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STOCK RETURNS, HEAVY-TAILED DISTRIBUTION AND RISK MANAGEMENT OF THE EQUITY MARKET IN PHILIPPINES

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ABSTRACT

The Philippine stock market is now the most expensive stock market in the Southeast Asia region. As of July 10, 2017, the total market capitalization is about 101 percent of the gross domestic product (GDP). Normally, the ratio between 75 percent and 90 percent is considered fairly valued. Thus, a risk management tool, which can quantitatively estimate the potential odds of a financial crisis, would be particularly useful for market participants. In this paper, we showed the Skewed *t* distribution could provide best goodness-of-fit for the Philippine stock market returns compared with several other widely used statistical distributions. The scenarios generated by the Skewed *t* distribution would be valuable for further risk analysis of the stock market.

Keywords: Skewed *t* distribution; Goodness of fit; risk management

JEL classification: C46; C58; G10

1. INTRODUCTION

In Philippines, while banks dominate the Philippine financial system and about two-thirds of total system assets, the stock market is growing very fast in recent years. The Philippine Stock Exchange, Inc. is the national stock exchange of the Philippines. The exchange was created in 1992 from the merger of the Manila Stock Exchange and the Makati Stock Exchange. Including previous forms, the exchange has been in operation since 1927. The main index for PSE is the

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PSE Composite Index (PSEi) is a capitalization-weighted index, which composed of thirty (30) listed companies.

Although the equity market is relatively underdeveloped, its total market capitalization is still in almost the same level as its GDP. Thus, risk management of the equity market has become a very important and challenging practice for financial regulators in Philippines. In 2008, the market capitalization dropped sharply to 54 percent of its GDP, and lots of households lost a significant portion of their family wealth (IMF, 2010). As mentioned by BSP (Central Bank of Philippines) Governor Tetangco, Jr. (2015), there are now much more financial securities from practically non-existent a decade ago, and investors have a fairly broad range of choices over the 175 that are listed and consequently face much more potential risk compared with eight years ago. Therefore, the need for governance so that risks are fully priced and managed to generate reasonable returns to the risk-taker is unprecedentedly urgent.

In this paper, we take an advantage a newly developed tool by Guo (2017a). Several widely-used heavy-tailed distributions are introduced to fit the PSEi Index returns. We showed the Skewed *t* distribution has the best goodness of fit. We further propose several quantitative risk scenarios which are meaningful for our future regulatory practices.

Literature Review

Guo (2017a) compared five widely-used statistical distributions in fitting the SP 500 index returns: normal, Student's *t*, Skewed *t*, normal inverse Gaussian (NIG), and generalized hyperbolic (GH) distributions. Guo showed the Skewed *t* distribution has the best goodness of fit and generates suitable hypothetical rare scenarios. Although the four heavy-tailed distributions have existed in the literature for a while, to the best of our knowledge Guo (2017a) is the first one who empirically compare them for regulatory risk management practice. The Skewed *t* distribution was introduced in Hansen (1994). The GH distribution was developed by Barndorff-Nielsen (1977). The NIG distribution is also investigated since it is one of the most popular subclass of the GH distribution in financial modeling (see Figueroa-Lopez, et al., 2011, for a survey). In this paper, we reconsider these five distributions but focus on the financial market in Philippines.

There are many other researches on the equity market in Philippines. However, most of these researches focus on either the relationship between the stock market and economic growth, or the linkage between the Philippine stock market with the stock markets in other countries, and there is no research on the topic of market risk management from a regulatory perspective for the Philippine stock market. For instance, Yang, Kolari and Min (2010) examined the long-run relationships and short-run dynamic causal linkages among the US, Japanese, and ten Asian

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emerging stock markets, with the particular attention to the 1997–1998 Asian financial crises. Jayasuriya (2011) investigated the stock market correlations between China and its emerging market neighbors, and found that the Philippine stock market is strongly correlated with the Chinese stock market. Bautista (2010) studied stock market volatility in the Philippines and found the stock market volatility is an idea indicator of the future real GDP growth. Finally, in contrast Sobrecarey, Sucuahi and Tamayo (2015) examined the relationship between the stock market performance and the economic growth of the Philippines and found there is almost no relationship between these two variables. Our main topic is different from the above researches.

In Section 2, we introduce the heavy-tailed distributions. Section 3 summarizes the data. The estimation results are in Section 4. Finally, we conclude in Section 5.

2. HEAVY-TAILED DISTRIBUTIONS

Similar as in Guo (2017a), four types of widely-used heavy-tailed distribution in addition to the normal distribution are studied: (i) the Student's *t* distribution; (ii) the Skewed *t* distribution; (iii) the normal inverse Gaussian distribution (NIG); and (iv) the generalized hyperbolic distribution (GH). All the distributions have been standardized to ensure mean and standard deviation equal to zero and one respectively. Their probability density functions are given as follows.

(i) Student's *t* distribution:

$$f(e_t \mid \nu) = \frac{\Gamma(\frac{\nu+1}{2})}{\Gamma(\frac{\nu}{2})[(\nu-2)\pi]^{1/2}} \left(1 + \frac{e_t^{\,2}}{(\nu-2)}\right)^{-\frac{\nu+1}{2}}, \tag{1}$$

where ν indicates degrees of freedom and e_t is daily equity market index return.

(ii) Skewed *t* distribution:

$$f(e_t \mid \nu, \beta) = \begin{cases} bc\left(1 + \frac{1}{\nu-2}\left(\frac{be_t + a}{1-\beta}\right)^2\right)^{-(\nu+1)/2} & e_t < -a/b \\ bc\left(1 + \frac{1}{\nu-2}\left(\frac{be_t + a}{1+\beta}\right)^2\right)^{-(\nu+1)/2} & e_t \geq -a/b \end{cases}, \tag{2}$$

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where e_t is the standardized log return, and the constants a, b and c are given by

$$a = 4\beta c\left(\frac{\nu-2}{\nu-1}\right),\ b^2 = 1+3\beta^2 - a^2, \text{ and } c = \frac{\Gamma(\frac{\nu+1}{2})}{\sqrt{\pi(\nu-2)}\Gamma(\frac{\nu}{2})}.$$

The density function has a mode of $-a/b$, a mean of zero, and a unit variance. The density function is skewed to the right when $\beta > 0$, and vice-versa when $\beta < 0$. The Skewed t distribution specializes to the standard Student's t distribution by setting the parameter $\beta = 0$.

(iii) Normal inverse Gaussian distribution (NIG):

$$f(e_t \mid \mu,\alpha,\beta,\delta) = \frac{\alpha\delta K_1(\alpha\sqrt{\delta^2+(e_t-\mu)^2})}{\pi\sqrt{\delta^2+(e_t-\mu)^2}}\exp(\delta\sqrt{\alpha^2-\beta^2}+\beta(e_t-\mu)), \tag{3}$$

where $K_\lambda(\cdot)$ is the modified Bessel function of the third kind and index $\lambda = 0$ and $\alpha > 0$. The NIG distribution is specified as in Prause (1997). The NIG distribution is normalized by setting

$$\mu = -\frac{\delta\beta}{\sqrt{\alpha^2-\beta^2}} \text{ and } \delta = \frac{\left(\sqrt{\alpha^2-\beta^2}\right)^3}{\alpha^2}, \text{ which implies } E(e_t) = 0 \text{ and } Var(e_t) = 1.$$

(iv) Generalized hyperbolic distribution:

$$f(e_t \mid p,b,g) = \frac{g^p}{\sqrt{2\pi}\left(b^2+g^2\right)^{\frac{1}{2}\left(p-\frac{1}{2}\right)} d(p,b,g) K_p(g)} q\left(\frac{e_t - m(p,b,g)}{d(p,b,g)};\ p,b,g\right), \tag{4}$$

where $\tilde{R}_n \equiv \dfrac{K_{n+p}(g)}{g^n K_p(g)}$, $d(p,b,g) \equiv \left[\tilde{R}_1 + b^2\left\{\tilde{R}_2 - \tilde{R}_1^2\right\}\right]^{-\frac{1}{2}} \geq 0$, and $m(p,b,g) \equiv -b\, d(p,b,g)\tilde{R}_1$.

p,b and g are parameters. The generalized hyperbolic distribution is a standardized version of Prause (1997).

3. DATA

We fit the heavy tailed distributions with the normalized returns of the PSEi Index. The Philippine Stock Exchange (PSE) is the only stock exchange in the Philippines. It is one of the oldest stock exchanges in Asia, having been in continuous operation since the establishment of

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the Manila Stock Exchange in 1927. The main index for PSE is the PSEi, which is composed of a fixed basket of 30 listed companies. The PSEi measures the relative changes in the free float-adjusted market capitalization of the 30 largest and most active common stocks listed at the PSE. The selection of companies in the PSEi is based on a specific set of public float, liquidity and market capitalization criteria. There are also six sector-based indices as well as a broader all shares index. We collected the standardized PSEi daily dividend-adjusted close returns from Yahoo Finance for the period from January 5, 1987 to July 10, 2017, covering all the available data in Yahoo Finance. There are in total 7785 observations. Figure 1 illustrates the dynamics of PSEi. There are significant volatilities observed in the 1987 Black Monday stock market crash, the Asian financial crisis, and the recent financial crisis.

Figure 1: PSEi returns

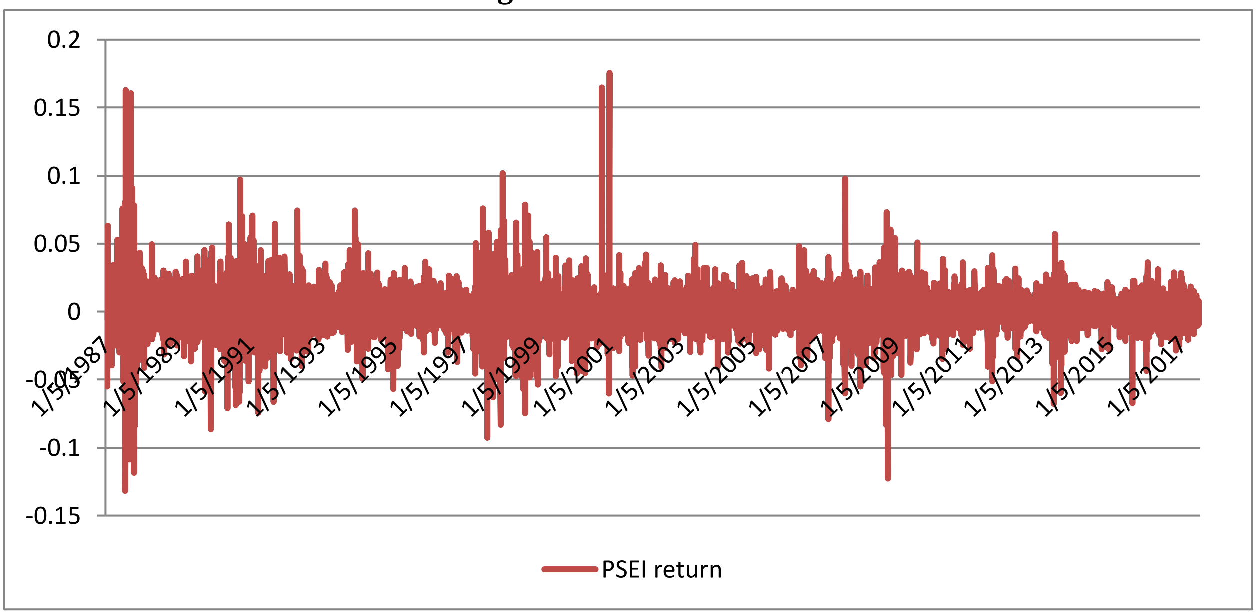

Table 1 exhibits basic statistics of the PSEi returns. The results show the PSEi daily returns are leptokurtotic and positively skewed. The extreme downside move is slightly less than the extreme upside move, which is at odds with most of major stock market indexes over the world.

Table 1: Descriptive statistics

min	max	mean	std	skewness	kurtosis
-13.19%	17.56%	0.05%	1.57%	0.40	12.64

Figure 2 is the histogram of the raw data. We fit the returns by the Gaussian distribution and the figure clearly exhibits heavy tails.

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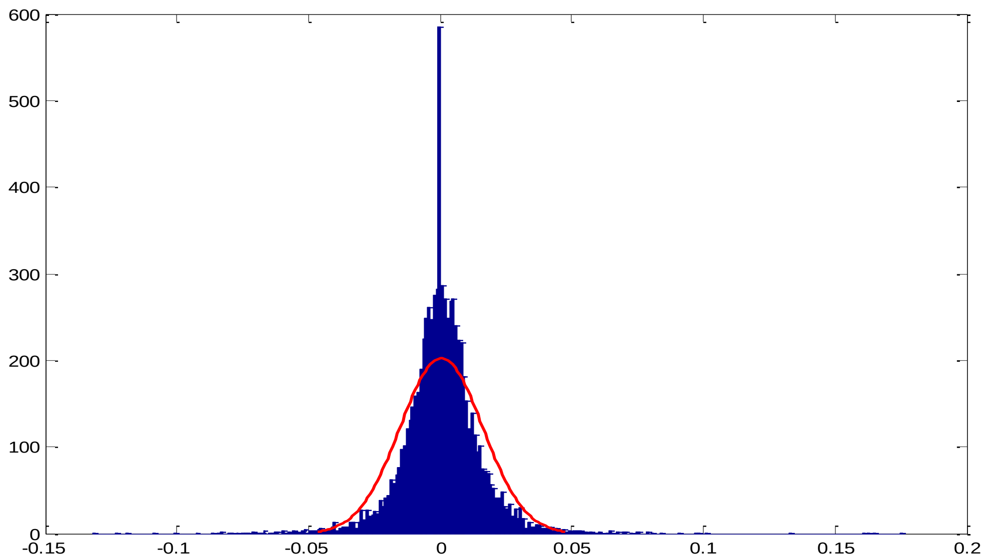
Figure 2: Histogram of PSEi returns



4. EMPIRICAL RESULTS

4.1 Parameters Estimation

The raw return series is normalized to allow zero mean and unit standard deviation. We use the maximum likelihood estimation (MLE) method to fit the series and the estimation results of the key parameters are given in Table 2. All the parameters are significantly different from zero at 10% significance level.

Table 2: Estimated values of key parameters

	Normal	Student's *t*	Skewed *t*	NIG	Generalized Hyperbolic
Symmetric	Y	Y	N	N	N
Fat-tailed	N	Y	Y	Y	Y
Estimated Parameters		Nu=3.13	Nu=3.15; beta=0.011	alpha=1.24; beta=0.021	p=-1.17; b=-.042; g=0.05

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4.2 Goodness of Fit

As discussed in Huber-Carol, et al. (2002) and Taeger and Kuhnt (2014), we compare the four heavy-tailed distributions and the benchmark normal distribution in fitting the PSEi daily returns through four different criteria: (i) Kolmogorov-Smirnov statistic; (ii) Cramer-von Mises criterion; (iii) Anderson-Darling test; and (iv) Akaike information criterion (AIC).

(i) Kolmogorov-Smirnov statistic is defined as the maximum deviation between empirical CDF (cumulative distribution function) $F_n(x)$ and tested CDF $F(x)$:

$$D_n = \sup_x |F_n(x) - F(x)|, \tag{5}$$

where $F_n(x) = \frac{1}{n}\sum_{i=1}^{n} I_{[-\infty,x]}(X_i)$.

(b) Cramer-von Mises criterion is defined as the average squared deviation between empirical CDF and tested CDF:

$$T = n\int_{-\infty}^{\infty} [F_n(x) - F(x)]^2 dF(x) = \frac{1}{12n} + \sum_{i=1}^{n}\left[\frac{2i-1}{2n} - F_n(x_i)\right]^2, \tag{6}$$

(c) Anderson-Darling test is defined as the weighted-average squared deviation between empirical CDF and tested CDF:

$$A = n\int_{-\infty}^{\infty} \frac{(F_n(x) - F(x))^2}{F(x)(1-F(x))} dF(x),$$

and the formula for the test statistic A to assess if data comes from a tested distribution is given by:

$$A^2 = -n - \sum_{i=1}^{n} \frac{2i-1}{n}\left[\ln(F(x_i)) + \ln(1-F(x_i))\right]. \tag{7}$$

(d) Akaike information criterion (AIC) is defined as:

$$AIC = -2k - 2\ln(L), \tag{8}$$

where L is the maximum value of the likelihood function for the model, and k is the number of estimated parameters in the model.

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The comparison results are showed in Table 3, indicating the Skewed *t* distribution has the best goodness of fit compared with other selected types of distribution, followed by the generalized hyperbolic distribution, and the Student's *t* distribution.

Table 3: Comparison of selected types of distribution

	Normal	Student's *t*	Skewed *t*	NIG	Generalized Hyperbolic
K-S Test	0.020	0.010	0.008	0.012	0.009
Cv-M Test	0.046	0.038	0.035	0.040	0.037
A-D Test	1.85	1.52	1.40	1.49	1.43
AIC	26572	25449	25035	25668	25279

4.3 Hypothetical rare scenarios

As the financial market regulator, we are interested in how the market performs under extreme conditions. To simulate hypothetical rare scenarios, we adopt the concept of Value at Risk (VaR), which has been widely used in the industry. In quantitative risk management, VaR is defined as: for a given position, time horizon, and probability *p*, the *p* VaR is defined as a threshold loss value, such that the probability that the loss on the position over the given time horizon exceeds this value is *p*.with the estimated parameters in Section 4.1, we calculate VaRs for different confidence levels:

$$VaR_{\alpha}(e_t) = \inf\{e \in \mathbb{R} : P(e_t > e) \leq 1-\alpha\}, \tag{9}$$

where $\alpha \in (0,1)$ is the confidence level. We select the following levels for downside moves: {99.99%, 99.95%, 99.9%, 99.5%}, and for upside moves: {0.01%, 0.05%, 0.1%, 0.5%}. From Equation (9), the hypothetical rare scenarios based on the VaR levels are given as in Table 4. Table 4 indicates that the Skewed *t* distribution has the closest VaRs to the nonparametric historical VaRs compared with other types of distributions.

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Table 4: Scenarios for PSEI shocks

Left Tail				
Confidence	99.99%	99.95%	99.90%	99.50%
Empirical	-13.14%	-10.44%	-9.58%	-7.74%
Normal	-9.01%	-8.07%	-7.58%	-6.80%
T	-14.49%	-13.04%	-11.96%	-9.88%
Skewed T	-13.60%	-10.82%	-9.90%	-7.91%
NIG	-14.03%	-12.60%	-10.79%	-9.53%
GH	-14.98%	-12.85%	-11.12%	-9.42%
Right Tail				
Confidence	0.01%	0.05%	0.10%	0.50%
Empirical	14.15%	12.98%	10.45%	8.23%
Normal	9.01%	8.07%	7.58%	6.80%
T	14.49%	13.04%	11.96%	9.88%
Skewed T	14.00%	13.05%	10.08%	8.38%
NIG	12.13%	11.28%	9.90%	9.13%
GH	13.63%	12.43%	10.75%	8.78%

5. CONCLUSIONS

Regulators are always interested in the odds when a potential financial crisis will happen in the future. Thus, statistical distributions which can explain tail parts of the empirical distribution would be particular useful for the industry. In this paper, we focus on the PSEi Index, the most important risk factor in the equity market in Philippines, and develop a methodology to construct its hypothetical rare scenarios. By comparing empirical performance of different statistical distributions, our results show the Skewed *t* distribution could generate the most suitable hypothetical rare scenarios for PSEi Index.

Two potential directions could be considered for further research. First, the extreme value theory is another strand of literature which is specifically for modeling tail events, and one may compare its performance with the Skewed *t* distribution. Second, if one could combine the fat-tailed distributions with the generalized autoregressive conditional heteroskedasticity (GARCH) framework as in Guo (2017b), it might further contribute to the literature.

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