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Value-at-Risk for South-East Asian Stock Markets: Stochastic Volatility vs. GARCH

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Academic Editor: name

Version March 12, 2018 submitted to J. Risk Financial Manag.; Typeset by L^AT_EX using class file mdpi.cls

Abstract: This study compares the performance of several methods to calculate the Value-at-Risk of the six main ASEAN stock markets. We use filtered historical simulations, GARCH models, and stochastic volatility models. The out-of-sample performance is analyzed by various back testing procedures. We find that simpler models fail to produce sufficient VaR forecasts which appears to stem from several econometric properties of the return distributions. With SV models, we obtain better VaR forecasts compared to GARCH. The quality varies over forecasting horizons and across markets. This indicates that despite a regional proximity and homogeneity of the markets, index volatilities are driven by different factors.

Keywords: ASEAN; GARCH; Stochastic Volatility; Value-at-Risk

JEL: C58, F37, G15, G17

1 Introduction

The members of the Association of Southeast Asian Nations (ASEAN)¹ already produce 3.43% of the world wide Gross Domestic Product (GDP) in 2016 and even the economically smaller countries such as Vietnam are on the rise. The ASEAN-6² have an annual GDP growth from 2016 to 2017 of 4.91% and share 4.48% of the world's average annual GDP growth of 3.6%.³

However, the crisis of Asian markets in 1997 shows that investors have to accept other risks than those in industrialized and developed western economies. The Asian crisis is characterized by an unparalleled contagion throughout the markets and extreme market and currency movements. While this crisis has almost only regional macroeconomic effects, consequences and lessons from it are drawn globally. Another example for very high contagion in these markets are disruptions in the wake of the global financial crisis beginning in 2007, as the ASEAN region does not offer diversification potential.

During times of crises as well as during more moderate times of daily business, investors and portfolio managers face the challenge to properly estimate and model dispersion in market

¹ The ASEAN consists of ten countries: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam.

² ASEAN-6 are the six biggest contributor to GDP of the ASEAN region, i.e. Indonesia, Thailand, Philippines, Singapore, Malaysia, and Vietnam.

³ Own calculations based on data.worldbank.org and www.imf.org.

prices, formalized in its volatility or variance. Depending on the trading position, financial risk has to be determined for the long and short position. While the long trading position (buying an asset) is concerned with falling prices or negative returns, the short trading position (short-selling an asset) faces rising prices or positive returns [1]. This is of particular importance if asymmetric distributions, such as the Skewed Student's- t distribution, are found to provide a better resemblance of the empirical price return distribution than symmetric distributions like the Normal or Student's- t distribution. In this work, we use the Value-at-Risk (VaR) as measure for financial risk which is determined by the volatility of an investment. Albeit the fact that VaR has been replaced by Expected Shortfall as the main tool to determine the minimum capital requirements for banks under the Basel framework, VaR is still in place for back testing the internally used risk models [2]. Here, we incorporate two competing classes of volatility models. Within the framework of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models [3,4], we model volatility conditional on its past. This allows to include volatility clusters with periods of high and low market movements. In the next step, the Asymmetric Power ARCH [5] is applied to account to asymmetric news impact on volatility. Another so-called stylized fact is the long lasting dependence of shocks in a time series known as long memory. The Fractionally Integrated GARCH [FIGARCH 6] model is able to depict this pattern. The Fractionally Integrated Asymmetric Power ARCH (FIAPARCH) of Tse [7] combines both long memory and asymmetry. The second class of models are stochastic volatility (SV) models introduced in Taylor [8]. We use both classes to forecast the volatility over specific horizons based on estimates of a training window. With these variance forecasts, we then predict the VaR. These VaR predictions are evaluated and compared over different markets against standard approach such as the non-parametric Historical Simulation (HS) approach.

In this work, we focus on six major ASEAN stock market indices. Given the regional proximity and general similarity of these markets, we aim to understand if this causes comparable variance properties. This would imply that methods of modeling and forecasting volatility as well as the VaR yield comparable performances across the markets and that these markets could be grouped. While there is a plethora of literature on variance modeling for commodities, stock markets, and exchange rates of developed countries, academic advances on Asian stock indices and their comparison is relatively sparse. Walther [9] identifies a sufficient performance of GARCH with a symmetric Student's- t distribution as well as FIAPARCH with a skewed Student's- t distribution in terms of variance and VaR forecasting for Vietnamese stock indices. Brooks and Persaud [10] show that asymmetric approaches work well to forecast the VaR for the Singapore and Thailand equity indices. So and Yu [11] use different GARCH models to estimate the VaR in 12 different stock markets including Indonesia, Malaysia, Thailand, and Singapore. Su and Knowles [12] perform a VaR analysis of Mixture Normal models on stock indices including Malaysia, Singapore, and Thailand. Lastly, McMillan and Kambouroudis [13] and Sharma *et al.* [14] provide large studies of different equity indices (including many ASEAN countries) for VaR forecasting.

The remainder of the paper is structured as follows: Section 2 presents methods of estimation of the volatility and forecasting and assessing the VaR. Section 3 provides the data basis. Section 4 presents the results and their discussion. Section 5 concludes.

2 Methodology

2.1 Estimating Volatility

We incorporate two alternatives to calculate the daily volatility. The first model belongs to the family of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models originating from Engle [3]. Within the GARCH framework, the process for returns r_t is formulated as

$$\begin{aligned} r_t &= \mu + \varepsilon_t, \\ \varepsilon_t &= \sqrt{h_t} z_t, \end{aligned}$$

where μ denotes the mean, the conditional variance is defined as $h_t = \mathbb{V}(r_t | \mathcal{F}_{t-1})$, and the random variable z_t follows a Skewed Student's- t distribution⁴ with $z_t \sim \text{SkSt}_{\nu, \zeta}(0, 1)$ i.i.d. for all $t = 1, \dots, n$ [15]. Here, \mathcal{F}_{t-1} is a sigma algebra containing all past information of returns and conditional volatilities up to time $t - 1$.

The distributional parameter for the Skewed Student's- t distribution, the degrees-of-freedom ν and the skewness ζ , are estimated along with the model parameters. For the conditional variance h_t , we consider the GARCH(1,1) specification of Bollerslev [4] which reads:

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}. \quad (1)$$

In order to cope with the well-known leverage effect, we implement the Asymmetric Power ARCH [APARCH, 5] which is defined as:

$$h_t^\delta = \omega + \alpha (|\varepsilon_{t-1}| - \gamma \varepsilon_{t-1})^\delta + \beta h_{t-1}^\delta, \quad (2)$$

where $\gamma \in (-1, 1)$ refers to the leverage parameter indicating whether negative or positive shocks have a larger impact on the daily volatility. For example, an estimated $\gamma > 0$ reveals that negative residuals increase the conditional volatility more than their positive equivalents which is of particular interest for shocks.

We include the Fractionally Integrated GARCH [FIGARCH, 16] to cover the long memory effect. The standard FIGARCH(1, d ,1) reads:

$$\begin{aligned} h_t &= \frac{\omega}{1 - \beta} + \left(1 - \frac{(1 - \phi L)(1 - L)^d}{1 - \beta L} \right) \varepsilon_t^2 \\ &= \frac{\omega}{1 - \beta} + \sum_{i=1}^{\infty} \lambda_i \varepsilon_{t-i}^2, \end{aligned} \quad (3)$$

where

$$\begin{aligned} \lambda_1 &= \phi - \beta - d, \\ \lambda_i &= \beta \lambda_{i-1} + \left(\frac{i-1-d}{i} - \phi_1 \right) \left(\frac{(i-2-d)!}{i!(1-d)!} \right), \end{aligned} \quad (4)$$

with the long memory parameter d and the lag operator L . To combine the leverage and the long memory effect Tse [7] proposed the Fractionally Integrated APARCH (FIAPARCH):

$$\begin{aligned} h_t^\delta &= \frac{\omega}{1 - \beta_1} + \left(1 - \frac{(1 - \phi_1 L)(1 - L)^d}{1 - \beta_1 L} \right) (|\varepsilon_t| - \gamma \varepsilon_t)^\delta, \\ &= \frac{\omega}{1 - \beta_1} + \sum_{i=1}^{\infty} \lambda_i (|\varepsilon_{t-i}| - \gamma \varepsilon_{t-i})^\delta. \end{aligned} \quad (5)$$

⁴ The assumption of Skewed Student's- t distributed errors is justified in the Data section.

Note that the ARCH(∞) representation in Eq. 3 and 5 is carried out using the fast fractional differencing method of Klein and Walther [17] with truncation lag 5000. All GARCH-type models introduced above are estimated with maximum-likelihood estimations (MLE), ensuring that non-negativity and stationarity conditions, if applicable, hold for each model. All parameter estimates and robust standard errors of Bollerslev and Wooldridge [18] are available upon request.

As an alternative to the GARCH framework, we also consider the stochastic volatility framework. Stochastic volatility models belong to the family of state-space models [19, Chapter 4]. The standard stochastic volatility (SV) model was introduced by Taylor [8] as

$$r_t = \mu + \sqrt{h_t} z_t \quad (6)$$

$$\log h_t = \alpha + \beta \log h_{t-1} + \sigma \eta_t \quad (7)$$

$$\begin{pmatrix} z_t \\ \eta_t \end{pmatrix} \sim \mathcal{N} \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \right) \text{ i.i.d. } t = 1, \dots, n. \quad (8)$$

The SV model contains two noise processes, $\{z_t\}_t$ and $\{\eta_t\}_t$, respectively accounting for the return shocks and the volatility shocks. In the SV model above $\{z_t\}_t$ and $\{\eta_t\}_t$ are independent.

Harvey and Shephard [20] introduce a more general setting where the noise processes $\{z_t\}_t$ and $\{\eta_t\}_t$ are correlated as

$$\begin{pmatrix} z_t \\ \eta_t \end{pmatrix} \sim \mathcal{N} \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right),$$

instead of being independent as in Eq. (8). The correlation coefficient ρ accounts for the leverage effect, defined as the negative correlation between shocks on return and volatility (i.e. $\rho < 0$). This model is called asymmetric SV model or SV-leverage (SV-L) model.

We consider a third stochastic volatility model where the return shocks $\{z_t\}_t$ follow Student's t -distribution with ν degrees of freedom. It allows more extreme observations than with Gaussian return shocks as the t -distribution has heavier tails. The volatility shocks $\{\eta_t\}_t$ follow the standard Gaussian distribution. In this model z_t and η_t are independent. It is referred to as the SV- t model.

We end up with three types of stochastic volatility models: SV model (Gaussian and independent shocks), SV-L model (Gaussian and correlated shocks), SV- t model (t -distributed return shock, Gaussian volatility shock, independent shocks). In the three models, the parameters are estimated by Bayesian inference using the Monte Carlo Monte Chain (MCMC) sampling algorithms from Chan and Grant [21].

Lastly, we consider the RiskMetrics approach, the historical simulation, as well as the semi-parametric filtered historical simulation, which we explain in detail in the next subsection.

2.2 Value-at-Risk Forecasting and Back Testing

One of the most important financial risk measures is the Value-at-Risk. The VaR is usually defined as a specific loss which is not exceeded for a given probability (e.g. $(1 - a)\%$).

When using GARCH models, the k -days ahead VaR forecast is simply derived by a k -steps forecast of the variance based on the estimated parameters at time T , $\hat{h}_{T+k} = \mathbb{E}(h_{T+k} | \mathcal{F}_T)$, which is then applied in the general VaR calculation scheme, yielding

$$\widehat{\text{VaR}}_{T+k} = \hat{\mu}_{T+k} + \sqrt{\hat{h}_{T+k}} Q_a(\hat{\nu}, \hat{\xi}),$$

where $\hat{\mu}_{T+k}$ is the estimated mean, \hat{h}_{T+k} is the estimated conditional variance, and $\hat{\nu}$ and $\hat{\xi}$ are the estimated distributional parameters from the training set $1, \dots, T$. $Q_a(\nu, \xi)$ denotes the a quantile function of the Skewed Student's- t distribution with degrees-of-freedom parameter ν and skewness ξ . Note that we only forecast the variance. Hence, in the VaR forecast, the quantile function depends

on the estimated insample parameters, which are not forecasted separately. The calculation of the forecasted variance depends on the specific GARCH model. In this sense, there exists a closed form solution for the GARCH(1,1) k -days ahead forecast while for the APARCH, FIGARCH, and FIAPARCH, the forecasts are calculated iteratively. For the RiskMetrics approach [22]—also known as Exponentially Weighted Moving Average (EWMA)—we use the standard GARCH-like case with preset parameters $\omega = 0.00$, $\alpha = 0.06$, and $\beta = 0.94$ for Eq. 1. Since the RiskMetrics model is not stationary, we use the estimate \hat{h}_T for all k -days ahead forecasts.⁵

With stochastic volatility (SV, SV-L, SV-t) models, we approximate non-parametrically the conditional distribution of the return at forecast horizon given the observed returns, i.e. the conditional distribution of r_{T+k} given r_1, \dots, r_T . We use particle filtering, a sequential Monte Carlo algorithm for state-space models [19, Chapter 7]. The particle filter approximates the conditional distribution of the volatility h_T given the returns r_1, \dots, r_T in the form of a sample of so-called "particles". This sample is propagated k times according to the volatility dynamics (Eq. (7)). Note that the dynamics equation is common to the three types of stochastic volatility models. Then, from the volatility sample at time $T + k$, a return sample is generated according to the return model Eq. (6). We compute the VaR by taking the empirical quantiles of this return sample.

Lastly, we derive VaR forecast non-parametrically by the Historical Simulation (HS) and the semi-parametric Filtered Historical Simulation (FHS). The former method takes the past 250 returns as possible scenarios of a future return distribution and the VaR is calculated from the empirical a -quantile of the past returns, i.e.

$$\widehat{\text{VaR}}_{T+k} = Q_a(\{r_t\}_{t=T-249}^T).$$

For the FHS, we follow Barone-Adesi *et al.* [24]. The technique combines the aforementioned GARCH and HS. To calculate the VaR, we estimate the parameters for a GARCH model with Skewed Student's- t innovations over the whole insample. From the parameters, we derive a k -days ahead volatility forecast. Moreover, we calculate the empirical a -quantile from the most recent 250 standardized and centered GARCH residuals. The volatility forecast is then multiplied with the empirical quantile to estimate the VaR:

$$\widehat{\text{VaR}}_{T+k} = \hat{\mu}_{T+k} + \sqrt{\hat{h}_{T+k}} Q_a(\{\tilde{z}_t\}_{t=T-249}^T),$$

where

$$\tilde{z}_t = \frac{r_t - \hat{\mu}}{\sqrt{\hat{h}_t}}$$

is the standardized and centered GARCH residual.

To evaluate the quality of the VaR forecasts for the different models and classes, we use four different VaR tests: the regulatory traffic light test, the conditional coverage test, the multi-level unconditional coverage test, and the loss function based comparison. In what follows, we refer to VaR violations or exceptions for the cases where $r_{T+k} < \widehat{\text{VaR}}_{T+k}$ for the long trading position and where $r_{T+k} > \widehat{\text{VaR}}_{T+k}$ for the short trading position.

The Basel traffic light back test [2] sorts VaR test results in three different zones. The test uses the 1-day ahead $a = 1\%$ VaR for the last 250 trading days. A model is considered in the *green zone*, if four or less VaR violations occurred in that period. The *yellow zone* includes models yielding between five and nine exceptions. Lastly, the *red zone* covers all models with more than nine violations. The idea behind this color scheme is that the yellow zone is a buffer area for models that violate the VaR

⁵ An outline of forecasting conditional variance can be found in Klein and Walther [23] and [9] for example.

too often due to "bad luck" (type I error). Thus, banks only have to adjust their calculated minimum capital requirements by a fixed factor. However, models in the red zone are not allowed to be used, instead the standard approach of the Basel framework has to be employed. Here, we calculate the traffic light test on a rolling time frame over the whole out-of-sample period and report how many days each model appears in the green, the yellow, or the red zone, respectively. Doing so, we gain a regulatory perspective of the results of the VaR forecasts.

In order to account for possible clustering of VaR violations, we include the conditional coverage test proposed by Christoffersen [25]. The test combines the unconditional coverage test with a test for the independence of VaR exceptions. Independence is assumed if the VaR violations do not follow a first order Markov chain. Thus, the test procedure penalizes models not only for an undesirable amount of violations, but also for not adjusting quickly after an exception occurred.

The multi-level coverage test of Pérignon and Smith [26] resembles a joint unconditional coverage test for three VaR levels at $\alpha = 1\%, 2.5\%$, and 5% . The test compares the actual coverage ratio (number of VaR violations to length of observation period) with the preferred one (i.e. the VaR level α) based on a likelihood ratio test. Hence, only the absolute number of VaR violations is important to that test and it penalizes too conservative models as well as too optimistic models.

Lastly, we incorporate a loss function based comparison. Here, we follow the idea of Angelidis and Degiannakis [27]. The authors suggest a two-stage approach: (1) all models are tested with a backtest such as the conditional coverage test. (2) For the models which pass this test, the following VaR loss function suggest by Lopez [28] is used:

$$L_{T+k} = \begin{cases} 1 + \left(r_{T+k} - \widehat{\text{VaR}}_{T+k}\right)^2, & \text{if } r_{T+k} < \widehat{\text{VaR}}_{T+k} \\ 0, & \text{if } r_{T+k} \geq \widehat{\text{VaR}}_{T+k}. \end{cases} \quad (9)$$

The results of the loss functions for each model is compared with the Superior Predictive Ability test by Hansen [29]. We deviate from this procedure using the Model Confidence Set [MCS, 30] in place of the Superior Predictive Ability test. The MCS yields a set of models of equally predictive ability. Thus, this procedure allows us to directly compare those models which pass the first-stage backtests.

3 Data

For our analysis of the main ASEAN financial markets, we include six country stock market indices. We choose the Indonesian Jakarta Stock Exchange Composite Index (JCI), the Kuala Lumpur Stock Exchange (KLSE) of Malaysia, the Philippines Stock Exchange PSEI Index (PCOMP), the Stock Exchange of Thailand (SET), the Singapore Strait's Time Index (STI), and the Vietnam Ho Chi Minh Stock Index (VNI). Hence, we exclude the smaller stock markets of Myanmar, Cambodia, Laos, and Brunei from our analysis. The data is retrieved from Bloomberg in USD denominations for the period from 07/01/2006 to 06/30/2017. The period is chosen such that we obtain an equal number of observations of around $n = 2700$ for all indices accounting for individual holidays. We note that the VNI has some zero volume trading days before our chosen period. We calculate the daily returns of the stock indices by logarithmic price differences. For the forecasting exercise, we use the in-sample data from 07/01/2006 to 06/30/2011. This leaves us with an out-of-sample period from 07/01/2011 to 06/30/2017 and six years of 1-, 5-, and 20-days ahead forecasts for each index.

Descriptive statistics, provided in Tab. 1, show evidence that the empirical distributions of the index returns are of leptokurtic shape, indicated by an increased excess kurtosis. The JCI has the highest kurtosis of 12.54 while the VNI features the lowest at 4.46. Moreover, all return series are skewed to the left; the series' distributions have large negative returns with a higher probability compared to their positive counterpart. In comparison to indices of developed countries and global benchmarks, the empirical moments are quite extreme for indices, in particular the

kurtosis, suggesting less diversification effects within each index. This highlights the relatively high risks associated with investing in these markets. In addition to the non-normal appearance of moments, we test for autocorrelation in the return series. The Ljung-Box (LB) test the ARCH test both reject the hypothesis of no autocorrelation in the returns. The Augmented Dickey-Fuller (ADF) test rejects the hypothesis of a unit root in the return series. Based on these results, we assume the underlying distribution for the GARCH framework as Skewed Student's-*t*. This distribution choice over alternatives such as the Normal or symmetric Student's-*t* distribution ensures that we cover heavy tails and skewness found in the series which impacts the parameter estimation and forecasting exercise. The series are depicted in Fig. 1.

Table 1. Descriptive statistics of the log-returns for the six ASEAN stock indices in the period 07/01/2006-06/30/2017. Rejection of the null-hypothesis is displayed with asteriks (* 1% level of significance).

	Obs.	Mean	Min.	Max.	Std. Dev.	Skewn.	Kurtosis	LB(12)	ARCH(12)	ADF
JCI	2674	0.0413	-16.3976	12.8918	1.5024	-0.5791	12.5428	58.6283*	414.1944*	-46.7885*
KLSE	2683	0.0493	-13.7896	9.5896	1.4425	-0.7345	10.2419	69.4031*	354.3988*	-45.7856*
PCOMP	2709	0.0152	-11.2295	5.7262	1.0244	-0.5489	10.5371	34.8944*	96.5796*	-46.7559*
SET	2687	0.0353	-16.0911	9.4139	1.3997	-0.9414	15.2982	41.0240*	308.1694*	-49.2268*
STI	2761	0.0158	-8.4502	9.1221	1.2931	-0.1834	8.5997	51.0448*	845.2581*	-49.7627*
VNI	2737	0.0027	-7.5612	4.9411	1.5211	-0.2330	4.4559	210.0781*	604.1086*	-40.7110*

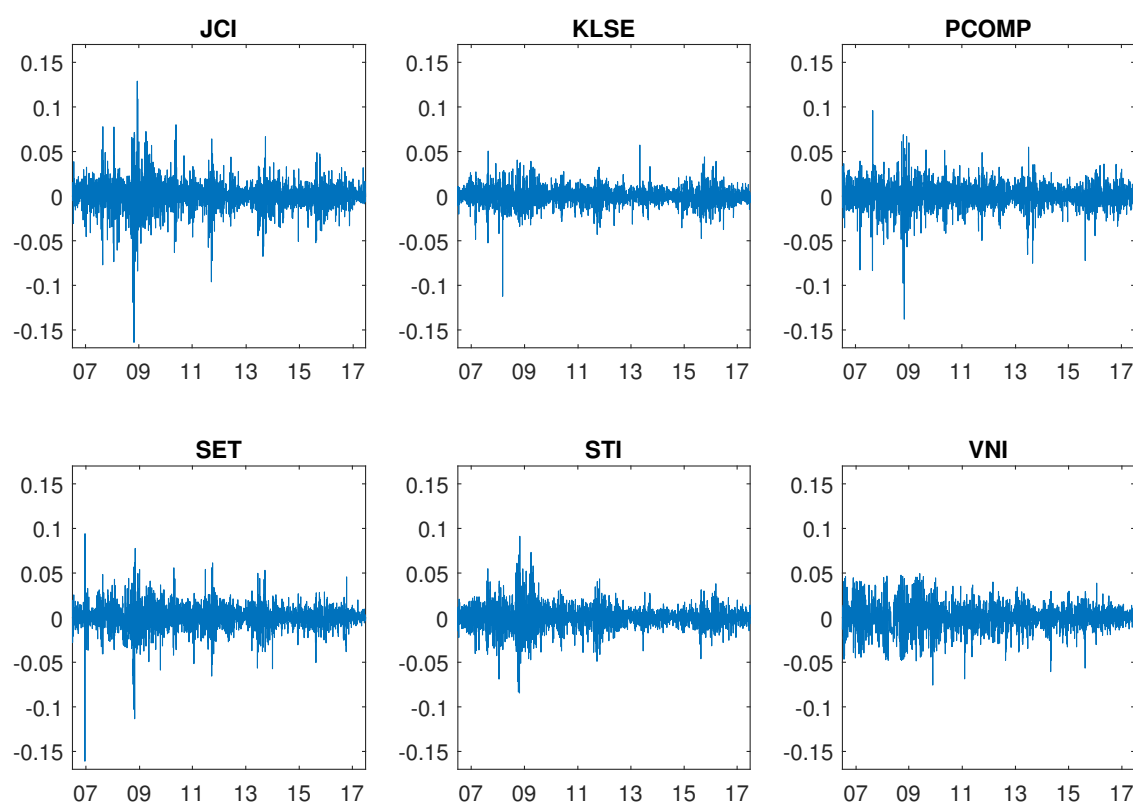


Figure 1. Log-returns for the period 07/01/2006-06/30/2017.

4 Results & discussion

In this section, we compare the VaR forecast results for the six ASEAN equity indices. Therefore, we first present the results for each index individually and compare the findings afterwards. For each model, we estimate 1-, 5-, and 20-days ahead predictions which correspond to forecasts a day, a week, and a month ahead. Note that we do not forecast the VaR for the whole period, but for a certain point in the future. The results are presented in Tab. 2-7.

We start our analysis with the results from the Indonesian JCI (Tab. 2). The traffic light test does not find any of the models to be in the red zone. Moreover, we see that the GARCH is only present in the green zone, i.e. it has never no more than four violations in the whole out-of-sample for the long and the short trading position. However, the GARCH model does not pass the conditional coverage test by Christoffersen [25] nor the multilevel Pérignon and Smith [26] test at any forecast horizon. There are a number of models which are able to depict the VaR at all quantiles under consideration for the 1-day ahead forecast on the long trading position: FHS, FIGARCH, SV-N, and SV-L, but only FIGARCH also shows the same ability on the short trading position. Its loss functions are satisfactory, but FIGARCH only belongs to the best performing models at the 2.5% quantile. Regarding higher forecast horizon it is only HS, which depicts good performance for all horizon on both trading sides with respect to the multilevel coverage test. It HS is not able to pass the conditional coverage test, may indicate that the model tends to build clustered violations, which is not covered by the multilevel coverage test.

The second equity index we analyze is the Malaysian KLSE (Tab. 3). Here, three models fail the regulatory traffic light test. While RiskMetrics has several days in the red zone of the long trading position, the HS and FHS models are included in the red zone for the short trading positions. Moreover, we observe some asymmetric behavior. RiskMetrics also completely fails to meet the criteria from coverage test for the long trading position. However, it passes all tests for the short trading position. Almost the same behavior is observed for FIGARCH, with only exception for the 2.5% VaR of the conditional coverage test of Christoffersen [25]. On the long trading position, APARCH archives good results especially for 1-day ahead predictions. All SV models pass the multilevel coverage test for the long trading position.

Next, we compare the results from the Philippine PCOMP index (Tab. 4). No model appears in the red zone of the traffic light test and thus, they could be used without being replaced by the regulator. Here, we find five complete failures of models regarding the two statistical coverage tests. Neither RiskMetrics for the long trading position, nor GARCH or any SV specification for the short trading position pass any of the tests. Also the two asymmetric GARCH models seem to have problems with the specific dynamics of the PCOMP index. Both APARCH and FIAPARCH perform very poorly with only a few passed tests. Generally, our model set does not include a clear candidate to be preferred in terms of VaR prediction performance. However, the HS and the FHS deliver the most promising results with respect to the multilevel test and the corresponding loss function results.

Table 5 presents the results from the VaR back tests for the SET, traded in Bangkok. From the traffic light test becomes apparent that RiskMetrics and FHS lead to several days in the red zone for the long trading position. The general results for SET is, that most models can cope with the long trading position to some extent, but complete fail to depict the dynamics on the short trading position. The results from HS suggest that it can be used for 1-day ahead predictions for the long trading position. Even though it is not rejected by the unconditional coverage tests, it has problems to avoid clustering of the VaR violations. This behavior is illustrated in Fig. 2. It shows the slow reaction on to VaR violations on the short trading position and the overall good coverage for 1% VaR forecasts. Additionally, SV-t shows somewhat good performance on the long trading position, which is reflected in the fact that it passes all multilevel tests and belongs to the set of the best models for 5- and 20-days ahead. For both trading positions however, only FIAPARCH and HS have good results with respect to the multilevel test at least.

Table 2. Value-at-Risk back test results for JCI returns.

Model	Traffic Light	1%					2.5%					5%					Pérignon and Smith [26]		
		1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days			
long trading position																			
EWMA/RiskMetrics	91 / 1120 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
Historical Simulation	755 / 456 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
Filtered Historical Simulation	1211 / 0 / 0	0.0740	—	0.0868	0.1526	—	—	0.2174	—	—	—	—	0.2996	0.3007	—	0.3053			
GARCH-SkSt	1211 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	0.2758	—	—	—			
APARCH-SkSt	1211 / 0 / 0	0.0828	—	—	—	—	—	—	—	—	—	—	0.2469	—	—	—			
FIGARCH-SkSt	758 / 453 / 0	0.1047	—	—	—	0.1526	—	—	—	—	—	—	0.3075	0.3007	—	0.3173			
FIAPARCH-SkSt	1173 / 38 / 0	0.0828	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
SV-N	653 / 558 / 0	0.1111	—	—	—	—	0.1813	0.2297	—	—	—	—	0.3130	0.2961	—	0.2695			
SV-t	362 / 849 / 0	—	—	—	—	—	0.1696	0.2312	—	—	—	—	0.3141	—	—	—			
SV-L	627 / 584 / 0	0.1141	—	—	—	—	0.1526	0.2205	0.2110	—	—	—	0.2914	0.2733	—	—			
short trading position																			
EWMA/RiskMetrics	847 / 364 / 0	0.1110	—	—	—	0.1655	0.1736	—	—	0.2126	0.2174	0.2174	0.2914	—	—	—			
Historical Simulation	961 / 250 / 0	0.0979	—	—	—	—	—	—	—	—	—	—	0.2891	0.2891	—	0.2926			
Filtered Historical Simulation	946 / 265 / 0	0.0907	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
GARCH-SkSt	1211 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
APARCH-SkSt	1019 / 192 / 0	0.0907	0.1047	0.0944	—	—	—	0.1434	—	—	—	—	—	0.2669	—	—			
FIGARCH-SkSt	926 / 285 / 0	0.1079	—	—	—	0.1716	—	—	—	0.2427	—	—	0.3162	—	—	—			
FIAPARCH-SkSt	1025 / 186 / 0	0.0907	0.0868	0.0828	—	—	—	—	—	—	—	—	—	—	—	—			
SV-N	1211 / 0 / 0	0.0740	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
SV-t	1211 / 0 / 0	0.0785	0.0868	—	—	—	—	—	—	—	—	—	—	—	—	—			
SV-L	1152 / 59 / 0	0.0785	0.0828	—	—	—	—	—	—	—	—	—	—	—	—	—			

Note: Numbers under the Basel traffic light test indicate the number of days in the green/yellow/red zone for a 250 rolling trading day window with 1-day ahead VaR forecasts at $\alpha = 1\%$. For the Christoffersen [25] test the 1-, 5-, and 20-days ahead forecasts results are reported for the $\alpha = 1\%$, 2.5%, and 5% VaR. If a specific test does not reject the null hypothesis, we present the corresponding VaR loss function result. — indicates that the null hypothesis is rejected at least at 10% level of significance. Bold faced loss functions represent the inclusion in the Model Confidence Set [30] with level of significant 10% and 10 000 bootstraps. The test by Pérignon and Smith [26] is reported in a similar manner, except for the fact that the three VaR levels (1%, 2.5%, and 5%) are tested jointly.

Table 3. Value-at-Risk back test results for KLSE returns.

Model	Traffic Light	Christoffersen [25]										Pérignon and Smith [26]		
		1%					2.5%					5%		
		1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days	20-days
long trading position														
EWMA/RiskMetrics	195 / 925 / 104	—	—	—	—	—	—	—	—	—	—	—	—	—
Historical Simulation	679 / 545 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—
Filtered Historical Simulation	569 / 655 / 0	0.1136	—	0.1074	—	—	—	—	—	—	—	—	—	—
GARCH-SkSt	974 / 250 / 0	0.0864	0.0939	0.0903	0.1542	0.1519	0.1474	0.2180	0.2101	0.2745	0.3016	0.2708	—	—
APARCH-SkSt	1034 / 190 / 0	0.0903	—	0.1009	0.1627	0.1519	—	0.2117	—	0.2818	0.2745	0.2842	—	—
FIGARCH-SkSt	523 / 701 / 0	—	—	—	—	—	—	—	—	0.3337	—	—	—	—
FIAPARCH-SkSt	1139 / 85 / 0	0.0864	0.1009	0.0782	0.1519	—	—	—	—	—	—	—	—	—
SV-N	468 / 756 / 0	—	—	0.1009	0.1786	—	—	0.2316	—	0.3159	0.3039	—	—	0.2695
SV-t	670 / 554 / 0	—	—	—	0.1767	—	—	0.2374	—	0.3181	0.3170	—	—	0.2794
SV-L	750 / 474 / 0	—	—	—	0.1767	0.1606	—	0.2286	—	0.3105	0.2994	—	—	0.2733
short trading position														
EWMA/RiskMetrics	890 / 334 / 0	0.1074	0.1106	0.1194	0.1497	0.1519	0.1668	0.2117	0.2117	0.2226	0.2806	0.2830	0.3027	—
Historical Simulation	792 / 353 / 79	0.1165	—	—	0.1648	—	—	—	—	—	0.3005	0.3072	—	—
Filtered Historical Simulation	735 / 402 / 87	—	0.1194	—	—	—	—	0.2444	—	—	—	0.3061	—	—
GARCH-SkSt	969 / 255 / 0	0.0940	0.0864	0.0864	—	—	—	—	—	—	—	—	—	—
APARCH-SkSt	1046 / 178 / 0	0.0940	0.0782	0.0824	—	—	—	—	—	—	—	—	—	—
FIGARCH-SkSt	974 / 250 / 0	0.0975	0.0975	0.1106	0.1648	0.1563	—	0.2241	0.2241	0.2286	0.2948	0.2902	0.3072	—
FIAPARCH-SkSt	1059 / 165 / 0	0.0824	—	—	—	—	—	—	—	—	—	—	—	—
SV-N	1046 / 178 / 0	0.0903	0.0824	—	—	—	—	—	—	—	—	—	—	—
SV-t	1059 / 165 / 0	0.0824	0.0782	—	—	—	—	—	—	—	—	—	—	—
SV-L	1216 / 8 / 0	0.0864	0.0737	—	—	—	—	—	—	—	—	—	—	—

Note: Numbers under the Basel traffic light test indicate the number of days in the green/yellow/red zone for a 250 rolling trading day window with 1-day ahead VaR forecasts at $\alpha = 1\%$. For the Christoffersen [25] test the 1-, 5-, and 20-days ahead forecasts results are reported for the $\alpha = 1\%$, 2.5%, and 5% VaR. If a specific test does not reject the null hypothesis, we present the corresponding VaR loss function result. — indicates that the null hypothesis is rejected at least at 10% level of significance. Bold faced loss functions represent the inclusion in the Model Confidence Set [30] with level of significant 10% and 10 000 bootstraps. The test by Pérignon and Smith [26] is reported in a similar manner, except for the fact that the three VaR levels (1%, 2.5%, and 5%) are tested jointly.

Table 4. Value-at-Risk back test results for PCOMP returns.

Model	Traffic Light	1%					2.5%					5%					Pérignon and Smith [26]		
		1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days			
long trading position																			
EWMA/RiskMetrics	216 / 996 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
Historical Simulation	968 / 244 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
Filtered Historical Simulation	1017 / 195 / 0	0.0906	—	—	—	—	0.1716	—	—	—	—	—	—	—	—	—			
GARCH-SkSt	1003 / 209 / 0	0.0785	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
APARCH-SkSt	1035 / 177 / 0	—	—	—	—	—	0.1360	—	—	0.2044	—	—	—	0.2550	—	—			
FIGARCH-SkSt	554 / 658 / 0	0.1199	—	—	—	—	0.1775	—	—	—	—	—	—	0.3289	0.3340	—			
FIAPARCH-SkSt	1043 / 169 / 0	0.0785	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
SV-N	661 / 551 / 0	0.1141	—	—	—	—	—	—	—	0.2384	—	—	—	0.3118	0.2890	—			
SV-t	767 / 445 / 0	0.1047	—	—	—	—	—	—	—	0.2326	—	—	—	0.3051	0.2914	—			
SV-L	916 / 296 / 0	0.0979	—	—	—	—	0.1433	—	—	0.2158	—	—	—	0.2769	0.2732	—			
short trading position																			
EWMA/RiskMetrics	983 / 229 / 0	0.1013	—	—	—	—	—	—	—	—	—	—	—	0.2769	—	—			
Historical Simulation	717 / 495 / 0	—	—	—	—	—	—	—	—	—	—	—	—	0.2960	0.3029	—			
Filtered Historical Simulation	613 / 599 / 0	0.1199	—	—	—	—	—	—	—	—	—	—	—	—	0.3161	—			
GARCH-SkSt	1212 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
APARCH-SkSt	1109 / 103 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
FIGARCH-SkSt	1009 / 203 / 0	0.0979	—	—	—	—	—	0.1696	—	—	—	—	—	0.3051	0.3073	—			
FIAPARCH-SkSt	1109 / 103 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
SV-N	1109 / 103 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
SV-t	1212 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			
SV-L	1109 / 103 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—			

Note: Numbers under the Basel traffic light test indicate the number of days in the green/yellow/red zone for a 250 rolling trading day window with 1-day ahead VaR forecasts at $\alpha = 1\%$. For the Christoffersen [25] test the 1-, 5-, and 20-days ahead forecasts results are reported for the $\alpha = 1\%$, 2.5%, and 5% VaR. If a specific test does not reject the null hypothesis, we present the corresponding VaR loss function result. — indicates that the null hypothesis is rejected at least at 10% level of significance. Bold faced loss functions represent the inclusion in the Model Confidence Set [30] with level of significant 10% and 10 000 bootstraps. The test by Pérignon and Smith [26] is reported in a similar manner, except for the fact that the three VaR levels (1%, 2.5%, and 5%) are tested jointly.

Table 5. Value-at-Risk back test results for SET returns.

Model	Traffic Light	1%			Christoffersen [25] 2.5%			5%			Pérignon and Smith [26]		
		1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days
long trading position													
EWMA/RiskMetrics	387 / 738 / 95	—	—	—	—	—	—	0.2363	—	—	—	—	—
Historical Simulation	699 / 521 / 0	0.1167	—	—	0.1630	—	—	0.2199	—	0.2260	0.2975	0.3032	0.3032
Filtered Historical Simulation	814 / 345 / 61	0.1167	—	—	0.1650	—	—	0.2290	—	—	0.3054	—	—
GARCH-SkSt	1009 / 211 / 0	0.0825	—	—	—	—	—	—	—	—	—	—	—
APARCH-SkSt	978 / 242 / 0	0.0904	0.0976	0.0865	0.1521	0.1453	—	0.2104	—	—	0.2749	—	—
FIGARCH-SkSt	613 / 607 / 0	0.1224	—	—	—	—	—	—	—	0.2245	—	—	—
FIAPARCH-SkSt	1159 / 61 / 0	0.0825	0.1076	0.0941	0.1381	0.1429	—	0.2071	—	—	0.2622	—	0.2557
SV-N	620 / 600 / 0	0.1107	—	0.0904	0.1808	—	—	0.2391	—	—	0.3196	—	—
SV-t	732 / 488 / 0	0.1107	0.1076	0.0904	0.1826	0.1566	—	0.2475	—	—	0.3269	0.2929	0.2583
SV-L	1015 / 205 / 0	0.0865	0.1076	0.0865	0.1608	0.1587	—	0.2245	—	—	0.2894	0.2858	—
short trading position													
EWMA/RiskMetrics	629 / 591 / 0	—	—	—	—	—	—	—	—	—	—	—	—
Historical Simulation	760 / 460 / 0	—	—	—	—	—	—	—	—	—	0.2798	0.2798	0.2858
Filtered Historical Simulation	759 / 461 / 0	—	—	—	—	—	—	—	—	—	0.3196	0.2648	—
GARCH-SkSt	1018 / 202 / 0	—	—	—	—	—	—	—	—	—	—	—	—
APARCH-SkSt	1220 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—
FIGARCH-SkSt	1043 / 177 / 0	—	—	—	—	—	—	—	—	—	0.2774	0.2774	—
FIAPARCH-SkSt	990 / 230 / 0	—	—	—	—	—	—	—	—	—	—	—	—
SV-N	1220 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—
SV-t	1146 / 74 / 0	—	—	—	—	—	—	—	—	—	—	—	—
SV-L	1220 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—

Note: Numbers under the Basel traffic light test indicate the number of days in the green/yellow/red zone for a 250 rolling trading day window with 1-day ahead VaR forecasts at $\alpha = 1\%$. For the Christoffersen [25] test the 1-, 5-, and 20-days ahead forecasts results are reported for the $\alpha = 1\%$, 2.5%, and 5% VaR. If a specific test does not reject the null hypothesis, we present the corresponding VaR loss function result. — indicates that the null hypothesis is rejected at least at 10% level of significance. Bold faced loss functions represent the inclusion in the Model Confidence Set [30] with level of significant 10% and 10 000 bootstraps. The test by Pérignon and Smith [26] is reported in a similar manner, except for the fact that the three VaR levels (1%, 2.5%, and 5%) are tested jointly.

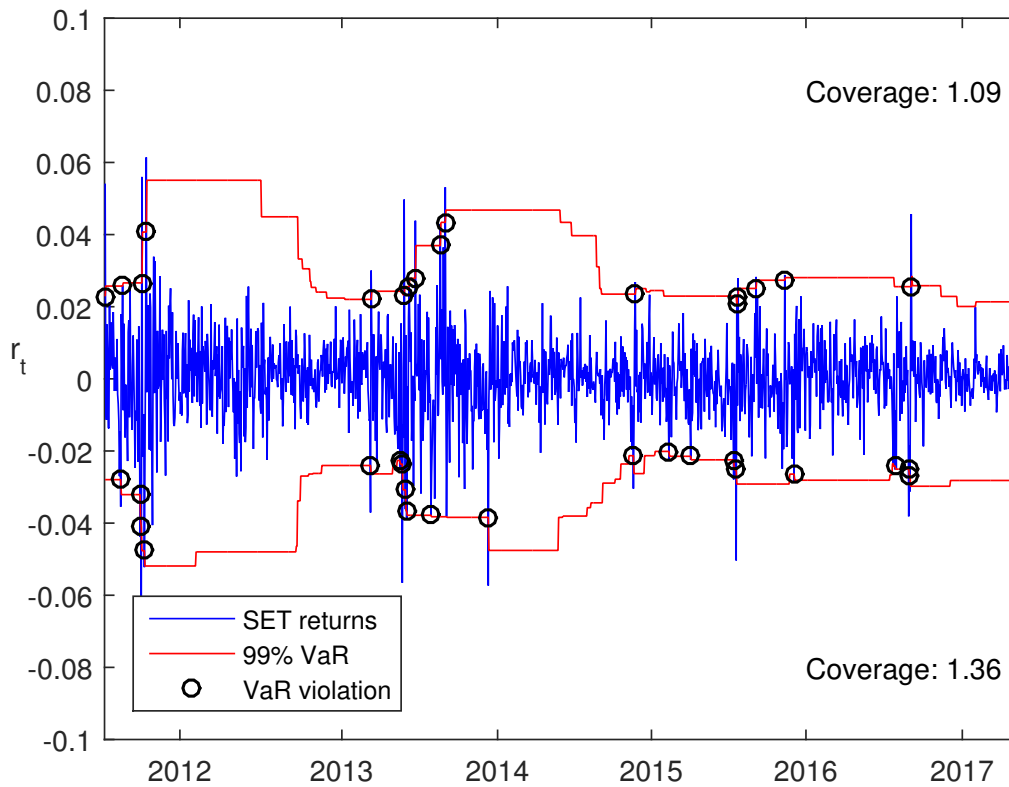


Figure 2. Value-at-Risk ($\alpha = 1\%$) 1-day ahead forecast with Historical Simulation for the SET index.

The STI from Singapore provides interesting results. From Tab. 6, we find that RiskMetrics (long) and FHS (short) are included in the red zone of the Basel traffic light test. Consequently the models would be replaced by the regulatory standard approach and the institution would be penalized with a higher factor on the minimum capital requirements accounting for the bad model choice. Interestingly, RiskMetrics shows a good performance on the short trading side, where it passes most of the tests. The worst results are achieved by the GARCH model, which fails all tests, even though it stays in the green zone over the whole out-of-sample period. The SV models show good performance on the long trading position, but cannot provide equally good result on the short trading position. APARCH provides very good results for both trading positions regarding 1-day ahead forecasts, which may indicate that asymmetries play an important role in the STI return structure.

Lastly, we compare the forecasting results for the Vietnamese equity index VNI (Tab. 7). Within our model set, which includes very widely used VaR estimation procedures, only the SV model provides an average to good performance. All other models are either in the red zone (RiskMetrics, FHS, FIGARCH) or fail most of the statistical coverage tests (GARCH, APARCH, FIAPARCH). The models in the red zone, however, are only included for one trading side. For the long trading position, FIGARCH and FHS provide good results from the coverage tests. The SV models show very good performance for 1- and 5-days ahead predictions on the long trading position and belong to the model confidence set at every test they pass.

Finally, we compare all results from the six different equity indices of Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam. GARCH seems to be regulator's darling with respect to the traffic light characterization. Although popular, it fails almost all statistical coverage tests, while for most indices it is a 100% of times in the green zone of the traffic light test. This indicates that the model yields too conservative VaR forecast which would result in particularly high minimum

Table 6. Value-at-Risk back test results for STI returns.

Model	Traffic Light	1%			Christoffersen [25] 2.5%			5%			Pérignon and Smith [26]		
		1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days	1-day	5-days	20-days
long trading position													
EWMA/RiskMetrics	234 / 1004 / 17	—	—	—	—	—	—	—	—	—	—	—	—
Historical Simulation	830 / 425 / 0	—	—	—	0.1710	—	—	—	—	—	0.2996	0.2996	0.3105
Filtered Historical Simulation	764 / 491 / 0	0.0965	—	—	0.1651	—	—	0.2157	—	—	0.2883	—	—
GARCH-SkSt	1255 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—
APARCH-SkSt	895 / 360 / 0	0.0893	—	—	0.1481	—	—	0.2014	—	—	0.2655	—	—
FIGARCH-SkSt	628 / 627 / 0	—	—	—	—	—	—	—	—	—	0.3302	—	0.3137
FIAPARCH-SkSt	950 / 305 / 0	0.0999	—	—	0.1436	—	0.1436	0.2419	—	—	0.3221	0.3148	0.2655
SV-N	747 / 508 / 0	—	—	0.0855	0.1768	—	0.1504	0.2433	—	—	0.3221	0.3105	0.2741
SV-t	608 / 647 / 0	—	—	—	0.1710	—	—	0.2173	—	—	0.2871	—	0.2473
SV-L	897 / 358 / 0	0.1031	—	—	0.1569	—	—	—	—	—	—	—	—
short trading position													
EWMA/RiskMetrics	1036 / 219 / 0	0.1094	0.1153	—	0.1691	0.1710	0.1691	0.2203	—	0.2203	0.2985	0.3018	—
Historical Simulation	729 / 526 / 0	0.1094	0.1124	0.1237	0.1730	—	—	—	—	—	0.2985	0.3007	—
Filtered Historical Simulation	809 / 387 / 59	0.1209	0.0999	0.1031	—	0.1526	0.1590	0.2391	—	—	0.3252	—	—
GARCH-SkSt	1255 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—
APARCH-SkSt	1030 / 225 / 0	0.0999	0.0965	0.0999	0.1526	0.1481	0.1389	0.2111	0.2047	—	0.2789	0.2704	—
FIGARCH-SkSt	619 / 636 / 0	0.1237	—	—	—	—	0.1749	0.2277	0.2363	—	—	0.3221	0.3116
FIAPARCH-SkSt	958 / 297 / 0	0.1031	0.0774	—	0.1459	—	—	—	—	—	0.2680	—	—
SV-N	1237 / 18 / 0	0.0855	—	—	—	—	—	—	—	—	—	—	—
SV-t	1117 / 138 / 0	—	—	0.0729	—	—	—	0.1997	—	—	0.2500	—	—
SV-L	1255 / 0 / 0	0.0774	—	—	—	—	—	—	—	—	—	—	—

Note: Numbers under the Basel traffic light test indicate the number of days in the green/yellow/red zone for a 250 rolling trading day window with 1-day ahead VaR forecasts at $\alpha = 1\%$. For the Christoffersen [25] test the 1-, 5-, and 20-days ahead forecasts results are reported for the $\alpha = 1\%$, 2.5%, and 5% VaR. If a specific test does not reject the null hypothesis, we present the corresponding VaR loss function result. — indicates that the null hypothesis is rejected at least at 10% level of significance. Bold faced loss functions represent the inclusion in the Model Confidence Set [30] with level of significant 10% and 10 000 bootstraps. The test by Pérignon and Smith [26] is reported in a similar manner, except for the fact that the three VaR levels (1%, 2.5%, and 5%) are tested jointly.

Table 7. Value-at-Risk back test results for VNI returns.

Model	Traffic Light	1%				Christoffersen [25] 2.5%				5%				Pérignon and Smith [26]		
		1-day	5-days	20-days	—	1-day	5-days	20-days	—	1-day	5-days	20-days	—	1-day	5-days	20-days
long trading position																
EWMA/RiskMetrics	325 / 764 / 159	—	—	—	—	—	0.1809	—	0.2268	—	—	—	—	—	—	—
Historical Simulation	1122 / 126 / 0	0.0731	0.0775	0.0731	—	—	—	—	—	—	—	—	—	—	—	—
Filtered Historical Simulation	748 / 500 / 0	0.0967	—	—	0.1529	—	—	—	0.2002	—	—	—	—	0.2699	—	—
GARCH-SkSt	1248 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
APARCH-SkSt	872 / 376 / 0	0.0857	0.0967	—	—	—	—	—	—	—	—	—	—	—	—	—
FIGARCH-SkSt	782 / 466 / 0	0.1127	0.1212	0.1185	0.1791	0.1791	—	—	—	0.2253	0.2253	—	—	0.3155	0.3123	0.3102
FIAPARCH-SkSt	1036 / 212 / 0	0.0775	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SV-N	864 / 384 / 0	0.0967	0.0967	—	0.1392	0.1368	—	—	0.2068	—	—	—	—	0.2674	—	—
SV-t	864 / 384 / 0	0.0967	0.0817	—	0.1343	0.1343	—	—	0.2068	0.2002	—	—	—	0.2649	0.2546	—
SV-L	929 / 319 / 0	0.0967	0.0932	—	0.1507	0.1368	—	—	0.1968	—	—	—	—	0.2661	—	—
short trading position																
EWMA/RiskMetrics	965 / 283 / 0	—	—	—	—	—	—	—	—	—	—	—	—	0.3025	0.3176	—
Historical Simulation	1072 / 176 / 0	0.0857	0.0857	0.0817	—	—	—	—	—	—	—	—	—	0.2636	0.2598	0.2546
Filtered Historical Simulation	845 / 384 / 19	0.0967	0.0731	—	0.1485	—	—	—	0.2051	—	—	—	—	0.2711	—	—
GARCH-SkSt	1248 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
APARCH-SkSt	1248 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
FIGARCH-SkSt	384 / 841 / 23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
FIAPARCH-SkSt	1248 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SV-N	1248 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SV-t	1248 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SV-L	1248 / 0 / 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: Numbers under the Basel traffic light test indicate the number of days in the green/yellow/red zone for a 250 rolling trading day window with 1-day ahead VaR forecasts at $\alpha = 1\%$. For the Christoffersen [25] test the 1-, 5-, and 20-days ahead forecasts results are reported for the $\alpha = 1\%$, 2.5%, and 5% VaR. If a specific test does not reject the null hypothesis, we present the corresponding VaR loss function result. — indicates that the null hypothesis is rejected at least at 10% level of significance. Bold faced loss functions represent the inclusion in the Model Confidence Set [30] with level of significant 10% and 10 000 bootstraps. The test by Pérignon and Smith [26] is reported in a similar manner, except for the fact that the three VaR levels (1%, 2.5%, and 5%) are tested jointly.

capital requirements. Also the very popular RiskMetrics model shows poor performance. McMillan and Kambouroudis [13] concludes that the model only performs well in small markets and high VaR quantiles. Our findings suggest that the selected six markets in this paper may already be too big for the RiskMetrics approach. Interestingly, the HS is rarely rejected by the multilevel coverage test, i.e. regardless of the specific forecast horizon, it provides sufficient coverage ratios. However, it is not able to provide satisfying results for the conditional coverage test in all indices. This might be due to the slow adaption of shocks resulting in clustering of violations. The SV model specifications provide a framework with a good overall performance at all markets, but only on the long trading position. However, especially for shorter forecast horizons the SV models belong to the model confidence sets.

5 Conclusion

We compare the forecasting performance of different GARCH-type and Stochastic Volatility models as well as non- and semi-parametric approaches in terms of the widely-used Value-at-Risk measure. We obtain results which are not consistent across markets as well as trading positions. The results imply that for the long and short trading positions, different forecasting methods should be implemented. According to this inconsistency, we find that for different ASEAN stock indices, the model performances vary, indicating that the markets volatility might be driven by different factors. The simple GARCH and the RiskMetrics framework provide insufficient forecasts in terms of coverage and clustering. With only a few exceptions, the two models fail for all forecasting horizons and for all markets. This is a clear indication that the index volatilities should not be modeled by short memory and symmetric processes. Long memory models with or without asymmetric news impact such as the FIGARCH, APARCH, or FIAPARCH, are potent alternatives.

Given the significant skewness of the empirical returns, skewed distributions driving the volatility processes are suggested. The Historical Simulation appears to be superior over its filtered extension and provides reasonably good results for the multilevel unconditional coverage test. With Stochastic Volatility models, we improve the quality of some forecasts. In general, we obtain better results for shorter horizons. Also, there is no clear pattern in the failure rate of the unconditional and conditional coverage tests. Interestingly, in the SV framework, we achieve a good overall VaR coverage which is, however, clustered for most markets across the forecasting horizons. The clustering might be caused by periods of extreme market movements paired with only a minor reaction of the volatility models.

In summary, the results show that simple volatility models do not provide VaR forecasts of practical value and that more sophisticated models, which cover different stylized facts, are needed to properly quantify financial risk on the long and short side for ASEAN stock market indices. Moreover, we conclude that despite their regional proximity and homogeneity of the markets, the stock index volatilities of the biggest ASEAN markets are driven by different factors. This needs to be addressed in further research.

Acknowledgments: We are thankful to three anonymous reviewers, whose valuable suggestions helped to improve an earlier version of this paper. We thank Hermann Locarek-Junge and Duc Khuong Nguyen for support, and Stanislas Augier for his excellent student assistance during his stay at John von Neumann Institute. Moreover, we are thankful to the participants of the 2nd Vietnam Symposium in Banking and Finance in Ho Chi Minh City (2017), especially to Maximilian Adelman for his discussion. Parts of the paper were written while Thomas Walther was a visiting researcher at John von Neumann Institute, Ho Chi Minh City. Thomas Walther is grateful for the funding received from Innosuisse (Swiss Innovation Agency) for conducting this research.

Author Contributions: Nam H. Nguyen and Paul Bui Quang implemented the Stochastic Volatility models and the corresponding Value-at-Risk estimation. Tony Klein and Thomas Walther jointly implemented and analyzed the GARCH models, carried out the back tests, and wrote the article.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ASEAN: Association of Southeast Asian Nations
 APARCH: Asymmetric Power Autoregressive Heteroskedasticity
 GARCH: Generalized Autoregressive Heteroskedasticity
 EWMA: Exponentially Weighted Moving Average
 FHS: Filtered Historical Simulation
 FIAPARCH: Fractionally Integrated Asymmetric Power Autoregressive Heteroskedasticity
 FIGARCH: Fractionally Integrated Generalized Autoregressive Heteroskedasticity
 HS: Historical Simulation
 JCI: Jakarta Stock Exchange Composite Index
 KLSE: Kuala Lumpur Stock Exchange
 MCS: Model Confidence Set
 PCOMP: Philippines Stock Exchange Index
 SET: Stock Exchange of Thailand
 STI: Singapore Strait's Time Index
 SV: Stochastic Volatility
 VaR: Value-at-Risk
 VNI: Vietnam Ho Chi Minh Stock Index

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