MODELLING OF NON-STATIONARITY IN EXTREME SHARE RETURNS

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DEDICATION

This thesis is dedicated:

To my beloved parents

My father, Marsani Bin Mohamad

My mother, Kamariah Binti Basri

To my lovely brothers and sisters

Noremi Binti Marsani

Allahyarham Kamarol Hisam Bin Marsani

Habibah Binti Marsani

Nur Farhana Binti Marsani

To my dearest wife,

Marianis binti Azwir

Alhamdulillah, praise be to Allah for blessing me with all your presence.

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ABSTRACT

Financial risk control depends on the assumptions made about the distribution of share returns. A study on the behaviour of share market returns provides a practical solution for identifying the adequate statistical distribution assumption and accurate predictive interpretation. Most studies on modelling extreme returns only focus on traditional stationary sequences technique. In many cases, however, the interpretation of the extremes in return series clearly shows the existence of non-stationarity in the series. As an alternative, a non-stationarity algorithm is proposed to produce a more efficient model using a much simpler approach. In this study, a new statistical procedure based on the state of the time series namely a two-stage (TS) method are formed to classify the best extreme distribution fitting. In general, the extreme returns are illustrated by a parametric model which is driven by the asymptotic theory of extreme values of independent and identically distributed (i.i.d) random variables. The TS method is applied to several common distribution models typically used in modelling extreme share returns namely Generalized Lambda Distribution (GLD), Generalized Extreme Value Distribution (GEV), Generalized Pareto Distribution (GPA), Generalized Logistic Distribution (GLO) and Laplace Distribution (LAP). Monte Carlo simulations from known and unknown samples are carried out to appraise the performance of the non-stationary and the stationary techniques. The simulation results reveals that the TS method yields relatively more accurate parameter estimates than the stationary method, especially when estimating positive and monotonous cases trend sequences. The extreme quantile measures using the TS method are found to be more efficient than the conventional approach. This is because the TS method takes into consideration of the information in the time series when evaluating extreme quantile periods. The TS method also has the benefit of being computationally simpler since the transformed process is closer to the actual process. In this respect, the data appear to be more closely meet the assumptions of a statistical inference procedure that is to be applied. The overall results in this study conclude that the proposed TS method could improve the estimation of extreme returns and is a useful instrument for financial risk management.

ABSTRAK

Pengendalian risiko kewangan bergantung kepada andaian yang dibuat mengenai taburan pulangan saham. Kajian mengenai tingkah laku pulangan pasaran saham mampu memberikan kaedah praktikal dalam mengenalpasti taburan statistik pulangan saham dan ramalan yang tepat. Kebanyakan kajian dalam pemodelan pulangan ekstrem hanya tertumpu pada teknik jujukan pegun yang tradisional. Walau bagaimanapun, dalam banyak kes, tafsiran mengenai siri ekstrem jelas menunjukkan wujudnya ketidak pegunan dalam siri. Sebagai alternatif, satu algoritma tidak pegun telah dicadangkan untuk menghasilkan model yang lebih efisien dengan cara yang lebih mudah. Dalam kajian ini, prosedur statistik baharu berdasarkan bentuk keadaan siri masa iaitu kaedah dua-peringkat (TS) telah dicadangkan dalam mengklasifikasikan penyesuaian taburan ekstrem yang terbaik. Secara amnya, pulangan ekstrem diwakilkan dengan model parametrik yang menggunakan teori nilai ekstrem (EVT) asimptotik bebas dan pembolehubah rawak tersebar sama (i.i.d). Kaedah TS telah dihasilkan bagi beberapa model yang biasa digunakan untuk pemodelan pulangan ekstrem iaitu taburan Lambda teritlak (GLD), taburan nilai ekstrim teritlak (GEV), taburan pareto teritlak (GPA), taburan logistik teritlak (GLO) dan taburan Laplace (LAP). Simulasi Monte Carlo daripada sampel yang diketahui dan tidak diketahui telah dijalankan untuk menilai prestasi teknik tidak pegun dan kaedah pegun. Hasil simulasi mendapati bahawa kaedah TS memberikan anggaran parameter yang secara relatifnya lebih tepat berbanding kaedah pegun, terutamanya apabila menganggar jujukan tren kes positif dan monoton. Analisis ukuran kuantil ekstrem menggunakan kaedah TS didapati lebih berkesan berbanding pendekatan konvensional. Ini kerana kaedah TS mengambil kira maklumat tingkah laku siri masa apabila menilai jangka masa kuantil yang ekstrem. Kaedah TS didapati mempunyai kelebihan pengiraan yang lebih mudah memandangkan proses transformasi yang dilakukan lebih dekat dengan proses asal. Dalam hal ini, data menjadi lebih sesuai dengan andaian prosedur inferensi statistik yang diterapkan. Hasil dapatan yang diperoleh di dalam kajian ini menyimpulkan bahawa kaedah TS yang dicadangkan mampu memperbaiki anggaran kuantiti pulangan yang ekstrem dan berguna sebagai alat dalam pengurusan risiko kewangan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$E[X]$	-	Expectation of order statistic
F	-	Non-exceedance Probability
F^{-1}	-	Inverse non-exceedance probability
f_i	-	Plotting position
$F(x)$	-	Cumulative distribution function
$f(x)$	-	Probability distribution function
H_i	-	Heterogeneity measure
k	-	Number of sub-period in data series group
n_i	-	Record length of the sub-period series
$t^{(i)}$	-	Coefficient of variation for the site i
$t_3^{(i)}$	-	Coefficient of skewness for the site i
t_r^R	-	Weighted average of the samples
x	-	Random variable
$x(F)$	-	Quantile function
μ	-	Population mean
$\overline{x}$	-	Sample mean
σ	-	Population standard deviation
s	-	Sample standard deviation
v	-	Population coefficient of variation
δ	-	Population coefficient of skewness
κ	-	Population coefficient of kurtosis
α	-	Scale parameter
ξ	-	Location parameter
k, h	-	Shape parameter
μ_r	-	r^{th} moments
β_r	-	r^{th} probability weighted moments

m_r	-	r^{th} sample moments
b_r	-	r^{th} sample probability weighted moments
λ_r	-	r^{th} sample partial probability weighted moments
l_r	-	r^{th} L-moments
C_v	-	Coefficient of variation (CV)
C_s	-	Coefficient of skewness (CS)
C_k	-	Coefficient of kurtosis (CK)
τ	-	L-coefficient of variation (L-CV)
τ_3	-	L-coefficient of skewness (L-CS)
τ_4	-	L-coefficient of kurtosis (L-CK)
$\hat{\tau}_r$	-	r^{th} sample L-moment ratios
$\eta^{(i)}$	-	Coefficient of variation for site i
$\eta_3^{(i)}$	-	Coefficient of skewness for site i
$\eta_4^{(i)}$	-	Coefficient of kurtosis for site i
η_r^R	-	r^{th} regional average L-moment ratios
γ	-	Euler's constant
$E(.)$	-	Exponential Integral function
$\Gamma(.)$	-	Gamma function
γ	-	Incomplete Gamma function
$B_{1-F_0}(.)$	-	Incomplete Beta function
LRD	-	L-moment ratio diagram
VaR	-	Value at risk
AD	-	Anderson Darling
NS	-	Non-stationary
S	-	Stationary
TS	-	Two-stages method
S	-	Conventional models
LM	-	Linear dependence of the mean on time models

QM	-	Quadratic dependence of the mean on time models
LMS	-	Linear dependence in both the mean and log standard deviation on time models
QMLS	-	Quadratic dependence in the mean but linear in log standard deviation on time models
GLD	-	Generalized Lambda Distribution
GEV	-	Generalized extreme value distribution
GLO	-	Generalized logistic distribution
LAP	-	Laplace
GPA	-	Generalized Pareto distribution
PWMs	-	Probability Weighted Moments
RBIAS	-	Relative bias
RRMSE	-	Relative root mean square error
RW	-	Random Walk

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The statistical distribution of share returns plays an essential role in financial modelling. Among the benefits of understanding the statistical distribution assumptions for extreme return behavior is that it can manage financial risk, evaluates derivatives that determine hedging strategies over time, tests asset pricing theory, and builds an efficient portfolio. However, it is not easy to find the correct economic theory for share return distribution. The assumption on empirical data distribution is a generally accepted principle to assess the exact distribution of returns. (Longin, 2017).

According to Longin (1996), the share return is a measure of company profitability on investment over some period of time. In its simplest terms, share return is the money made or lost on an investment. Extreme Value Theory (EVT) theory is a useful application to model the risk in share return in financial risk management. EVT is concerned with the extremal behaviour of random variables and its role is to develop scientific procedures able to describe their behaviour. Extreme share return can be defined as the lowest daily returns (the minimum) or the highest daily returns (the maximum) of the share market index over a given period (selection interval).

The modelling of extreme share returns distribution has become a prominent research topic and could contribute immensely to the improvement of risk management (Hussain and Li, 2015). The motivation behind this research is the need to develop a model that can accurately explain the share returns data. Thus, this study aims to construct a model that has the capability to capture the extreme movement of data series. There is growing evidence that inappropriate estimation assumptions can lead to the miscalculation of the load of the disproportionate share returns restrained at the tail distribution. The invalid assumption on a single distribution could be attributed to the non-stationary behaviour in the series as the data samples possessing uncertainty effects due to unusual events. For example, political news, natural disasters, etc., such that the share returns become more volatile and non-stationary. (Tolikas, 2014; Ribeiro-Oliveira *et al.*, 2018; Kupiec and Güntay, 2016; Karoglou, 2010; Blattberg and Gonedes, 2010). Previous studies have failed to consider the contexts in which the non-stationarity of share return could provide biased and inaccurate return estimates. Therefore, new models should be proposed to capture the dynamic evolution of extreme returns properties over time.

Our primary interest in this research is the presentation of the extreme value theory (EVT) to investigating the behaviour of non-stationary in financial share returns. Hence, this chapter introduces the share market background and highlights the problem arising in the analysis. This section also includes the objectives, scope, and significance of the research and organization of the thesis.

1.2 Background of the Study

The share market is an institution that brings together buyers and sellers of a business where the share is traded privately. Each share sold by the seller represents a claim of ownership from the buyer, which benefits both parties. The equity crowdfunding platform enables businesses to raise money by offering shares and corporate bonds to buyers. Meanwhile, participating buyers gain money by receiving dividends from the company's capital. However, buyers or shareholders are exposed to financial loss when they sell shares at a price lower than the purchased price; this situation is known as market risk.

Market risk is defined as the probability of incurring loss or lower financial return from the share market. Investors tend to manage market risk actively because they want profitable returns. However, volatility in the share market is difficult to predict and is influenced by economic events (Suleman, 2012; Oseni and Nwosa, 2011; Tsai, 2017). Value-at-risk (VaR) is a measurement of the maximum possible loss of a portfolio over a specific time horizon at a certain confidence level. VaR is known as the minimum capital requirement (MCR) for every firm. A good VaR estimation suggests an accurate explanation of extreme events of share returns at the tails of the distribution. Lately, the VaR has become the standard measurement for every company in determining capital adequacy so as to prepare for the possibility of extreme financial events.

Extreme events can be defined as events that rarely happen but can have devastating consequences when they do arise. From the share market viewpoint, extreme return movement can be the result of market adjustments that occur during standard settings or may be due to economics, political, speculative and social factors. They may even ascend due to the pandemic outbreak such as Coronavirus disease (COVID-19), which has affected the share industry worldwide (Baker *et al.*, 2020).

According to Longin (1996), extreme return movement entail the lowest daily return and the highest daily return of the share market index observed over a given period. In maintaining extreme price switches with sensible clarification, a branch of statistics called the extreme value theory (EVT) is used to study the extremal behaviour of random variables. It focuses exclusively on these extremes and their associated probabilities by directly studying the tails of probability distributions. In the extreme value theory, there are two fundamental approaches namely the block maxima (BM) method and the peaks over threshold (POT) method (Ferreira and De Haan, 2015). EVT is also the basis for the development of analytical procedures for describing extreme behaviours and for calculating the probability of future extreme events (Tolikas, 2008; Tolikas, 2014).

In this research, the study highlights the significance of the non-stationary procedure through the two-stage (TS) method in estimating the extreme return that incorporates volatility persistence in the modelling process. At the end of the study, the implementation of this design will be applied to the Malaysian economic share sector. This chapter subsequently presents the problem statement, the research objective, the scope of the study, the significance of the research, and finally, the organization of the thesis.

1.3 Problem Statement

Despite the importance of managing market risk, there remains a paucity of evidence on the effect of non-stationarity when explaining extreme share returns. According to Ang and Timmermann (2012), the fundamental features of the share return in financial markets are continuously and significantly changing. Notably, share return variability is significantly influenced by economic news and subsequently causes extreme price movements (Broadstock and Filis, 2014; Sun, Najand and Shen, 2016; Elder, Miao and Ramchander, 2013; Kang and Ratti, 2013). In this case, the probabilities of losses or gains would be much higher than the actual observation implied by inaccurate estimation technique. Moreover, financial models tend to be inadequate with catastrophic consequences. For example, a risk model that fails to capture the probabilities of extreme events could mishandle future risk predictions. Analysis of extreme share market returns using the non-stationary framework is still incomprehensive and should receive more attention. Proposing a non-stationary procedure is subject to tackling the limitations of the previous research.

Large data series are often non-stationary or have means, variances and covariance that change over time. Non-stationary behaviours can be trends, cycles, random walks or combinations of the three. Non-stationary modelling in share returns has long been practiced in econometric literature that focuses on modelling financial returns as a stationary conditional paradigm (Granger *et al.*, 2005). A critical aspect of the analysis of share market returns is the assurance that the series is stationary as non-stationary data series are unpredictable and cannot be modelled or forecasted. Among the necessary assumptions of stationarity is that firstly, the results of the classical econometric theory are derived under the assumption that the variables of concern are stationary. Secondly, estimation process are mainly inadequate when the data is non-stationary. Thirdly, non-stationary time-series regressions often lead to the problem of spurious regressions. One such case is when the regression equation shows a significant relationship between two variables when such relation should not even exist. Moreover, autocorrelation may occur because the time series is non-stationary. Therefore, analysing non-stationary time series data in risk management produces unreliable results and leads to poor understanding and estimation.

The theory of economic forecasting is applicable to time-dependent models, which can be transformed into stationarity by differencing and co-integration (Lal *et al.*, 2010; Kuwornu, 2012; Engle and Granger, 2015). This theory allows the econometric model to misquantify the mechanism generating the data, with parameters estimated from data evidence. In such a situation, many useful results can be proven about the statistical properties of forecasting procedures. Although studies have acknowledged the significance of stationarity in time-dependent models (ARIMA, ARCH and GARCH), little is known about the effect of non-stationary in time-independent models (e.g. GLD, GEV, GPA, GLO and LAP) where there is uncertainty in returns distributions (Kang and Ratti, 2015). This thesis support the notion that past return series are not always stationary and non-stationarity behaviour should be treated as a source of risk, which should be helpful in predicting extreme returns. Hence, our study take into account the non-stationary panel count data to reduce the risk premiums of share returns.

In the analysis of extreme share markets return distribution, a conventional approach is to map the components of the portfolio without considering whether the series is stationary or not. Hence, the uncertainty and non-stationarity of data series to estimate risks are ly ignored in both theoretical works and practice. By far the most comprehensive account of non-stationarity in distribution modelling is to be found in the work of Strupczewski et al. (2001a). The authors developed a two-stage (TS) method for solving modelling problems involving the non-stationary in the flood frequency analysis. The idea of relaxing the stationarity assumption in flood frequency modelling (FFM) is implemented by the identification of distribution and trend (IDT) method. This idea was presented as a way of overcoming some of the limitations associated with trends. These techniques enable an optimum non-stationary share return model to be identified through the probability distribution function and a time pattern in the first two statistical moments. Although TS models have been applied in hydrology fields, there has been no detailed investigation for extreme share returns modelling. Therefore, this study is concentrating on the application of TS method to improve the fitting performance of extreme returns.

In this research, the conceptual framework and an appropriate algorithm using the two-stage (TS) method will be investigated to measure the non-stationarity of share returns in a time-independent distribution model. The L-moment method is used for parameter estimation and a class of competing models is selected through the minimisation of the error measurement. From a market risk perspective, the identification of distribution and trend investigation procedure from the different conditions of share returns data appear to be principally essential in exploring the non-stationary and scale trend effect.

The study on the importance of the stationarity share return series by Kheradyar et al. (2011) and Granger (2005) stated that market efficiency studies that rely on a model that does not account for non-stationary returns might be biased. This matter has led us to propose a new standard procedure in modelling the non-stationarity in share returns. The stationary assumption needs to be investigated in order to improve prediction accuracy. It is necessary to have a model that covers the features of asymmetry, high peak, and fat tails.

Investing in the share market without proper preparation and planning will merely create unwanted costs for the investor. From this research, these share market apprehensions should be addressed to reduce the risk of loss. Firstly, what is the effect of non-stationarity on the inference concerning share? Secondly, what are the criteria of the non-stationary series when monitoring the risk premium? Lastly, how can the different economic circumstances affect the share returns inference? Hence, precise knowledge related to the magnitude and frequencies of the market risk fundamentally deals with all the problem statement above is needed.

1.3.1 Research Questions

The procedure for the current and previous non-stationary time series in share returns has not been well established. Hence, this study proposed a new standard in the procedure of non-stationary time series that includes the interval length of weekly and monthly returns. These components need to be investigated to improve the forecasted values and to achieve forecasting accuracy. The primary goal of this research is to analyse the behaviour of extremely volatile returns on the share market. To solve this research problem, several research questions need to be addressed:

i. Is there any presence of non-stationary and trend in the extreme share returns?
ii. Do the shapes of the different share return distributions show similar kinds of anomalies?
iii. How to assign the appropriate procedure for the non-stationary extreme returns?
iv. How to evaluate the probability of extreme values using statistical distributions?
v. Is there any relation between economic circumstance and the shape of the share return distribution?

1.4 Research Objectives

This study aims to identify the best distribution in share returns. The specific objectives of this study are as follows:

(a) To identify the presence of non-stationarity in share market returns.

(b) To assess the sampling properties of the non-stationary (NS) two-stage method model in comparison to the classic stationary (S) model in characterizing uncertain events in the sample using the Monte Carlo simulation data generated from the known and unknown parent distribution function.

(c) To evaluate the performance of the non-stationary (NS) two-stage method model in comparison to the classic stationary (S) distribution model in analysing financial market risks using the permutation simulation analysis.

(d) To assess the performance of the developed model in (b) by considering the different economic time frames.

1.5 Scope of the Study

In this research, two aspects need to be made clear such as:

1. Data scope

   Two types of data are used in this study:

   i. The Kuala Lumpur Composite Index (KLCI) daily share market data for 22 years, starting from 1994 until 2016. Record of the daily share price was obtained from Yahoo Finance and classified as ratio scales.

   ii. Data simulation attained from the Monte Carlo method. This simulation can generate artificial share returns from various background distributions of the time-independent model.

2. Forecasting scope

   This study focuses on the unconditional distribution model of equity returns that is the fundamental distribution assumption for the homoscedastic and heteroscedastic forecasting models. For example, the residuals in the ARMA, ARCH and GARCH models will follow the distributions assumption considered in this study.

1.6 Research Significance and Contribution

In this research, the non-stationary procedure is proposed to model the extreme returns. Although many studies have been conducted to model extreme share returns, previous studies have failed to demonstrate significant advantages of using non-stationary two-stage (TS) technique to estimate the risk in share returns. This study attempts to use the TS method as a tool to evaluate extreme share returns. The expected study contributions of this study are four.

i. The provision of non-stationary solutions using TS approach to model daily, weekly and monthly share returns by revisiting the popular time-independent share returns models.
ii. The derivation of a parameter estimation for each of the TS models for GLD, GEV, GPA, GLO and LAP distributions.
iii. Highlighting the importance of non-stationarity procedure in reducing the forecast error in various levels of censoring quantile
iv. Investigating the characteristics of the distribution present in the financial data for different economic timeframes.

The proposed technique for extreme share return modelling is the combination of TS method with four types of transfer functions namely linear in location (LM), quadratic in location (QM), linear in location and scale (LMS), and quadratic in location and linear in scale (QMLS). Previously, only conventional stationary (S) approach was used to model the extreme share return. Hence, the modifications to the available technique are made by addressing the non-stationarity behaviour to improve estimation accuracy. The procedure for the TS method is presented in Chapter 3.

This study proposes the TS method to reduce the complexity when modelling the extreme share return using probability density function (PDF). The analysis of the complexity in modelling extreme share returns is grouped into two categories namely known and unknown parental distribution. The details of the simulation study in measuring the complexity of the extreme share returns can be found in Chapter 5. The simulation study shows that the TS method had successfully reduced the complexity of the extreme share returns in some cases.

This research is expected to contribute to the application of risk measures such as Value at Risk (VaR) and Expected Shortfall (ES) in accessing the financial risk. The results obtained from the demonstration of the proposed model displays higher estimation accuracy in comparison to previous models available in literature.

1.7 Organization of the Thesis

This thesis consists of seven chapters as described below:

Chapter 1 presents the background, introduction, objectives and scope of this research.

Chapter 2 provides an overview and literature review on stationary and non-stationary share return analysis and the development of the two-staged model in a different distribution. It also describes the conventional non-stationary share return analysis and opportunities to explore the two-staged model method for risk management problems. The advantages of the two-staged model method in modelling the non-stationary share return series are also highlighted.

Chapter 3 presents the research methodology which describes the related theories to the extreme value theory (EVT), the L-moment estimation method, the probability distribution function (PDF) and the cumulative distribution function (CDF) of each distribution. The parameter estimation using the methods of L-moments is revisited for each distribution, namely GLD, GEV, GLO, GPA and LAP.

Chapter 4 discusses the non-stationary design procedure used in this study. The Two-Stage (TS) method of the proposed models namely LM, QM, LMS and QMLS for each distribution is shown in detail.

Chapter 5 describes the implementation of the proposed design that is used to evaluate the sampling properties of the non-stationary two-stage (TS) method model. The justification of each model is verified using known and unknown parent distribution function.

Chapter 6 presents the analysis of the non-stationary two-stage method using real data namely, daily, weekly maximum, weekly minimum, monthly maximum and monthly minimum returns. The data properties are explained based on the box plot, homogeneity test and locally weighted scatterplot smoothing as a preliminary study.

The non-stationary models are also implemented to the market risk measurement analysis.

Chapter 7 concludes the discussion on the procedures and analysis of the research. Recommendations for areas related to the findings and possible directions for future studies are also presented.

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LIST OF PUBLICATIONS

Indexed Journal

1. **Marsani, M.F**. and Shabri, A. (2020). Two Stages Fitting Techniques Using Generalized Lambda Distribution: Application On Malaysian Financial Return. Sains Malaysiana 49(5): 1153-1164. **(Q4, IF:0.643)**
2. **Marsani, M.F**. and Shabri, A. (2020). The distribution of extreme share return in different Malaysian economic circumstances. Malaysian Journal of Fundamental and Applied Sciences. 16(1), 75–80. **(Indexed by ISI)**
3. **Marsani, M.F**. and Shabri, A. (2020). Non-Stationary in Extreme Share Return: World Indices Application. ASM Science Journal. 26, 1–9. **(Indexed by SCOPUS)**
4. **Marsani, M.F**. and Shabri, A. (2019). Random Walk Behaviour of Malaysia Share Return in Different Economic Circumstance Formula. MATEMATIKA: Malaysian Journal of Industrial and Applied Mathematics. 35(3). **(Indexed by ISI)**
5. **Marsani, M.F**., Shabri, A. and Jan, N.A.M. (2017). Examine generalized lambda distribution fitting performance: An application to extreme share return in Malaysia. Malaysian Journal of Fundamental and Applied Sciences. 13(3), 230–237. **(Indexed by ISI)**

INTERNATIONAL / NATIONAL CONFERENCES

Marsani, M.F. and Shabri, A. (2020). Extreme share return distribution: international application. ASIA International Multidisciplinary Conference (AIMC 2017), UTM Skudai, 1-2 May

Marsani, M.F. and Shabri, A. (2018). Random Walk Tests for Malaysian Extreme Share Return: Peaks Over a Threshold Method. 4th ISM International Statistical Conference (ISM-IV), Sunway University, 1-2 August

Marsani, M.F. and Shabri, A. (2018). Non-stationary in extreme share return: Block maxima minima method. 26th National Symposium On Mathematical Sciences (SKSM 2018), Universiti Malaysia Sabah, 28th 29th November 2018