
EWMA	**4.2%**	**0.8%**	**4.2%**	**1.4%**	**3.5%**	**1.0%**	**4.6%**	**0.6%**	**5.3%**	**2.0%**	**5.2%**	**2.7%**	**6.2%**	**2.3%**	**5.8%**	**2.2%**
Lruc	0.323	0.098	0.323	0.305	1.170	0.001	0.058	0.392	0.048	1.639	0.027	4.541 *	0.669	2.931	0.25	2.311
BTC	-0.840	-0.458	-0.840	0.888	-1.555	0.045	-0.361	-0.881	0.336	2.201 +	0.253	3.919 +	1.286	3.048 +	0.777	2.668 +
Lrind	0.512	--	0.512	--	1.007	--	0.315	--	0.644	--	0.667	0.325	0.793	0.517	0.03	0.626
LRcc	0.835	--	0.835	--	2.177	--	0.373	--	0.692	--	0.695	4.866	1.462	3.448	0.28	2.938
DQT	1.909	0.541	0.729	0.591	1.085	0.39	0.925	0.063	1.691	0.223	1.541	0.838	2.946 ^	0.975	1.618	1.679
EGARCH	**3.6%**	**0.4%**	**4.6%**	**1.6%**	**2.9%**	**0.8%**	**4.0%**	**1.0%**	**3.2%**	**0.6%**	**3.9%**	**1.0%**	**4.5%**	**1.4%**	**4.2%**	**1.2%**
Lruc	1.014	1.032	0.083	0.658	2.417	0.077	0.445	0.000	1.804	0.434	0.634	0.002	0.129	0.268	0.338	0.076
BTC	-1.454	-1.355	-0.430	1.337	-2.176 +	-0.409	-0.980	0.023	-1.905	-0.924	-1.163	-0.066	-0.537	0.83	-0.858	0.43
Lrind	0.079	--	0.328	--	1.579	--	0.606	--	0.177	--	0.027	1.971	0.001	1.361	0.514	--
LRcc	1.093	--	0.411	--	3.996	--	1.051	--	1.981	--	0.661	1.972	0.13	1.63	0.852	--
DQT	1.504	0.406	0.756	0.529	1.998	0.093	1.066	0.09	0.807	0.129	0.594	3.461 ^	0.961	2.647 ^	1.043	0.089
T-EGARCH	**2.6%**	**0.2%**	**3.4%**	**1.2%**	**2.4%**	**0.8%**	**2.6%**	**0.2%**	**3.0%**	**0.6%**	**3.9%**	**0.6%**	**4.3%**	**1.0%**	**3.8%**	**0.8%**
Lruc	3.213	2.104	1.341	0.079	3.562	0.077	3.062	2.056	2.249	0.434	0.634	0.463	0.249	0.001	0.759	0.101
BTC	-2.478 +	-1.803	-1.659	0.440	-2.591 +	-0.409	-2.423 +	-1.784	-2.109 +	-0.924	-1.163	-0.952	-0.739	-0.058	-1.267	-0.466
Lrind	0.401	--	0.121	--	0.489	--	0.392	--	0.241	--	0.027	2.979	0.002	1.967	0.748	--
LRcc	3.614	--	1.462	--	4.051	--	3.454	--	2.49	--	0.661	3.443	0.25	1.969	1.508	--
DQT	2.16	0.817	0.933	0.376	0.982	0.12	2.118	0.534	0.825	0.132	0.589	12.109 ^	0.933	4.18 ^	1.212	0.591

Note: We use several models to estimate the indexes' variance: *GARCH* is the GARCH(1,1) model. *EWMA* is the exponential moving averages model used by Riskmetrics. *EGARCH* is the best model for each index. This model is always the Exponential GARCH model as proposed by Nelson (1991), which was estimated assuming that residuals follow a conditional Normal distribution. All indexes are EGARCH(1,1) with one asymmetric term, except S&P which has two asymmetric terms. *TEGARCH* is the best model for each index assuming that the residuals follow a conditional Student's t-distribution. Percentage of VaR exceptions. LRuc is the unconditional coverage test. BTC is the back-testing criterion. LRind is the statistic for the serial independence. LRcc is the conditional coverage test. DQT is the Dynamic Quantile test. *, +, ~, #, ^ denote the rejection of the VaR estimate is accurate. The shaded cells indicate that the null hypothesis that the VaR estimate is accurate is not rejected by any test.

Table 2. Monte Carlo Simulation

	S&P		Dow Jones		Nikkei		Hang Seng		IBEX-35		CAC-40		DAX		FTSE-100	
	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%
	Volatile period															
BOOTS	**12.8%**	**2.8%**	**16.0%**	**5.8%**	**8.1%**	**1.0%**	**1.8%**	**0.2%**	**11.2%**	**1.8%**	**10.8%**	**3.5%**	**14.3%**	**4.0%**	**11.1%**	**3.8%**
Lruc	19.81 *	4.775 *	35.931 *	23.946 *	3.766	0.001	5.885 *	2.028	13.259 *	1.142	12.003 *	8.702 *	26.97 *	11.12 *	12.967 *	9.946 *
BTC	8.003 +	4.045 +	11.286 +	10.787 +	3.199 +	0.041	-3.22 +	-1.773	6.378 +	1.804	6.026 +	5.761 +	9.545 +	6.686 +	6.295 +	6.25 +
Lrind	2.773	1.609	1.206	2.225	0.284	--	--	--	0.008	0.922	1.284	0.897	0.316	0.626	0.05	0.047
LRcc	22.583 #	6.383 #	37.136 #	26.172 #	4.05	--	--	--	13.267 #	2.064	13.287 #	9.599 #	27.286 #	11.747 #	13.017 #	9.993 #
DQT	4.059 ^	3.446 ^	3.692 ^	4.432 ^	0.778	3.592 ^	1.719	0.118	2.899 ^	2.018	1.827	1.775	5.856 ^	2.166 ^	2.249 ^	3.448 ^
NORMAL	**13.4%**	**4.4%**	**16.0%**	**8.6%**	**6.9%**	**1.8%**	**1.6%**	**0.2%**	**11.4%**	**3.0%**	**10.6%**	**4.9%**	**13.9%**	**6.7%**	**11.7%**	**6.3%**
Lruc	22.552 *	13.802 *	35.931 *	48.661 *	1.493	1.199	6.836 *	2.028	14.028 *	5.734 *	11.286 *	17.649 *	25 *	31.914 *	15.298 *	28.601 *
BTC	8.618 +	7.641 +	11.286 +	17.08 +	1.957	1.855	-3.427 +	-1.773	6.583 +	4.504 +	5.822 +	8.883 +	9.137 +	12.947 +	6.908 +	12.069 +
Lrind	1.459	1.363	1.206	4.137 ~	0.028	--	--	--	0.176	0.232	3.015	0.197	0.534	3.357	0.326	1.6
LRcc	24.01 #	15.165 #	37.136 #	52.798 #	1.521	--	--	--	14.204 #	5.966	14.301 #	17.845 #	25.534 #	35.271 #	15.624 #	30.201 #
DQT	0.016	--	3.029 ^	0.004	3.792 ^	0.055	9.898 ^	--	3.452 ^	1.923	2.459 ^	3.225 ^	5.622 ^	4.912 ^	1.84	5.657 ^
	Stable period															
BOOTS	**0.2%**	**0.0%**	**4.0%**	**0.2%**	**2.2%**	**0.4%**	**0.6%**	**0.0%**	**0.4%**	**0.0%**	**0.4%**	**0.0%**	**0.8%**	**0.0%**	**0.4%**	**0.0%**
Lruc	18.654 *	--	0.508	2.104	4.243 *	0.97	13.823 *	--	16.354 *	--	16.683 *	--	12.76 *	--	16.23 *	--
BTC	-4.935 +	-2.252 +	-1.044	-1.803	-2.798 +	-1.317	-4.485 +	-2.236 +	-4.758 +	-2.263 +	-4.802 +	-2.281 +	-4.386 +	-2.276 +	-4.742 +	-2.256 +
Lrind	--	--	0.622	--	0.608	--	--	--	--	--	--	--	--	--	--	--
LRcc	--	--	1.13	--	4.852	--	--	--	--	--	--	--	--	--	--	--
DQT	2.906 ^	3.859 ^	3.312 ^	3.411 ^	0.785	2.132	2.474 ^	0.222	0.054	0 ^	0.029	0 ^	8.336 ^	0 ^	0.029	0 ^
NORMAL	**0.2%**	**0.0%**	**3.8%**	**1.0%**	**1.6%**	**0.6%**	**0.2%**	**0.0%**	**0.2%**	**0.0%**	**0.4%**	**0.4%**	**0.6%**	**0.0%**	**0.4%**	**0.0%**
Lruc	18.654 *	--	0.737	0	6.806 *	0.375	18.354 *	--	18.868 *	--	16.683 *	1.101	14.532 *	--	16.23 *	--
BTC	-4.935 +	-2.252 +	-1.249	-0.009	-3.42 +	-0.863	-4.898 +	-2.236 +	-4.962 +	-2.263 +	-4.802 +	-1.395	-4.588 +	-2.276 +	-4.742 +	-2.256 +
Lrind	--	--	0.746	--	1.1	--	--	--	--	--	--	--	--	--	--	--
LRcc	--	--	1.483	--	7.906 #	--	--	--	--	--	--	--	--	--	--	--
DQT	0.096	--	2.66 ^	3.151 ^	4.616 ^	15.746 ^	0.217	--	0.045	0 ^	0.066	0.066	19.128 ^	0 ^	0.003	0 ^

Note: We use two techniques to simulate: assuming that residuals follow a Normal distribution (*NORMAL*), and using Bootstrap techniques (*BOOTS*). Percentage of VaR exceptions. LRuc is the unconditional coverage test. BTC is the back-testing criterion. LRind is the statistic for the serial independence. LRcc is the conditional coverage test. DQT is the Dynamic Quantile test. *, +, ~, #, ^ denote the rejection of the VaR estimate is accurate. The shaded cells indicate that the null hypothesis that the VaR estimate is accurate is not rejected by any test.

Table 3. Unconditional Extreme Value Theory

	S&P		Dow Jones		Nikkei		Hang Seng		IBEX-35		CAC-40		DAX		FTSE-100	
	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%
	Volatile period															
Unconditional	**11.8%**	**2.0%**	**15.8%**	**4.6%**	**7.7%**	**1.0%**	**2.2%**	**0.2%**	**10.4%**	**1.8%**	**10.6%**	**4.1%**	**13.3%**	**4.0%**	**9.7%**	**4.0%**
Lruc	15.555 *	1.700	34.820 *	15.140 *	2.907	0.001	4.268 *	2.028	10.357 *	1.142	11.286 *	12.28 *	22.153 *	11.12 *	8.152 *	11.147 *
BTC	6.977 +	2.247 +	11.081 +	8.090 +	2.785 +	0.041	-2.806 +	-1.773	5.556 +	1.804	5.822 +	7.099 +	8.524 +	6.686 +	4.864 +	6.697 +
Lrind	2.481	0.762	2.496	5.824 ~	0.170	--	--	--	0.032	--	2.199	0.522	0.943	0.626	1.006	0.624
LCR	18.036 #	2.462	37.316 #	20.964 #	3.077	--	--	--	10.389 #	--	13.485 #	12.802 #	23.096 #	11.747 #	9.158 #	11.771 #
DQT	2.432 ^	1.346	2.312 ^	6.038 ^	1.07	3.299 ^	0.928	0.778	1.53	1.479	2.414 ^	2.998 ^	6.674 ^	6.494 ^	3.329 ^	3.34 ^
	Stable period															
Unconditional	**0.2%**	**0.0%**	**3.8%**	**0.0%**	**2.0%**	**0.4%**	**0.4%**	**0.0%**	**0.2%**	**0.0%**	**0.4%**	**0.0%**	**0.6%**	**0.0%**	**0.4%**	**0.0%**
Lruc	18.654 *	--	0.737	--	5.005 *	0.970	15.861 *	--	18.868 *	--	16.683 *	--	14.532 *	--	16.23 *	--
BTC	-4.935 +	-2.252 +	-1.249	-2.252 +	-3.006 +	-1.317	-4.692 +	-2.236 **+**	-4.962 +	-2.263 +	-4.802 +	-2.281 +	-4.588 +	-2.276 +	-4.742 +	-2.256 +
Lrind	--	--	0.746	--	0.747	--	--	--	--	--	--	--	--	--	--	--
LCR	--	--	1.483	--	5.753	--	--	--	--	--	--	--	--	--	--	--
DQT	0.016	0 ^	2.554 ^	0 ^	2.721 ^	0.103	27.684 ^	0 ^	0.77	0 ^	0.557	0 ^	19.477 ^	0 ^	0.04	0 ^

Note: *Unconditional* . Percentage of VaR exceptions. LRuc is the unconditional coverage test. BTC is the back-testing criterion. LRind is the statistic for the serial independence. LRcc is the conditional coverage test. DQT is the Dynamic Quantile test. *, +, ~, #, ^ denote the rejection of the VaR estimate is accurate. The shaded cells indicate that the null hypothesis that the VaR estimate is accurate is not rejected by any test.

Table 4 (a).Conditional Extreme Value Theory

	S&P		Dow Jones		Nikkei		Hang Seng		IBEX-35		CAC-40		DAX		FTSE-100	
	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%
	Volatile period															
GARCH	**5.6%**	**0.8%**	**9.2%**	**2.6%**	**7.3%**	**0.4%**	**5.7%**	**0.6%**	**9.8%**	**2.2%**	**5.7%**	**0.6%**	**7.9%**	**0.4%**	**7.7%**	**1.2%**
Lruc	0.159	0.094	6.532 *	3.897 *	2.148	0.975	0.212	0.378	8.376 *	2.364	0.223	0.438	3.371	1.048	2.982	0.076
BTC	0.616	-0.449	4.309 +	3.596 +	2.371 +	-1.320	0.714	-0.866	4.94 +	2.704 +	0.733	-0.927	3.012 +	-1.364	2.82 +	0.43
Lrind	0.114	--	2.273	3.908 ~	0.024	--	0.124	--	0.145	0.619	0.032	--	0.251	--	1.215	--
LCR	0.272	--	8.805 #	7.805 #	2.172	--	0.336	--	8.521 #	2.983	0.256	--	3.622	--	4.197	--
DQT	1.693	0.582	1.463	0.696	1.32	0.053	2.117	0.018	3.045 ^	1.313	0.448	0.302	2.496 ^	0.04	2.309 ^	3.826 ^
EWMA	**6.2%**	**1.0%**	**8.4%**	**3.0%**	**6.1%**	**1.0%**	**6.7%**	**1.2%**	**6.0%**	**1.8%**	**6.7%**	**1.2%**	**8.5%**	**1.0%**	**8.1%**	**2.4%**
Lruc	0.614	0.000	4.427 *	5.716 *	0.518	0.001	1.206	0.099	0.44	1.142	1.209	0.069	4.755 *	0	3.839	3.039
BTC	1.231	0.000	3.488 +	4.495 +	1.129	0.041	1.750	0.494	1.037	1.804	1.751	0.41	3.624 +	-0.022	3.229 +	3.116 +
Lrind	0.878	--	3.309	7.914 ~	0.007	--	0.011	--	0.208	0.922	0.018	--	0.23	--	2.564	--
LCR	1.492	--	7.737 #	13.630 #	0.525	--	1.217	--	0.648	2.064	1.227	--	4.985	--	6.403 #	--
DQT	3.102 ^	5.384 ^	2.85 ^	0.175	2.432 ^	3.826 ^	1.54	1.041	1.722	2.615 ^	1.23	2.431 ^	2.611 ^	3.555 ^	4.766 ^	5.932 ^
EGARCH	**5.6%**	**1.8%**	**9.2%**	**2.6%**	**6.1%**	**0.4%**	**4.3%**	**0.4%**	**6.0%**	**0.6%**	**5.3%**	**0.4%**	**8.9%**	**0.2%**	**7.1%**	**0.4%**
Lruc	0.159	1.135	6.532 *	3.897 *	0.518	0.975	0.246	0.975	0.44	0.406	0.045	1.064	5.789 *	2.125	1.879	1.043
BTC	0.616	1.798	4.309 +	3.596 +	1.129	-1.320	-0.735	-1.320	1.037	-0.895	0.326	-1.373	4.033 +	-1.811	2.207 +	-1.361
Lrind	0.054	--	2.273	3.908 ~	0.007	--	0.005	--	0.236	--	0.072	--	0.666	--	0.034	--
LCR	0.213	--	8.805 #	7.805 #	0.525	--	0.252	--	0.676	--	0.117	--	6.455 #	--	1.912	--
DQT	1.612	2.295 ^	1.463	0.696	0.669	0.614	0.573	0.029	1.022	0.107	0.538	0.118	0.786	0.057	1.041	0.018
T-EGARCH	**5.6%**	**1.8%**	**9.2%**	**2.8%**	**5.9%**	**0.4%**	**3.9%**	**0.4%**	**5.8%**	**0.6%**	**5.5%**	**0.4%**	**8.3%**	**0.2%**	**7.1%**	**0.4%**
Lruc	0.159	1.135	6.532 *	4.775 *	0.349	0.975	0.620	0.975	0.286	0.406	0.118	1.064	4.271 *	2.125	1.879	1.043
BTC	0.616	1.798	4.309 +	4.045 +	0.921	-1.320	-1.149	-1.320	0.832	-0.895	0.529	-1.373	3.42 +	-1.811	2.207 +	-1.361
Lrind	0.054	--	1.471	3.509	0.023	--	0.041	--	0.091	--	0.106	--	0.423	--	0.034	--
LCR	0.213	--	8.003 #	8.283 #	0.372	--	0.661	--	0.377	--	0.224	--	4.694	--	1.912	--
DQT	1.612	2.295 ^	0.895	0.571	0.63	0.552	0.488	0.033	1.161	0.146	0.564	0.11	1.217	0.056	1.048	0.016

See Note table 2.

Table 4 (b).Conditional Extreme Value Theory

	S&P		Dow Jones		Nikkei		Hang Seng		IBEX-35		CAC-40		DAX		FTSE-100	
	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%
	Stable period															
GARCH	**4.2%**	**0.4%**	**4.2%**	**1.2%**	**3.1%**	**0.6%**	**4.8%**	**0.6%**	**1.4%**	**0.0%**	**3.3%**	**0.8%**	**3.7%**	**1.2%**	**3.8%**	**0.6%**
Lruc	0.323	1.032	0.323	0.079	1.943	0.375	0.010	0.392	8.414 *	--	1.537	0.122	0.863	0.061	0.759	0.424
BTC	-0.840	-1.355	-0.840	0.440	-1.969 +	-0.863	-0.155	-0.881	-3.739 +	-2.263 +	-1.769	-0.509	-1.347	0.386	-1.267	-0.913
Lrind	0.512	--	0.008	--	1.367	--	0.242	--	--	--	0.13	2.397	0.052	1.633	0.047	--
LCR	0.835	--	0.331	--	3.310	--	0.252	--	--	--	1.667	2.52	0.914	1.694	0.806	--
DQT	2.218 ^	0.187	0.503	0.312	1.63	0.096	0.46	0.03	0.212	0 ^	0.727	5.806 ^	1.005	4.279 ^	0.913	0.025
EWMA	**5.2%**	**1.4%**	**5.8%**	**1.6%**	**5.1%**	**1.6%**	**6.7%**	**1.8%**	**5.3%**	**2.0%**	**5.0%**	**2.5%**	**6.2%**	**2.3%**	**5.2%**	**2.2%**
Lruc	0.015	0.305	0.264	0.658	0.005	0.722	1.143	1.170	0.048	1.639	0.001	3.69	0.669	2.931	0.011	2.311
BTC	0.184	0.888	0.799	1.337	0.104	1.407	1.701	1.830	0.336	2.201 +	0.051	3.477 +	1.286	3.048 +	0.164	2.668 +
Lrind	0.135	--	2.238	--	0.845	1.100	0.132	--	0.644	--	0.15	0.415	0.793	0.517	0.137	0.626
LCR	0.150	--	2.503	--	0.850	1.823	1.275	--	0.692	--	0.152	4.105	1.462	3.448	0.148	2.938
DQT	2.17 ^	0.638	0.608	1.047	1.365	1.77	2.163	0.543	1.694	0.229	1.266	0.841	2.935 ^	0.98	1.513	1.681
EGARCH	**4.2%**	**0.2%**	**4.6%**	**1.2%**	**3.3%**	**0.8%**	**4.6%**	**0.8%**	**3.0%**	**0.6%**	**3.9%**	**0.8%**	**4.7%**	**1.0%**	**4.0%**	**0.8%**
Lruc	0.323	2.104	0.083	0.079	1.529	0.077	0.058	0.086	2.249	0.434	0.634	0.122	0.05	0.001	0.526	0.101
BTC	-0.840	-1.803	-0.430	0.440	-1.762	-0.409	-0.361	-0.429	-2.109 +	-0.924	-1.163	-0.509	-0.334	-0.058	-1.063	-0.466
Lrind	0.008	--	0.328	--	1.177	--	0.315	--	--	--	0.027	2.397	0.007	1.967	0.624	--
LCR	0.331	--	0.411	--	2.706	--	0.373	--	--	--	0.661	2.52	0.056	1.969	1.15	--
DQT	2.614 ^	0.842	0.735	0.403	1.305	0.144	0.617	0.099	0.609	0.128	0.563	5.84 ^	0.908	4.182 ^	1.097	0.53
T-EGARCH	**4.2%**	**0.2%**	**4.6%**	**1.2%**	**3.9%**	**0.8%**	**5.1%**	**0.8%**	**3.4%**	**0.6%**	**3.9%**	**0.8%**	**4.9%**	**1.0%**	**4.0%**	**0.8%**
Lruc	0.323	2.104	0.083	0.079	0.610	0.077	0.001	0.086	1.415	0.434	0.634	0.122	0.008	0.001	0.526	0.101
BTC	-0.84	-1.803	-0.430	0.440	-1.140	-0.409	0.052	-0.429	-1.702	-0.924	-1.163	-0.509	-0.132	-0.058	-1.063	-0.466
Lrind	0.008	--	0.328	--	0.717	--	0.179	--	0.124	--	0.027	2.397	0.02	1.967	0.624	--
LCR	0.331	--	0.411	--	1.327	--	0.180	--	1.539	--	0.661	2.52	0.028	1.969	1.15	--
DQT	2.614 ^	0.842	0.724	0.414	0.98	0.155	0.603	0.096	0.86	0.139	0.558	5.838 ^	0.947	4.155 ^	1.054	0.538

See Note table 2.

Table 5(a). Historical Simulation

	S&P		Dow Jones		Nikkei		Hang Seng		IBEX-35		CAC-40		DAX		FTSE-100	
	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%
	Volatile period															
N=1250	**8.6%**	**1.8%**	**12.4%**	**3.4%**	**5.9%**	**0.8%**	**1.4%**	**0.2%**	**8.2%**	**1.2%**	**8.1%**	**3.0%**	**10.5%**	**2.2%**	**7.5%**	**3.2%**
Lruc	4.921 *	1.135	18.060 *	7.775 *	0.349	0.079	7.898 *	2.028	3.986 *	0.084	3.723	5.576 *	10.741 *	2.301	2.589	6.64 *
BTC	3.694 +	1.798	7.592 +	5.394 +	0.921	-0.413	-3.634 +	-1.773	3.297 +	0.454	3.176 +	4.423 +	5.666 +	2.661 +	2.616 +	4.907 +
Lrind	2.069	0.925	1.816	2.520	0.168	--	--	--	0.36	--	0.39	0.242	2.591	0.716	2.289	0.174
LRcc	6.990 #	2.060	19.876 #	10.294 #	0.518	--	--	--	4.346	--	4.114	5.818	13.332 #	3.017	4.878	6.814 #
DQT	2.874 ^	1.798	2.787 ^	6.432 ^	1.089	5.496 ^	2.943 ^	0.074	0.917	3.846 ^	1.609	1.636	8.033 ^	3.942 ^	6.278 ^	3.167 ^
N=500	**6.4%**	**1.4%**	**12.4%**	**3.4%**	**6.5%**	**1.2%**	**2.4%**	**0.2%**	**6.4%**	**1.8%**	**7.9%**	**2.2%**	**10.5%**	**2.8%**	**6.9%**	**2.4%**
Lruc	0.826	0.312	18.060 *	7.775 *	0.947	0.099	3.585	2.028	0.839	1.142	3.29	2.27	10.741 *	4.696 *	1.562	3.039
BTC	1.436	0.899	7.592 +	5.394 +	1.543	0.494	-2.599 +	-1.773	1.448	1.804	2.972 +	2.64 +	5.666 +	4.003 +	2.003 +	3.116 +
Lrind	2.659	--	1.816	2.520	0.339	--	--	--	0.739	0.922	0.482	0.632	1.817	1.62	1.968	0.506
LRcc	3.485	--	19.876 #	10.294 #	1.287	--	--	--	1.579	2.064	3.772	2.902	12.558 #	6.316 #	3.53	3.545
DQT	2.624 ^	0.197	2.787 ^	6.432 ^	1.541	2.877 ^	1.02	0.01	1.011	2.504 ^	1.387	3.594 ^	6.384 ^	3.78 ^	5.158 ^	3.985 ^
N=250	**6.0%**	**1.0%**	**7.0%**	**1.4%**	**5.1%**	**0.8%**	**3.1%**	**0.2%**	**5.0%**	**1.2%**	**6.7%**	**1.4%**	**7.5%**	**0.8%**	**6.3%**	**1.4%**
Lruc	0.431	0.000	1.635	0.312	0.004	0.079	1.961	2.028	0	0.084	1.209	0.285	2.566	0.103	0.776	0.298
BTC	1.026	0.000	2.052 +	0.899	0.093	-0.413	-1.977 +	-1.773	0.01	0.454	1.751	0.856	2.603 +	-0.47	1.39	0.877
Lrind	3.216	--	4.306 ~	4.094 ~	0.030	--	--	--	0.184	--	0.105	--	1.547	--	2.682	1.347
LRcc	3.647	--	5.941	4.407	0.034	--	--	--	0.184	--	1.314	--	4.113	--	3.458	1.645
DQT	4.424 ^	0.475	4.708 ^	6.122 ^	1.734	5.447 ^	1.335	0.014	1.158	3.719 ^	0.946	3.243 ^	5.504 ^	6.597 ^	5.715 ^	5.397 ^
N=125	**5.6%**	**1.0%**	**6.2%**	**1.4%**	**5.3%**	**0.8%**	**4.3%**	**0.6%**	**5%**	**1.2%**	**6.1%**	**1.8%**	**7.1%**	**1.6%**	**6.0%**	**1.4%**
Lruc	0.159	0.000	0.614	0.312	0.038	0.079	0.246	0.378	0.071	0.084	0.529	1.079	1.859	0.642	0.395	0.298
BTC	0.616	0.000	1.231	0.899	0.300	-0.413	-0.735	-0.866	-0.401	0.454	1.14	1.748	2.195 +	1.319	0.981	0.877
Lrind	3.848 ~	--	2.929	1.342	0.055	--	--	--	0.321	--	0.275	--	1.934	--	4.687 ~	1.347
LRcc	4.007	--	3.542	1.654	0.093	--	--	--	0.392	--	0.804	--	3.793	--	5.082	1.645
DQT	4.261 ^	0.899	7.283 ^	2.448 ^	3.545 ^	0.416	1.81	0.246	2.902 ^	4.075 ^	0.414	2.191 ^	5.486 ^	1.602	6.216 ^	5.052 ^

Note: We consider different sizes of samples: N= 1250, 500, 250 and 125 daily observations. Percentage of VaR exceptions. LRuc is the unconditional coverage test. BTC is the back-testing criterion. LRind is the statistic for the serial independence. LRcc is the conditional coverage test. DQT is the Dynamic Quantile test. *, +, ~, #, ^ denote the rejection of the VaR estimate is accurate. The shaded cells indicate that the null hypothesis that the VaR estimate is accurate is not rejected by any test.

Table 5(b). Historical Simulation

	S&P		Dow Jones		Nikkei		Hang Seng		IBEX-35		CAC-40		DAX		FTSE-100	
	5%	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**	**1%**
	Stable period															
N=1250	**0.2%**	**0.0%**	**1.4%**	**0.0%**	**1.8%**	**0.4%**	**1.0%**	**0.0%**	**0.2%**	**0.0%**	**0.2%**	**0.0%**	**0.0%**	**0.0%**	**0.2%**	**0.0%**
Lruc	18.654 *	--	8.252 *	--	5.856 *	0.970	10.564 *	--	18.868 *	--	19.211 *	--	--	--	18.74 *	--
BTC	-4.935 +	-2.252 +	-3.707 +	-2.252 +	-3.213 +	-1.317	-4.073 +	-2.236 +	-4.962 +	-2.263 +	-5.004 +	-2.281 +	-5.196 +	-2.276 +	-4.946 +	-2.256 +
Lrind	--	--	--	--	0.910	--	--	--	--	--	--	--	--	--	--	--
LRcc	--	--	--	--	6.766 #	--	--	--	--	--	--	--	--	--	--	--
DQT	0.208	0 ^	2.419 ^	0 ^	3.712 ^	0.108	6.757 ^	0 ^	0.086	0 ^	0.286	0 ^	0 ^	0 ^	0 ^	0 ^
N=500	**1.4%**	**0.4%**	**5.4%**	**2.2%**	**3.5%**	**0.8%**	**3.0%**	**0.4%**	**1.8%**	**0.2%**	**2.5%**	**0.0%**	**2.5%**	**0.0%**	**2.2%**	**0.2%**
Lruc	8.252 *	1.032	0.064	2.332	1.170	0.077	2.031	0.996	6.345 *	2.139	3.5	--	3.455	--	4.595 *	2.118
BTC	-3.707 +	-1.355	0.389	2.682 +	-1.555	-0.409	-2.011 +	-1.333	-3.332 +	-1.817	-2.578 +	-2.281 +	-2.563 +	-2.276 +	-2.902 +	-1.809
Lrind	--	--	1.542	0.625	1.007	2.357	--	--	0.934	--	1.888	--	1.882	--	0.626	--
LRcc	--	--	1.606	2.957	2.177	2.434	--	--	7.279 #	--	5.388	--	5.337	--	5.221	--
DQT	1.758	0.191	4.909 ^	3.727 ^	6.429 ^	12.951 ^	2.175 ^	26.665 ^	1.974	0.055	3.119 ^	0 ^	3.13 ^	0 ^	2.083	0.096
N=250	**2.8%**	**1.0%**	**5.6%**	**1.4%**	**4.5%**	**1.0%**	**3.4%**	**0.6%**	**2.8%**	**0.2%**	**4.3%**	**0.2%**	**4.3%**	**0.2%**	**3.4%**	**0.6%**
Lruc	2.653	0.000	0.148	0.305	0.121	0.001	1.240	0.392	2.754	2.139	0.262	2.196	0.249	2.182	1.371	0.424
BTC	-2.273 +	-0.009	0.594	0.888	-0.518	0.045	-1.598	-0.881	-2.313 +	-1.817	-0.758	-1.838	-0.739	-1.833	-1.676	-0.913
Lrind	0.312	--	3.865 ~	--	4.286 ~	1.930	0.115	--	0.316	--	0.437	--	0.433	--	1.041	--
LRcc	2.965	--	4.013	--	4.407	1.931	1.356	--	3.07	--	0.699	--	0.682	--	2.412	--
DQT	0.828	0.691	2.932 ^	1.836	9.045 ^	5.819 ^	1.853	9.984 ^	0.836	0.073	1.535	0.229	1.575	0.215	1.744	16.662 ^
N=125	**4.0%**	**1.0%**	**5.6%**	**0.6%**	**4.5%**	**0.8%**	**4.2%**	**1.0%**	**3.9%**	**0.2%**	**4.3%**	**0.2%**	**3.7%**	**0.4%**	**4.0%**	**1.2%**
Lruc	0.508	0.000	0.148	0.417	0.121	0.077	0.273	0.000	0.555	2.139	0.262	2.196	0.863	1.091	0.526	0.076
BTC	-1.044	-0.009	0.594	-0.906	-0.518	-0.409	-0.773	0.023	-1.09	-1.817	-0.758	-1.838	-1.347	-1.389	-1.063	0.43
Lrind	0.023	--	5.472 ~	--	1.324	2.357	0.497	--	3.349	--	1.416	--	0.77	--	0.624	--
LRcc	0.530	--	5.620	--	1.445	2.434	0.770	--	3.904	--	1.678	--	1.632	--	1.15	--
DQT	1.24	1.438	4.731 ^	0.717	2.952 ^	11.915 ^	1.258	3.341 ^	3.99 ^	0.09	1.842	0.437	1.107	0.493	1.383	3.574 ^

Note: We consider different sizes of samples: N= 1250, 500, 250 and 125 daily observations. Percentage of VaR exceptions. LRuc is the unconditional coverage test. BTC is the back-testing criterion. LRind is the statistic for the serial independence. LRcc is the conditional coverage test. DQT is the Dynamic Quantile test. *, +, ~, #, ^ denote the rejection of the VaR estimate is accurate. The shaded cells indicate that the null hypothesis that the VaR estimate is accurate is not rejected by any test.

Table 6. Magnitude of the losses experienced: High volatility

	Extreme theory value		Parametric method		Friedman	Wilcoxon		
	(1) EGARCH	(2) T-GARCH	(3) EGARCH	(4) T-EGARCH		(4) vs. (1)	(4) vs. (2)	(4) vs. (3)
S&P VaR(1%)								
Average	0,0005	0,0005	0,0012	**0,0003**	35,91*	-2,67*	-2,67*	-3,18*
					(0,00)	(0,01)	(0,01)	(0,00)
S&P VaR(5%)								
Average	0,0046	0,0046	0,0050	**0,0033**	59,54*	-4,62*	-4,62*	-4,78*
					(0,00)	(0,00)	(0,00)	(0,00)
Dow Jones VaR(1%)								
Average	0,0028	0,0037	0,0055	**0,0019**	36,62*	-2,20*	-3,30*	-3,52*
					(0,00)	(0,03)	(0,00)	(0,00)
Dow Jones VaR(5%)								
Average	0,0185	0,0201	0,0192	**0,0141**	75,41*	-4,92*	-5,91*	-5,91*
					(0,00)	(0,00)	(0,00)	(0,00)
Nikkei VaR(1%)								
Average	0,0003	**0,0003**	0,0006	0,0006	0,60	-0,45	-0,40	-0,40
					(0,90)	(0,65)	(0,69)	(0,69)
Nikkei VaR(5%)								
Average	0,0050	0,0048	0,0043	**0,0040**	4,79	-0,69	-0,60	-2,50*
					(0,19)	(0,49)	(0,55)	(0,01)
Hang Seng VaR(1%)								
Average	0,0025	0,0025	0,0034	**0,0016**	5,40	-1,34	-1,34	-1,34
					(0,14)	(0,18)	(0,18)	(0,18)
Hang Seng VaR(5%)								
Average	0,0078	0,0078	0,0073	**0,0056**	37,11*	-4,01*	-3,82*	-3,72*
					(0,00)	(0,00)	(0,00)	(0,00)
IBEX-35 VaR(1%)								
Average	0,0001	0,0001	0,0004	**0,0000**	22,82*	-0,53	-1,60	-2,67*
					(0,00)	(0,59)	(0,11)	(0,01)
IBEX-35 VaR(5%)								
Average	0,0053	0,0050	0,0048	**0,0028**	49,00*	-4,00*	-4,70*	-4,70*
					(0,00)	(0,00)	(0,00)	(0,00)
CAC-40 VaR(1%)								
Average	0,0022	0,0021	0,0027	**0,0021**	12,79*	-1,34	-0,45	-2,02*
					(0,01)	(0,18)	(0,65)	(0,04)
CAC-40 VaR(5%)								
Average	0,0071	0,0070	0,0076	**0,0064**	76,81*	-4,54*	-4,62*	-4,70*
					(0,00)	(0,00)	(0,00)	(0,00)
DAX VaR(1%)								
Average	0,0001	0,0001	0,0002	**0,0000**	5,25	-1,00	-1,00	-1,34
					(0,15)	(0,32)	(0,32)	(0,18)
DAX VaR(5%)								
Average	0,0050	0,0044	0,0048	**0,0026**	98,35*	-5,84*	-5,65*	-5,65*
					(0,00)	(0,00)	(0,00)	(0,00)
FTSE-100 VaR(1%)								
Average	0,0001	0,0001	0,0002	**0,0001**	15,55*	-1,34	-1,34	-2,20*
					(0,00)	(0,18)	(0,18)	(0,03)
FTSE-100 VaR(5%)								
Average	0,0039	0,0036	0,0040	**0,0029**	82,33*	-5,23*	-4,93*	-5,23*
					(0,00)	(0,00)	(0,00)	(0,00)

Note: The first four columns report the Average of the loss function of each VaR model in the volatility period. The average was multiplied by 1000. Boldface figures denote the minimum value for the average of the loss function for each index. Friedman denotes Friedman test statistic. Wilcoxon denotes the Wilcoxon test statistic for making a comparison between Parametric T-EGARCH model (4) and each of the other VaR models. For VaR (1%) Nikkei we make a comparison between ETV T-EGACH model (2) and (1), (3) and (4), respectively. * indicates significance of at least 10%. p-value is in parentheses.

Table 7. Magnitude of the losses experienced: Low volatility

	Extreme theory value		Parametric method		Friedman	Wilcoxon		
	(1) EGARCH	(2) T-GARCH	(3) EGARCH	(4) T-EGARCH		(4) vs. (1)	(4) vs. (2)	(4) vs. (3)
S&P VaR(1%)								
Average	0,00001	0,00001	0,00001	**0,00000**	2,20	-1,00	-1,00	-1,34
					(0,53)	(0,32)	(0,32)	(0,18)
S&P VaR(5%)								
Average	0,00028	0,00028	0,00024	**0,00017**	48,26*	-4,01*	-4,01*	-3,29*
					(0,00)	(0,00)	(0,00)	(0,00)
Dow Jones VaR(1%)								
Average	0,00045	0,00047	0,00075	**0,00027**	21,17*	-2,20*	-2,20*	-2,52*
					(0,00)	(0,03)	(0,03)	(0,01)
Dow Jones VaR(5%)								
Average	0,00223	0,00229	0,00232	**0,00181**	49,07*	-4,20*	-4,20*	-4,20*
					(0,00)	(0,00)	(0,00)	(0,00)
Nikkei VaR(1%)								
Average	0,00079	0,00091	0,00084	**0,00032**	8,40*	-1,83*	-1,83*	-1,83*
					(0,04)	(0,07)	(0,07)	(0,07)
Nikkei VaR(5%)								
Average	0,00341	0,00368	0,00291	**0,00239**	44,76*	-3,52*	-3,82*	-3,30*
					(0,00)	(0,00)	(0,00)	(0,00)
Hang Seng VaR(1%)								
Average	0,00009	0,00010	0,00015	**0,00003**	9,52*	-1,83*	-1,83*	-2,02*
					(0,02)	(0,07)	(0,07)	(0,04)
Hang Seng VaR(5%)								
Average	0,00154	0,00161	0,00115	**0,00064**	59,94*	-4,20*	-4,37*	-3,92*
					(0,00)	(0,00)	(0,00)	(0,00)
IBEX-35 VaR(1%)								
Average	0,00005	0,00008	0,00010	**0,00004**	9,00*	-1,60	-1,60	-1,60
					(0,03)	(0,11)	(0,11)	(0,11)
IBEX-35 VaR(5%)								
Average	0,00068	0,00085	0,00064	**0,00056**	29,02*	-2,12*	-3,62*	-2,28*
					(0,00)	(0,03)	(0,00)	(0,02)
CAC-40 VaR(1%)								
Average	0,00004	0,00004	0,00009	**0,00004**	13,96*	-1,83*	-1,83*	-2,02*
					(0,00)	(0,07)	(0,07)	(0,04)
CAC-40 VaR(5%)								
Average	0,00101	0,00103	0,00105	**0,00088**	40,02*	-3,36*	-3,73*	-3,92*
					(0,00)	(0,00)	(0,00)	(0,00)
DAX VaR(1%)								
Average	0,00015	0,00019	0,00021	**0,00013**	12,10*	-0,13	-1,21	-2,37*
					(0,01)	(0,89)	(0,22)	(0,02)
DAX VaR(5%)								
Average	0,00143	0,00156	0,00142	**0,00125**	42,67*	-2,40*	-4,08*	-3,98*
					(0,00)	(0,02)	(0,00)	(0,00)
FTSE-100 VaR(1%)								
Average	**0,00002**	0,00002	0,00006	0,00003	16,15*	-1,83*	-2,20*	-1,83*
					(0,00)	(0,07)	(0,03)	(0,07)
FTSE-100 VaR(5%)								
Average	0,00058	0,00059	0,00060	**0,00053**	27,06*	-2,24*	-2,95*	-4,01*
					(0,00)	(0,03)	(0,00)	(0,00)

Note: The first four columns report the Average of the loss function of each VaR model in the stable period. The average was multiplied by 1000. Boldface figures denote the minimum value for the average of the loss function for each index. Friedman denotes Friedman test statistic. Wilcoxon denotes the Wilcoxon test statistic for making a comparison between Parametric T-EGARCH model (4) and each of the other VaR models. For VaR (1%) FTSE-100 we make a comparison between ETV EGACH model (1) and (2), (3) and (4), respectively. * indicates significance of at least 10%. p-value is in parentheses.

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