

# Stress Testing and Risk Management of the Equity Market in New Zealand

Andrew Maree<sup>1</sup>

<sup>1</sup> Reserve Bank of New Zealand

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## Abstract

The banking supervision sets out the need to conduct stress tests for the financial institutions in New Zealand. For the purpose of stress tests, the paper develops a methodology to calculate a series of severe but plausible economic scenarios. Five widely-used statistical distributions are investigated in fitting the return series of NZ 50. We show that the Skewed t distribution has the best goodness of fit and generates the most suitable stress test scenarios. Our approach could be an important component of sound risk management for the Reserve Bank of New Zealand. The financial institutions are expected to continue to develop their stress testing frameworks, and to use the results in our paper to inform their capital management and risk appetite setting processes.

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**Index terms**— tail risk; goodness of fit; stress test scenarios.

## 1 Introduction

The New Zealand banking system was about NZD 500 billion in June 2016, around twice New Zealand annual GDP (IMF, 2017). In New Zealand, registered banks are required to conduct stress tests and report the results as part of their Internal Capital Adequacy Assessment Process (ICAAP) (Reserve Bank of New Zealand, 2015). Stress testing a bank's portfolio of assets (such as loans) involves evaluating what would happen to the portfolio in the face of various adverse events. Applied across a bank, a stress test can be described as "the evaluation of a bank's financial position under a severe but plausible scenario." Stress testing is an important risk management tool for banks in evaluating their vulnerability to various types of risk across their balance sheet. The Basel II international capital framework has a specific role for stress testing to help ensure banks have sufficient capital to absorb unanticipated losses in severe economic downturns (BCBS, 2011).

A stress test may examine the consequences for banks of a full macroeconomic scenario that affects multiple aspects of the banks' business, or concentrate on a downturn in a particular sector. According the Reserve Bank of New Zealand (2015), a combination of risk factors determines the full macroeconomic scenario. In this paper, we are particularly interested in the risk factor of the stock market in New Zealand, since this risk factor is the most important factor in determining market risk of banks.

To design stress test scenarios of the stock market in New Zealand, we consider the NZX 50 Index (NZ50). NZ50 is the main stock market index in New Zealand. It comprises the 50 biggest stocks by free-float market capitalisation trading on the New Zealand Stock Market (NZSX). The calculation of the free-float capitalisation excludes blocks of shares greater than 20% and blocks between 5% and 20% that are considered strategic. The index was introduced as the NZSX 50 Index in March 2003 and replaced the NZSE 40 Index as the headline index. It was renamed the NZX 50 Index in late 2005. The NZSE 40 Capital Index replaced the Barclays index in 1992, although the Barclays index is still compiled by the NZX but not made widely available.

To quantitatively design stress test scenarios of the stock market, we model daily returns of NZ50. As early as 1963, Mandelbrot recognized the heavy-tailed and highly peaked nature of certain financial time series. Guo (2017) creatively introduced several widely-used heavy-tailed distributions to fit the Standard&Poor's 500 index

returns, and showed the Skewed t distribution has the best goodness of fit. Guo further successfully quantified scenarios of the stock market index return in the United States. With the insights from Guo (2017), this paper considers the widely-used heavy-tailed distributions discussed in Guo, and shows the Skewed t distribution also provides the best goodness of fit among these heavy-tailed distributions in modeling the stock market returns in New Zealand.

The aftermath of the recent Financial Crisis emphasized the importance of stress testing practice. Stress tests offer useful information to the Reserve Bank in its role as a prudential regulator. Our results are crucial for the Reserve Bank to determine the ability of banks or financial institutions to deal with a financial crisis.

## 2 a) Literature Review

Guo (2017) compared five widely-used statistical distributions in fitting the Standard&Poor's 500 index returns: normal, Student's t, Skewed t, normal inverse Gaussian (NIG), and generalized hyperbolic other types of asymmetric Student's t distribution as in Zhu and Galbraith (2012). In this paper, we also consider the Skewed t distribution as in Hansen (1994) for its simplicity and empirical performance. Since Barndorff-Nielsen (1977) introduced generalized hyperbolic distributions into the equity market, the GH distribution has gained increasing attentions in financial econometrics. In this paper, we also consider the normal inverse Gaussian distribution since the NIG distribution 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 New Zealand.

Recently, researchers and practitioners have gained rapid increasing interests in design of stress test scenarios in the financial industry. There are two main strands of the interests. The first strand is on the Mahalanobis distance based method to construct stress scenarios for risk factors. Breuer, Jandacka, Rheinberger and Summer (2009) proposed a suitable region of plausibility in terms of the risk-factor distribution and search systematically for the scenario with the worst portfolio loss over this region. Darne, Levy-Rueff and Pop (2013) suggested a rigorous and flexible methodological framework to select and calibrate initial shocks to be used in bank stress test scenarios. The second strand focuses on the nonparametric likelihood based method to construct stress scenarios for risk factors. Glasserman, Kang and Kang (2014) presented a method for selecting and analyzing stress scenarios for financial risk assessment, with particular emphasis on identifying sensible combinations of stresses to multiple factors. Flood and Korenko (2014) introduced a technique for selecting multidimensional shock scenarios for use in financial stress testing. Finally, Kapinos and Mitnik (2016) developed a simple, parsimonious, and easily implementable method for stress-testing scenarios choices using a top-down approach that incorporates the heterogeneous impact of shocks to macroeconomic variables on banks' asset valuation. In this paper, we focus on parametric methods and consider a single risk factor as a starting point.

There are many other researches on the stock market returns in New Zealand, such as in Firth (1997) and Choi, Pang and Fu (2009). However, there is no research on the topic of designs of stress test scenarios. There are some researches on stress test of New Zealand's banking system as in Jang and Kataoka (2013), but not specifically focusing on the financial market. The remainder of the paper is organized as follows. 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.

## 3 II.

The Heavy-Tailed Distributions Similar as in Guo (2017), we consider four types of widely-used heavy-tailed distribution in addition to the normal distribution: (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  $f(t) = \frac{\Gamma(\frac{n+1}{2})}{\Gamma(\frac{n}{2})} \frac{1}{\sqrt{n\pi}} \left(1 + \frac{t^2}{n}\right)^{-\frac{n+1}{2}}$  where  $n$  indicates degrees of freedom and  $t$  is daily equity market index return in New Zealand.

ii. Skewed t distribution  $f(t) = \frac{\Gamma(\frac{n+1}{2})}{\Gamma(\frac{n}{2})} \frac{1}{\sqrt{n\pi}} \left(1 + \frac{t^2}{n}\right)^{-\frac{n+1}{2}} \left(1 + \frac{t}{n}\right)^{-\frac{n+1}{2}}$  where  $n$  indicates degrees of freedom and  $t$  is daily equity market index return in New Zealand.

## 4 B

where  $t$  is the standardized log return, and the constants  $a$ ,  $b$  and  $c$  are given by 2 iv. Generalized hyperbolic distribution  $f(t) = \frac{K_p(\sqrt{a^2 - b^2} |t|)}{K_p(\sqrt{a^2 - b^2})} \frac{1}{\sqrt{2\pi} \sqrt{a^2 - b^2}} \exp\left(-\frac{a^2 + b^2}{2(a^2 - b^2)} |t| + \frac{b^2}{2(a^2 - b^2)} t\right)$  where  $K_p$  is the modified Bessel function of the second kind,  $a > b > 0$ ,  $p > 0$ , and  $c = \sqrt{a^2 - b^2}$ .

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

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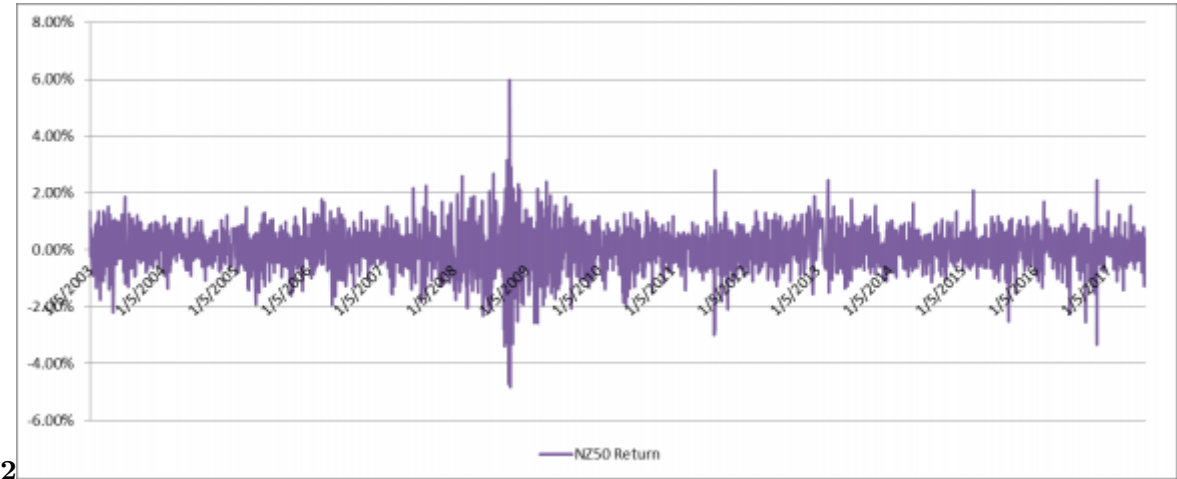
## 6 Empirical Results

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Figure 1: 2 )

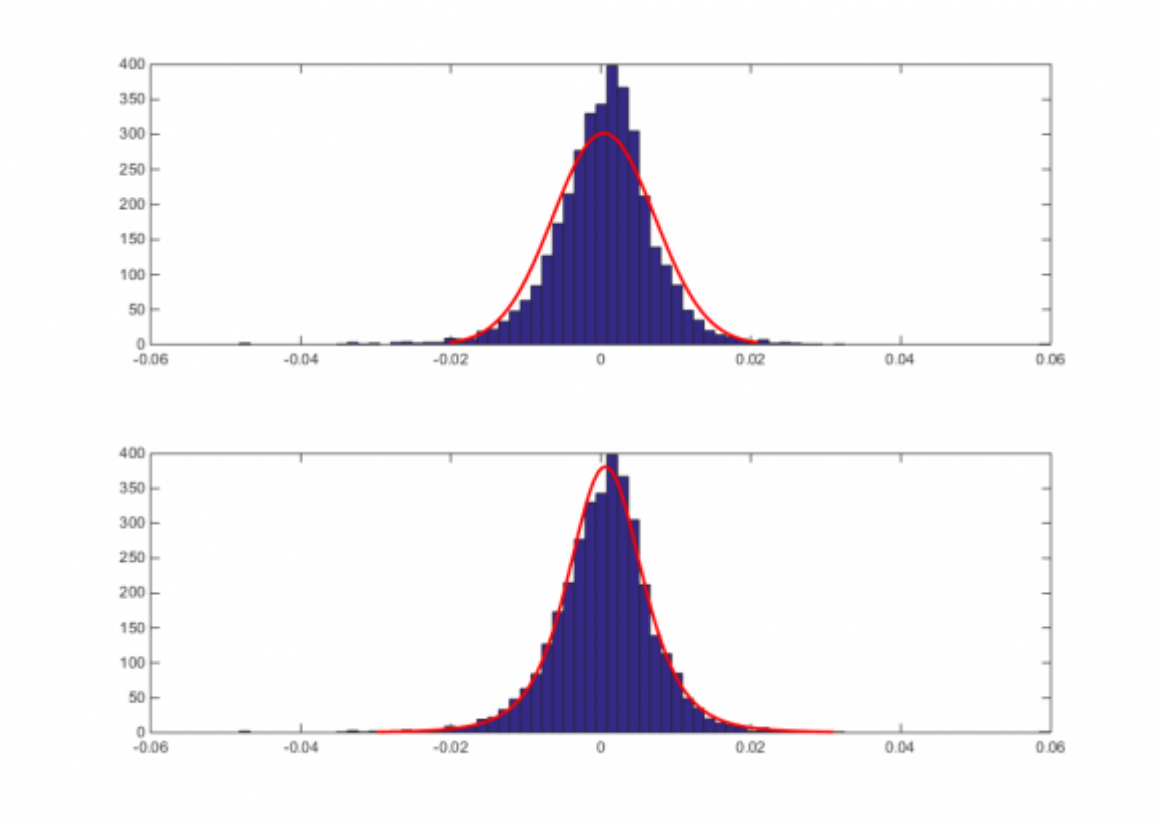


Figure 2: .

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| min    | max   | mean  | std   | skewness | kurtosis |
|--------|-------|-------|-------|----------|----------|
| -4.82% | 5.99% | 0.04% | 0.68% | -0.35    |          |

[Note: 2017© 2017 Global Journals Inc. (US) 1]

Figure 3: Table 1 :

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|                      |                |
|----------------------|----------------|
| Normal               | Student's<br>t |
| Symmetric            | Y Y            |
| Fat-tailed           | N Y            |
| Estimated Parameters | Nu=4.56        |

b) Goodness of Fit Based on Huber-Carol, et al. (2002) and Taeger and Kuhnt (2014), we investigate the following distributions and the benchmark normal distribution in fitting the NZ50 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).

a. Kolmogorov-Smirnov statistic is defined as the maximum deviation between empirical CDF

Figure 4: Table 2 :

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|           | Normal  | Student's t | Skewed t | NIG     | Generalized<br>Hyperbolic |
|-----------|---------|-------------|----------|---------|---------------------------|
| K-S Test  | 0.015   | 0.007       | 0.005    | 0.008   | 0.006                     |
| Cv-M Test | 0.021   | 0.014       | 0.011    | 0.015   | 0.013                     |
| A-D Test  | 1.43    | 1.21        | 1.13     | 1.19    | 1.15                      |
| AIC       | 12811.8 | 12201.2     | 11976.3  | 12320.4 | 12108.7                   |

Figure 5: Table 3 :

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|            | Left Tail |        |        |        |        |
|------------|-----------|--------|--------|--------|--------|
| Confidence | 99.99%    | 99.95% | 99.90% | 99.50% | 99.00% |
| Empirical  | -4.82%    | -4.35% | -3.34% | -2.45% | -1.92% |
| Normal     | -2.56%    | -2.21% | -2.03% | -1.74% | -1.56% |
| T          | -4.59%    | -4.05% | -3.65% | -2.88% | -2.34% |
| Skewed T   | -4.76%    | -4.38% | -3.19% | -2.51% | -2.01% |
| NIG        | -4.01%    | -3.67% | -3.12% | -2.81% | -2.31% |
| GH         | -4.61%    | -4.13% | -3.46% | -2.67% | -2.11% |

Figure 6: Table 4 :



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